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REPORT

From:	European Commission
To:	Friends of the Presidency Group on the European Defence Fund (EDF)
Subject:	External study contracted by the European Commission on the impact of EU funding for collaborative defence research and development programmes

Delegations will find attached an external study contracted by the European Commission on the impact of EU funding for collaborative defence research and development programmes.

The study was commissioned by the Commission to prepare the Impact Assessment on the EDF proposal. It includes a disclaimer underlining that the external studies were commissioned by the Commission in parallel to the Staff Working Document 2018 (345) supporting the proposal COM (2018) 476 on the European Defence Fund 2021-2027. The content of the external studies adds to the evidence-based for the Commission's proposal, but the information and views set out in the studies are those of the author(s) and do not necessarily reflect the official opinion of the Commission.

ECORYS

VEDETTE

VVA Valdani Vicari & Associati

Impact assessment study on EU funding for collaborative defence research and development programmes

Final Report

Client: DG GROW

Brussels/Rotterdam, 31 May 2018

Impact assessment study on EU funding for collaborative defence research and development programmes

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This study was executed by a team of Ecorys and Vedette Consulting. Additional support was received from Dr Nikolaos Karampekios, Dr Martin Lundmark and quality management was provided by VVA. The work undertaken has benefited much from the active engagement of a variety of stakeholders, both Member States, NGOs and industry representatives, who provided useful information, data and opinions on the matter at hand. We would like to thank the stakeholders but also DG GROW for their active involvement and feedback in the study.

ECORYS

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i. Glossary

Acronym	Description
APAC	Asia-Pacific
CALA	Caribbean and Latin America
CARD	Coordinated Annual Review on Defence
CIP	Competitiveness and Innovation Framework Programme
CSDP	Common Security and Defence Policy
(D)ARPA	(Defense) Advanced Research Projects Agency
DG GROW	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
EC	European Commission
EDA	European Defence Agency
EDAP	European Defence Action Plan
EDF	European Defence Fund – the 'Programme'
(E)DTIB	(European) Defence Industrial and Technological Base
EEAS	European External Action Service
EIB	European Investment Bank
EIF	European Investment Fund
FP	Framework Programme for Research and Technological Development
GDP	Gross Domestic Product
ICT	Information and Communications Technology
SIPRI	Stockholm International Peace Research Institute
IP	Intellectual Property
IPR	Intellectual Property Rights
LOI	Letter of Intent
MEA	Middle East and Africa
MFF	Multiannual Financial Framework
NATO	North Atlantic Treaty Organization
PADR	Preparatory Action on Defence Research
PCP	Pre-Commercial Procurement
PESCO	Permanent Structured Cooperation (on security and defence)
R&D	Research and Development
R&I	Research and Innovation
R&T	Research and Technology
SME	Small and Medium-sized Enterprises
TRL	Technology Readiness Level
SWOT	Strengths, Weaknesses, Opportunities, Threats
UAV	Unmanned aerial vehicle

ii. Executive summary

Introduction

This study was commissioned to assess the impact of the European Defence Fund (EDF – 'the Programme') in increasing the competitiveness of the European Defence Industrial and Technological Base (EDTIB)

The study was conducted between February and May 2018 on behalf of Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) in order to address four objectives: first, a baseline assessment of the EDTIB and its likely evolution without further EU intervention; second, to assess policy design options for the Programme; third to consider potential funding models; and fourth, to assess relevant impacts.

The defence sector is a unique market with a number of particular characteristics

The EDTIB is a strategic European asset and plays a key part in underpinning the defence and security of European nations. It has few customers, limits on exports and sensitivities around security. Conventional definitions of market competitiveness are not fully applicable to the sector. For the purposes of this study, we have defined competitiveness of the EDTIB as "*the ability to fulfil the EU Member States defence capability needs in a cost effective and efficient manner*".

A mix of qualitative and quantitative methods were used in this study

To deliver the objectives of the study, a range of methodological approaches were employed, primarily:

- Analysis of available data on spending patterns and of the macroeconomic impacts of defence investments;
- Literature review on previous work relevant to this topic;
- Compilation of a series of case studies to explore salient issues in more detail;
- Semi-structured key informant interviews and an workshop with senior stakeholders from the EDTIB;
- Expert assessment and analysis by the study team.

Context and problem assessment

The EDTIB faces significant future challenges.

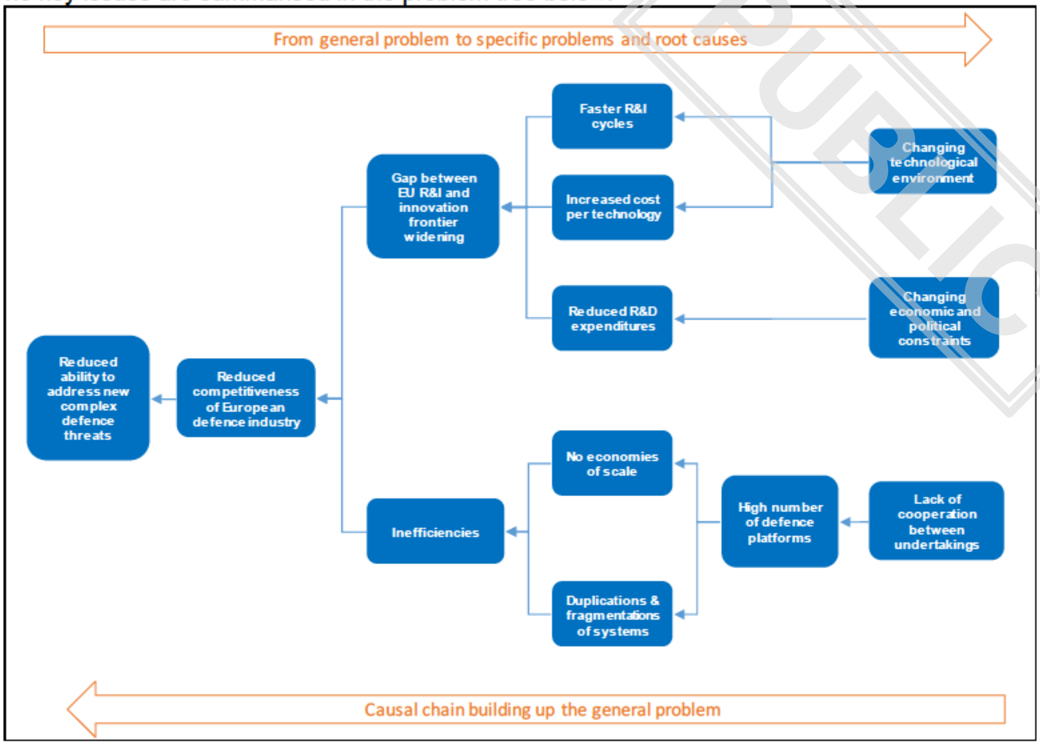
Historically, Europe has benefited from a strong indigenous EDTIB that has provided Member States with assured access to battle-winning technology; moreover, the industry has been an important economic asset in terms of technology spillovers, high-skilled jobs and exports.

However, recent years have seen a number of trends that are likely to adversely affect the future competitiveness of many parts of the EDTIB, in particular:

- Stagnant defence budgets and increasing costs of defence equipment. In real terms, defence budgets in Europe are lower in 2018 than at the start of the decade. At the same time, defence Research and Development (R&D) spending in the US, China and other global regions has increased through this period. These trends, combined with increasing costs of defence technology means that the gap between the EDTIB and the innovation frontier is widening;
- A fragmented market in terms of demand from Member States. Military requirements are largely defined at the national level with little true harmonisation of demand. Data indicates that only about a fifth of total equipment spending across Europe is on collaborative equipment programmes with no discernible increase in cooperative spending over the past decade;

- A high level of duplication and overcapacity on the supply side. Linked to the second point, is a fragmented EDTIB with significant duplication and overcapacity, resulting in inefficiencies and a lack of economics of scale, scope or learning at the European level.

The key issues are summarised in the problem tree below.



Establishment of a baseline

While European investment in defence R&D and equipment programmes will increase in the period to 2026, this will be more than offset by rising costs and global patterns

Forecasts of European defence spending indicate a small real-terms increase between 2018 and 2026, driven both by increasing prosperity and a changing geopolitical security environment. However, the evidence suggest that these increases are unlikely to keep pace with the rising costs of defence R&D and defence technology, with a gap of between one and three percent per year. This issue is exacerbated by the European share of global defence spending (and global defence R&D spending) declining through the period. The implication of these trends is that there will be further pressures on the EDTIB without major changes in terms of greater coherence on the demand side or substantial integration on the supply side.

A more efficient EDTIB and greater harmonisation of requirements are key to a sustainable and competitive sector, but major change seems unlikely under the baseline scenario

Recent developments, such as the North Atlantic Treaty Organization (NATO) Smart Defence initiative and the Pooling and Sharing approach championed by European Defence Agency (EDA), highlight the importance of coordination between allied states in the provision and development of military capability. There have been some notable successes in operational issues, although significant overcapacity remains when European forces are considered as a collective whole. However, there has been more limited focus on coordination of R&D and harmonisation of demand between European nations. The recently-launched initiatives – primarily Permanent Structured Cooperation (PESCO), Coordinated Annual Review on Defence (CARD) and the financial toolbox – should help improve coherence on the demand side. Better alignment of procurement cycles and activities would enhance the effective and efficient use of available defence budgets. However, without the European Defence Fund, these initiatives do not address the issues around R&D and future technologies: issues that will be particularly problematic with the Preparatory Action and the EDIDP coming to an end before the next Multiannual Financial Framework (MFF).

Under the baseline scenario, it is likely that the EDTIB will become less competitive in the period to 2026

Our overall assessment of the available projections – combined with the stakeholder workshop and expert interviews conducted in this study – is that the EDTIB will become progressively less competitive over the next eight-year period under the baseline scenario. There are challenges on both supply and demand sides; and while there are some positive trends (rising defence budgets and the raft of targeted EU initiatives) these will be outweighed by the global context and the structural barriers for collaboration that exist. Looking further ahead, it is difficult to conceive of a positive long-term outcome (beyond 2026) for the EDTIB without some major catalyst for change.

Policy options and design considerations

An assessment of the proposed governance structure for the European Defence Fund - and synthesis of inputs from key stakeholders – indicated six particular issues for consideration in the EDF.

- Synergies with other defence R&D fund providers (e.g. Member States, NATO, PESCO) is important in aligning with other initiatives and maximising the value added;
- A focus on the staffing strategy when it comes to additional personnel, independent experts and potential project managers is key for Programme success. In particular, the pool of experts should be diverse with a real focus on impacts induced in the organisation;
- A portfolio approach should be taken to the Programme across funding models and Technology Readiness Level (TRL) levels with a balanced approach to risk and a focus on ground-breaking technologies;
- A considered approach to Intellectual Property Rights (IPR) ownership which creates the right incentives for active participation by the EDTIB, while making the benefits of European Commission (EC) R&D funding available to Member States;
- The tools under the Financial Toolbox, are expected to pave the path for successful cooperation, hence those under development and other tools or actions according to the needs of the stakeholders should be made available as soon as possible;
- A focus on communicating and promoting the Programme to different stakeholders is important to encourage and facilitate their involvement.

In practice the Programme should be composed of a targeted mix of different funding modalities. The eventual mix will need to be tuned to the ultimate objective of the programme in terms of enabling technologies and key military capabilities.

In the design of the Programme use should be made of different funding modes. A summary of the funding modes; their characteristics; and pros and cons is presented in the table overleaf.

Summary of characteristics and pros and cons of funding modes

Funding modes	Key characteristics	Main pros and cons
Grants	Co-financing of R&D. Funding rate depending on innovation stage and specific purpose. Can be up to 100% of eligible costs (TRL 1-7) IPR usually owned by the industry consortium	• Tested, well established R&D funding modality • Funding rates can be adjusted related to objectives/aim • Creates leverage depending on funding rate • Co-financing from other sources is required to cover costs which are not covered/eligible • Application procedures can be cumbersome, in particular of co-financing needs to be applied from other sources which follow different procedures and time scales • Requires harmonisation of programming if co-financing from EC with Member States is required
Inducement prizes	Competition model with a cash reward for the best solution. Prizes normally do not go beyond several € million (TRL 2-5) IPR usually stays with the winning company	• Strong demand driven approach which gives much freedom for innovative solutions • Leverage in terms of own R&D resources mobilised • Own investment required may deter participation • Can invite participation beyond the "usual suspects" • Transaction costs can be low
Guarantee	Guarantee to financial intermediary that eases access to finance (loans) to SMEs and MidCaps (TRL 4-6) IPR remains the property of the company benefitting from the guarantee	• Enables access to finance SMEs and Midcaps to overcome financing issues in the "Valley of Death" phase • Creates medium scale funding leverage (factor of 2 in comparable examples) • Application procedures can be burdensome • Lower visibility of the EC
Pre-Commercial Procurement	Procurement instrument targeted at R&D procurement. Risk-benefit sharing instrument by definition (TRL 2-7) IPR typically is owned by the industry consortium and the procurer receives a user right or a royalty-bearing licence.	• Stronger demand driven approach compared with grants (stronger focus on user requirements) • Still limited experience in comparable situations • Suitable if no near-the-market solution are yet available • Can trigger stronger participation of SMEs in procurement is designed correctly • Can potentially increase the efficiency of R&D • In principle not able to fully cover the all costs of the procurement
Procurement	Procurement can be applied to specific R&D activities or R&D combined with (pre-) production activities (prototyping/ supplies of equipment). IPR depends strongly on how the contract is set up. It can remain with the contractor subject to specific restrictions	• Demand driven approach in which user requirement are normally defined ex-ante; • Commonly used in Member States • Can be effective in triggering collaborative R&D funded from various Member States • Less relevant for EC funding as there are challenges in EC owning defence capabilities

Funding modes	Key characteristics	Main pros and cons
	or be an exclusive benefit of the contracting authority.	

Impacts of the Programme

Analysis suggests significant benefits from the programme both in terms of economic impact and wider defence/security impacts

An updated budget proposal indicates an increased annual spending of **€1.85 bn under this policy option (€583 m for collaborative defence research and €1226 m for the collaborative development of defence capabilities).**[1] In economic terms the Programme is expected to generate additional multiplier impacts on Gross Domestic Product (GDP) of €1.3 bn to €3.5 bn per year; and create between 35,000 and 60,000 additional jobs, many of which would be in high-tech and highly-skilled areas. Technological spinoffs are likely through the implementation of the Programme and spillovers from defence R&D may positively impact a number of civil sectors and activities (e.g. health, transport, Information and Communications Technology (ICT) etc.).

It is anticipated that the additional collaborative funding would act as a catalyst to induce greater cross-Europe integration of the EDTIB, create economies of scale, and thus enhance competitiveness of EU industry. It also provides a mechanism to foster innovation through a balanced approach to risk yielding the potential of unique breakthrough innovations.

There are significant potential benefits in terms of European defence capabilities and strategic autonomy to deploy military force. The medium and longer-term impact of the Programme are to develop battle-winning technologies and ensure Member States can act (in concert with other allies) to ensure regional security and global interests. If the Programme is successful, there is significant opportunity to increase commonality of systems and interoperability between European forces, hence increasing the effectiveness of joint deployment of forces on Common Security and Defence Policy (CSDP) missions.

In order to exploit the full potential of the Programmes, several risks need to be addressed. The main risks that could affect the programme are linked with the active participation of Member States and EDTIB stakeholders; design considerations of the programme; and external factors. It will be key that effective mitigation measures are taken to ensure that these risks do not adversely affect the Programme and reduce the impacts that are realised.

The table below summarises the impact compared with the baseline scenario.

Impacts	Policy option 1 Baseline	Policy option 2 EDF programme	Remarks to option 2
Economic and innovative impacts			
R&D expenditure	Approximately €9 bn annual spend. Limited increase year on year.	Increase of up to 21% in comparison to baseline	• Maximally €1.85 bn additional funding. The net effect can be lower in case national defence R&D funding is displaced; • The possible reduction of R&D overlaps (analogue to the McKinsey study this could be up

[1] In the original proposal €1.5 bn were planned. According to the updated budget proposal an average annual spending of €1.85 bn will be provided.

Impacts	Policy option 1 Baseline	Policy option 2 EDF programme	Remarks to option 2
			to 30%) could be reduced enhancing the net effect of the collaborative funding by freeing up resources.
R&D collaboration in defence	Limited increase	Strong increase	• This build on the existing tendency in the baseline for more cooperation. EDF is a strong incentive to raise the cooperation level.
Competitiveness of the EDTIB	Relative decrease in a global context & absolute decrease	Positive contribution with possible multiplying effects	• EDF provides an impulse for further integration of the EU value chains & creation of economies of scale. This is expected to enhance the level of innovation and accelerate cross Europe consolidation.
Innovation, quality and variety of technologies developed	Under pressure	Expected positive effect	• EDF can enable to reduce pressure due to limited funding available at a national level and strive for higher innovation and more disruptive technologies
Impacts on SMEs	Unclear	Potential positive effect	• Incentives for SMEs to be included in consortia can be built in R&D funding procedures; • In general there is more funding available, also for SMEs.
Wider economic impacts			
Multiplier effects on GDP	Additional multiplier impacts on GDP of €5.4 bn - €12.7 bn	Additional multiplier impacts on GDP €1.1 bn - €3.0 bn per year (compared to the baseline)	• The size of the multiplier depends on e.g. existing infrastructure, institutions, and innovation ecosystem, Geographically the multiplier might be more diverse. Potential displacement impacts might also be relevant to indirect economic impacts.
Tax income	Currently €1 bn – €3.8 bn	An additional €0.2 bn – €0.7 bn compared to the baseline	• Directly linked to the enhanced direct and indirect additional turnover created.
Technological externalities/spill overs in civil sector	Spill overs (potentially less important overtime)	More spill overs	• A stronger focus on innovative research has higher likelihood of spillovers.
Social impacts			
Number of persons	145-260 thousand	210 - 370 thousand	• Approximately 65-110 thousand additional jobs in R&D (however possible displacement impact).

Impacts	Policy option 1 Baseline	Policy option 2 EDF programme	Remarks to option 2
employed (direct and indirect)			
Quality of employment/skills	Sustaining high skilled jobs	Additional high skilled jobs	• More research, will have a positive impact on the creation for high skilled jobs. Where the labour market for high skilled jobs is tight this might create a certain level of competition with other sectors.
Wider security impacts			
Quality of defence products and technologies	Small relative decrease	Increased potential for new innovation and battle-winning technologies	• Allows to remain competitive and state of the art.
Duplication of costs of equipment	Small positive change expected due to PESCO, CARD and EDA initiatives	Greater collaboration leading to greater commonality of systems	• The impacts will only be achieved in the medium- to long-term.
Level of interoperability	Small positive change expected due to PESCO, CARD and EDA initiatives	Greater collaboration leading to greater commonality of systems	• The impacts will only be achieved in the medium- to long-term.
Strategic autonomy	Reduction in strategic autonomy	Sustainment and development of key systems	• Would require focused efforts on key battle-winning technologies.

1 Introduction

This chapter provides an overview of the objectives, methodological considerations and outline of the report. It is designed to facilitate the reader's understanding and to provide an overview on what to expect from subsequent chapters.

1.1 Objectives of this study

This report was conducted in support of an EU Impact Assessment. It has as a general objective the assessment of potential impacts of a possible EU financing Programme for defence research and development, which should allow policy makers to understand the added value of the Programme and the impacts of possible policy options for implementation. It thus aims to:

- **Assess the baseline development**: each Impact Assessment needs to assess policy options in relation to the 'no EU intervention' scenario. Therefore, building on a solid problem assessment and understanding of the contextual setting, an outlook of what would happen without the Programme needs to be developed;
- **Assess policy design options**: the EU has essentially two realistic options at hand, to either implement the Programme or not implement it. It is, however, relevant to understand which factors influence the effectiveness and efficiency of the Programme, and to incorporate the conclusions in programme design. The study has thus a particular focus on understanding the funding options available;
- **Assess relevant impacts:** the implementation of the Programme will have a variety of impacts. The assessment focuses on all relevant intended and unintended impacts and aims to provide insights regarding their specific effects on relevant stakeholders;
- **Compare and conclude**: having conducted the assessment of the policy options and their impacts, a structured comparison is presented including general conclusions and recommendations for the Programme.

1.2 Methodological considerations

Time and availability constraints

The study makes use of a set of primary and secondary information sources and combines them through the methods of triangulation and cross-validation, having established clear research hypotheses at the beginning of the study. There were two key constraints for the study team: first, the limited time (14 weeks) available to conduct the study; and second, the dependence on cooperation and availability of relevant stakeholders. The latter was mitigated through early involvement of stakeholder representatives.

The tasks and activities are interlinked and our approach can best summarised as an iterative approach following three primary activities (see Figure 1):

Figure 1: Research approach

1. **Literature review / data collection:** the starting point was a review of literature and collection of secondary data;
2. **Stakeholder Specification & validation:** the information and hypotheses were then specified, completed and validated by stakeholders in the form of interviews and a workshop;
3. **Analysis & (preliminary) judgement:** based on the information collected and validated, the analysis was conducted and (preliminary) judgements were made. The findings were then further specified and deepened with additional literature and/or data, checked with stakeholders and updated.

Data constraints

In order to develop evidence-based policies concerning the potential impact of EU defence funding, one critical aspect is reliable, comparable and accurate data on R&D and innovation indicators. However, there are question marks over the robustness of data in this field due largely to how defence spending is captured and reported differently by Member States. More fundamentally, there is an increasing overlap with the security sector and also the wider civilian technology sector which means it the "defence sector" does not exist in isolation but rather as part of a wider industrial and technological eco-system.

Definition of competitiveness

One of the key aims of the Programme is to strengthen the competitiveness of the European Defence and Technology Industrial Base (EDTIB) through increased funding of research and development. Therefore, it is important to specify what is meant by "competitiveness" when talking about the EDTIB.

In a traditional sense of sector competitiveness studies, "competitiveness" consists of three aspects:

1) **EU competitiveness vs. non-EU**: defining the ability of EU industries to compete with companies outside the EU on the global market;
2) **Competitiveness between EU Member States**: defining the competitive position of industries of specific Member States with other Member States;
3) **Competitiveness of individual companies vs. others**: defining the ability of individual companies to compete with other companies within their market[2].

[2] Ketels, Christian (2016): Review of Competitiveness Frameworks

However, in the context of the defence sector, this traditional definition of competitiveness is not valid. This is because the defence industry is not a "normal" industry competing for private sector clients, but a highly regulated sector with strict controls on what can be sold and to whom. In addition, it is a sector of strategic importance in terms of defence and security capabilities of EU Member States. For the purposes of this study, then, we have defined competitiveness of the EU defence industry as "*the ability to fulfil the EU Member States defence capability needs in a cost effective and efficient manner*" while having regard to other metrics where appropriate.

1.3 Outline of this report

Hereafter, this report is divided into the following four chapters:

- **Chapter 2 – Context and problem assessment**: a summary of contextual information relevant to understand the assessment of policy options and their impacts. It includes a summary of the problem assessment;
- **Chapter 3 – Establishment of a baseline scenario**: an assessment of the most likely trends for the coming years without additional EU intervention;
- **Chapter 4 – Policy options and design considerations**: a presentation of an alternative policy option including an assessment of the design factors influencing the efficiency and effectiveness of the Programme;
- **Chapter 5 – Impacts of the Programme**: an assessment of relevant intended and unintended impacts of the Programme, a comparison of the policy options, and conclusions.

In addition there are three annexes:

- ANNEX I – List of consulted stakeholders;
- ANNEX II – Bibliography;
- ANNEX III – Case Studies.

2 Context and problem assessment

This chapter begins with a very brief overview of the global strategic context. It then focuses on the European defence industrial and technological base and provides a summary of the key contextual information relevant to understanding the assessment of policy options and their impacts. The chapter also includes a brief assessment of the problem to be addressed by the Programme.

2.1 The Global Strategic Context

It is not the intention of this study to explore in any detail the future threat environment or synthesise the capability requirements of Member States; although defining clear priority capabilities for the future is an underpinning aspect of strategic autonomy.

In recent decades, there have been major changes in European defence at strategic, political and operational levels. Much of this change has also affected the EDTIB. Key drivers at the strategic level have included the end of the Cold War, the terrorist attacks of 9/11 and advent of international terrorism, and the emergence of China and other Asian states, as strategic players in the global security context. Moreover, other trends – such as technological developments and their translation into increasing cyber security threats – have widened the range of potential threats, blurring the distinctions between security and defence; and between the national and international sphere.

Operationally, changes in the strategic environment, political priorities and technological advances have contributed to significant evolutions in tactics and capability requirements. The humanitarian interventions of the 1990s and engagements in Iraq, Afghanistan and Libya have led to some force restructuring and a review of operational concepts.

On the political level, there have been moves towards greater coordination on defence issues at the European level, such as consideration of security issues as part of numerous treaties; the development of the CSDP; the creation of the EDA to encourage a European approach to collaborative defence capability development; the European External Action Service (EEAS); and more recently the launch of PESCO and other European initiatives. However, despite progress towards greater integration and cooperation at the European level, there remain large differences across Member States in terms of security concerns, defence policy and balance between expeditionary forces, border security and homeland defence.

The stated purpose of the CSDP is to "*enable the Union to take a leading role in peace-keeping operations, conflict prevention and in the strengthening of the international security. It is an integral part of the EU's comprehensive approach towards crisis management, drawing on civilian and military assets.*"[3]

[3] EEAS (2018) The Common Security and Defence Policy https://eeas.europa.eu/headquarters/headquarters-homepage/431/common-security-and-defence-policy-csdp_en accessed 15 April 2018

2.2 The European Defence Industrial and Technological Base

A strong defence industry is a key tenet of Europe's future security and also forms an important part of the European economy. This section sketches some important trends affecting the EDTIB and outlines their associated policy priorities.

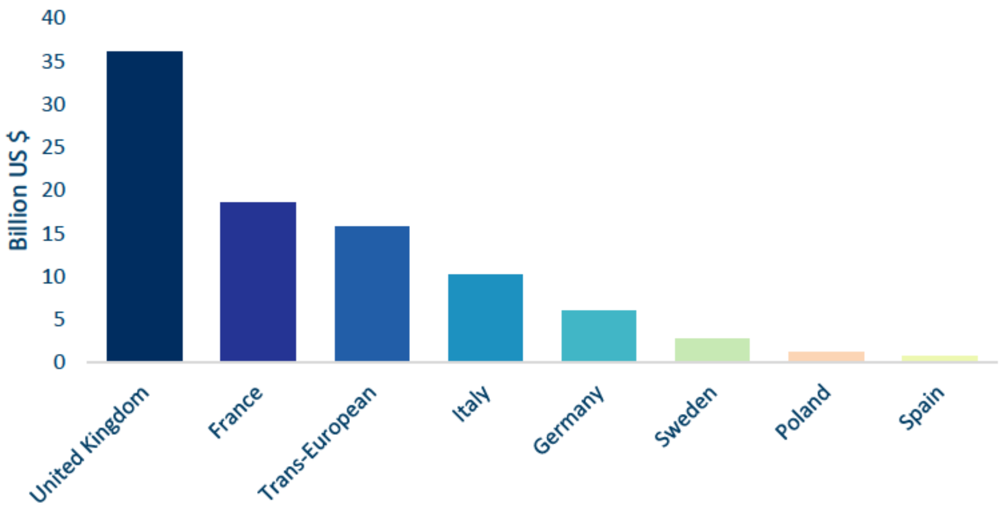
2.2.1 *The EDTIB has been an important component of European security and also an economic asset*

Historically, Europe has benefited from a strong indigenous EDTIB that has provided Member States with assured access to battle-winning technology. Moreover, the industry has been an important economic asset in terms of technology spillovers, jobs, and exports. A key specificity of the defence industry is that its research and development have mainly been financed by Member States, which are at the same time the main customers and beneficiaries of the industry products. In comparison, in other industries, the public sector supports development of the private sector. In 2015, the European defence sector (as defined by the European trade body, Aerospace and Defence Industries) directly employed an estimated 430,000 people (and generated approximately 1.2 m jobs indirectly) with a turnover of €102 bn. In recent years, defence industry turnover has been relatively static.[4] However, the EDTIB faces an uncertain future due to several driving factors that are outlined in this chapter.

2.2.2 *The EDTIB is concentrated in a small number of countries and within relatively few large firms*

The European defence sector is comprised of a few top players concentrated in a handful of countries: most notably the six so-called Letter of Intent countries (UK, France, Italy, Germany, Sweden and Spain).

Figure 2: Arms sales by EU Member States in 2016



Source: Ecorys calculations based on SIPRI[5]

[4] ASD (2016), KEY FACTS & FIGURES 2015
[5] SIPRI (2016), *SIPRI Arms Transfers Database*, available at https://www.sipri.org/databases/armstransfers

When considering sales of the 24 biggest European companies in the Stockholm International Peace Research Institute (SIPRI) list, the considerable difference between the UK and France when compared with other EU countries is revealed. Sales for the UK alone are almost as high as the combined sales of the third placed trans-European companies (i.e. companies whose ownership and control structures are located in more than one European country) and those of the five smaller supplier countries.

According to SIPRI, in 2016 there were 24 European companies in the global top 100 arms-producing and military services companies, with four (BAE Systems, Airbus Group, Leonardo and Thales) ranked in the top ten.[6] The US, in comparison, has six firms in the top ten, and 44 companies in the global top 100, which makes the US the world leader in terms of total arms sales.

Table 1: European companies in top 10 global arms manufacturers ranking

Rank	Company name	Country	Arms Sales[7] in $ m	Total Sales in $ m	Arms sales as a % of total sales	Total profit in $ m	Total employment
4	BAE Systems	United Kingdom	22,790	24,008	95	2,351	83,000
7	Airbus Group	Trans-European	12,520	73,652	17	1,101	133,780
9	Leonardo	Italy	8,500	13,277	64	561	45,630
10	Thales	France	8,170	16,471	50	1,073	64,100

Source: Ecorys based on SIPRI (2016)

The European firms' presence in the list of top 100 arms-producing and military services companies demonstrates the advanced industrial capacities and the globally competitive nature of the EDTIB. These companies are based in five different countries, with two "trans-European" companies, Airbus (Germany, France, Spain, UK) and MBDA (France, UK, Italy, Germany) also included in this list.

2.2.3 *The EDTIB also includes an ecosystem of Small and Medium-sized Enterprise (SMEs) and strong linkages to civil R&D*

Large companies make up a significant part of the overall turnover of the EDTIB, primarily due to the high fixed costs and capital intensity involved in the design and manufacture of complex defence systems. However, an important feature of the defence sector is the strong linkages with other high-tech industries and the cross-cutting nature of many technologies, infrastructures and organisational competences. There is now increasing alignment between defence requirements and civilian technologies (for example in cyber, communications, and power plant technologies) which means that EDTIB is composed of a diverse range of companies.[8] This aggregate of companies incorporates different dimensions, technological and production maturity levels; and different positions in the overall value chain. The complexity of the industry makes it important to combine data on the overall sector with additional quantitative analysis and qualitative assessments to draw useful insights. Such an approach is also needed when designing policies to target the industry.[9]

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[6] Idem
[7] Arms sales are defined by SIPRI as sales of military goods and services to military customers, including both sales for domestic procurement and sales for export.
[8] Penny, M.; Hellgren, T.; Bassford, M. (2013) Future Technology Landscapes
[9] EP (2013), The development of a European Defence Technology and Industrial Base3 (EDTIB) p.16; ASD (2016)

The EU defence industry includes some 1600 SMEs. Smaller companies tend to mostly focus on weapons and ammunition, while larger companies are particularly active in vehicle and aircraft production.[10]

2.3 Issues and Problem Assessment

The current portfolio of European defence technology, equipment and services reflect historic investments in defence R&D. It is broadly accepted that, historically, investment in defence R&D has had a 10 to 25-year associated payback period.[11] In recent years there have been several trends that are likely to adversely affect the future health of many parts of the EDTIB. The key trends within Europe that threaten the EDTIB are:

- Stagnant defence budgets and increasing costs of defence equipment;
- A high level of duplication and overcapacity on the supply side; and
- A lack of coherent demand.

At the same time, defence R&D spending in the US, China and other global regions continues to increase which – if no action is taken – is likely to reduce the competitiveness of the EDTIB.

2.3.1 Stagnant defence budgets

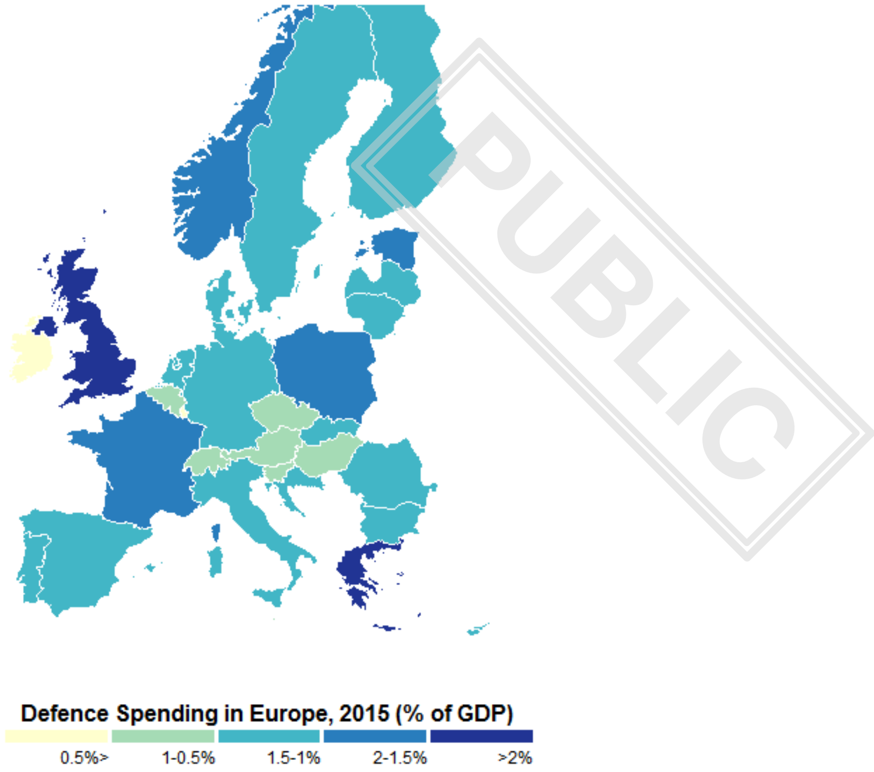
The dominant trend on the demand side over the past decade has been a decline in defence spending across Europe. This trend, already started at the end of the Cold war, was further exacerbated by the recent economic and fiscal crisis in Europe. Collectively, in real terms, defence spending across European Member States fell by 8.5% between 2007 and 2016 (from €247 bn to €226 bn), while established and emerging global powers (US, China, Russia, India) increased their military spending over this period.

Since the early part of this century, NATO members have talked about a minimum threshold that each country should commit to defence: with 2% of GDP being set as the minimum level of defence spending for aspirant states. This figure became an unofficial benchmark and in 2014, NATO leaders committed more formally to the 2% spending level with an agreed timeline for members to achieve the threshold by 2024.

However, Europe overall falls well short of this target. This is illustrated in Figure 3, which indicates that the majority of European countries devote between 1% and 1.5% of their GDP to defence, while the EU28 average is 1.4%. In 2015, only the UK and Greece spent above the 2% NATO threshold, while Estonia and France allocate somewhat less of their budgets for this purpose (with 1.9% and 1.8%, respectively). Recent analysis by McKinsey indicates that spending by EU-28 plus Norway would be around $272 bn in 2024 if current spending levels are maintained, which is $114 bn short of the total aggregate amount if each state were to meet the 2% NATO target.[12] The authors note that this forecast may turn out to be overly-optimistic, given that defence budgets across Europe as a percentage of GDP have exhibited a downward trend since 2005, as shown in Figure 4.

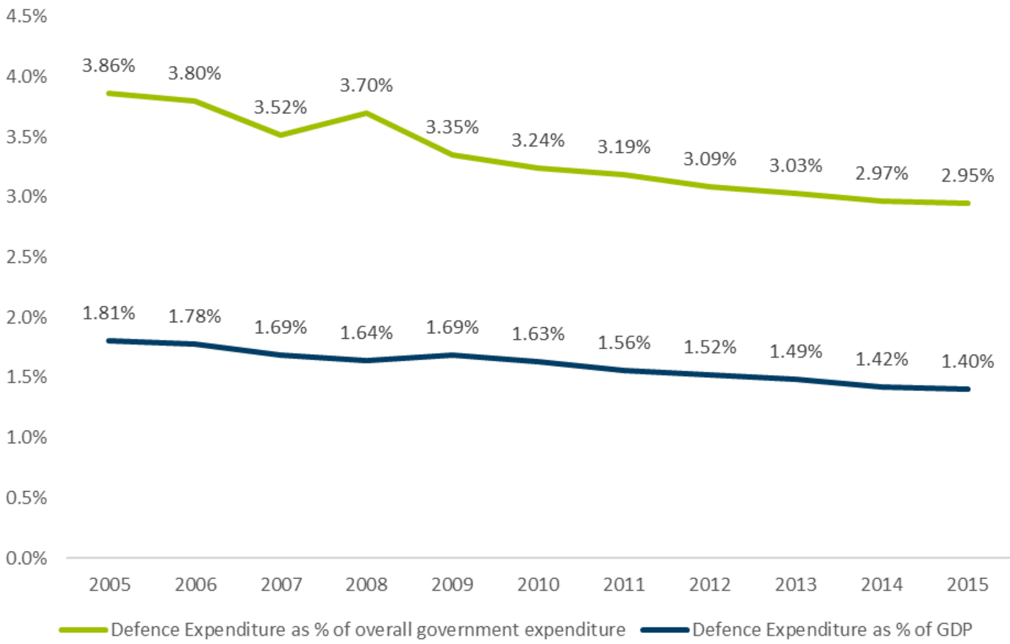
[10] IHS (2016), Analysis of defence-related SMEs' composition in EU,
[11] Bowns, S. (2007), Strategic Directions for UK Defence Research and Development in Britain and Security
[12] Munich Security Report (2017) Post-Truth, Post-West, Post-Order?

Figure 3: Defence spending in Europe 2015



Source: Ecorys based on Eurostat

Figure 4: Average EU-28 Defence Spending Relative to Total Government Spend and GDP

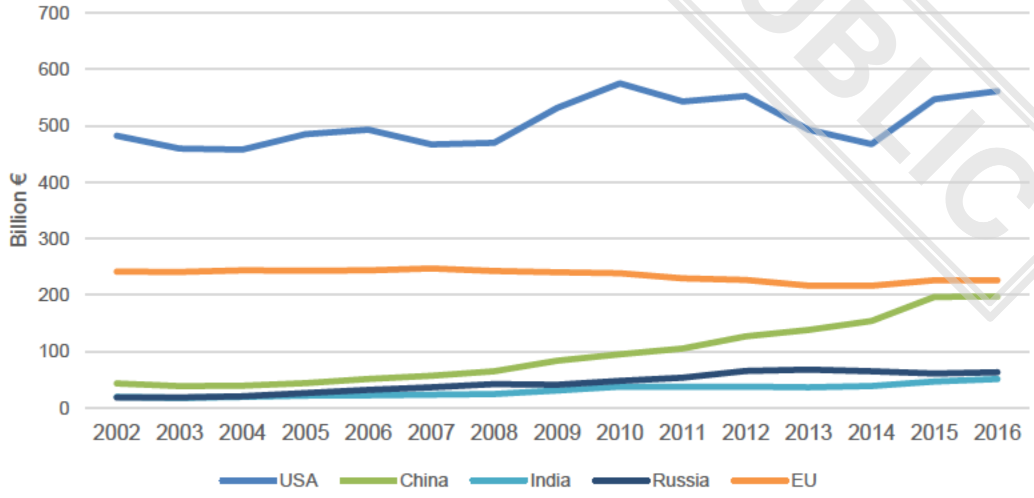


Source: Ecorys based on EDA (2016)

As shown in Figure 5, total defence spending by European nations was broadly unchanged in real terms between 2002 and 2009. However, as a result of Member States' austerity policies in 2010, defence spending started to slowly decline. As the European economy started picking up in 2014, so did defence spending, however in 2016, total spending remained below the pre-crisis baseline.

Collectively, when compared with other global powers, Europe is still in second place in terms of total defence expenditure. However, over the period 2005-2016, existing or emerging powers have either maintained their expenditure at comparable levels (US) or significantly increased it (by 150% in the case of Russia, and over 350% in China). Very rapid increases in Chinese defence spending in recent years mean that it is approaching the level of EU spending (Figure 5).

Figure 5: Total defence spending, in billions of 2018 €, 2002-2016



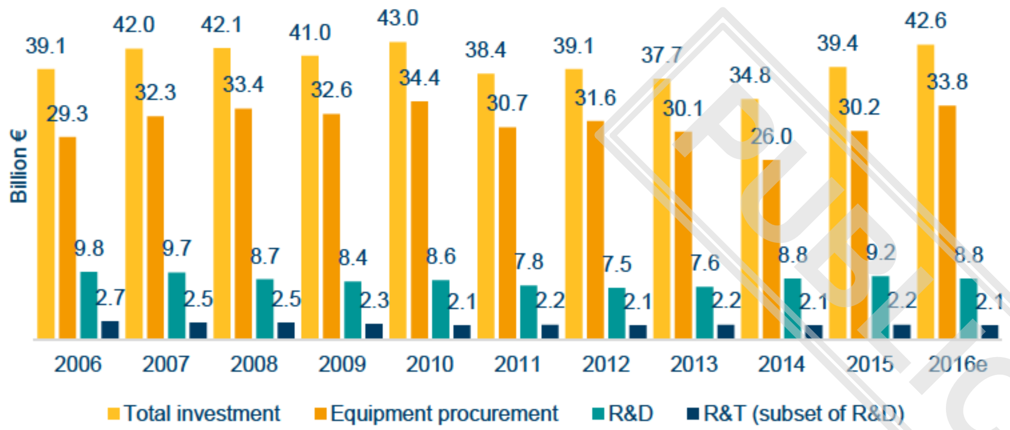
Source: Ecorys based on SIPRI data (2016)

2.3.2 *Investment in defence R&D/T and equipment can be disproportionately affected by short-term pressures on national budgets*

The largest component of most national defence budgets is personnel, often followed by maintenance and support of in-service equipment. These costs are relatively fixed in the near-term. While proportionally smaller, spending on defence R&D can become a target for short-term savings measures in response to budgetary pressures, due to the shorter time frames of spending commitments. This is borne out by analysis of defence spending patterns over the past decade. As shown in Figure 6, the total investment in defence equipment and R&D decreased significantly in the aftermath of the global financial crisis (2011-2013) but then recovered in the period after that (2014-2016).

Compared with many other markets, the defence sector has relatively few customers, has long development cycles and is capital intensive. The time lag between initial investment in research and development through to in-service military capability can be up to twenty years. Consequently, there are often relatively few incentives for private investment by the defence industry given the timing and unpredictability of financial returns – thus research and development into new technologies relies to a large extent on government investment. Given that large-scale investment in R&D is the bedrock of an effective defence capability, the future competitiveness of the EDTIB relies on increased investment in both R&D and equipment programmes. However, the stagnant spending over the past decade is likely to have already weakened elements of the EDTIB.

Figure 6: Investment in defence, equipment procurement, R&D and R&T in EDA countries (2018€)

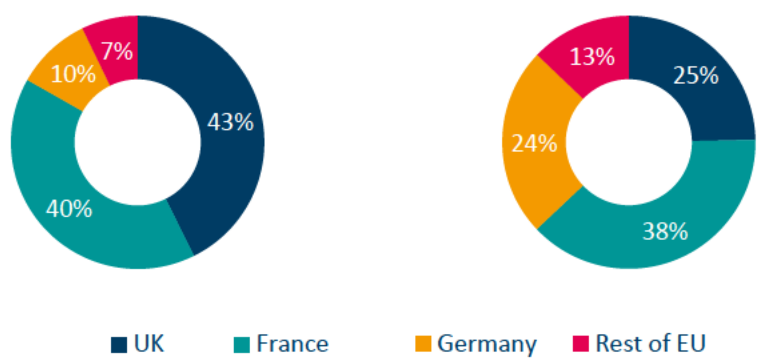


Source: Ecorys based on EDA

In comparison, in 2016 the US spent €66.7 bn on defence R&D – over six times more than the total spend in European countries. Moreover, countries like Russia, China and India have also invested heavily in defence R&D in recent years. The EP 2016 study on the future of EU defence research estimated that in 2014 China spent around €20 bn for defence R&D (under the assumption that its relative investment in R&D is of similar proportion to the US and Russia - 10% of its defence budget), while Russia increased its R&D spending by 50% between 2012 and 2015.[13]

Defence R&D spending is also heavily concentrated in a few countries. An analysis of the share of R&D and Research and Technology (R&T) spending of individual Member States in total EU spending shows that the UK, France and Germany account for almost all European expenditure on defence R&D (93%) and R&T (87%).[14] Consequently, EU Member States are divided into two groups: defence consumers and defence producers, which leads to divergence on regulatory subjects like open market procurement or protected markets.[15]

Figure 7: Share of R&D (left circle) and R&T (right circle) as a percentage of the EU total (2014)



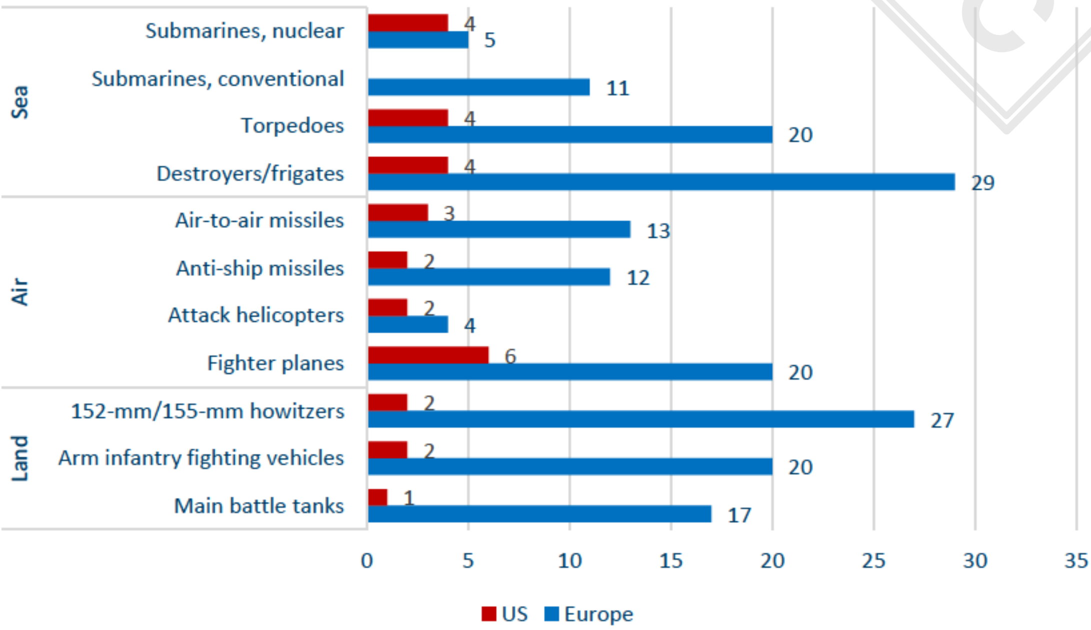
Source: Ecorys based on EDA

[13] EP (2016), The future of EU defence research
[14] Although there are differences in how spending on defence R&D is reported across Member States (for example in precise definitions of R&D and R&T), the overall picture is clear
[15] EP (2016)

2.3.3 There is a high level of duplication and overcapacity on the supply side

Despite some consolidation in recent years, the EDTIB remains characterised by overcapacity and fragmentation; particularly for major military platforms (i.e. aircraft and ships). Recent analysis by McKinsey (Figure 8) based on information from IISS *The Military Balance* showed that European nations have six times as many different weapon systems as the US (EU: 178 vs US: 30).[16] Related work by McKinsey concluded that European nations could save around $15 bn per year (around 30% of total spending on new equipment) through increased collaborative defence procurement.[17] Moreover, it is reasonable to assume that a broadly comparable saving could be achieved during the in-service phase of weapon systems, due to savings in maintenance, servicing and spares, since maintenance costs typically account for over half of the total cost of ownership of weapon systems.

Figure 8: Number of different systems from selected weapon system categories in service, 2016



Source: Ecorys based on McKinsey analysis

2.3.4 There are major differences between component parts of the EDTIB

It is also important to note that there are marked differences between the four main defence sectors (namely air, land, naval and C4ISTAR[18])[19]:

- The **military aerospace sector** is at something of a crossroads, marked by an absence of major new programmes. Despite the presence of regional champions such as EADS, there remains significant scope for further consolidation as EADS, BAE Systems, Dassault and SAAB operate in similar markets. In contrast to these four European firms, there are only two major US aerospace firms (Lockheed Martin and Boeing). Looking ahead, the key driver of change is the advent of unmanned aerial vehicles (UAVs), which continue to be a priority area, while requiring very advanced technology in terms of command and control, data fusion, machine learning and aerodynamics.[20] Efforts are underway in Europe for collaborative R&D and technology

[16] Munich Security Report (2017)
[17] McKinsey research published in *Munich Security Report* (2017)
[18] C4ISTAR is a commonly-used military term denoting Command, Control, Communications, Computers, Information/Intelligence, Surveillance, Targeting Acquisition and Reconnaissance.
[19] This analysis was informed both through the expertise of the team and insights gained from a wide range of sources including: previous studies and reports from the European Commission; European Defence Agency reports and databases; IHS Janes; IISS Military Balance; the SIPRI Yearbook; the Munich Security Report; company websites and annual reports.
[20] For a full list of key skills required for development of unmanned aerial vehicles see: Bassford, M. et al (2010), Sustaining Key Skills in the UK Military Aircraft Industry

demonstrator programmes (see for example: Flight Global report August 17[21]; Dassault website[22]). In contrast, the **complex weapons** sector is highly consolidated, with one European champion, MBDA, which is globally competitive with annual sales of €3 bn equating to around a quarter of the weapons market[23];

- The **land sector** remains highly fragmented, both at European level and within national borders. Demand in the land sector is often for a series of smaller programmes and projects. While there have been some innovations regarding 'grand challenges' and 'prize funding' at the level of soldier equipment, the vehicle technology market has less cross over with the civilian sector and there is significant overcapacity and lack of coherence across Europe[24];
- A number of competing companies operate in the **naval sector** and provide similar products and services, including: BAE Systems, Thales, DCNS, Babcock International Group, Navantia, ThyssenKrupp and Fincantieri. The naval sector is expected to further rationalise due to the combination of the following trends[25]:
  - A decrease in European naval demand: reduction of ships in service and numbers being procured;
  - Different demand profiles for integrators/assemblers and system suppliers as platforms evolve towards open architecture and modular design;
  - Significant declines in the civilian sector mean that military sales are seen as providing stability;
- The **C4ISTAR** (and cyber) sector is qualitatively different from other sectors, as it cuts across the segments of the EDTIB. It is characterised by a large proportion of SMEs, although specialised C4ISTAR division are found in all major European Original Equipment Manufacturers, such as Thales, BAE Systems, EADS, Finmeccanica, Safran, Saab, Rheinmetall, Kongsberg Gruppen, Ultra Electronics, Selex Galileo and Indra. There are also substantial cross-overs with the civilian communication world, which are increasing due to the rapid pace of technological development in ICT, including in applications such as cryptography, positioning, data analytics and sensor technology.[26] Recent years have seen some restructuring, driven by:
  - Greater emphasis on systems upgrade rather than new programmes;
  - The withdrawal of several major telecommunications equipment companies such as Nokia and Siemens from the military market;
  - Increases in the use of commercial telecommunications technology by the armed services in many countries to carry their non-battlefield communications traffic;
  - The use of multimedia broadband systems to enhance communications between combat vehicles and command headquarters.

2.3.5 A lack of coherent demand

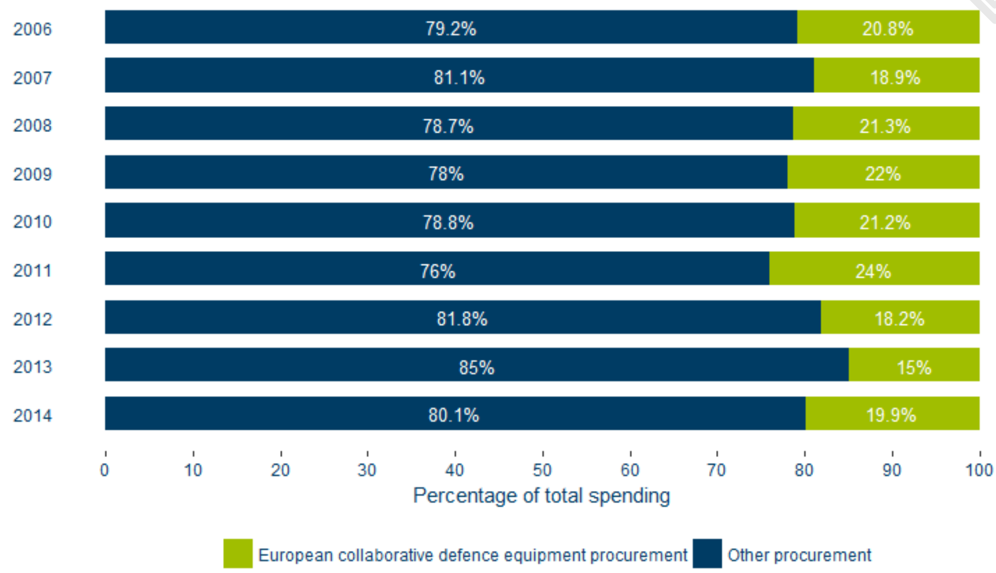
Since the creation of what is now the European Union, a primary focus has been on the construction of an internal market that reduces trade barriers and simplifies trading rules. In many markets there have been significant successes but the defence market has remained relatively immune to these efforts, due in part to national security and sovereignty issues. Where consolidation has occurred – for example MBDA, Airbus and Leonardo – the result has been a more globally competitive company than its antecedents. In addition to greater efficiencies, such companies are better able to fund R&D through better financial reserves. The creation of these companies has often been stimulated by major collaborative procurement programmes.[27]

[21] Fight Global (2017) Future European MALE UAV will be twin turboprop https://www.flightglobal.com/news/articles/future-european-male-uav-will-be-twin-turboprop-440022/ accessed 15 April 2018
[22] https://www.dassault-aviation.com/en/defense/neuron/introduction/
[23] https://www.ft.com/content/bb65b6de-aa52-11e6-809d-c9f98a0cf216
[24] Mölling, C et al (2014) European Defence Monitoring (EDM) p.22 and 24
[25] https://www.ft.com/content/473fb57c-c462-11e7-b2bb-322b2cb39656
[26] See, for example, Penny, M.; Hellgren, T.; Bassford, M. (2013)
[27] For example, an important factor in the ultimate creation of MBDA was the collaborative Meteor missile programme; and the Eurofighter programme was instrumental in greater co-operation between a number of European defence aerospace firms and integration of the supply chain.

Developments, such as the NATO Smart Defence Initiative, and the Pooling and Sharing approach championed by the EDA, have increased cooperation on military operational issues. More efficient allocation of capital and greater aggregation of Europe's limited defence investment would provide more room to invest in new and emerging technologies. The intention to combine and improve the coherence of defence research efforts is not new. Several collaborative platforms have been established during the past decades to foster more structured and permanent cooperation between European countries as described in section 2.5.3.

Despite these efforts, there is very limited success in terms of coordination of R&D funding and in collaborative procurement. This is evidenced by Figure 9, which shows no discernible improvement in cooperation between Member States on defence procurement in the period between 2006 and 2014, with only a fifth of overall spending directed through collaborative programmes.

Figure 9: Collaborative vs other procurement in the EU



Source: Ecorys based on EC (2017d)

The analysis conducted in the current study suggests that there are three primary reasons for this lack of effective collaboration.

1. A misalignment of military requirements between the larger expeditionary forces in Europe (primarily UK and France) and smaller forces with a focus on homeland and regional defence and security;
2. A desire to maintain sovereignty of defence decision-making and hence over national defence industries;
3. Protectionism over industrial infrastructure, jobs, and defence firms.

These are non-trivial challenges to overcome, but harmonisation of requirements; greater collaborative investment in defence R&D, and more collaborative programmes are critical ingredients of a solution to strengthen the long-term health of the EDTIB.

2.4 The Global Context for Defence Technology

2.4.1 Industrial policy and relations between Member States and the US

The US is the key global defence ally of the EU, not only as the leading defence power in NATO (and the collective defence this provides to many European states) but also in terms of the military equipment capability that Member States acquire from US manufacturers and the joint programmes that exist between Member States and the US (F-35 Joint Strike Fighter being a particular example). However, there are significant differences between industrial policies of Member States vis-à-vis the US, which were explored in a 2017 report by a panel of European researchers.[28] Their findings are summarised below:

- **France** has sought to maintain a high degree of strategic autonomy through close interaction between public and private sector in the development of its DTIB. Its technological and capability-related reliance on the United States has thus remained limited. Nonetheless, cooperation is sought when it is mutually beneficial while French companies seek to invest in the US market, as do other European DTIBs;
- The **German** DTIB was rebuilt belatedly after World War II, partly on the basis of French-German cooperation. German industry is now privatised and the scope of the German DTIB's partnerships has widened to other European countries and to the US. The German supply chain is now well established in American armament programmes;
- The **Italian** DTIB has consistently pursued a policy of active cooperation, whether with the US or with EU Member States. Links with the US have notably been built in the context of NATO and through bilateral agreements. In parallel, Italy has developed partnerships with European countries. Rome's cooperation policy is thus inclusive, and has considered diverse factors such as political links, capability requirements, the need to develop certain technologies and to preserve industrial capabilities and jobs in Italy;
- The **British** DTIB has historically had deeper links with US industry, as a result of the cultural closeness between the UK and the US, and of the strategic proximity that dates back to the end of World War II. The links between US and UK DTIBs thus follow a model of strategic partnership. Nevertheless, the UK's industrial and defence policy is also pursued within a European framework;
- While **Sweden** seeks to preserve its industrial capabilities in two sectors – submarines and military aircraft – it appears to be the most technologically reliant on the US among the surveyed countries. It is worth noting also that these links are long-standing, dating back to the Cold War and the Soviet threat, and that they have developed despite Sweden not being a NATO member state.

The links with the US are thus very different from one country to another and carry varying implications. While there are benefits for European states acquiring American equipment (interoperability with NATO ally, off-the-shelf purchase of advanced equipment, leveraging historic US investment in R&D), there are often constraints on their use and restrictions on technologies that will not be transferred, or that will be unusable for other partnerships. Procuring off-the-shelf US technology rather than developing European systems also has the obvious implication of increasing future reliance on US defence equipment and damaging the competitiveness of the EDTIB.

[28] Belin, et al (2017), Defence Industrial Links between EU and US, Report # 20, Ares, Paris.

2.4.2 *The impact of a resurgent Russia*

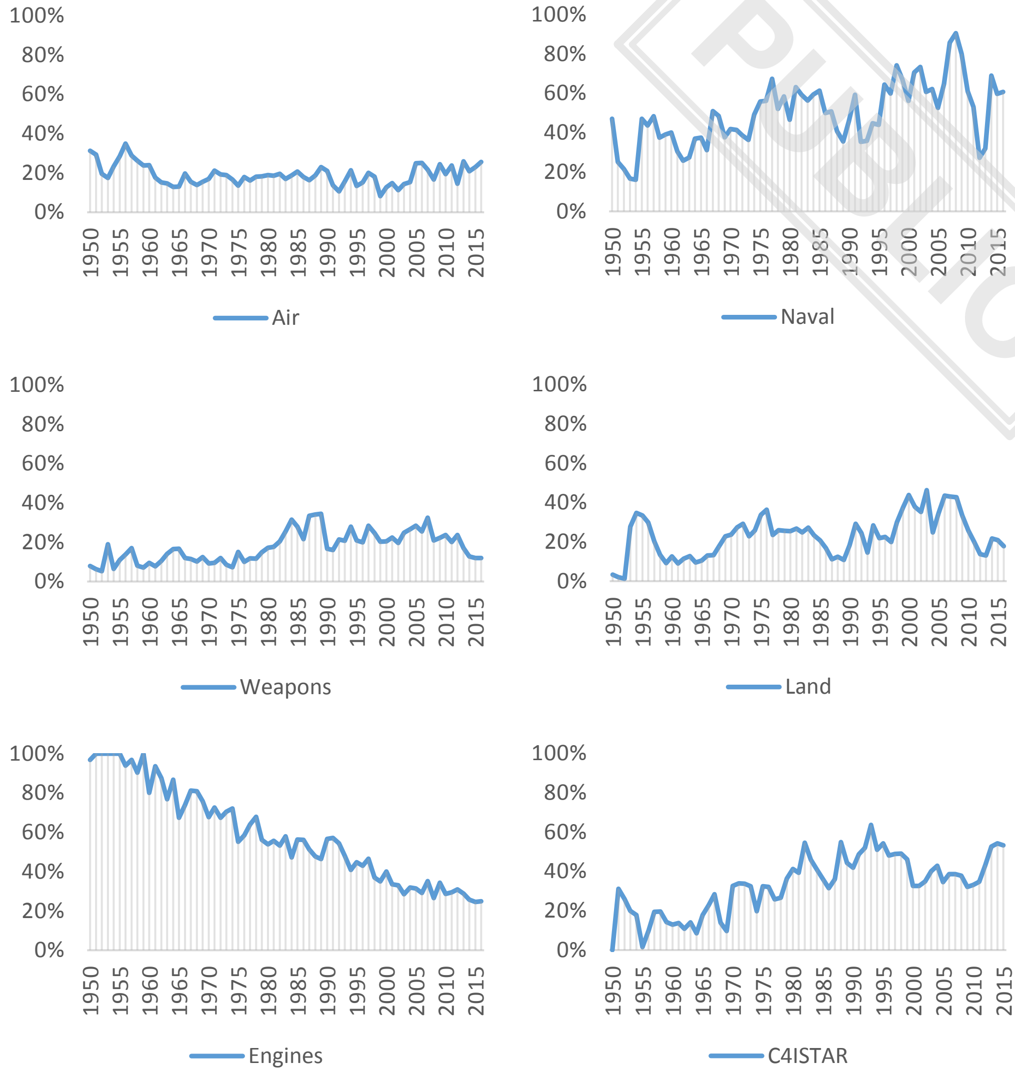
In recent years, Russia has become far more active in its near-abroad, which represents an important geopolitical issue with a clear impact on the defence priorities of EU countries. A number of trends can be observed:

- **Pressuring renewed increases in Defence spending**
  Despite the fact that average EU defence budgets have been declining in the past decade, a resurgent Russia has triggered the Baltic countries to strive for defence budgets of 2.0% of GDP (the NATO recommendation for national defence budgets). Also Sweden, Finland and Poland and several other nations have shifted years of slow decline in defence budgets towards higher levels;
- **Closer links to the US**
  Several European countries have strengthened their bilateral links with the US: using a variety of political, military and industrial mechanisms. In security policy as well as in military priorities; strong links with the US are seen to increase national security. Several nations have procured vital strike, missiles or air defence systems from the US, thereby creating strong links and interoperability with the US. For example, Sweden declared in 2016 three bilateral military relations as the most important: Denmark, Finland and the US. This is likely to have influenced Sweden's choice for the Patriot system for medium range air defence. The alternative was the French-Italian Eurosam system SAMP/T which would have meant Swedish participation in the system's development;
- **Bilateral/multilateral partnering; more military exercises and focus on readiness**
  Since 2014, there has been an increase in military exercises among EU and NATO members that are centred on threats from the east. The exercises focus on cooperation with geographically close neighbours, with NATO or with the US. EU and NATO members prioritise having credible readiness and operative capabilities. This requires trimming and upgrading of logistics – domestic and with partner nations – as well as trained and capable military units on short alert;
- **EU defence initiatives still prioritised in rhetoric, in practice less so**
  In those countries nearest to Russia, there is also evidence that of a more or less implicit tendency to favour NATO-related alternatives over EU alternatives. Rhetorically, government bills and other defence-related central documents will still underline the importance and priority of engaging in EU defence R&DT initiatives. NATO and US priorities however tend to have a higher priority and swifter decision-making;
- **Concern about cyber and hybrid warfare**
  Russia has shown impressive capabilities and skills in using cyber and hybrid warfare operations, in Ukraine and through covert cyber operations aimed at testing the resilience of neighbouring countries. Cyber operations can destabilise societies as well as military capabilities. This creates uncertainties and unclear risks. Cyber capabilities – defensive as well as offensive – are therefore prioritised in many EU countries. This is also enhanced by interests of financial systems, industrial espionage and possible infringements on national elections.

2.4.3 *European defence exports*

An analysis of the share of European exports to global defence market by sector between 1950 and 2016 (Figure 10) demonstrates that exports to non-EU countries are significant in global terms but that they display volatility over time. While the overall share of EU exports has increased incrementally, the patterns of individual weapon systems display important differences. The share of European exports in aerospace and weapons has been broadly stable at around 20% of the global defence market, while the share in the engines market has decreased dramatically from a dominant position until the 1960s to only 25% in 2016. European industry presence in the C4ISTAR global market on the other hand has been increasing steadily and currently stands at over 50%, while the share of European exports in naval and land markets has displayed large volatility over the past few decades.

Figure 10: European exports as a share of the global defence market by sector, 1950-2016



Source: Ecorys based on SIPRI data (2016)

Furthermore, the analysis of data on EU defence exports to third countries reveals that the EU defence industry remains globally competitive. According to the European Council data[29] on defence exports for 2016, the total value of EU exports to third countries was €13.4 bn (compared with €5.5 bn in 2010) with countries in the Middle East accounting for €5.4 bn or 40% of that total (compared to 32% in 2010). The second top destination - North America - accounted for 12% (down from 16% in 2010) and exports to South Asia constituted 11% of the total (down from 14% in 2010).

In recent years, sales of fighter jets (Rafale/Dassault), the Eurofighter Typhoon (Airbus/BAE Systems), and Gripen/Saab) have made a significant contribution to exports. This can be seen largely as a result of significant R&D investments and development programmes through the 1990s and early part of this century. With the advent of the Lockheed Martin F-35, future prospects for fighter jet exports from Europe are, however, challenging.

[29] European Council (2018) Nineteenth Annual Report according defining common rules governing the control of exports of military technology and equipment, (2018/C 056/01); Official Journal of the European Union

While exports are important for the European defence industry, the EDTIB still relies heavily on domestic demand (if exports of approx. €13 bn are compared to the total turnover of the European defence industry of slightly over €100 bn) with governments being the main buyers. National governments are not only important in creating demand for the defence industry but also play a critical role in facilitating exports of weapon systems to third countries by granting export licences.[30]

2.5 Policy Priorities and EU-Level Actions

2.5.1 Policy priorities focus on enhancing the competitiveness of the EDTIB through R&D and strengthening the single market

The evolution of European science and technology policy has led to ever increasing financial commitments at EU level from the first Framework Programme for Research and Technological Development (FP) programme to Horizon 2020. However, until very recently, these investments focused mainly on civilian technology innovation and development; and they excluded defence R&D[31]. In 2016, as part of the broader defence package agreed during the Bratislava summit, and in line with the Juncker Commission's identification of defence policy as a priority area of action in the political guidelines, the Commission launched the European Defence Action Plan (EDAP). The EDAP is a comprehensive defence package, aimed at enhancing the competitiveness of the European defence industry, fostering cooperation and spending defence budgets more efficiently. The EDAP has three main measures.

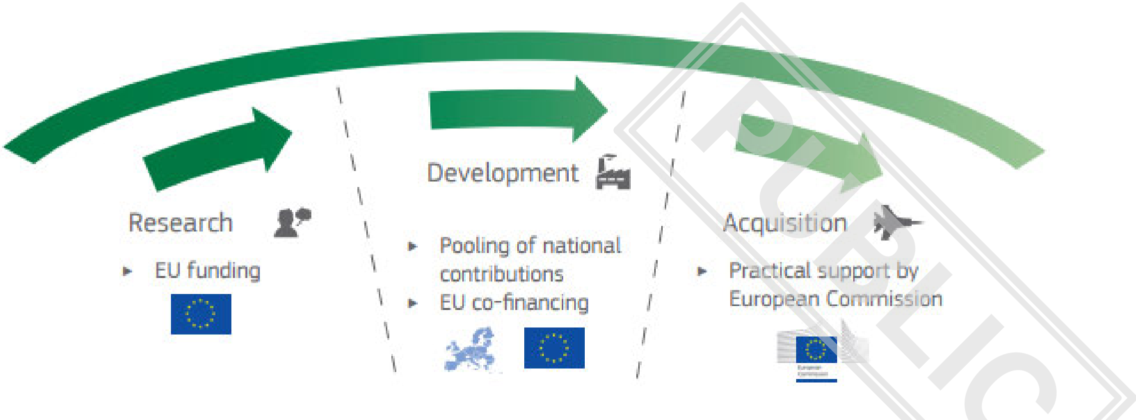
1. The establishment of a EDF to support collaborative research, development and acquisition;
2. A commitment to support SMEs throughout the defence value chain[32];
3. A proposal to strengthen the single market for defence.[33] This follows the introduction of the Defence Package in in 2007, a set of measures designed to establish a modern policy and legislative framework to improve competitiveness, introduce greater transparency and cut unnecessary red tape.

2.5.2 The European Defence Fund

The EDF was announced in 2017 in a Commission Communication. It consists of two legally-distinct financing windows. As presented in Figure 11 the research window funds collaborative defence research projects at EU level and is already under way and delivering in the form of the Preparatory Action on Defence Research (PADR). €65 m out of €90 m PADR budget has been approved and first projects, accepted in 2017, are currently being implemented. A new call for proposals was launched in April 2018.

[30] Bailes. A. and Depauw, S. (2011), The EU Defence Market: balancing effectiveness with responsibility. Flemish Peace Institute.
[31] Karampekios N. et al (2018), The Emergence of EU Defense Research Policy
[32] SMEs are the focus of a parallel study commissioned by DG GROW and consequently are only covered in passing in our study
[33] EC (2016) European Defence Action Plan, COM/2016/0950; DG GROW European Defence Industrial Policy

Figure 11: European Defence Fund: Research-Development-Acquisition



Source: European Defence Fund Factsheet

As a new element for the implementation of the EDAP, the EC published on 7 June 2017 a new proposal for the regulation on a European Defence Industrial Development Programme (EDIDP). EDIDP constitutes the development component of the EDF's capability window. The primary objective of EDIDP is to improve the competitiveness and innovative capacity of the EU defence industry. It aims to fund very diverse projects, including the definition of common technical specifications, prototyping, testing, qualification and certification of new and updated defence products. Under the proposal, the types of financial support provided through EDIDP will vary from grants and financial instruments to public procurement for projects implemented by at least three undertakings established in at least two Member States. A designated part of the overall budget will be directed at SMEs. The proposal suggests a budget of €500 m for 2019 and 2020, with a planned increase to €1 bn annually after 2020.[34]

In November 2017, a Permanent Structured Cooperation on security and defence was confirmed, with the ambition of advancing integration and defence cooperation among Member States within the EU framework.

2.5.3 Existing cooperation in defence R&D

The EU already has a range of mechanisms to move away from the current patchwork of bilateral and multilateral military cooperation to more efficient forms of defence integration.[35] Some examples of existing cooperation frameworks in defence R&D in Europe are presented below.

- **CARD - Coordinated Annual Review on Defence** announced at the end of 2016 is the mechanism designed to meet the objectives of the EU Global Strategy (EUGS). CARD aims to foster capability development addressing shortfalls, deepen defence cooperation and ensure more optimal use (including coherence), of defence spending plans. In May 2017 the Council endorsed the modalities to establish the CARD, starting with a 'trial run' involving all Member States starting in autumn 2017. This should allow Member States to test, adapt and validate the approach ahead of the first full CARD implementation in autumn 2019;
- **PESCO - Permanent Structured Cooperation** is a Treaty-based framework and process to deepen defence cooperation among EU Member States. The aim is to jointly develop defence capabilities and make them available for EU military operations. The difference between PESCO and other forms of cooperation is the binding nature of the commitments undertaken by participating Member States (participation is however voluntary and currently 25 Member States

[34] Legislative Train Schedule, EDIDP
[35] EC (2017b): A Europe that defends: Commission opens debate on moving towards a security and defence union. Press release

participate). PESCO was initiated in 2017 and in March 2018 the Council formally adopted a first set of 17 different projects and their participants as well as set out a roadmap for the further implementation of PESCO;

- **EDA - European Defence Agency** is an intergovernmental agency of the Council of the European Union. Currently, 27 countries – all EU Member States except Denmark – participate in EDA. It was established under a Joint Action of the Council of Ministers in July, 2004 as a Common Foreign and Security Policy (CFSP) body. The agency is headed by the High Representative of the Union for Foreign Affairs and Security Policy and reports to the Council of the European Union. EDA has three main missions: supporting the development of defence capabilities and military cooperation among the European Union Member States; stimulating defence Research and Technology (R&T) and strengthening the European defence industry; and acting as a military interface to EU policies;
- **OCCAR - Organisation Conjointe de Coopération en matière d'Armement** / Organisation for Joint Armament Co-operation is a European intergovernmental organisation whose primary role is to bring together Member States to facilitate and manage cooperative European Armament Programmes throughout their life cycle, as well as Technology Demonstrator Programmes. It was established in 1996 by the Defence Ministers of France, Germany, Italy and the United Kingdom. Currently, OCCAR is made up of six Member States, as Belgium and Spain joined the organisation in January 2001. However, other States (including non-EU members) can participate in OCCAR programmes without being members, as is the case for Finland, Lithuania, Luxembourg, The Netherlands, Poland, Sweden and Turkey. The main purpose of the organisation is to improve the efficiency and reduce the costs of armaments cooperation among Member States, along with strengthening the European Defence Technological and Industrial Base (EDTIB). The OCCAR Programme portfolio includes 13 armament programmes with a total operational budget in 2018 of about €3.6 bn;
- **PADR - Preparatory Action for Defence Research 2017-2019** aims at assessing and demonstrating the added-value of EU supported defence research and technology (R&T). The relevant results from PADR activities should foster further cooperation between MoDs and between EU defence industries and prepare for a basic act to launch a substantial defence research programme (European Defence Research Programme - EDRP) from 2021 onwards;
- **LOI**: the Letter of Intent (LoI) Framework Agreement (FA) is an inter-governmental treaty that was signed by the defence ministers of France, Germany, Italy, Spain, Sweden and the UK on 27 July 2000. It was intended to create the political and legal framework necessary to facilitate industrial restructuring aimed at promoting a more competitive and robust EDTIB in the global defence market. Six broad areas of intervention were identified within the LoI FA: security of supply, transfer/export procedures, security of information, research, treatment of technical information and harmonisation of military requirements. The strategic framework has evolved throughout the years to respond to the challenges posed by major changes in political, industrial and military landscape, especially the increasing globalization of the defence industrial base.

2.6 Conclusions and problem assessment

As outlined in this chapter, the key trends that threaten the future competitiveness of the EDTIB are as follows:

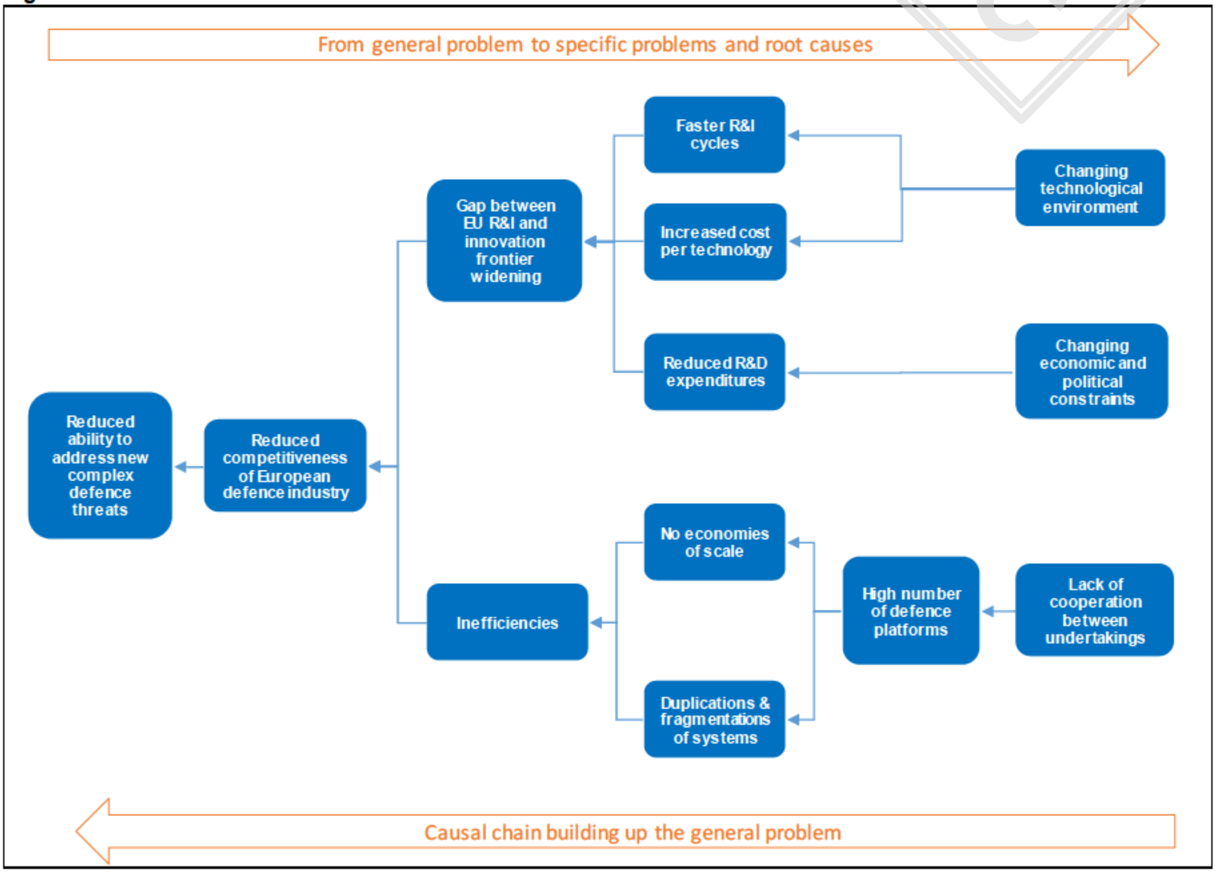
- **Stagnant defence budgets and increasing costs of defence equipment**. In real terms, defence budgets in Europe are lower in 2018 than at the start of the decade. At the same time, defence R&D spending in the US, China and other global regions continues to increase which – if no action is taken – is likely to reduce the competitiveness of the EDTIB. These trends, combined with increasing costs of defence technology means that there is an increasing gap between the EDTIB and the innovation frontier;

- **A lack of coherent demand from Member States.** Despite efforts between Member States and at the European level, military requirements are largely defined at the national level with little true harmonisation of demand. Data on collaborative equipment programmes shows that there has been no increase in cooperative spending over the past decade;
- **A high level of duplication and overcapacity on the supply side.** Linked to the second point is a fragmented EDTIB with significant duplication and overcapacity, resulting in inefficiencies and a lack of economics of scale, scope or learning at the European level.

The result of these factors is a reduced competitiveness of the EDTIB and a potential reduction in the ability of the EDTIB to meet the future defence and security needs of European Member States.

The overarching drivers, problems and potential consequences are summarised in Figure 12.

Figure 12: Problem tree



Source: Ecorys

3 Establishment of a baseline scenario

This chapter considers the baseline scenario in terms of the likely evolution of the EDTIB should the Programme not be funded. The chapter begins with an overview of the framework for the baseline scenario, followed by a strategic analysis of the EDITB (using a Strengths, Weaknesses, Opportunities, Threats - SWOT assessment), forecast defence spending, and finally a summary of multinational initiatives for collaboration. Then, it concludes with the key characteristics of the future EDTIB.

3.1 Analytical Framework

Policy option 1 represents the baseline or *status quo* scenario, defined as the "Business as Usual" option by the Better Regulation Guidelines.

3.1.1 Trends and drivers of change

In our analysis we consider the most important factors regarding the future competitiveness of the EDTIB in terms of economic, market, technological, military, political and regulatory/legal dimensions. The analysis is based on review of available qualitative and quantitative data; stakeholder interviews and workshops; extrapolation of existing trends; and the expert judgement of the study team. It begins with a high-level assessment of the current situation.

On the demand side, the key drivers of change in the period to 2025 will include:

- R&D and technology investments by Member States and existing commitments by the European Commission and other agencies: both in absolute terms and also relative to other global powers;
- Harmonisation of military requirements: whether initiated between Member States or catalysed by action at the European level;
- The global geopolitical context and the perceived threat environment for Member States;
- Major new programmes to develop/enhance new military capability.

On the supply side, the key drivers of change are as follows:

- Consolidation, mergers and acquisition activity;
- Co-operation on collaborative programmes: including partnerships and networks between private sector companies and research organisations;
- International competition for European military requirements and exports to non-EU countries.

In this chapter, we project forward the most realistic continuation of current trends out to 2025 as regards investments in defence R&D and acquisition programmes. The assumption under this scenario, is that there will be no EU financing of cooperative defence research and development beyond existing commitments to 2020.

The prospective withdrawal of the UK from the European Union in March 2019 presents a potential major strategic fork in the road for the future EDTIB. In this study – and through consultation with DG GROW – we have assumed that the UK will continue to be an active member of European defence collaboration in politico-military terms; financial contribution; and from an industrial perspective.

The context beyond 2025 is too uncertain for extrapolation of existing trends to be valid. Instead, we include four potential scenarios for the post-2025 EDTIB based on the key drivers of change. These scenarios are presented at the end of this chapter.

3.1.2 Describing the 'Baseline' policy option (policy option 1)

Under this policy option, cooperation would be limited to existing forms of cross-border cooperation: both those initiated directly by alliances of Member States and those facilitated by multinational organisations (namely EDA, OCCAR and NATO). It includes the ongoing Preparatory Action for Defence Research 2017-2019, the proposed European Defence Industrial Development Programme 2019-2020, and actions announced in the June Communication on the European Defence Fund on the financial toolbox. Also, the announced non-financial interventions under the European Defence Action Plan from November 2016 (apart from the Defence Fund) and the announced intergovernmental initiatives like CARD and PESCO are included in the Policy Option.

Under the baseline scenario (*status quo)*, EU budget support for collaborative projects would come through the PADR and the EDIDP up until 2020. While the PADR addresses the research stage, the EDIDP focuses on development. The PADR will focus on a relatively limited number of research projects, with €90 m earmarked for this purpose. The budget for the 2019-20 EDIDP will be €500 m. These programmes are intended to prepare the introduction of a European defence research programme for the post-2020 MFF and are both designed to catalyse EU cooperation. They are thus expected to spark an increase in the number of collaborative projects. Nevertheless, given their preparatory nature and limited resources, they are unlikely to completely reverse the current trends. In addition, they will both expire after 2020 without further action.

The European Commission is also expected to develop a 'financial toolbox' to incentivise collaborative development and procurement. This would provide a set of funding arrangements which could help overcome challenges often faced by cooperative projects. The introduction of such a toolbox could help synchronise national budget cycles and would contribute to fair risk and cost sharing among partners. It does not, however, mobilise additional EU funds aimed at spurring growth in collaborative projects.[36]

Besides the financing available under the PADR and the EDIDP, there are other funding mechanisms that will contribute to research projects that will have implications for the defence industry, especially in the form of dual-use technologies. Additional EU support for such innovative projects is primarily available for SMEs. There are several sectors where SMEs can contribute to the development of dual-use technologies, such as energy, aerospace, telecommunications and navigation, just to name a few. Horizon 2020 and COSME are two major programmes that can reinforce these activities. In addition, initiatives with broader objectives can also contribute to developments in the defence sector. These include the European Fund for Strategic Investments and the European Structural and Investment Funds.

[36] ASD (2017) ASD Welcomes the Launch of a European Defence Fund,; EC (2017d), Ex-ante Evaluation Accompanying the document Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the European Defence Industrial Development Programme aiming at supporting the competitiveness and innovative capacity of the EU defence industry SWD(2017) 228 final

3.2 Strategic analysis of the EDTIB

Informed by the data analysis in Chapter 2, we conducted a strategic analysis of the EDTIB using a simple SWOT (strengths, weaknesses, opportunities and threats) analysis. It is recognised that this overview masks substantial differences between segments of the overall defence sector; between countries; and between large transnational companies and SMEs. These differences mean that the practical implementation of the EDF would need to be considered for different technology areas and for these market segments. However, the summary at Table 2 – and the discussion that follows – is useful in considering the likely evolution of the sector and providing a framework for subsequent analysis. The opportunities and threats are aligned with the baseline scenario.

Table 2: SWOT analysis

STRENGTHS	WEAKNESSES
• In some sectors Europe houses some of the most advanced industrial capacity (infrastructure and knowledge); • Globally competitive players with complementary industrial strengths and competencies between European Member States; • Established R&D ecosystem within and between Member States; • Institutional, regulatory and operational frameworks required for regional cooperation are in place; • Experience of defence cross-border cooperation at industrial, political and operational levels.	• Large differences across Member States on industrial, political and operational issues (including incoherent vision for strategic autonomy and security of supply); • Flat or declining real defence spending across Europe with additional pressures on R&D spend when compared to other defence spending categories; • High level of duplication of capacities in a small number of states; • Inherent barriers, such as sovereignty, to the EDTIB structure restricting cooperation opportunities.
OPPORTUNITIES	**THREATS**
• Stronger single market for Defence across Europe leads to reduction in duplication and greater efficiencies; • Opportunities for greater synergy with civilian markets; • Forecasted flat real defence spending across Europe with relatively low proportion of R&D spend when compared with personnel etc.; • BREXIT may present a major stimulus for much greater European collaboration on defence.	• Further divergence of European states in terms of defence requirements; • More competitive and congested global market threatening future exports and increasingly demanding requests for technology transfers from 3rd parties; • Discrepancies between national interests and globally competitive EDTIB; • Potential future turbulence at European institutional level and lack of coordination between institutions and initiatives; • BREXIT leads to withdrawal of UK from joint defence R&D programmes and equipment collaboration with European partners.

Source: Ecorys analysis

Strengths of the EDTIB focus on existing capabilities and frameworks

In certain sectors, Europe has some of the most advanced defence industrial capacity, both in terms of labour and infrastructure, and hosts globally competitive companies. Moreover, there are complementary industrial strengths and competencies in EU Member States. Consequently, the current EDTIB has established a competitive position in both European and export markets across the spectrum of defence products. There are also examples of successful co-operative programmes including the Eurofighter combat aircraft, the Meteor missile system and the FREMM multi-purpose frigate. Additionally, through various waves of rapprochement over the last decades, Europe has put in place a range of institutional, regulatory and operational frameworks required for increased regional cooperation. The rationalisation and greater coordination of both industrial and equipment capacities has been acknowledged by all political actors as the only way to ensure the future of the EDTIB and European armed forces. Finally, the EDTIB has a history of successful export campaigns and major industry suppliers in certain sectors have been able to balance their portfolios with international sales and to increase their international footprints through M&As, joint ventures and development.

The EDTIB's weaknesses are linked to the differences across Member States and uncertainty around future demand levels

EU Member States are the key actors in ensuring the future of the EDTIB, but there exist large differences between them on industrial, political and operational issues. Consequently, depending on the emphasis on external operations, capability requirements vary substantially in terms of the reliance on transatlantic relations and the nature of key security threats. Similarly, the industrial strategies and market ideologies of the three main producers – France, Germany and the UK – have fundamental differences in such areas as the role played by exports, or the importance placed on sustaining national key skills. Furthermore, there is a high level of duplication of capacities in the LOI countries. Consequently, the difficulties encountered by the EDTIB are found mostly within the largest defence spenders, while the smaller spenders are mostly concerned about the future prospects for their SME networks. This presents a challenge in defining common policies and actions that are relevant to all Member States and reduces willingness to cooperate. Moreover, the dip in defence R&D investment between 2011 and 2014 will have an adverse impact on the number of new programmes commissioned, consequently affecting future competitiveness of the EDTIB. As the ultimate goal of defence equipment is to ensure national security and sovereignty, there is likely to be continued limits on the level of cooperation and information sharing required for a truly integrated and efficient EDTIB.

There are opportunities for the EDTIB presented by existing initiatives; an acknowledgement of the need to change; and increasing synergies between defence and civil R&D

The Defence Package and transposition of the legal instruments has provided the basis for a stronger single market for Defence across Europe, which should enable a reduction in duplication and greater efficiencies. Other EU initiatives (including PESCO and CARD) provide the prospect of increased policy and operational alignment. There are increasing opportunities for greater synergy with civilian sectors and markets, which result from the combination of several trends. First, changes in the strategic environment have blurred the lines between internal and external issues and, therefore, the division of responsibilities between security and defence. Second, a large proportion of the EDTIB's activities are in non-defence products – and this is likely to increase as major defence suppliers seek to diversify revenue streams and increase the resilience of the EDTIB. Third, changes in the nature of products, and the increasing importance of electronics, have helped shift a significant proportion of innovation towards civilian industries. Finally, investment in R/T&D not only ensures the development of future products but also the possibility of exports to third countries. However, the absolute target amount of European R&D is relatively small compared to other budgets and to its impact on both the defence industry and the wider economy more generally.[37] Therefore, a substantial difference to R&D can be made with a small effort in absolute terms. Finally, while the impact of Brexit could present a major threat to the EDTIB, during consultations held as part of this study[38], certain stakeholders voiced a counter-narrative that the UK exit from the EU could provide a substantial catalyst for different EU initiatives, including cooperative defence research.

[37] Oxford Economics (2009), The Economic Case for Investing in the UK Defence Industry
[38] See Annex I for a list of consulted stakeholders

Threats to the future of the EDTIB include both external trends, such as more competitive global defence markets, and internal challenges

Current trends suggest that the global defence market will become increasingly competitive and congested due to changes in demand, supply and regulatory regimes. Increased R&D spending in the US will lead to more advanced military technologies and exports from the US. Moreover, as other non-EU states seek to develop indigenous industrial capabilities, they will continue to increase defence spending and make stronger technology transfer requirements. This implies a need for European companies to remain ahead on the technology curve. It is critical to the future of the EDTIB that it can reduce overcapacity in order to increase the efficiency of the sector. The Procurement and the ICT Directives provide the tools required to normalise the defence market by providing a framework for increased competition and facilitating industry rationalisation. However, depending on the speed at which Member States and industry apply the new regulation and the extent to which the conditions for using the Article 346 Treaty for European Union (TFEU) are respected, the impact of Defence Package on rationalisation and normalisation of EDTIB may be too late. However, there are some discrepancies between national interests and a globally competitive EDTIB. For instance, the consolidation of industries at the European level encourages the creation of regional monopolies that are no longer dependent on individual domestic governments. This can have an impact on prices, as well as on the transfer of risks towards lower tiers of the supply chain. Moreover, although there are limits to the normalisation of the defence sectors and Member States will ensure they maintain sufficient control over policies and decisions, European institutions have been, and will continue to be, instrumental in providing frameworks for greater cooperation, alignment of requirements and capabilities, and forums for dialogue and negotiating. However, future turbulence at the European institutional level as well as a lack of coordination between institutions and initiatives will limit the cooperative benefit these institutions can provide. In particular, the exit of the UK from the European Union presents a major threat to future cooperation which is of real concern given the leading position that the UK (along with France) plays in the EDTIB.

3.3 Future defence spending

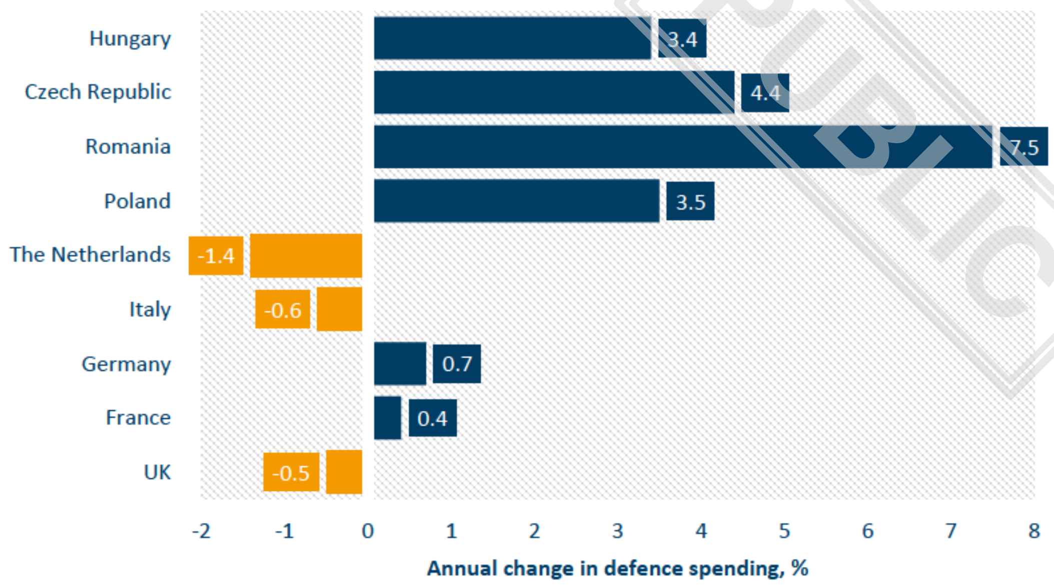
The evolution of defence budgets – particularly investment in R&D and procurement programmes – across the continent is a key determinant on both the potential for cooperation and the future competitiveness of the EDTIB.

3.3.1 Future European Defence spending is likely to increase again in the period to 2020 but only to the levels of total defence spending in 2011

As discussed in Chapter 2, there was a decrease in European defence spending in the period following the financial crises, reflecting more general austerity measures across European governments. Since 2015, there has been a return to real-terms increases in defence spending across Europe, which seems very likely to continue in the period to 2020. However, the net impact of these changes is that, in aggregate, defence spending by the end of the current decade will be broadly similar to spending at the start of the decade in 2011.

This is illustrated at the national level in Figure 13, which compares estimates of defence spending in 2020 with the spending levels of 2011. This analysis reveals a nuanced picture of the evolution of European defence spending. The report estimates that, in real terms, the UK's budget will in fact be 0.5% lower in 2020 than it was nine years before that, while it projects a real-terms growth of 0.7% and 0.4% for Germany and France over the same period, respectively. While the sharpest cut is expected in the Netherlands, the 0.6% decrease of Italian defence spending – also among the biggest budgets in Europe – will have a more pronounced impact on the overall European figure. A number of Central and Eastern European states are expected to show larger increases over the period but the relatively small defence budgets of these countries mean that these increases have only a small impact on total aggregate spending.

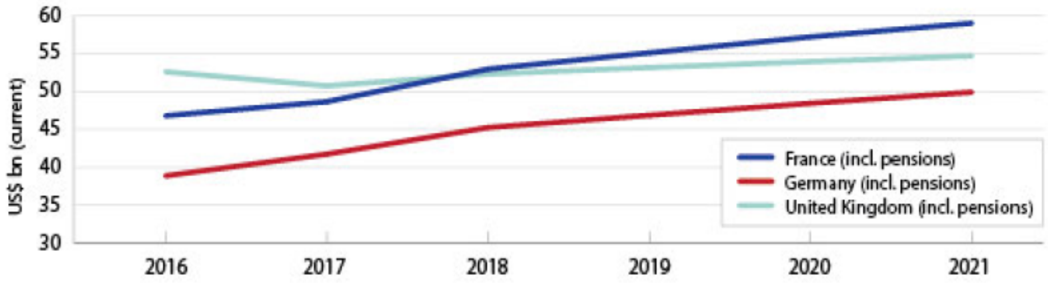
Figure 13: Percentage change in defence spending between 2011 and 2020



Source: Ecorys based on Munich Security Report 2017

This evolution is shown in more detail in Figure 14 for the three largest European defence spending countries – with France and Germany having announced significant increases in their defence budgets for the upcoming years and a modest increase in spending is also expected from the UK.

Figure 14: Spending forecasts for the top three defence spenders



Source: IISS[39]

3.3.2 *European Defence spending is expected to see small real terms increases in the period to 2026 but fall relative to total global defence spending*

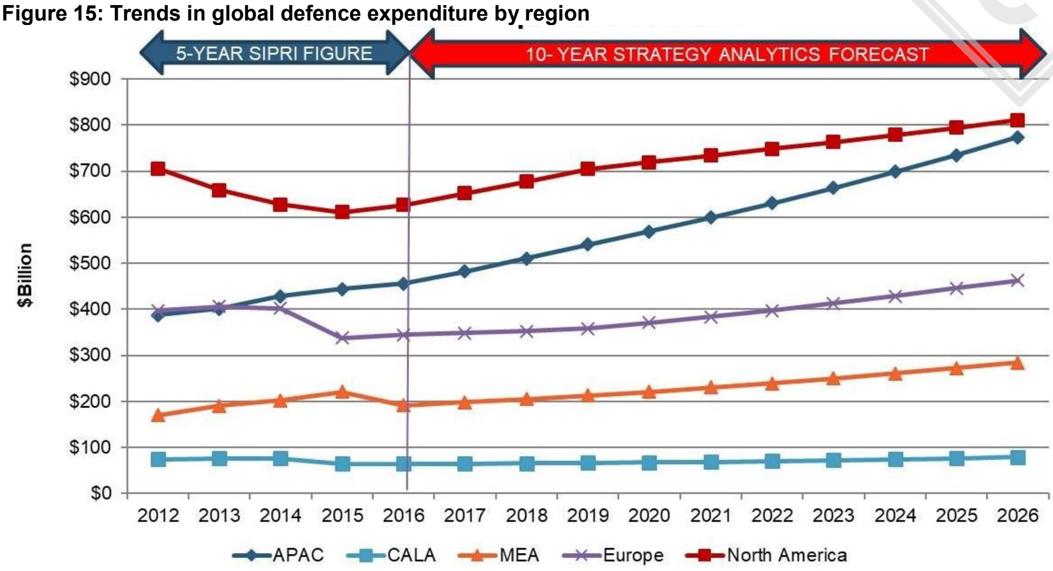
While there is some degree of certainty in defence spending over the next few years it is more challenging to forecast longer term trends with any real certainty. However, looking ahead, it now seems likely that there will be real terms increases in European defence spending in the period to 2026. This is shown in Figure 15 which projects an annual increase in European defence spending of four percent in the years from 2022.

[39] IISS (2018) European defence spending: the new consensus https://www.iiss.org/en/militarybalanceblog/blogsections/2018-f256/february-1c17/europe-defence-spending-0695 accessed on 15 April 2018

However, when considered against other global regions, the projected share of European spending relative to the total global spending is expected to fall. It is important to consider defence spending in a wider context for two reasons: first, because military capability is essentially a relative metric compared with one's adversaries; and second, because the competitiveness of the EDTIB is linked to the relative cost-effectiveness in comparison with defence technology available from Europe's allies (in particular the equipment available from US manufacturers).

Most notable is the Asia-Pacific (APAC) region which is expected to follow the strongest growth trajectory with a 5.4% yearly increase, far above both the North American and European figures. The Middle East and Africa (MEA) region also exhibits some increase, broadly in line with Europe. The Caribbean and Latin American (CALA) baseline remains low in terms of its global position but with some increase over the period.

Figure 15: Trends in global defence expenditure by region



Source: Strategy Analytics (2017)[40]

3.3.3 *Forecasted investments in defence R&D across Europe are likely to follow a similar pattern to total defence spending*

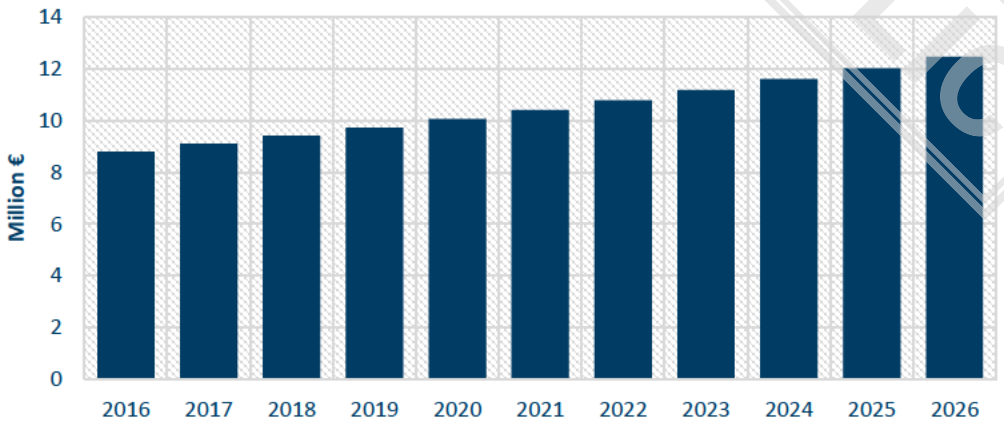
It is very challenging to obtain reliable future estimates on R&D spending across Europe. This is partly due to how different Member States categorise research spending but also due to a lack of certainty as to future investments at the national level. As noted earlier, R&D spending tends to be more variable than other categories of defence spending.

However, it is likely that overall R&D spending by Member States will follow overall defence spending. Consequently, our assessment is that there will be small real-terms increases in European defence R&D investment in the baseline scenario but that the relative share of Europe in global defence investment is likely to decrease. As competitors are increasing their defence expenditure, constant – or even slowly growing – European defence spending is unlikely to keep pace.

[40] Strategy Analytics (2017), Global Defense Spending Outlook 2016-2026

Based on an extrapolation of current R&D spending across European states using the projected increases from Figure 15, it is possible to estimate approximate future R&D spending.[41] This assumes that the share of R&D remains constant in the total defence spend. Using this approach, we estimate that total R&D spending across Europe in 2021 could amount to as much as €10.4 bn.[42] Further projections can be made according to the forecasted growth rates after 2021 of around 3.7%. Based on these assumptions, European defence R&D spending in 2026 would total somewhere in the region of €12 bn.[43] Nevertheless, in the context of total global R&D investment, the relative European share will decrease.

Figure 16: Forecast of EU R&D spending (real terms)



Source: Ecorys calculations based on Strategy Analytics and IISS projections

3.3.4 *The increasing cost of Defence technology will reduce the impact of R&D spending*

Defence specific costs have increased substantially in line with the ever-higher levels of technological complexity. While this is true for production, maintenance, repair and operation; the costs of R&D in particular have accelerated. Literature on the topic generally cites the need to develop systems capable of ever-higher performance as the main cause of this increase. This is because marginal differences in capabilities can give the upper hand against potential foes with military equipment only having value in "relative" terms, i.e. only when compared to the equipment of rivals.[44] A lack of technological advantage risks defeat against an adversary with more advanced technology and equipment. In the long run, this approach leads to an emphasis on technological superiority and spiralling R&D costs.[45] Empirical research on defence cost escalation indicates a higher level of cost escalation for technology-intensive weapon systems, most of which are produced in small quantities. Figure 17, below, shows the classification of military equipment based on their scale of production and the relative importance of having state of the art equipment.

[41] According to the first figure, the growth of defence budgets of the top three EU military spenders between 2017 and 2021 will be 3.7%. This rate is roughly 3.1% in the following figure. It is important to note that on Figure 15, the classification of the regions follows the SIPRI definitions. Therefore, "Europe" includes non-EU countries as well. Thus, Russia also forms part of these projections

[42] This projection takes the 2016 defence expenditure of EDA Member States as a basis. It uses the 4.2% average share of R&D expenditure within the overall defence budget between the years 2010-15 to estimate future R&D spending.

[43] See assumptions above

[44] Hove, K., and Lillekvelland, T. (2014), Defence investment cost escalation – A refinement of concepts and revised estimates, p.9

[45] Hove, K., and Lillekvelland, T. (2014) p. 17 and p. 26; Bellais (2017) p.97

Figure 17: Production scale and relative importance of state of the art

Production scale \ Relative importance of state of the art	Mid	High	Very high
High	Small arms		
Mid	Helicopters	Transport aircraft, infantry fighting vehicles, main battle tanks	
Low	Fast attack crafts(e.g. motor torpedo boats)	Submarines	Fighter aircraft, frigate

Source: Ecorys based on Hove and Lillekvelland (2014), p.33

Investment Cost Escalation (ICE) for defence equipment was analysed in some detailed through a meta-analysis conducted by Hove and Lillekvelland (2014)[46]. The key results from this analysis are summarised in Table 3, which presents the conclusions of seven studies conducted on the escalation of defence costs. It shows estimates of annual growth rates for specific types of defence equipment in percentage terms and reveals a substantial ICE for defence equipment, substantially higher than other measures of inflation for non-defence sectors. Importantly, as the ICE is also substantially higher than planned increases in European defence investment budgets, the implication for future military capability is a reduced purchasing power for new technologies. Analysis by the RAND Corporation identifies increasing complexity and increases in labour rates as the two most significant factors influencing the ICE of new defence systems.[47,48,49] These can be offset by larger production runs through economies of scale and in particular spreading the high R&D costs and fixed infrastructure costs across a higher number of production units.

ICE is reported to be highest in the category of fighter aircraft ranging from 7 to 11% annual cost increases. This is explored further in a study by Bellais (2017) which contains a practical example on the unit price increase of successive generations of French fighter aircraft. While unit prices of have increased exponentially, the budgetary resources available did not keep pace, resulting in diminishing purchasing power. Albeit the capabilities of newer generations are far superior to prior ones, the absolute increase in R&D costs for developing such systems risks becoming unsustainable on a purely national level.[50]

[46] This meta-amalysis is based on the following studies: Kirkpatrick and Pugh (1983), Pugh (1986), Pugh (1993), Kvalvik and Johansen (2008), Nordlund et al (2011), Davies et al (2011), Analysis conducted by Hove and Lillekvelland (2014).
[47] Arena at al (2006a) Why has the Cost of Navy Ships Risen? RAND Corporation
[48] Arena et al (2006b) Historical Cost Growth of Completed Weapon System Programs. RAND Corporation
[49] Arena et al (2008) Why has the Cost of Fixed-Wing Aircraft Risen? RAND Corporation.
[50] Bellais (2017) p.97

Table 3: Results of defence Investment Cost Escalation studies, annual growth of costs. %

	K1983	P1986	P1993	K2008	N2011	D2011	H2014
Fighter aircraft	8%	10%	11%	7%	7%	6%	7%
Infantry fighting vehicles				6%	8%		5%
Submarines		9%	9%	6%	4%	3%	5%
Fast attack craft				8%	7%		4%
Helicopters		8%	10%	5%	5%		3%
Frigates				4%		4%	2%

Source: Hove and Lillekvelland (2014)

The combination of the two trends outlined in this section implies a reduction in the number of equipment units that defence budgets can afford in the future, as these are unlikely to keep up with the increase in defence costs. The R&D spending forecasts and the estimates for the yearly increases in defence cost are also in line with this statement. Even the more optimistic figures imply that the increase of defence R&D budgets will be insufficient to keep up with the escalation in the cost of equipment. At a conservative estimate, the overall ICE across defence systems is between 5% and 7% when averaged across different systems. With a projected increase in defence R&D and equipment investment across Europe of less than 4% (using optimistic figures) there is a significant gap between the required investment to keep pace with rising costs and likely future spending.

This is especially the case for equipment with high-end capabilities, such as fighter aircraft. Consequently, collaboration on future defence technology programmes is not just desirable but essential in order to create greater economies of scale, scope and learning.

3.3.5 New export markets present potential new opportunities for suppliers, but exports are only a partial solution

Success in the global defence market plays a role in the overall health and vitality of the European defence equipment market, as exports provide revenues for further investment and can also offset fixed costs. The data presented earlier in this report shows that export of European defence equipment and services to third countries has contributed to the health of the sector. Looking ahead, the growth of markets in the Middle East, Asia and South America presents opportunities for European suppliers to offset the reductions in member state demand. This contrasts with a likely contraction in export opportunities in the US defence market for European firms, and it should be expected that the global market is expected to become increasingly competitive. As noted above, exports are typically reliant on the development of systems for domestic European customers.

3.4 Outlook for Collaboration and Cooperation on Defence programmes

Since the creation of what is now the European Union, a primary focus has been the construction of an internal market that reduces trade barriers and simplifies trading rules. In many markets there have been significant successes; however, the defence market has remained largely immune in this area, often due to quite legitimate national security and sovereignty issues. Consequently, many parts of the sector do not benefit from potential economies of scale, scope and learning that would result from a more integrated and efficient industrial base. Where consolidation has occurred – for example MBDA, EADS and Leonardo – the result has often been a more globally competitive company than its antecedents. In addition to greater efficiencies, such companies are often more financially resilient than their constituent parts would be due to a diversified product suite and customer base. The introduction of the Defence Package provides the legal instruments through which to stimulate greater efficiencies. However, even with effective and robust enforcement by the

European Commission these legal instruments are unlikely to lead to fundamental changes in this regard. Under the baseline scenario, the institutional setup will remain similar to that described in the context section above. EP (2016) concludes that these structures have produced mixed results. According to the paper, OCCAR has been relatively successful in achieving its purpose. However, the EDA currently lacks the resources and mandate to effectively address the challenges facing Europe's defence industrial capabilities outlined in the problem assessment section.

Progress on **PESCO** marks a substantial improvement for the institutional structure defining European defence cooperation. It will provide added value through coordination of national planning processes, contributing to more coherent planning at the European level. PESCO will also provide additional stimulus for member countries to invest together. **CARD** is intended to assist PESCO participants – in particular national Ministries of Defence – in the coordination process. However, CARD recommendations are implemented only on a voluntary basis. PESCO also entails a commitment to strengthening the EDTIB. Currently, there are only two initiatives under PESCO that are related to combat capabilities. More importantly, projects aimed at developing high-end capabilities, such as main battle tanks or a next generation fighter aircraft, are lacking.[51] Therefore the establishment of the EDF is crucial for the overall PESCO framework, as it is intended to complement and strengthen its work on this area. Consequently, our assessment is that in itself, PESCO and CARD will be important enablers of progress towards greater harmonisation of requirements and activity (where member state support exists already) but insufficient in and of themselves to drive fundamental change in terms of EDTIB competitiveness.

The **EDA** has benefitted from the impetus injected into European defence cooperation following the EU Global Strategy (2016). Under the Lisbon Treaty, the EDA was intended to help implement and assess compliance with PESCO commitments. Currently, it acts as the PESCO secretariat, together with the EEAS, including the EU Member States; it has a major role in the implementation of CARD (EDA is part of the secretary, gathers information and provides analyses and reports); it is working on the PADR implementation. Nevertheless, as critics point out, its track record is rather mixed. One of the main reasons for this is the intergovernmental setup of the agency, relying on consensus-based decision making. Therefore, the extent to which it will be able to drive forward EU defence research remains to be seen.

While **OCCAR** is not an EU organisation, it plays a vital role in European defence cooperation for the delivery of collaborative projects. It manages 13 projects with an overall budget of €50 bn. OCCAR's €3.6 bn operational budget in 2018 dwarfs the EDA's €6.6 m relevant expenditure[52], and it is also more than double the €1.5 bn currently intended for the post-2020 EDF. It also has strong links with the EDA. Because of this track record, the organisation would play an important role in EU capability development projects under the baseline scenario.

NATO has also some initiatives that drive collaborative projects forward. For instance, it can lead panels and working groups for defining requirements. On the other hand, it does not run procurement programmes. These are carried out under ad hoc arrangements using the NATO label, but might only consist of a limited number of participants. An example for this is NATO Eurofighter and Tornado Management Agency. [53] In addition, NATO's Smart defence initiative was launched in 2012. It aims to create value for money in European defence by incentivising synergies through economies of scale. Smart Defence is, however, focused on the integration of operational defence capabilities rather than on the input side.[54] NATO has also used OCCAR as a contracting agency for joint

[51] Pirozzi (2018) PESCO: A misunderstood tool for EU integration?; EPRS (2018) Permanent structured cooperation (PESCO): Beyond establishment,; European Council (2018) COUNCIL RECOMMENDATION concerning a roadmap for the implementation of PESCO
[52] The EDA figure is for 2017
[53] Zandee (2017) Developing European defence capabilities, Clingendael
[54] Centre for Military Studies (2013) Get it Together

procurement or support programmes, most recently on the Multinational MultiRole Transport Aircraft Fleet which will be owned by NATO. The acquisition phase and initial in-service support for this programme is being managed by OCCAR as the Contract Executing Agent for NATO, before transfer to the NATO Support and Procurement Agency for life-cycle management of the fleet, which will be operated in a pooling arrangement to provide additional tanker and transport aircraft capability for Europe.

It is likely that collaboration will continue along the lines of previous programmes: particularly where two or more of the LOI countries share a common requirement for a complex defence system. One such area is future aerospace systems (both manned and unmanned). This is well demonstrated by the fact that the largest of the three projects launched under the PADR in 2017 (OCEAN2020) mainly focuses on this area. Under the baseline scenario, with the absence of the EDF, such projects are likely to be implemented on a bilateral or multilateral basis, with the involvement of a few main actors.

3.5 Conclusions on the Baseline Scenario

The concept of sourcing defence equipment exclusively from national defence industries has long been untenable for even the largest European states. There is a huge cost in maintaining national industry architectures capable of conducting long development cycles and meeting highly specialised technical requirements, particularly when production runs are small and sporadic. In the context of European defence spending remaining under the NATO target of 2.0% of GDP, it is simply unaffordable. These financial pressures are augmented by rising costs of defence R&D and equipment; changing threat environment for European security; and a need for faster innovation and development cycles to leverage new technologies.

The following section summarises the key findings from this chapter in terms of the likely evolution of the EDTIB under the baseline scenario.

3.5.1 While European investment in defence R&D and equipment programmes will increase in the period to 2026, this will be more than offset by rising costs and global patterns

Forecasts of European defence spending indicate a small real-terms increase between 2018 and 2026, driven both by increasing prosperity and a changing geopolitical security environment. Based on a review of available projections, total spending of around €12 bn on defence R&D across Europe in 2026 appears plausible. However, the evidence suggests that these increases are unlikely to fully keep pace with the rising costs of defence R&D and defence technology; with potentially a one to three percent annual deficit between increases in R&D spending and cost increases associated with defence investment. This issue is exacerbated by the European share of global defence spending (and global defence R&D spending) declining through the period.

The implication of these three trends is that there will be further pressures on the EDTIB without major changes in terms of coherence on the demand side or substantial integration on the supply side.

3.5.2 A more efficient EDTIB and greater harmonisation of demand are key to a sustainable and competitive sector but major change seems unlikely under the baseline scenario

Recent developments, such as the NATO Smart Defence initiative and the Pooling and Sharing approach championed by EDA, highlight the importance of coordination between allied states in the provision and development of military capability. There have been some notable successes in operational issues, although significant overcapacity remains when European forces are considered as a collective whole. However, there has been more limited focus on coordination of R&D and harmonisation of demand between European nations.

The recently-launched initiatives – primarily PESCO, CARD and the financial toolbox – should help improve coherence on the demand side. Better alignment of procurement cycles and activities would enhance the effective and efficient use of available defence budgets. On the other hand, this setup does not ensure sufficient progress on R&D/T. This will prove to be particularly problematic with the PADR and the EDIDP coming to an end before the next MFF. As unit costs are expected to further increase, the current level of cooperation would only leave room for the development of a smaller number of products.

3.5.3 Under the baseline scenario, it appears most likely that the EDTIB will become less competitive in the period to 2026

Our overall assessment of the available projections – combined with the stakeholder workshop and expert interviews conducted in this study – is that the EDTIB will become progressively less competitive over the next eight-year period under the baseline scenario. There are challenges on both supply and demand sides; and while there are some positive trends (rising defence budgets and the raft of targeted EU initiatives) these will be outweighed by the global context and the structural barriers for collaboration that exist.

3.5.4 It is difficult to conceive of a positive long-term outcome (beyond 2026) for the EDTIB without some major change

Given the uncertainties around the long-term future it would be implausible to forecast a baseline scenario beyond 2026 by extrapolating forecasted trends. Rather, we consider potential outcomes based on the two critical dimensions that influence the EDTIB:

- Aggregate European spending on defence R&D and equipment programmes;
- Harmonisation of requirements and integration of EDTIB.

These are outlined in Table 4.

The most likely outcome under the baseline scenario is a significant decline in competitiveness of the EDTIB by the end of the 2020s due to declining investment (as relative total of global investment) combined with little or modest increases in harmonisation of requirements and integration of the EDTIB.

Table 4: Future Outcomes for EDTIB beyond 2026

	Low ← Degree of harmonisation/integration → High		European Defence Investment
High	***Low Integration/High Investment*** • *Increased competitiveness of EDTIB through major increases in spending from national Ministries of Defence* • *Preservation of national industries* • *Very unlikely outcome*	***High Integration/High Investment*** • *Increased competitiveness of EDTIB through major increases in spending from national Ministries of Defence* • *Increased harmonisation of requirement and integration of EDTIB* • *Very unlikely outcome*	*High*
Low	***Low Integration/Low Investment*** • *Small or no increases in defence spending* • *No real increase in harmonisation of requirements or integration of EDTIB* • *Significant decline in competitiveness of EDTIB towards end of 2020s* • *Most likely outcome under baseline scenario*	***High Integration/Low Investment*** • *Small or no increases in defence spending* • *Harmonisation of requirements and some integration of EDTIB* • *EDTIB preserved through greater efficiencies and targeted investments* • *Plausible outcome under baseline scenario stimulated in part by existing initiatives*	*Low*

Low ***Degree of harmonisation/integration*** ***High***

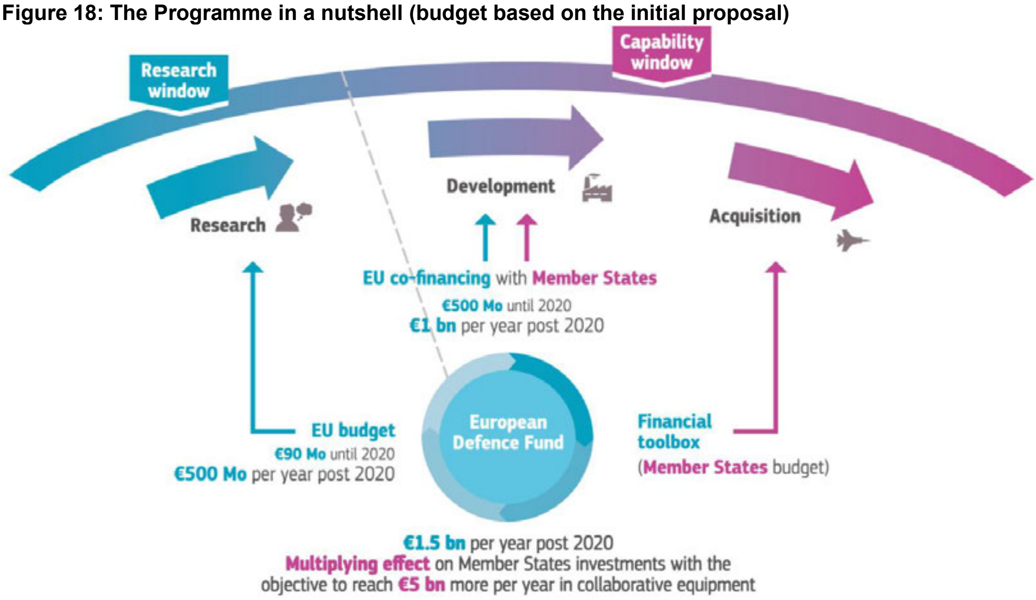
4 Policy option 2: Implementing the EDF

This chapter addresses the alternative scenario to the baseline (Policy Option 2), which is the implementation of the EDF. It first provides a description of the alternative policy option – Programme, then focuses on design considerations when implementing the Programme. An assessment of the impacts of the Programme is presented in Chapter 5.

4.1 The framework of the Programme

The alternative policy option is the implementation of the “Programme”. The Programme consists of the European Defence Fund, launched by the European Commission in June 2017, with proposed annual spending through dedicated programme(s) of €500 m for collaborative defence research and €1 bn for the collaborative development of defence capabilities for the period after 2020. An updated budget proposal indicates an increased annual spending of **€1.85 bn under this policy option (€583 m for collaborative defence research and €1226 m for the collaborative development of defence capabilities).**[55] The Programme aims to unlock further investments from the Member States and potentially reach a budget of up to €5 bn per year in collaborative equipment programme spending. The programme comprises of two complementary windows, the Research and the Capability windows, which are linked as presented in the figure below.

Figure 18: The Programme in a nutshell (budget based on the initial proposal)



Source: European Commission, COM (2017) 295 final on Launching the EDF

The **Research window** will be funded by the EU, which is expected to invest an annual budget of €500 m per year in defence research. Until 2020 the PADR will take place, for which a total budget of €90 m is dedicated (for the period 2017-2020).

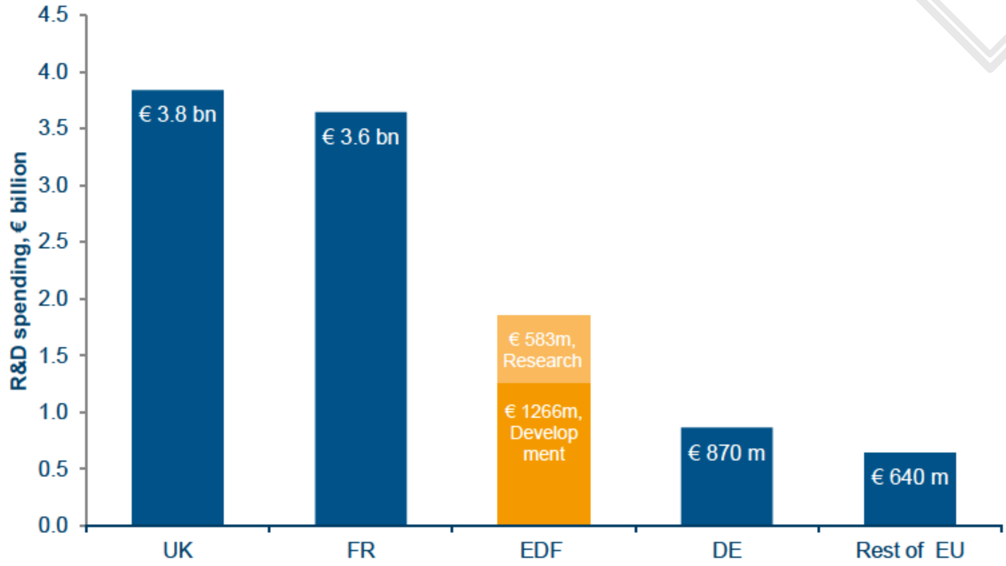
The **Capability window** supports the joint development and acquisition of defence capabilities. Taking advantage of potential outcomes from the Research window, a combination of EU and Member States’ funds will be allocated to projects under the Capability window. The EU budget of €1

[55] In the original proposal €1.5 bn were planned. According to the updated budget proposal an annual average spending of €1.85 bn will be provided.

bn per year after 2020 will aim to reduce risks in early development stages and enhancing cooperation. Before 2020, the European Defence Industrial Development Programme (EDIDP) will take place, for which a dedicated development budget of €500 m is foreseen (for the years 2019 and 2020). In addition, EDIDP is expected to unlock further investments from the Member States' budgets of at least €2.5 bn. Projects will eventually be transitioned into technologies or products acquired by the Member States.

The figure below presents the three biggest spenders for defence R&D in the EU (in 2014), as well as the foreseen average annual spending of EDF, post 2020 *(Note: a lower amount per year is expected in the first years with an increase over time)*. It highlights the relevant importance of the Programme, compared to national budgets of Member States.

Figure 19: R&D budgets 2014 (2018 prices) and EDF budget after 2020 (based on the updated EDF budget proposal)



Source: Ecorys based on EDA

The programme aims to promote cooperation, supplement and leverage Member States' funding in order to trigger change, by focusing on capability priorities defined by Member States. It requires synergies with existing programmes at national and supranational levels to ensure complementarity, as well as the commitment of the Member States for further development and acquisition of developed capabilities. Member States remain at the centre of the programme's implementation and play an essential role in setting the strategic objectives and priorities.

4.1.1 Objectives

The overarching objective of the Programme is to foster an **innovative, sustainable and competitive EDTIB** able to meet Europe's priority defence capability needs. This will ensure security of supply for critical military equipment, technology and defence material and enhance military autonomy of EU Member States; with the ultimate objective being to provide security to EU citizens.

A key element in achieving this objective is **increasing cooperative efforts among Member States** for the development of new capabilities and establishment of competitive cross-border supply chains. Increased cooperation is essential in achieving the aforementioned objective as it would:

- Reduce duplication of effort by bringing together complementary actors, hence saving resources;
- Increase efficiency by creating economies of scale through an integrated industrial base;

- Trigger more initiatives than the ones funded under the Programme, by tackling cooperation barriers or by initiating research in less explored areas (i.e. similar to the effect Galileo had in the Space industry);
- Unlock the potential to commence larger initiatives by facilitating access to a larger market size.

More specifically, the **Research window** aims to finance and contribute to **capability-driven research**. This could be done through:
- Providing additional resources for R&D;
- Research targeted at low TRL levels, which is speculative in nature and supports breakthrough research;
- Research relating to essential defence systems for uptake in short and long time horizons;
- Development of innovative EU business and research relationships and practices.

The **Capabilities window** aims to support the **development of innovative competitive technology and products**, and in cooperation with the Member States, to increase the overall value-for-money of defence acquisition (in terms of the quality of technology per Euro invested). This could be done by:
- Provision of risk financing for the early development and adoption of new technology and products and supporting EU companies reaching a critical mass;
- Fostering collaboration between companies, including SMEs, academia and other actors in the development of defence products or technologies within the EU;
- Closing the gap between research and development and fostering better exploitation of the results of defence research.

4.2 Design considerations for the Programme

Alongside the budgetary element and the aforementioned factors, the specific design considerations of the Programme are expected to have an impact on its success. This section presents a short overview of the Programme's governance structure (assuming that it will be similar to the structure until 2020) and raises the main design considerations that could affect the success of the Programme.

4.2.1 Governance structure, Portfolio approach and other design elements

Governance structure

The EDF proposal[56] already indicates a governance structure until 2020, as presented in the figure below. It also indicates that the Commission will lead the Programme, and the EDA will play a role in setting the capability priorities and harmonisation of technical requirements. The governance structure consists of the following four main blocks as presented in Figure 20.

Block 1: EU-level ambition is defined by Member States and reflected in Programme objectives (as presented in the previous section 4.1.1)

Block 2: As a consequence of the general objectives and EU-level ambition, Member States also take the lead in defining the specific capability priorities that the Programme should focus on based on their needs. For instance, in the case of PADR, priorities were set by the As-If Programme Committee for Defence Research, set up to support the Commission with the implementation of the PADR and the preparation of the Programme. This committee comprises all EU Member States as well as Norway.

[56] EC (2017e) Launching the European Defence Fund COM(2017) 295 final,

Block 3: In general, the Commission would have overall responsibility for Programme coordination. The structure differs under each of the Programme windows. Regarding the research window, the Commission will decide on the work programme after consultation with the Member States and the EDA (as an observer). Under the Capability window, again the Commission will take charge of the work programme after consulting with a Programme Committee, comprising Member States and the EDA, together with EEAS (as observers). For the project selection the Commission will engage independent experts and before adoption of cooperative projects Member States would have the opportunity to provide input into on the selected projects. A Coordination Board acts as a liaison between the previous blocks which are led by the Member States and this block led by the Commission.

However, this structure differs in practice, as manages the implementation of the annual work of the Preparatory Action in accordance with the Delegation Agreement signed on 31 May 2018.[57] Based on this agreement, the Commission delegated to EDA the implementation of the PADR. Thus, EDA is currently in charge of preparing and launching the call for proposals, organising the evaluation of the proposals, signing the grant agreements, monitoring and controlling the progress of the projects.[58]

Block 4: This last block refers to the implementation of the projects which will be performed by selected consortia. For the EDIDP and the Programme, the Commission will be in charge of the direct management. A Project Manager may be appointed by the Member States co-financing the projects. EDA, a lead nation or OCCAR can play the role of Project Managers, depending on the area of the project.

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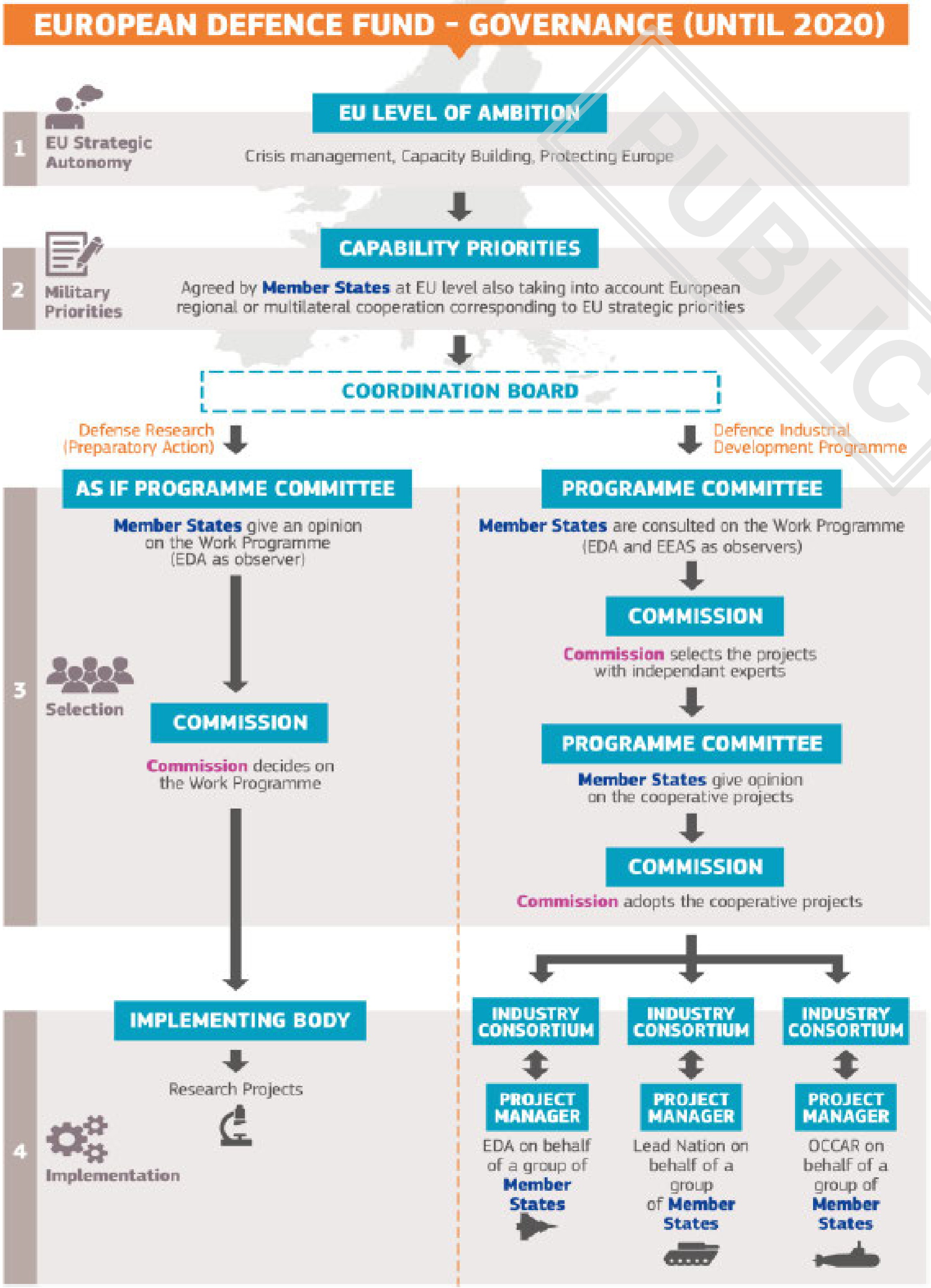
[57] EDA (2017a) Commission and EDA sign Delegation Agreement for Preparatory Action on Defence Research https://www.eda.europa.eu/info-hub/press-centre/latest-news/2017/05/31/commission-and-eda-sign-delegation-agreement-for-preparatory-action-on-defence-research accessed 15 April 2015

[58] EC (2017f) COMMISSION DECISION of 11.4.2017 on the financing of the 'Preparatory action on Defence research' and the use of unit costs for the year 2017, COM/2017/2262

Figure 20: The Programme's governance (until 2020)



Source: European Commission, COM (2017) 295 final on Launching the EDF

Portfolio approach

As mentioned above, while Member States are responsible for defining the capability priorities and ambitions, the Commission is in charge of project selection with the support of independent experts. In terms of thematic areas under the PADR proposals were invited in the following areas:

- Unmanned systems;
- Research in technology and products in the context of force protection and soldier Systems;
- Strategic technology foresight.

Other design elements

A few more elements included in the communication launching the EDF[59] provide an indication with regards to further design considerations of the Programme. Some examples are the following:

- In terms of scope the Programme aims to reach EU Member States (and Norway) and projects initially require involvement of at least three companies from at least two Member States;
- To ensure participation of different type of undertakings the Programme will reserve a specific proportion of the budget for cross-border participation of SMEs;
- Synergies with the capability pillar of PESCO are anticipated;
- A flexible Financial Toolbox is being set up to support the process of collaborative acquisition of defence capabilities. The financial toolbox will include useful information and a set of standardised and predefined financial tools. For instance:
  - EDA's Cooperative Financial Mechanism is a proposed pooling mechanism of national resources for funding collaborative projects;
  - Cost recovery mechanisms which could be set on a project basis and would include a compensation scheme from Member States that procure a capability to the Member States that funded the development of the capability;
  - Alternative ownership structures of capabilities such as joint ownership or leasing structures;
- An internal Task Force will be set-up to assist Member States on demand. For instance, it could advise on funding instruments to be used.

The EDF factsheet[60] indicates that a flexible "Financial Toolbox" including a set of standardised and predefined financial tools will be made available.

4.2.2 Considerations on the governance structure, portfolio approach

Even though it is not the purpose of this study to assess different design elements of the Programme, some key issues were identified during our analysis (based on case studies, desk research, the workshop organised by Ecorys on 20 March 2018, and expert interviews[61]). Design elements that arose during our research included, the institutional governance, administrative procedures, portfolio approach and staffing of the Programme. Some of the collected insights are summarised below.

Considerations on governance structure

To reach out to as many stakeholders as possible (e.g. all Member States, large multinational defence manufacturers, research institutes, SMEs) it was suggested that the Programme has a simple and understandable design as well as concrete strategic objectives linked with Member States needs and procurement plans. Project management in EU collaborative programmes can be challenging due to the procedures of different funding parties involved (e.g. Member States, NATO, PESCO, EDF). The Programme should go beyond adopting a simple governance structure and foresee synergies (as it is the case with PESCO) with other initiatives which would facilitate co-financing structures. The experience of Defense Advanced Research Projects Agency (DARPA) as identified through our case study supports these arguments (see Annex III). In particular, one success factor of DARPA is the flat governance structure which is designed to eliminate slow bureaucratic procedures and focus on impacts rather than processes.

The staff in charge of the execution of the Programme are another aspect of governance that was raised during the study. The Commission will need a staff increase for managing the Programme, and several stakeholders and academics agreed that the Selection Committee should consist of experts with various backgrounds, including academia and industry. The case of the European security research programme (ESRP) model where the assessors were drawn from academia,

[59] COM(2017) 295 final, Launching the European Defence Fund
[60] European Commission (2017a), "The European Defence Fund: Questions and Answers"
[61] For more information on stakeholder consultations see Annex I and on case studies see Annex III

industry and the public sector could be used as a basis. While, in principle, academics are well-suited to assess the scientific aspects of a specific research project, they lack the experience to assess its industrial potential. This may present a bottleneck given the increased industrial importance attached to the field. Additionally, the Commission may consider some collaboration structure to take advantage of existing expertise of agencies (i.e. EDA and EEAS), when necessary.

DARPA staffing approach

An insight from DARPA case study (see Annex III) is their staffing approach. Programme managers are often identified as a source of the agency's success. Apart from efficient recruitment practices in terms of identifying and recruiting appropriate experts, two more elements that have an overall positive impact on the effectiveness and efficiency of DARPA and could be relevant for the design of the Programme are:

- **The limited tenure of Programme Managers and the urgency it creates**
  Programme managers in DARPA are hired for rather short periods (4-5 years). This gives them an urgency to generate results and create impacts in that short period.
- **The level of trust and autonomy that DARPA shows to Programme Managers.**
  Programme managers are given a rather significant role in initiation of projects, selection of industry consortia and termination of programmes. This sense of ownership and the encouragement to select programmes relevant to their expertise and interest, seems to work positively for DARPA.

Considerations on the portfolio approach

The portfolio approach (referring to the approach for selection of projects for funding) is another essential factor that drives the success of the Programme. Engagement with a range of stakeholders during the study suggests that the application, selection and evaluation processes must be clear and transparent. Potential consortia should be aware of the possibilities and limitations, such as whether non-EU companies with a presence in the EU are eligible and under which conditions. This issue would have considerable impact in the Programme's portfolio, particularly in the light of Brexit.

Member states have been the main investors in R&D in Europe so far with limited coordination of national initiatives at EU level. **The Programme should be complementary to the work performed by the Member States and it should not replace or duplicate any national initiatives or funding**. It should not focus on capabilities that would be developed in the Baseline Scenario but aim at new ambitious capabilities that would not exist without the EDF.

Most stakeholders indicated that the Programme should adopt a 'portfolio approach' and include a combination of enabling technologies, thematic capability-driven research and technology demonstration (including prototypes). Many also stressed that a culture of considered risk-taking and a tolerance of failure is needed, to create the conditions for the development of game-changing technologies and products. Additionally, projects funded under the Programme should be those that require scale and that would not be possible without a Member State collaboration. In other words, the Programme should focus on those areas where the EU has added value and can deliver impacts that would be more challenging for the Member States.

Again, there are lessons that can be drawn from DARPA in this regard. The portfolio approach adopted by DARPA has been widely reported as being effective in delivering ground-breaking research that is relevant for defence technologies. A short overview of DARPA's approach is presented in the box below and a more thorough review in Annex III.

DARPA Portfolio approach

DARPA seeks to invest in **high-risk, high-impact technologies** in order to develop and promote early adoption of novel capabilities. DARPA's portfolio consists of projects that are in line with their four strategic priorities:

- Re-think complex military systems;
- Harness biology as technology;
- Expand the technological frontier;
- Master the information expansion;

and fit under the scope of its offices, which are the following:

- Biological Technologies Office;
- Defense Sciences Office;
- Information Innovation Office;
- Microsystems Technology Office;
- Strategic Technology Office;
- Tactical Technology Office.

What is unique about DARPA is that with a budget of approximately **$ 3 bn per year** (approximately €2.4 bn)[62], it has demonstrated a track record in generating or playing a role in the development of breakthrough innovations to name a few: the Internet, synthetic biology, carbon nanotubes, stealth aircraft, pilotless drones, the chipsets enabling mobile communications, stealth, night vision, laser guided weapons, nurturing the materials science and computer science communities.[63]

In terms of project selection DARPA follows a **risk-taking approach and is tolerant of failure**. This is reflected in their project selection, which may lead to rejecting projects for not being ambitious or risky enough or accept projects against the technical risk assessment's conclusions. DARPA's project evaluations do not focus only on the final outcome, but they are based on milestones, rewarding valuable work even if it is not successful. **To mitigate the costs of failed programmes, projects are only funded for a limited time** and either funds from underperforming programmes are reallocated, or performers are reassigned new work.

Considerations on other design elements

Co-ordination of administrative processes was indicated as crucial for the Programme. For instance, currently Member State procurement procedures have their own timeframes and requirements (administrative and other). National procurement cycles should align, so that collaboration among Member States would be practically feasible. National requirements should be harmonised, so that all Member States could instantly make use of the developed capabilities. Non-harmonisation could potentially block co-operation with certain Member States, due to differences in requirements (e.g. technical specifications of the final product). Some actions in this direction are already foreseen as indicated in the previous section (4.2.1). These and any additional co-ordination actions that would optimise conditions for collaboration should be taken at an early stage of the Programme.

The proportion of national budgets dedicated to defence R&D varies amongst Member States (as presented in Chapter 2), and so do the size and effectiveness of their defence industries. It is key that the Programme is effectively communicated to all different types of relevant entities (large companies, SMEs, universities etc.) from all Member States. By distributing the funding throughout the EU, more Member States are likely to benefit from its outcomes and more national initiatives may complement and leverage the Programme's investments. This is essential as less prominent players – such as SMEs or companies in eastern European Member States – could be a fresh source of creativity and innovation.

[62] Budget request for FY2019 is $3.44 bn (approximately €2.8 bn) and for FY2018 it was $3.17 bn (approximately €2.6 bn).
[63] For more, see DARPA's timeline, available at: https://www.darpa.mil/Timeline/index.html

4.2.3 *Other factors affecting the effectiveness and efficiency of the policy option*

A number of external factors may also affect the effectiveness and efficiency of the Programme. Several of these, can be used to the Programme's advantage (i.e. maximise its benefits or reduce obstacles) if addressed at an early stage. The main factors identified during the study are presented in this section.

- The defence industry is strongly linked with national security, and supranational co-operation in defence has its limits. Member states set strategic priorities and needs for capabilities which they would be willing to develop in a collaborative way. There is a risk that there will be limited willingness for collaboration for development of key capabilities. Effective promotion of the Programme and communication of its intended benefits will be important in building political will and foster further collaboration in the area to the extent it is feasible;
- Brexit is another commonly-mentioned issue, as it could limit available national funding for the development of EU capabilities. Also, it could disrupt current supply chains, for instance, by increasing the costs of key technologies or products due to customs or by limiting access. All final products based on those inputs would be affected. SMEs as well as some large companies using these inputs could be severely affected if they are unable (e.g. due to IPR) to develop these in house;
- Global developments in the defence industry could also affect the Programme's outcomes. As presented in Chapter 2, non-EU countries are investing in Defence R&D. If the EU does not succeed in developing advanced capabilities in a timely manner, Member States will rely on procuring necessary capabilities from non-EU allied countries (e.g. U.S.). This would limit the potential complementary funds to EDF. On the other hand, increased defence spending by other non-EU countries (e.g. Russia, China) may have a positive effect, boosting willingness to cooperate within EU to remain competitive in a global context.

4.2.1 *Identification and assessment of possible funding instruments*

Under the Programme the selection of appropriate specific funding modes will be performed on a case-by-case basis, based on the distinct characteristics and needs of each initiative. This subsection presents the options for different funding modes as well as the advantages and disadvantages of each.

In assessing the funding modes and instruments it is important to take stock of the particularities of the defence sector, before assessing the appropriateness of various financing tools. As flagged by industry representatives[64], the defence sector cannot be characterised as an open market where R&D efforts can be justified by commercial interests. Hence market forces fail to create sufficient demand to fund R&D in defence. Member States exercise direct control over product design and also over the sale of defence systems to third countries. Also, an advanced defence industry is linked with national autonomy and the ability of a country to provide security to its citizens.

The particularities of R&D in the defence sector is also recognised in the Defence Procurement Directive which contains several articles and clauses related to the specificities of R&D procurement and support in this sector.

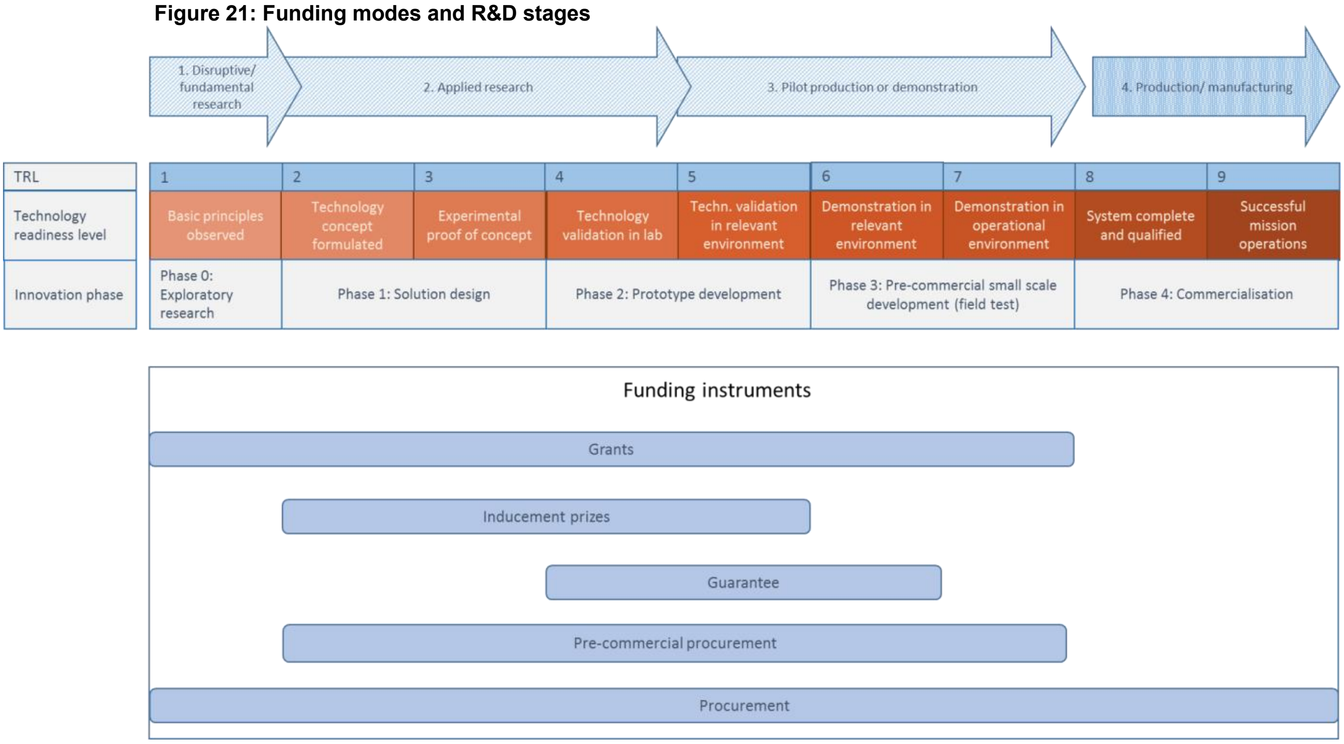
The main funding modes used in funding R&D in Europe are **grants**. In addition, other modes can be considered based on experiences in other sectors or in use in other countries. Typical additional funding modes include **inducement prizes, pre-commercial procurement (PCP)** and **procurement.** Next to these financial instruments can be considered. Whereas a number of these are of limited relevance due to the absence of regular market conditions in the defence sector (e.g.

[64] Inputs from Industry representatives at the workshop organised by Ecorys on 20 March 2018

equity or quasi-equity participations) others can be relevant. This is particularly true for the **guarantee** instrument, as also recognised by the Commission to allow greater access for defence (sub) contractors (SMEs)[65]. Such an instrument would assist SMEs in providing better access to capital in pre-commercial development stages and better enable them to bridge the phase which is often labelled the “valley of death”.

The utility of these instruments for R&D purposes is closely related to the innovation phase and the Technology Readiness Level (TRL) of the research and development activities. R&D in the sense of the Programme would normally cover TRL levels 1 to 7 which range from fundamental scientific research on basic principles of a technology to technology demonstration outside laboratory conditions . Beyond TRL 7 R&D moves towards the commercialisation and manufacturing stages of technology and product development. The TRL level can be also linked to the phases of the innovation cycle as pointed out among other things in the communication on pre-commercial procurement . As mentioned earlier, the applicability of different funding modes is related to the TRL or innovation phase in the R&D cycle. Whereas grants may be used for all R&D stages, other instruments, such as guarantees or inducement prizes have a more limited scope. This is summarised in Figure 21.

Figure 21: Funding modes and R&D stages



Source: Ecorys based on various sources

In the next sections, the different funding instruments are further explained and the pros and cons of the instrument are clarified. This includes a short section on IPR and ownership related to the instrument (see also the text box below). It should be noted that this only describes the general directions of IPR and ownership as under most funding modes IPR can be specifically arranged in the eventual agreement or conditions.

[65] See EC (2017e) and EC (2018b) Commission Recommendations (2018/624) on cross-border access for sub-supplier and SMEs in the defence sector.

Ownership and Intellectual Property Rights

R&D under the Programme's funding may lead to the creation of Intellectual Property (IP), such as patent, utility mode, industrial design, copyright, trademark and confidential information. Depending on the specific agreement the options for IPR created under EDF funding could be:

- IP owned by the EU (i.e. European Commission);
- IP owned by the Member State (s);
- IP owned by the industry consortium;
- Shared IP ownership.

Depending on the strategy the IPR framework may benefit certain parties by providing ownership of the IP to them. However, those who do not obtain the IPR may receive a (exclusive or non-exclusive) royalty-free license or the (exclusive or non-exclusive) right to exploit commercially the IPR, potentially in exchange with a royalty-free or royalty-bearing license. These cases concern the "foreground", meaning the outcomes of a project and not the "background" which refers to information and knowledge held by one of the parties before entering the Programme.[66]

The exact ownership structure is defined by the specific agreement and not so much by the financing mode even though there are general directions that can be observed from previous experiences. Hence the assessment regarding ownership structures considers if in practice certain financing modes are linked with specific IPR strategies or any other IP related issues. Apart from who gets the ownership, a few more issues may increase complexity of IPR management.[67] These include:

- Participation in the Programme should not affect ownership of the background; however, it should be ensured that the background will not hamper use of the outcome. Thus, definition of the generated IP may be a complex task in order to isolate it from background IP.
- The scope and definition of IPR may in itself be a complex task, as it is related to the value of potential market deployment. As described earlier the defence sector has numerous particularities, which makes it harder to estimate future values.
- In cross-border collaborative projects as foreseen under the Programme, an additional challenge arises when critical or restricted information needs to be disclosed. For instance, if information is shared between member state (s) and industry consortium.

Grants

Grants are direct financial contributions from the EU budget that finance an action intended to help achieve an EU policy objective or the functioning of a body which pursues an aim of general EU interest (operating grants). Grants may take the form of a reimbursement of a specific proportion of eligible costs, reimbursement on the basis of unit costs, lump sums, flat-rate financing or a combination of those. In most cases, grants take the form of co-financing where the co-financing rate is dependent on the risk level of the research. The riskier the research, the higher the co-financing rates. In many cases this is linked to the TRL level or innovation phase of the R&D where the co-financing rate is lower for higher TRL levels. The part of the costs which are not co-financed by the EU need to be financed by industry itself or needs to apply for co-financing from other sources (in particular Member State co-financing).

Grants under the EDF

Under the EDF, grants are the most common funding instrument. Under the Research window (PADR) of the EDF 100% of eligible costs for collaborative research are being supported, whereas under the Development the main objective is to support the joint development of prototypes by Member States, whereby the EU co-finances up to 20% of the budget. If projects are conceived in the framework of PESCO a 10% higher co-financing rate can be applied.

[66] European Commission, Guide to Intellectual Property Rules for FP7 projects, Version 3
[67] Ecorys (2011), Study on pre-commercial procurement in the field of Security

Grants under H2020[68]

Horizon 2020 is the main research and development programme of the EU. In the current programme a distinction is made between Research & Innovation Actions and Innovation Actions (among other actions).

Research & Innovation Actions aim "*to establish new knowledge and/or to explore the feasibility of a new or improved technology, product, process, service or solution. For this purpose, they may include basic and applied research, technology development and integration, testing and validation on a small-scale prototype in a laboratory or simulated environment. Projects may contain closely connected but limited demonstration or pilot activities aiming to show technical feasibility in a near to operational environment.*" The EU funding rate for this type of activities is 100% of eligible costs.

Innovation actions aim "*at producing plans and arrangements or designs for new, altered or improved products, processes or services. For this purpose, they may include prototyping, testing, demonstrating, piloting, large-scale product validation and market replication. Projects may include limited research and development activities.*" The funding rate is 70% (except for non-profit organisations where it may be up to 100%).

Applicable TRL level

TRL 1-7

Ownership and IPR

Whereas IPR management under the Horizon 2020 framework places emphasis on the dissemination of research results to stimulate wider innovation in the EU, the defence sector requires an alternative approach. Under the Preparatory Action, the draft grants agreement indicates that IPR is owned by the industry consortium.[69]

Pros and cons

Grants are well established R&D methods, offered through different EU, national and other programmes. Grants have been proven effective and efficient in reaching their objectives and are used under several initiatives (e.g. Horizon 2020, DARPA) including the PADR.

Demand driven character of grants

Grants are often awarded based on calls for proposals. The call for proposal text is in most cases of a more general open nature (and are much shorter), compared to requirements stated in regular procurement procedure (where the terms of reference or tender specifications have a higher level of detail). To a certain extent this was also valid for the earlier PADR call texts which cover a few pages maximum on the content of the call. The more general and open character of call for proposal texts offers a larger flexibility in the type of solutions offered and enables more parties (or consortia of parties) to respond to calls for proposals. The downside can be that there is less control on the specific output that are being created under activities for which the grants are supplied.

It should be noted that the above reflects the general practice in grants as compared to procurement but that also more detailed call texts can be developed if it this is judged to be relevant.

Grants are flexible and can cover a wide range of research and development activities. They can, for example, cover fundamental research, but also the development and prototyping of components which can be used in the development of large complex systems. In the latter case the EU has opted

[68] EC (2018b) What you need to know about Horizon 2020 calls http://ec.europa.eu/research/participants/docs/h2020-funding-guide/grants/applying-for-funding/find-a-call/what-you-need-to-know_en.htm accessed 15 April 2018
[69] EDA (2017b), PADR: Multi-Beneficiary Model Grant Agreement

to promote the pooling of resources from Member States to create more leverage, enhance cross-country collaboration and create critical mass.

Based on the stakeholder interviews and workshop conducted in this study, a particular disadvantage is the fact that application procedures can sometimes be perceived as complex and burdensome, in cases where co-financing from Member States and the EU needs to be pooled. This can be further aggravated as different procedures can be introduced and timelines might deviate. The Commission's initiative to develop a financial toolbox for EDF aims to a certain extent to reduce the administrative burden by developing standard templates and tools.

Another disadvantage mentioned by industry is that the eligible cost rule does not allow for full coverage by the industry even in case of a 100% funding rate. This is obviously more challenging in case of lower funding rates as it may not create sufficient incentive for industry participation. As also expressed in the Group of Personalities report[70] full coverage of costs can be an issue in the defence sector where normal market conditions do not apply. It is also argued to be less advantageous compared to the public funding that non-EU competitors receive from their national governments.

Inducement prizes

Inducement prizes (also known as "challenge" or "innovation" prizes) offer cash rewards (lump sum) to whomever can most effectively meet a defined challenge for a particularly difficult problem. Prizes in this sense are demand side instruments that intend to accelerate change and drive innovation by defining a specific target.[71] Inducement prizes have existed for a long time but have become more popular since the end of the last century; in particular in the US. A typical inducement prize awards a prize amount to the competitor who best reaches a certain output/or feat. The amount spent on an inducement prize is in general much more limited than the total funds allocated to grant funding (prizes normally don't go beyond several million euros), so in that sense it should be considered as an additional funding instrument.[72]

Prize challenges in DARPA

Prize challenges are a common instrument in DARPA. Since the launch of the DARPA Grand Challenges in 2004 and 2005, aiming at the development of autonomous ground vehicles in combat environments, seven additional challenges have been issued. The latest challenge is the spectrum collaboration challenge which is a "collaborative machine-learning competition to overcome scarcity in the radio frequency (RF) spectrum". The team that wins the competition can win USD 3.5 m.[73]

Prize competition "Blockchain for the Social Good"

In 2017 the European Innovation Council launched the competition on blockchain for the social good. In total five prizes are available of €1 m each. The prizes will be awarded to "*innovators that use blockchain technology to bring about positive social change, including for support of fair trade, allowing transparency in production processes, decentralising data governance and enhancing privacy, enabling accountability and contributing to financial inclusion. This prize encourages the development of scalable, efficient and effective solutions using Distributed Ledger Technology, the ground-breaking digital technology supporting decentralised methods of consensus reaching or transactions.*" The prizes are funded through the H2020 programme.[74]

[70] ISS (2016), Report of the Group of Personalities on the Preparatory action for CSDP-related research
[71] See: https://ec.europa.eu/research/horizonprize/index.cfm?pg=about
[72] Gök,A. (2013), The impact of Innovation Inducement Prizes
[73] See: https://www.darpa.mil/work-with-us/public/prizes
[74] See: https://era.gv.at/object/news/3722

Applicable TRL level

Normally inducement prices range from TRL 2-5 where the end result in most cases is a proof of concept or involves first validation of prototypes (in case of a technology).

Ownership and IPR

IPR under inducement prizes normally sits with the team that wins the challenge in the case of publicly launched prize competitions, also because rather often the own investment that is put in the outcome is significant.

Pros and cons

When successful, prizes can achieve a challenging objective with relatively low transaction costs; and potentially at a cost lower than the actual costs. In the case of the DARPA Grand challenge, it has been estimated that the prize leveraged investments by competing teams worth 50 times the value of the prize.[75] Another benefit frequently quoted in relation to prizes is that they encourage unconventional, novel approaches and only pay out for success. The downside of this approach is that only stakeholders with the access to the capital necessary to pre-finance R&D can participate; however, in other respects there are relatively low barriers to entry. Overall, prizes are less advantageous for industry consortia, as they would only be paid upon successful outcome, which means there is high risk not to get paid for R&D that has been conducted. This might also lead to low participation if the investment costs are deemed too high by potential participants.

The open nature of prizes also provides an opportunity to all stakeholders to participate without pre-selecting specific participants and does not require significant administrative costs for evaluation, selection and monitoring of projects.

Evidence on the effectiveness of prizes is limited[76] in particular related to the question if they lead to more innovation outputs. The open, experimental character of innovation that is triggered by prizes, however, is underlined in most cases. The consensus is that inducement prizes should be seen as complementary to other R&D funding modes.

Guarantee

A guarantee is part of the wider package of EU financial instruments, which are the financial support measures aiming to address specific policy objectives of the EU. Such instruments may take the form of equity or quasi-equity investments, loans or guarantees, or other risk-sharing instruments, and may, where appropriate, be combined with grants. Financial instruments are offered directly or through financial intermediaries.

Guarantees in particular are aimed to support SMEs and Midcaps who have a limited self-financing capacity to access loans. They are particularly useful in supporting them through the "Valley of Death" which is the innovation stage in which companies are not yet able to sell their technology and products to third parties and hence face liquidity issues.

A guarantee can be given to a company directly, but more often is channelled through a financial intermediary, where the guarantee functions as a safety net for the intermediary who provides loans to SMEs or MidCaps. A typical example of a guarantee for R&D purpose is presented in the text box below.

[75] Schroeder, A. (2004), The application and administration of inducement prizes in technology.
[76] Gök, A (2013) for a good overview of the fndings in literature on the impact of inducement prizes.

InnovFin – SME Guarantee Facility

Under Horizon 2020 the Commission in collaboration with European Investment Bank (EIB) has introduced InnovFin – EU Finance for Innovators. InnovFin products are intended to make more than €24 bn available in the period 2014-2020 for financing for research and innovation (R&I) by small, medium and large companies and the promoters of research infrastructures[77].

The EIB Group - through European Investment Fund (EIF) - provides the guarantee to financial intermediaries (which can be local banks or guarantee institutions) to cover potential losses incurred on their loans and leases to SMEs. The instrument builds on the earlier Risk Sharing Initiative which was in place at the time of FP7. The instrument intends to support lending to research-based and innovate SMEs and small Midcaps in the EU.

At the end of 2017, the instrument was expected to provide over €13 bn financing to SMEs, supporting over 11,000 companies.[78]

Applicable TRL level

As the Valley of Death, where companies require most pre-financing is normally associated with TRL phases 4-6 this instrument is applicable to R&D activities which cover these TRLs.

Ownership and IPR

IPR under the guarantee instrument remains with the company benefitting from the guarantee, even though financial intermediaries might in very specific cases require IPR as a collateral in case of default on the loan which are not covered by the guarantee.

Pros and cons

Experience with the use of financial instruments applied under the H2020 are positive. In the case of InnovFin under Horizon2020 a recent evaluation[79] identified that the programme is being efficiently implemented in line with expectations. However, application procedures were considered by certain intermediaries as burdensome (e.g. adaptations to banks' IT systems were required). Regarding the leverage effect of the available funding, it is judged as being on the way of reaching its objectives. Regarding effectiveness, the same programme is effectively reaching innovative enterprises and generally judged to be performing well but to a lesser extent than expected.

The main advantage is in line with earlier recommendation by the Commission, that this type of instrument can be particularly beneficial for SMEs as they can provide access to funds that would be impossible for SMEs to raise by other means. The instrument provides risk-sharing opportunities for them and might create a higher leverage as compared to direct grants. In general, the funding made available under InnovFin is expected to leverage twice the amount of financing to R&D activities.

As with inducement prizes, this instrument is seen as complementary to other means of R&D funding (in particular grants).

Pre-commercial procurement

Pre-Commercial Procurement (PCP), is a procedure for public procurement of R&D services before they enter the stage of commercialisation as outlined in the PCP communication.[80] PCPs can cover the three innovation phases from solution exploration to prototype development and prototype testing

[77] EIB (2014) EU and EIB Group join forces to support up to €48 bn in R&I investment http://www.eib.org/infocentre/press/releases/all/2014/2014-134-eu-and-eib-group-join-forces-to-support-up-to-eur48-billion-in-r-i-investment.htm accessed 15 April 2018

[78] EIF (2016), InnovFin SME Guarantee Facility http://www.eif.org/what_we_do/guarantees/single_eu_debt_instrument/innovfin-guarantee-facility/index.htm accessed 15 April 2018

[79] EC (2017c), Interim Evaluation of Horizon 2020's Financial Instruments

[80] EC (2007)

(up to TRL 7). Fundamental research is excluded from PCP. In the PCP Communication, procurement of technologies from TRL level 8 and 9 is seen as public procurement of innovative solutions. Also, this falls outside the scope of PCP. The instrument intends to develop goods and services currently not available which categorizes it as a demand side innovation policy. As such it intends to reach a higher level of innovation driven by user demands.

In PCP, the needs and requirements are defined exclusively by the procurer, as are the terms and conditions (including financing) of each specific request. Several competing consortia provide R&D services so that comparison of alternative solutions is achieved. Industry consortia are reduced after each phase.[81] As PCP is intended to be a risk-benefit sharing instrument, where risks and benefits are shared between the contracting authority and the contractor, PCP does not allow the contracting authority to bear the full costs of the procurement.[82]

Pre-Commercial Procurement under FP7, CIP and Horizon 2020[83]

Under FP7, Competitiveness and Innovation Framework Programme (CIP) and Horizon 2020 16 PCPs have been already completed and three more are ongoing at the time this report is written. IPR ownership, under the PCP scheme goes to the contractors, providing possibilities for further commercialisation. In the period 2018-2020 €124 m (1% of H2020 budget) has been allocated to PCP actions. Areas where PCP projects have been procured, include: ICT, security, energy, e-health, high performance Computing.

The Commission has already reported on impacts of these projects, these include:

- 56,2% of total value of contracts directly won by SMEs (this proportion is 29% in public procurement across EU) and participation of SMEs in 73% of contracts awarded;
- 25% of contracts awarded in consortia including universities/R&D centres;
- 36.5% of contracts won by entities located in a different country than the procurers;
- PCP achieve 50% more R&D for the same budget as R&I actions;
- All PCPs have delivered solutions fulfilling the requirements set by the procurers.

PCP in the security sector[84]

Ecorys (2011) conducted a study on the implementation of PCP in the security sector. The findings are to some extent relevant also for defence sector as the two are strongly linked and have several similarities. However, a main difference is that security technologies and products are in some cases more easily commercialised, while restrictions may exist for further commercialisation in the defence sector.

Some key findings of the study include:

- Governments that have introduced PCP are favourable to its use (even-though there's limited assessment on its efficiency, in EU only United Kingdom and the Netherlands have funded PCP security programmes until 2011);
- More evidence available under the U.S. Small Business Innovation Research (SBIR) programme (launched in 1983), shows positive results (i.e. 30-40% of the products have reached the market thanks to the programme);
- PCP is attractive in sub-sectors with high international organisation, public involvement and security awareness (i.e. maritime borders and airport security);
- PCP can be beneficial for smaller countries with few R&D structures of their own;
- Low awareness of PCP, organising multi-level cooperation and IPR management are major challenges for the adoption of PCP.

[81] Cloud for Europe (2017), Pre-Commercial Procurement for Beginners: Lessons learnt in the cloud for Europe project
[82] Rigby, J. (2013), Review of Pre-Commercial Procurement Approaches and Effects on Innovation. NESTA Working Paper 13/14
[83] EC (2015), Results from EU funded Pre-Commercial Procurements
[84] Ecorys et al. (2011)

Applicable TRL level
Related to the innovation phases, PCP is applicable to TRLs 2-7.

Ownership and IPR
IPRs are decided upfront and published in the tender documentation (available to all potential bidders). Typically, IP is owned by the industry consortium and the procurer receives a user right or a royalty-bearing licence. IPR stay with the industry as further commercialisation is typically within the objectives of PCP schemes. This is even regulated by law in the EU, as the contracting authority is not allowed to acquire the exclusive rights to the development.[85] According to Ecorys (2011), IPR management can be a challenge under PCP, however it also indicates that stakeholders in general do not feel it would constitute a barrier in their involvement.[86]

Pros and cons
PCP use is considered effective in cases that require capabilities which are technologically demanding. Specifically, when there are no near-to-the-market solutions available, suppliers are proposing alternative approaches for developing the desired output but none have been tested yet.[87] Ecorys (2011) also identifies that PCP is increasing R&D efficiency (in the field of security).[88]

The same study on PCP[89] indicates a rather positive overall impact of PCP. In detail, PCP has the potential to reduce the time a capability would reach the market by identifying and promising and feasible R&D concepts. However, a negative impact in terms of timely delivery is caused by the expression of interest and selection procedures. This may be aggravated if the PCP process is split up in multiple contracts and phasing of R&D. On the other hand, this may enable the contracting authority to reduce development risks as opposed to large deployment contract as it enables separate evaluation moments during the process.

PCP can decrease of unit prices by fostering economies of scale, increase competition in the market by providing multiple PCP contracts and also increase on returns on R&D. As it does not procure off –the-shelf products and services, PCP is sometimes seen to potentially promote SME participation in SMEs, in particular when the PCP R&D procurement process is split in different phases to enabling fine-tuning of the most promising of competing functions.[90]

Procurement
Public procurement for defence R&D is covered by the Directive 2009/81/EC. The way procurement is shaped depends on the delineation of the research and development phase that is procured. According to the Guidance note on the award of research and development contracts in the fields of defence and security, a choice has to be made either to award a contract that covers only R&D (as defined by Article 1(27) to limits R&D to performance of a new concept in a relevant environment (TRL 6), or a contract which combines R&D with other pre-production or even production activities. In case of the former pre-production or production contracts have to be awarded through separate procurement (unless excluded in the Directive for legitimate purposes).

According the same guidance note, article 13 (j) provides further exclusions of the Directive in those cases for R&D services where the benefits are not only accrued exclusively to the contracting authority, in other words where the contracting authority and the contractor share costs and/or benefits.[91] This is in principle, the same approach as in grant financing, although differences may

[85] idem
[86] Ecorys et al. (2011)
[87] European Commission, “Pre-commercial procurement & public procurement of innovative solutions”
[88] Ecorys et al. (2011)
[89] Idem
[90] Idem
[91] In the guidance note it is indicated that the term “benefits” includes “IPR and all rights to use and/or disclose foreground and (embedded) background information related to the finding of the research conducted under the contract in question.

occur. Similarly, cooperative programmes, as opposed to national programmes) are excluded from the Directive (including not only R&D but also subsequent phases of the life cycle) according to article 13 (c) of the Directive.

Procurement by the EC of R&D is uncommon, although in some cases studies can be procured by the EC, which can involve R&D activities. Procurement as opposed to grants does not need to be very different. . The key difference is that procurement offers the possibility to own IPR or the end product (assets). A grant on the other hand, in particular those commissioned by the EU, follows more closely a risk/benefit sharing approach. Becoming the sole owner of the IPR or assets is in normal situations not required by the EC (the satellite system Galileo is a clear exception to this rule). In Member Sates however, procurement is a rather often, if not most common used tool.

The below boxes present examples of procurement where R&D is linked with (pre)production.

Meteor – procurement example[92]

The Meteor Missile system is a beyond-visual-range air to air missile (BVRAAM) developed by MBDA through collaborative R&D procurement. It can equip the Eurofighter Typhoon, Dassault Rafale and Gripen. It is also compatible with other advanced fighter aircraft and will be integrated to the F-35 Lightning II Joint Strike Fighter. A collaboration managed by an International Joint Programme Office (IJPO) located at the UK's Defence Procurement Agency, included the following partners and intended cost bearings: UK (34.6%), Germany (21%), Italy (12%), France (12.4%), Spain (10%), and Sweden (10%).

In support of the project a Project Definition and Risk Reduction programme was launched in the form of pre-procurement with the funds from partner Member States. A number of issues occurred during the development phase risking the engagement of partner Member States and leading to significant delays. Nevertheless, Meteor Missile system has reached operational status and is generally considered to be a state-of-the-art system.

Eurofighter – procurement example

The Eurofighter Typhoon is a supersonic, twin-engine, multi-role aircraft originally designed as an air superiority fighter. It is a result of the collaboration of four countries, namely Germany, the UK, Italy and Spain. It is also the largest European military programme.

At the industry level, the management of the programme goes through a holding company (Eurofighter Jagdflugzeug GmbH) formed by the prime contractors of the four nations. Additional consortia were formed for development and production of the Typhoon's systems. Besides the main contractors, there are more than 400 European companies involved in building the Eurofighter.

Summarising few key findings from the Eurofighter case study (see Annex III):

- Despite, delays and cost overruns of the programme, the literature seems to agree that such a programme could not have been carried out within the same scope on a purely national level.
- Broader cooperative programmes involving several nations would need to be managed differently (e.g. prime contractor and one single customer) to be carried out effectively and efficiently.
- Delays in decision making that lead to a break in the production have an adverse effect on the learning process and can lead to additional costs and delays.
- Different national priorities and requirements hamper the Typhoon's upgrade programmes.
- The need to secure an agreement with a consortium of four countries in order to export and transfer the technology burdens the ability to further commercialise Eurofighter.

[92] See: http://www.defense-aerospace.com/articles-view/release/3/5664/five-more-partners-for-meteor-missile-program-(june-20).html & http://researchbriefings.files.parliament.uk/documents/RP03-78/RP03-78.pdf & http://www.mbda-systems.com/product/meteor/

Applicable TRL level

Procurement in theory can be applied for all TRLs but is more applicable at later TRLs.

Ownership and IPR

IPR under procurement depends strongly on how the contract is set up. If a risk-benefit sharing approach is followed, IPR can remain with the contractor but can be subject to specific restrictions and use rights by the contracting authority. When procurement is to the exclusive benefit of the contracting authority, IPR developed in a project can be transferred to the contracting authority. However, IPR can be specifically arranged in contracts governing the R&D which deviate from the above principles given the particularities of the defence sector (as long as they are in line with the procurement directive). As the need for knowledge transfer under PADR and EDIPD is limited due to the specific character of the R&D in defence, the Commission has accepted that it should not have ownership or IPR over the products or technologies that result from funded actions.

Pros and cons

Procurement is commonly used for defence R&D as the main national funding mode for several countries. Procurement is an effective instrument due to the close monitoring and client relationship with the industry consortium. In terms of efficiency it can also be considered as rather successful.

Procurement through service contracts is in theory possible to the EC, however related to funding R&D activities more commonly grant agreements are used, which enables a stronger risk and benefit sharing approach, and is also in line with how R&D activities are financed by the EC. The needs to obtain the exclusive rights to the benefit of the R&D, being IPR in case of solely R&D activities or IPR and assets in case of contracts with combine the procurement of R&D and assets (equipment), is also of limited relevance for the EC as it does not require defence capabilities of its own. This is clearly different from the situation for Member States for which this might be necessary to be able to control knowledge (and have assets at their disposition). Such procurement of R&D by the EC will almost automatically take the form of grant financing.

4.3 Comparative assessment of design considerations and concluding remarks

Based on the proposed governance structure of the EDF and in line with inputs from stakeholders there are a few issues that could be considered and potentially incorporated in EDF:

- Synergies with other defence R&D fund providers (e.g. Member States, NATO, PESCO) would help taking advantage of current initiatives' developments;
- A focus on the staffing strategy when it comes to additional personnel, independent experts and potential project managers would be key for the Programme's success. In particular, the background of experts should be diverse and some urge to generate impacts should be induced;
- Regarding the project portfolio, it would be beneficial to avoid duplications, focus on large scale projects and adopt a risk taking and tolerant to failure approach;
- Ease of access, and efficient administrative procedures surrounding EDF funding of R&D and further initiatives towards harmonisation and interoperability are beneficial in the success of a future EDF. The creation of standard templates and tools under the Financial Toolbox, are expected to further pave the path for successful cooperation;
- Any additional actions to communicate and promote the Programme to different stakeholders and facilitate their involvement could be useful.

In the design of the programme use can be made of different funding modes. A summary of the funding modes their characteristics and pros and cons is presented in Table 5, below.

Table 5: Summary of characteristics and pros and cons of funding modes[93]

Funding modes	Key characteristics	Main pros and cons
Grants	Co-financing of R&D. Funding rate depending on innovation stage and specific purpose. Can be up to 100% of eligible costs (TRL 1-7) IPR usually owned by the industry consortium	• Tested, well established R&D funding modality • Funding rates can be adjusted related to objectives/aim • Creates leverage depending on funding rate • Co-financing from other sources is required to cover costs which are not covered/eligible • Application procedures can be cumbersome, in particular of co-financing needs to be applied from other sources which follow different procedures and time scales • Requires harmonisation of programming if co-financing from EC with Member States is required
Inducement prizes	Competition model with a cash reward for the best solution. Prizes normally do not go beyond several million euros (TRL 2-5) IPR usually stays with the winning company	• Strong demand driven approach which gives much freedom for innovative solutions • Leverage in terms of own R&D resources mobilised • Own investment required may deter participation • Can invite participation beyond the "usual suspects" • Transaction costs can be low
Guarantee	Guarantee to financial intermediary that eases access to finance (loans) to SMEs and MidCaps (TRL 4-6) IPR remains the property of the company benefitting from the guarantee	• Enables access to finance SMEs and Midcaps to overcome financing issues in the "Valley of Death" phase • Creates medium scale funding leverage (factor of 2 in comparable examples) • Application procedures can be burdensome • Lower visibility of the EC
Pre-Commercial Procurement	Procurement instrument targeted at R&D procurement. Risk-benefit sharing instrument by definition (TRL 2-7) IPR typically is owned by the industry consortium and the procurer receives a user right or a royalty-bearing licence.	• Stronger demand driven approach compared with grants (stronger focus on user requirements) • Still limited experience in comparable situations • Suitable if no near-the-market solution are yet available • Can trigger stronger participation of SMEs in procurement is designed correctly • Can potentially increase the efficiency of R&D • In principle not able to fully cover the all costs of the procurement
Procurement	Procurement can be applied to specific R&D activities or R&D combined with (pre-) production activities (prototyping/ supplies of equipment).	• Demand driven approach in which user requirement are normally defined ex-ante; • Commonly used in Member States • Can be effective in triggering collaborative R&D funded from various Member States

[93] With respect to IPR, the ownership is determined in a contract and depends and thus can vary. However certain funding models tend to be characterised by certain IPR types as presented in the table.

Funding modes	Key characteristics	Main pros and cons
	IPR depends strongly on how the contract is set up. It can remain with the contractor subject to specific restrictions or be an exclusive benefit of the contracting authority.	• Less relevant for EC funding as there are challenges in EC owning defence capabilities

In practice, a programme can be composed of several windows which represent a mix between different funding modalities. The eventual mix will need to be tuned to the objectives of the programme. This is not only valid for the mix of funding instruments itself, but also of the fine-tuning of the instrument itself (e.g. regarding the funding rate, IPR arrangements and specific condition, but also the administrative procedures in applying for financial support). In addition, it may be worthwhile to keep a certain level of consistency with the way PADR and EDIDP are structured to avoid confusion among stakeholders, while at the same time taking note of early experiences with the programme in the current period and drawing lessons from this.

In general, it can be observed that most of the funding modes are complementary to one another and it is possible to create a mix of funding modes. The possible exception is the use of procurement as a funding mode which, in the specific case of the EC as a contracting authority, does not appear to offer many additional advantages compared with more common grant R&D financing, even more so if the use of PCP as an instrument is being introduced.

Finally, it should be noted that also grant schemes can be prepared in a stronger demand driven manner by introducing more specific calls for proposals with a stronger elaboration of the specific (user/output) requirement of proposals.

5 Impacts of the Programme

This chapter describes the impacts of the Programme when compared with the baseline scenario. As a starting point the assessment follows the same logic as the problem assessment since the Programme intends to address these issues. In assessing the impacts, we analyse the extent to which the Programme is able to address the identified shortcoming of the baseline, but also which unintended impacts (either positive or negative) might occur and what risks and uncertainties exist. The chapter concludes by summarizing and comparing the baseline scenario with the Programme on its key aspects.

In line with the Better Regulation Guidelines, the assessment of impacts focuses on the most ‘relevant’ impacts only. Relevant impacts can be defined as having sufficient magnitude (overall magnitude, particularly strong impact on certain stakeholders or horizontal policies for the Commission), which can thus influence the choice of policy option. These impacts can be both intended and unintended.

5.1 The logic from intervention to impacts

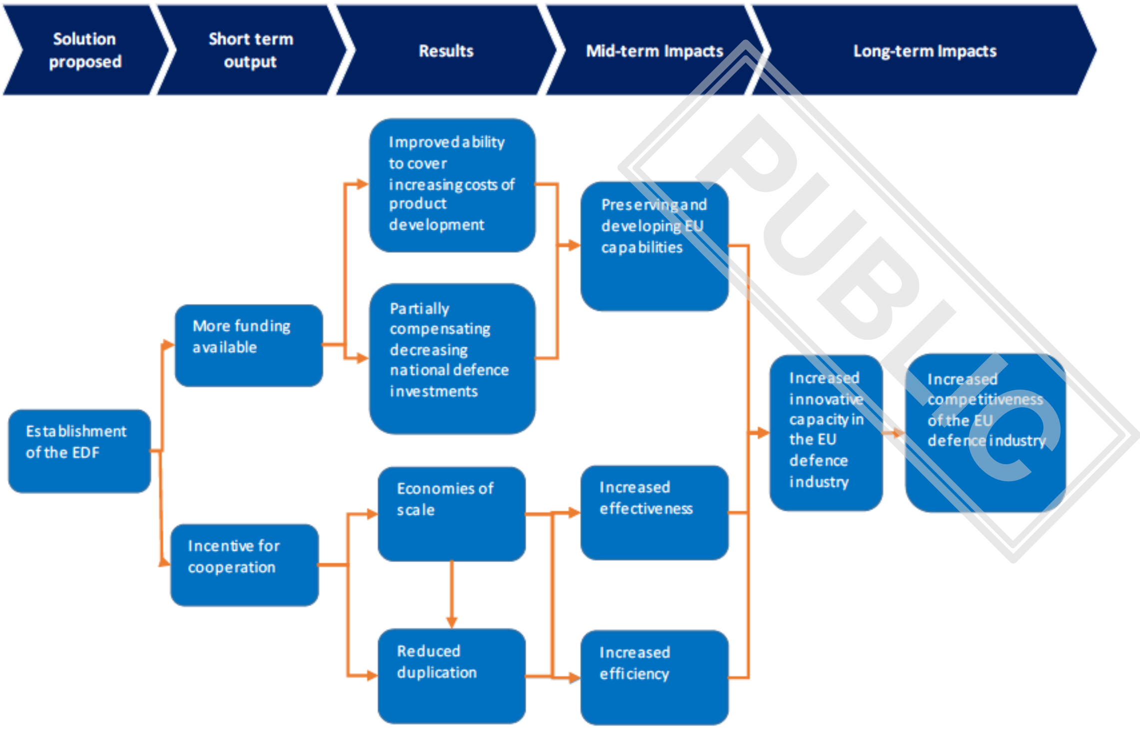
This section describes the mechanisms through which the EDF is intended to respond to the problems highlighted in previous sections, and how it is expected to achieve its objectives.

In the short term, the implementation of the Programme is expected to tackle problem drivers through two key elements:

- **Make more funding available:** The establishment of the EDF will make an increased amount of funding available in the EU in the post-2020 period. This increasing funding should better equip the EDTIB to cope with the ever-increasing unit costs of product development. Making more funding available will contribute to preserving existing industrial, technological and military capabilities and to potentially developing new ones;
- **Incentivise cooperation***:* EU funding is expected to incentivise – and be linked to – the condition of cross-border cooperation. This is expected to decrease fragmentation, create economies of scale and catalyse a further streamlining of R&D activities. As a result, it will also lead to increased effectiveness and efficiency in the use of available funding and thus, in the longer term, increase the innovative capacity of the EU defence industry in as well as its competitiveness.

The linkages between activities, outputs, and impacts of the Programme are illustrated in Figure 22.

Figure 22: Solution tree – from intervention to impacts



Source: Ecorys

Following the logic of the solution tree, the two short-term outputs will translate into four "results". These results will address problem drivers through:

- **The ability to keep up with escalating costs:** The analysis carried out as part of the baseline policy options revealed that the budgets of EU Member States are unlikely to keep pace with the rapidly escalating costs of defence equipment. By pooling resources, the EDF can help reduce the burden on individual country budgets, while also ensuring that Europe has the technological capability required to produce the most advanced defence systems;
- **Achieving better value-for-money through reducing duplication:** As a result of fragmented markets, there is a lot of duplication in the EU defence R&D base. The EDF should help reduce this duplication by incentivising cooperation. This would in turn lead to more efficiency, and better value-for money;
- **Increased economies of scale, scope and learning:** Through the reduction of duplications and the creation of a wider market for the products developed, the Programme will contribute to achieving higher economies of scale. In addition, pooling resources makes it possible to conceive more ambitious projects with a broader scope. The flow of information between participants also creates opportunities for sharing knowledge, and to develop know-how across Member States;
- **Compensating for the decreasing share of European defence spending:** Although European defence spending is forecast to increase in the near future, under the baseline scenario, it will fail to keep up with the increases in some other regions. Spending the available budgets more efficiently could compensate for this relative decline.

The medium and long-term impacts are further assessed in the sections below. A distinction is made between the economic impact related to the competitiveness of EDTIB and to the (external) security related and more strategic defence impacts.

5.2 Elaboration of the impacts

In the impact assessment, and linked to the overall aims of the programme, a distinction has been made between:

- The economic impacts resulting from the Programme; and
- The wider security related impacts.

5.2.1 *The economic impacts*

The increased spending through EDF will lead to additional funding being available and additional cooperation between MS industries. This not only allows to scale-up activities but also strengthen the value chains across Europe.

Based on the latest available feedback, the budget window for EDF financing in the post-2020 period is planned to be €1.85 bn per year for R&D of which €583 m is intended to finance research activities and €1226 m is targeted at development. If a similar approach is followed as currently in place, the Development budget of €1.48 bn will leverage up to another €5.92 bn of Member State financing (in view of a 20% EU funding rate). It is not expected that these latter funds will be additional, even though theoretically it may trigger additional funding if the new programme will enable to initiate development activities which were hard to realise previously.

The additional budget made available through EDF is significant; as for the past few years the EU Member States have spent on average between €7.5 and €9 bn per year on defence R&D. It also means that a significant part of their current R&D budgets will be matched with the EDF funding, once again illustrating the potential impact of the Programme in shaping Europe's future R&D agenda.

Additionality of R&D funding

The introduction of sizeable R&D funding through EDF may trigger a number of different funding decisions. On the one hand it may initiate additional funding in Member States if the programme makes it possible to develop activities which would not have been possible otherwise. As such it may unlock additional options building on already existing structures. On the other hand, some Member States might opt to reduce their own R&D budgets as activities are now funded through the EU. In other words, the additional EDF funding can displace some of the national funding. This risk is expected to be higher in the case of smaller Member States, which do not have large defence R&D budgets. To a certain extent this may be limited by MS wanting to fund activities for their "own" industry within the boundaries set by the Defence Procurement Directive. To which extent the above two mechanisms take place still has to be seen.

Yet another but positive aspect on the total additional funding that becomes available is that strengthening R&D programming through a collaborative approach can free up R&D finding in MS which are duplicated across MS as a result of the current fragmented R&D landscape. This would have a positive effect on the net funding available. Previous estimates from McKinsey concluded that European Member States could save around $15 (€12.9) bn per year (around 30% of total spending on new equipment) through increased collaborative defence procurement.[94]

[94] McKinsey research published in *Munich Security Report* (2017)

Macro-economic impacts

The additional R&D expenditure will create an impulse on the European economy. Apart from the positive impact on innovation, through an increased focus on R&D and a reduction of fragmentation the increased spending will lead to additional economic activities through increased expenditure and potential spill-over effects. This is expected to have a positive impact on GDP and employment. It may also trigger additional exports, even though not the prime objective of the Programme.

Several previous studies have attempted to measure the impact of defence investment on the wider economy. Relevant economic analysis generally focuses on estimating the multiplier effect of such spending, i.e. the multiple by which a certain indicator will increase as a result of a change in spending. Defence expenditure can affect several areas:

- Positive multiplier effects on GDP;
- Tax revenues;
- Employment, specifically in high-skilled jobs;
- Productivity of other types of R&D (through human capital accumulation).[95]

There is also supplementary evidence that collaborative defence projects such as Eurofighter engage a significant amount of personnel (estimated to be in the region of 65,000-100,000). Since many jobs related to defence programmes are high-skilled, defence R&D projects have a potential to contribute to the **creation of a transferable and highly skilled labour** force in EU. On the other hand, employing a sizeable part of the skilled workforce on defence projects creates the risk of displacement from other industries, thereby creating labour shortages in other parts of the economy.

In the text box below, the finding of two studies are presented that have assessed the impacts of defence expenditure on the GDP multiplier, tax revenues, number of (skilled) jobs created and export revenues. These have been used to assess the potential impact of the additional EDF spending on the European economy.

Macroeconomic impacts: a comparison of two studies[96]

The two studies compare the impact of spending on defence with spending on other sectors (education, health, and transport in case of Europe Economics study) and conclude that investing in the military sector would be comparable to the other sectors in terms of macroeconomic benefits.[97] Comparing the results of two analyses conducted on the macroeconomic impacts of defence spending provides a good illustration of how these multipliers translate into actual outputs for the wider economy. The first study covers the whole of the EU, while the second one concentrated on the UK. The table below presents the findings of the two studies in the different areas considered through the analyses:

Indicator	€100 m defence investment in the EU	£100 m (€116.5 m) defence investment in the UK
GDP multiplier	1.6	2.3[98]
Tax revenues	€42 m	£11.5 m (€13.4 m)
Jobs created	2,870	1,885
Skilled jobs created	760	283[99]
Exports revenue	€16.6 m	N/A

[95] Oxford Economics (2009); Europe Economics (2013): The Economic Case for Investing in Europe's Defence Industry Dunne and Braddon (2008) Economic Impact of Military R&D.; Eliasson G. (2017) The Swedish Military Aircraft Industry: The Development, Upgrading, Modernization, and Exporting of the Gripen Combat Aircraft

[96] The two are: Oxford Economics (2009) and Europe Economics (2013)

[97] Multipliers for other sectors compared are: Transport 1.5, Education 1.6, Health 1.6

[98] Multipliers for other sectors compared range from Water distribution (1.8) to Auxiliary transport activities (2.8). Defence represents the median multiplier of 2.3.

[99] This value is estimated based on the following data provided by the study: 39% of all defence jobs are highly-skilled and direct defence jobs created were estimated at 726.

While enlightening, the results of these studies and their extrapolation to the EDF should be taken with caution. **Institutional and infrastructural breadth and sophistication as well as absorptive capacity are required** for defence spending to generate wider positive macroeconomic effects. The spillovers to other sectors of the economy depend on the local entrepreneurial capacity to identify and commercialise them.

Moreover, the two studies considered an increased investment in the defence sector as a whole without distinguishing between different TRL levels or different sectors within the sector, which makes the extrapolation of the results more difficult as the expected benefits will vary according to different spending categories. For example, the results obtained by the Europe Economics study apply solely in the short-term, however R&D activities tend to take decades before their full impact on the economy materialises.

Nevertheless, it is clear that EDF can still **bring wider positive economic benefits** for the EU economy, particularly in Member States that have the right institutional conditions and an innovation ecosystem able to commercialise the technological developments that arise from the programme. If the numbers presented in the above table is taken as guidance, the EDF R&D investment of €1.85 bn per annum would generate an additional €1.3 bn to €3.5 bn in GDP growth through multiplier impacts and would be expected to create additional 35,000 to 60,000 jobs.

Obviously, these estimated numbers are at an aggregate level and do not yield insight in the distribution of economic impacts. On the one hand a stronger focus on collaborative research may lead to a further cross-European involvement of companies and SMEs, while on the other hand it can lead to a further strengthening and consolidation the position of dominant firms. In itself the latter does not have to be negative as also the industrial companies need to be strong enough to be competitive and secure European defence capabilities, however, care should be taken that sufficiently strong cross-European value chains are established and that access for innovative SMEs is secured. The following text box provides further considerations regarding the issue of concentration.

Concentration of benefits

A possible unintended impact of the Programme is that the design of EDF will have consequences for the distribution of benefits among Member States and among large and small firms. The results of the interviews conducted for this assignment have indicated that focusing on "European champions" – France, the UK, Germany – may lead to a disincentive for smaller Member States to invest in defence R&D. They will simply focus on purchasing off-the-shelf equipment and they might predominantly go for Government-to-Government solutions, like the US Foreign Military Sales programme. Under the EDF, the requirement for the collaborative project is that it includes at least three MS, but it has no specifications with regards to the geographical distribution of participating MS.

From certain Member States' perspective, it is easier to cooperate with non-EU countries than with European partners because of the high level of protectionism of some MS. This represents a barrier for cooperation. Participation of firms from smaller Member States is also limited by cultural and language barriers as well as by fixed cooperation patterns (within the same supply chains) and by problems with finding partners for cooperation, who are not from that respective region. Moreover, there is a risk that the EDF might be more accessible for large companies, hence disadvantaging smaller and medium sized enterprises. Young innovative SMEs may be excluded from applying for the EU level funding due to the complicated and costly procedures of such applications. However, the EDF envisions a proportion of its budget to be earmarked for projects with cross-border participation of SMEs.

On the other hand, there is a risk related to encouraging too many firms or Member States to collaborate because it can lead to poorly-managed programmes and even larger inefficiencies. Interviewees pointed out that adopting a "cohesion fund approach" with the EDF would result in a programme that would fail to meet its objectives. Instead, partners to projects should be selected on the basis of their competence (i.e. proven knowledge and experience).

The evidence so far, however, does not support the concern about concentration. Participation in currently running programmes has been broad and included many smaller MS. Within PADR, there are currently five projects being implemented with an average of seven Member States involved in each project. A total of 15 MS is presently engaged, with the Netherlands and Portugal participating in four projects, while France, Spain and Sweden are involved in three projects.

Technological spin-offs

Technological spin-offs are positive externalities, which are well documented in the literature. Military and **defence-related R&D and procurement have been major sources of technology development** across a broad spectrum of industries and contributed to a number of inventions used widely in the civilian sector (e.g. jet engines, computers, radars, nuclear power, semiconductors, the GPS and the Internet). Collaborative defence projects such as Eurofighter (see box below) have also been identified as source of technological spin-offs with a monetary value of externalities related to technology estimated at €7.2 bn (in 2004 prices, €8.9 bn in 2018 prices). Eurofighter Typhoon technology in the areas of carbon fibre technology, super plastic forming and fusion bonding, modular avionics, the flight control system and aero-engine technology has been applied in various products (Airbus and Boeing jet aircraft, Formula 1 racing cars and the motorcar industry).

Technology transmission mechanisms and the example of the Eurofighter

The case of the Eurofighter provides a good example of how technology used on the Eurofighter Typhoon spun out to the civilian economy. As Europe's largest military aircraft programme to date, the project had far-reaching economic and social impacts. It also boasts an impressive set of examples where its technology and the skills acquired during the programme have been used in other areas.

There are various mechanisms through which this knowledge was transmitted to other parts of the economy:[100]

- The first one is Typhoon staff acting as consultants for other projects. For instance, the technology acquired through the Eurofighter programme has been applied to the Formula 1 racing car industry through such consultants.
- The second one is labour turnover; whereby skilled workforce apply their knowledge in other companies/sectors. The German motor car industry benefitted from the skilled workforce that previously worked on the Typhoon.
- The third is the creation of a range of modern business practices. This includes IT, sales, management and commercial practices, among others.
- The fourth mechanism comes through cooperation with universities. MTU Aero Engines and Rolls Royce involved universities when faced with development problems related to the EJ200 engine.

On the other hand, recent **changes in civil-military technology interactions** have led to a shift in focus away from spin-offs and **towards 'spin-in' from civil to military sectors**. More and more often, producers of military equipment are turning to civilian technology, which they can adapt for military applications. This suggests that **defence technological spin-offs may be less important in the future,** thus reducing positive externalities of defence R&D. Despite playing a minor role in the

[100] Based on Hartley, K. (2006a) The industrial and economic benefits of Eurofighter Typhoon

future R&D, defence R&D will still have an important role to play as it focuses on covering gaps left by civilian R&D as well as integrating civilian and military R&D in particular projects.[101]

5.2.2 *Wider security impacts*

As discussed earlier in this report, the baseline scenario (Policy Option 1) presents major issues for the future competitiveness of the EDTIB – and hence risks further decline in strategic autonomy for European defence forces. The small real-terms increase in aggregate European defence budgets would see a relative decline in European defence spending which would be exacerbated by the decline in R&D spending in the first part of the 2010-2019 decade.

It is more difficult to forecast the impact of the Programme on wider security impacts but the increased investment in defence R&D and increased collaboration between Member States offers the potential for significant benefits to European defence and security

In the medium and long run, the impact of the Programme is expected to strengthen the competitiveness of the EU defence industry and to enhance the strategic defence autonomy of Europe. Arguably, the most important aspect of this competitiveness is **the ability of the EDTIB to meet Europe's defence needs**, as well as the military requirements of the Member States. Technological independence is a key component of strategic autonomy. Therefore, the security of supply for critical military equipment, technology and defence material is considered essential. By ensuring the competitiveness of the EU defence industry, the establishment of the EDF will contribute to the wider security objectives of the EU.

The second aspect is **the EDTIB's competitiveness vis-á-vis global competitors**. The value of defence systems can only be interpreted in relative terms, i.e. as compared to the performance of the equipment possessed by rivals. As a result, being able to keep ahead of – or at least keep pace with – potential adversaries is essential for the armed forces. The EDF is expected to strengthen the EDTIB's ability to deliver such high-end equipment for EU Member States' defence forces.

These impacts could be delivered through four core mechanisms:

1. Development of new defence technology through investment in a portfolio of innovative R&D programmes;
2. Greater harmonisation of requirements leading to greater commonality of systems and increased interoperability between European nations thus increasing the ability of European forces to fight effectively together;
3. Maintaining and developing high-end industrial competences and infrastructure that preserve European strategic autonomy in key military capabilities (including support, maintenance and upgrade of existing systems);
4. Creation of a more efficient defence enterprise across Europe that is better able to target spending on battle-winning capabilities and strategic advantage over adversaries.

However, realisation of these benefits requires careful identification, alignment and prioritisation of military capabilities and the underpinning technology.

[101] Brzoska, H. J. (2006), "Trends in Global Military and Civilian Research and Development (R&D) and Their Changing Interface."

5.2.3 Risks and uncertainties

In addition to the negative unintended impacts, there are some risks that could arise during implementation, and that might hinder the overall success of the Programme. The following table provides an overview of these potential risks and uncertainties identified. It contains a short description on what the respective issues are, with the appropriate measures proposed to mitigate them.

Table 6: Risks Overview table

Risks and uncertainties	Description	Mitigation measure
Weak content of the Programme	If the design of the project is a result of several compromises made to accommodate the needs of all partners, the content might suffer.	• Maintain a simple and clear Programme design with regards to application procedures and participation of different stakeholders.
Low willingness to cooperate	There are several issues related to cooperative projects (e.g. ownership of IPR) that might lead to lower willingness to cooperate from the part of Member States. This can lead to low uptake of the Programme.	• The potential benefits of the Programme (i.e. increased competitiveness) should be effectively communicated with the Member States; • The Financial Toolbox tools and templates are expected to facilitate cooperation and tackle potential obstacles.
Export licensing	Export licensing becomes more complicated with the involvement of several countries since approval procedures risk being lengthy. This could deter potential customers.	• Conditions on future commercialisation should be agreed upon before the contract signature.
Eligibility	The participation of non-EU controlled companies (in or outside EU territory) is uncertain. A large amount of EU defence industry could be unable to benefit from EU financing. This might create a risk for jobs as well. Condition for third country entities to participate are also unclear (i.e. how assurance that there is no threat is defined).	• Clear rules should be set on who is eligible, after consultation with stakeholders.
Brexit	The UK might not participate in future efforts to deepen defence cooperation because of the country leaving the EU. Another risk is related to the potential exclusion of British EU based companies from the programme. The exclusion/non-participation of one of the biggest military spenders and strongest defence industry in Europe would have important implications for the overall EU defence landscape.	• Design of the programme should make it sufficiently flexible to make it possible for UK industry to participate
Administrative complexity	With a higher number of participants and administrative levels, there is a risk that the process becomes overly complex. An example of this would be, having to report to two different entities (the EC and MS) while	• The distribution of standard templates and tools under the Financial Toolbox, are expected to improve conditions for potential collaboration;

Risks and uncertainties	Description	Mitigation measure
	dealing with a large consortium. This might in turn lead to higher costs and might also deter countries from further cooperation.	• The Programme's planning should be aligned to the extent possible with national procurement procedures and other international initiatives in the area; • EDF Project managers' can providing support and facilitating participation in the Programme.
Lack of risk sharing and tolerant to failure approach	In general more limited R&D budgets in Europe tend to favour more secure approaches (in comparison to the US) rather than highly risky ones which have a higher risk of failure. In addition, partial financing of R&D may trigger companies to reduce the risk of failure in their R&D projects and op for less risky, disruptive initiatives. approaches	• A proportion of the overall budget could be reserved for more ambitious and risky projects. To mitigate for potential losses, these projects could be funded for shorter duration and be evaluated on a milestones approach. In addition the funding level could be reconsidered for this window.
Uncertain and long-term benefits	Companies participate in R&D programmes as an investment for entering in a new technology area that may create new capabilities or anticipating that future initiatives in the same area will be launched. While the benefits are foreseen in a long-term period, losses may occur short-term.	• Financing models should be selected on a case-by-case basis, in line with appropriateness for the TRL level of each project.

5.3 Comparison of options

The below table summarises the main impacts related to the baseline (policy option 1) and the introduction of the EDF for the post-2020 period.

Table 7: Indicative Impact overview table

Impacts	Policy option 1 Baseline	Policy option 2 EDF programme	Remarks to option 2
Economic and innovative impacts			
R&D expenditure	Approximately €9 bn annual spend. Limited increase year on year.	Increase of up to 21% in comparison to baseline	• Maximally €1.85 bn additional funding. The net effect can be lower in case national defence R&D funding is displaced; • The possible reduction of R&D overlaps (analogue to the McKinsey study this could be up to 30%) could be reduced enhancing the net effect of the collaborative funding by freeing up resources.

Impacts	Policy option 1 Baseline	Policy option 2 EDF programme	Remarks to option 2
R&D collaboration in defence	Limited increase	Strong increase	• This build on the existing tendency in the baseline for more cooperation. EDF is a strong incentive to raise the cooperation level.
Competitiveness of the EDTIB	Relative decrease in a global context & absolute decrease	Positive contribution with possible multiplying effects	• EDF provides an impulse for further integration of the EU value chains & creation of economies of scale. This is expected to enhance the level of innovation and accelerate cross Europe consolidation.
Innovation, quality and variety of technologies developed	Under pressure	Expected positive effect	• EDF can enable to reduce pressure due to limited funding available at a national level and strive for higher innovation and more disruptive technologies
Impacts on SMEs	Unclear	Potential positive effect	• Incentives for SMEs to be included in consortia can be built in R&D funding procedures; • In general there is more funding available, also for SMEs.
Wider economic impacts			
Multiplier effects on GDP	Additional multiplier impacts on GDP of €5.4 bn - €12.7 bn	Additional multiplier impacts on GDP €1.1 bn - €3.0 bn per year (compared to the baseline)	• The size of the multiplier depends on e.g. existing infrastructure, institutions, and innovation ecosystem, Geographically the multiplier might be more diverse. Potential displacement impacts might also be relevant to indirect economic impacts.
Tax income	Currently €1 bn – €3.8 bn	An additional €0.2 bn – €0.7 bn compared to the baseline	• Directly linked to the enhanced direct and indirect additional turnover created.
Technological externalities/spill overs in civil sector	Spill overs (potentially less important overtime)	More spill overs	• A stronger focus on innovative research has higher likelihood of spillovers.
Social impacts			
Number of persons employed (direct and indirect)	145-260 thousand	210 - 370 thousand	• Approximately 65-110 thousand additional jobs in R&D (however possible displacement impact).
Quality of employment/skills	Sustaining high skilled jobs	Additional high skilled jobs	• More research, will have a positive impact on the creation for high skilled jobs. Where the

Impacts	Policy option 1 Baseline	Policy option 2 EDF programme	Remarks to option 2
			labour market for high skilled jobs is tight this might create a certain level of competition with other sectors.
Wider security impacts			
Quality of defence products and technologies	Small relative decrease	Increased potential for new innovation and battle-winning technologies	• Allows to remain competitive and state of the art.
Duplication of costs of equipment	Small positive change expected due to PESCO, CARD and EDA initiatives	Greater collaboration leading to greater commonality of systems	• The impacts will only be achieved in the medium- to long-term.
Level of interoperability	Small positive change expected due to PESCO, CARD and EDA initiatives	Greater collaboration leading to greater commonality of systems	• The impacts will only be achieved in the medium- to long-term.
Strategic autonomy	Reduction in strategic autonomy	Sustainment and development of key systems	• Would require focused efforts on key battle-winning technologies.

By making €1.85 bn available for defence R&D (24% increase on current EU R&D expenditure) and incentivising cooperation, the Programme is expected to leverage up to another €5.8 bn through member state financing of collaborative equipment investment. The additional collaborative funding would induce faster cross Europe integration of the EDTIB, create economies of scale, and thus enhance competitiveness of EU industry. It is also expected to achieve higher levels of innovation, with the potential of unique breakthrough innovations, which is essential in a globally competitive global environment with rising costs and new entrants in the market.

In order to exploit the full potential of the Programme several risks need to be effectively tackled. The main risks that could affect the Programme are linked with the motivation of Member States and stakeholders to participate, design considerations of the programme and external factors. It will be key that effective mitigation measures are taken to ensure that these risks do not adversely affect the Programme and reduce the impacts that are realised.

In economic terms the Programme is expected to generate additional multiplier impacts on GDP of €1.3 bn to €3.5 bn per year, on tax, of €0.3 bn to €0.9 bn as well as on employment by creating approximately 35,000 – 60,000 (direct & indirect) additional jobs in research and in particular high-skilled jobs. Technological spinoffs may be born through the implementation of the Programme and spill overs from defence R&D may positively impact a number of civilian sectors and activities (e.g. health, transport, ICT etc.).

There are significant potential benefits in terms of European defence capabilities and strategic autonomy to deploy military force. The medium and longer-term impact of the Programme are to develop battle-winning technologies and ensure Member States can act (in concert with other allies) to ensure regional security and secure global interests. If the Programme is successful, there is significant opportunity to increase the commonality of systems and interoperability between European forces making joint deployment of forces on CSDP missions more effective.

ANNEX I – List of consulted stakeholders

Name	Company/entity
Workshop participants	
[redacted]	Saab group
[redacted]	Safran EU & Multilateral Affairs
[redacted]	MAXAM Defence Expal Systems, S.A
[redacted]	INDRA
[redacted]	Head of MBDA Brussels Office
[redacted]	Leonadro Spa
[redacted]	Borchert Consulting & Research AG
[redacted]	Naval Group
[redacted]	Airbus Defence & Space
[redacted]	Defence and Security to the EU - BDI/BDSV
[redacted]	Naval Group
[redacted]	Airbus Brussels
[redacted]	Airbus Defence and Space GmbH
Interviewees	
[redacted]	ASD - Aeronautics, Space, Defence and Security Industries in Europe
[redacted]	Fraunhofer INT, Germany
[redacted]	RAND Europe
[redacted]	Polish Development Fund Group
[redacted]	York University
[redacted]	Fraunhofer Ernst-Mach-Institut
[redacted]	Fundacja im. Kazimierza Pulaskiego
[redacted]	ASW and Austrian Industrial Cooperation & Aviation Technology - AICAT
[redacted]	PKR Solutions
[redacted]	NIDV (Dutch Industry for Defence and Security)
[redacted]	BAE Systems

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ANNEX III – Case Studies

1. Eurofighter

Description

The Eurofighter Typhoon is a supersonic, twin-engine, multi-role aircraft originally designed as an air superiority fighter. It is a result of the collaboration of four countries, namely Germany, the UK, Italy and Spain. It is also the largest European military programme.

At the industry level, the management of the programme goes through a holding company (Eurofighter Jagdflugzeug GmbH) formed by the prime contractors of the four nations. These are BAE Systems for the UK (final assembly at Warton), Airbus Group (formerly EADS) for Germany (final assembly at Manching), Airbus Group for Spain (with final assembly at Getafe) and Leonardo (formerly Finmeccanica) for Italy (final assembly at Turin). In addition, EUROJET (owned by Rolls-Royce of the UK, MTU Aero Engines of Germany, Avio of Italy and ITP of Spain) manufactures the Eurofighter's EJ200 engine system.[102] Additional consortia were formed for development and production of the Typhoon's systems. Besides the main contractors, there are more than 400 European companies involved in building the Eurofighter.

The share of production was originally allocated according to the number of aircraft ordered, thus creating a link between production and demand. These have changed quite considerably as the participating countries have progressively decreased the number of Typhoons to be purchased. The UK and Germany have a 33% share, while Italy and Spain have 21% and 13%, respectively. It was agreed that each of the parent nations would host the production line and final assembly for the components of the aircraft it was responsible for. Thus, for instance, Leonardo produces the left wing, outboard flaperons, rear fuselage sections, while BAE produces the front fuselage, canopy, dorsal spine etc.

In addition to the 472 Typhoons ordered by the participating countries, contracts for 151 Eurofighters with Austria (15), Saudi Arabia (72), Qatar (24), Kuwait (28) and Oman (12) were signed, bringing the total number of Eurofighters to be manufactured to 623.

The Eurofighter development process was plagued by delays, cost overruns and has been accused of mismanagement and inefficiency. The German Federal Court of Auditors in 2014 found that while in 1997, the Bundeswehr planned to purchase 180 Eurofighters for about 11.8 bn euros, the intended funds would be almost completely exhausted with the purchase of only 140 aircraft. It also estimated that the lifetime costs of The Typhoon has doubled from the original €30 bn.[103] The report of the National Audit Office of the UK from 2011 came to similar conclusions.[104] It has revealed that the development costs of the Typhoon have doubled from the originally approved sum to as high as £6.7 bn (€7.85 bn). While the production cost of Typhoon at £13.5 bn (€17.93 bn)[105] is within the limit set in 1996, this is because the UK purchased 30% (or 72) fewer aircraft than planned (from 232 to 160). According to the report, taking into account the development and production costs, the unit cost of each aircraft ordered has risen by 75 per cent. On the other hand, these costs are generally in line with comparable types of aircraft. The National Audit Office therefore concludes that the increase in

[102] Heinrich, M.N (2015) The Eurofighter Typhoon programme: economic and industrial implications of collaborative defence manufacturing
[103] Bundesministerium der Verteidigung (2014) Kostentransparenz beim EUROFIGHTER herstellen
[104] NAO (2011) Management of the Typhoon Project
[105] 2011 and 1996 conversion rates were applied for the sums in EUR, respectively

costs is mostly due to unrealistic cost assumptions made at the project start. One study estimates the total cost of development of Typhoon to be €22.19 bn (or €18 bn in 2004 Euros).[106]

Decisions were to be made with the consensus of all participating nations. The timescale for making such decisions was set at 40 days. Nevertheless, this turned out to be very difficult to meet, leading to delays. R&D on the Typhoon took 18 years from start to first service delivery. Nevertheless, this work will continue throughout the life-cycle of the aircraft to develop further capabilities.

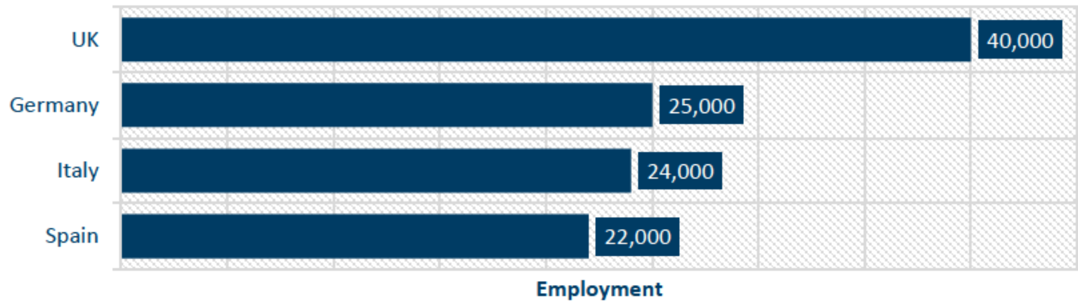
Impacts

Literature on the Eurofighter programme generally agrees that it could not have been implemented on a national level within the same scope. In addition, sources highlight the programme's overall contribution to maintain the strategic and technological independence of the continent, and its contribution to the European defence industrial base.[107]

Somewhat surprisingly, there is very limited information available on the economic impacts of the Eurofighter. Nevertheless, the existing sources agree that it is the largest European military programme with a significant impact on the economy. For instance, it employs a large number of high-skilled workers and provides work for over 400 companies across Europe.[108]

According to Eurofighter estimates[109], employment in the programme is above 100,000, spread across the four parent countries (for a breakdown, see figure below). However, these estimates cannot be verified as the underlying assumptions are unknown. A 2006 study[110] puts this figure at significantly less, 66,500 personnel. This, however, still demonstrates the overall importance of the project for the European industry, and the EDTIB in particular. In addition, employment in supporting Typhoon is quite substantial. This includes training of air and ground crew, supply of spares, repairs, etc. Support costs are quite substantial, and are estimated to be around half of the production costs.

Figure: Employment in the Typhoon project (direct and indirect)



Source: Ecorys elaboration on Eurofighter data

An important aspect of the employment on the programme is that the labour skills are **highly transferable**. This means that for development and production workers could make use of their knowledge in the motor car and electronics industries. The same goes for the production of the engine (turbines for marine propulsion) or transfer of skills between military and civil work (e.g. skills and technology for the Typhoon can be applied to Airbus A380). An important aspect for the EU is that the creation of a transferable and highly-skilled labour force for Typhoon also contributed to **harmonising European standards in skills**.

[106] Hartley (2006b), The industrial and economic benefits of Eurofighter Typhoon
[107] EF (1992), Impact of Eurofighter on German Economy, study by IFO Institute, Munich for Eurofighter.; BICC (1996) Eurofighter 2000: Consequences and Alternativest ; Hartley (2006b) ; Heinrich (2015)
[108] NAO (2011); Hartley (2006b); Heinrich (2015)
[109] Eurofighter.com/About, https://www.eurofighter.com/about-us
[110] Hartley (2006b)

The Hartley (2006) study also made a point closely related to this aspect of the project. It found that breaks in production have an adverse impact on the learning (which was the case for instance during the delays with the second tranche). It claims that **a break of one year in the production results in having to re-start the whole learning process**. This is because staff has to be laid off, or leave for other industries (transferability of skills), and once the production can continue, new inexperienced labour has to be recruited and trained. This leads to additional delays and costs. **This underlines the importance of the management and decision making setup from the beginning** of the programme, so that no such breaks occur at the production stage.

Several areas for spin-offs and spillovers resulting from the Eurofighter project have been identified. Typhoon technology has been applied to Airbus and Boeing jet aircraft, Formula 1 racing cars and the motor car industry. Areas include carbon fibre technology; super plastic forming and fusion bonding; modular avionics; the flight control system; and aero-engine technology. The externalities related to technology were valued at a minimum of €7.2 bn (in 2004 prices - €8.88 bn in 2018)[111].

The Hartley study identified four main vehicles for technology transmission. The first one is labour turnover, whereby skilled workforce apply their knowledge in other companies/sectors. The second one is Typhoon staff acting as consultants for other projects. The third is the creation of a range of modern business practices (e.g. IT, sales, management and commercial practices etc.) throughout the supply chain. The fourth mechanism comes through cooperation with universities (e.g. development problems with the EJ200 engine).

The programme also led to the transfer of technology between countries. For instance, Spain was able to enter the aerospace industry thanks to the acquisition of technology of the EJ200 engine. This transfer of knowledge was not only concentrated at the prime contractor level, but also affected the suppliers of the programme, as 80% of them reported that the work on the project resulted in technology benefits for them.[112]

While it could be argued that the opportunity costs of such a substantial programme should be taken into account when assessing the benefits and disadvantages, the most likely counterfactual would be another defence procurement process, most likely an off the shelf purchase of aircraft from competitors. A study cited by Hartley[113] states that some 70% of the costs borne by Germany flowed back as tax revenues to the German Government. The same figure would have been around only 10% in the case of the purchase of US aircraft.[114]

On the other hand, it is important to mention here that the very optimistic interpretation described above does not reflect the complete set of views on the question. A paper from 1996[115] claims that, as opposed to Hartley's findings, the Eurofighter programme was actually running through spin-ins, i.e. using already existing technology from the civilian sphere.

An important question to look at regarding the setup is whether the work arrangements contributed to some extent to the achievement of economies of scale. For this to happen, the main principle of the production would be a single source for major units and sub-systems. According to Hartley (2006), single source production constitutes more than 95% of unit costs. Less than 5% can be attributed to the final assembly lines, which can be considered as the main source of inefficiency in this context. Albeit having to operate separate assembly lines in the four nations can be considered inefficient

[111] Van de Vijver and Vos, b. (2006) THE F-35 JOINT STRIKE FIGHTER AS A SOURCE OF INNOVATIon AND EMPLOYMENT: SOME INTERIM RESULTS
[112] Hartley (2006b) p.16
[113] EF (1992)
[114] Hartley (2006b) p.7
[115] BICC (1996)

from the production perspective, the article claims that the technology transfer occurring as a result is an important benefit that should be considered as well.

Finally, it is also important to mention the programme's overall contribution to maintain the strategic and technological independence from the US, and its contribution to maintain the European defence industrial base.

The table below is based on the list of industrial and economic benefit presented in Hartley (2006).

Table: Industrial and economic benefits of the Eurofighter programme

Industrial benefits	Economic benefits
• European collaborative working • Partners understand different culture of different European partners • Retains EU capability for collaborative high-technology programmes • Prestige project/technical gain/R&D funds available by the customer • Improves capability to work in complex and multi-national environments • Upgrade of facilities • Steady production volumes, sustained revenue and flow down into hinterland business • Operational and product improvements have/will be achieved	• Risk and cost sharing • When active = increased sales and profits • Long-term predictability of significant amount of company business • Funding of development activity and advance payments for materials procurement and obsolescence risk mitigation have been beneficial

Source: Hartley (2006b)

Costs of cooperation and comparative cost analysis

As already described in the previous sections, the Typhoon has been subject to criticism for its cost overruns and delays. It is thus worth exploring how the programme measures up against similar projects.

As a 'rule of thumb' widely cited by the literature on collaborative defence programmes, development costs amount to the square root of the number of participating countries as compared to a programme implemented on a purely national basis. A similar estimate for the delays is the cube root of partner nations. Regarding development costs, there seems to be some quantitative evidence backing up this assumption. The UK National Audit Office study estimated that the development costs of the Eurofighter were 1.96 times the cost of a national alternative. Regarding the delays, it proves much more questionable: the Gripen and Rafale were developed only 10-40% faster, which is lower than the 60% implied by the abovementioned rule of thumb.[116]

However, while collaborative arrangements lead to higher costs through more complex arrangements, these costs are shared between the partners. Thus, if the National Audit Office's 1.96 estimate of development costs is accurate, it would still imply an overall cost reduction of more than 50% for the four participating countries' budget.[117]

The table below shows unit prices, delivery dates and total unit lifecycle costs of eight fighter aircraft, both from the EU and the US. While it reveals that the Typhoon is costlier than its European rivals and some of the US aircraft, it is cheaper than the F-22 and F-35. This also applies to lifecycle unit

[116] Hartley (2017), The Economics of European defence industrial policy, In: The emergence of EU defense research policy, p. 50

[117] Europe Economics (2013), The Economic Case for Investing in Europe's Defence Industry, p. 50

costs, albeit no estimate is available for the F-22. Nevertheless, the lifecycle cost of an F-35 is significantly higher than that of a Typhoon, and is almost the triple of that of a Gripen. On the other hand, the time between the first flight and entry into service in the case of US aircraft is generally shorter than the time for the three European fighter jets, which implies a US competitive advantage in development timescales.[118]

Table: Unit prices, delivery dates and life-cycle unit costs

Aircraft	Unit production cost (€m, 2018 prices)	Unit total cost (€m, 2018 prices)	Date of first flight	Date of service entry	Total unit lifecycle cost (Gripen=100)
Gripen	62.61	69.17	December 1988	September 1997	100
Rafale C	56.25	122.92	May 1991	June 2001	137
Typhoon	94.27	130.11	March 1994	August 2003	174
F-15 Eagle	100.63		July 1972	January 1976	
F-16	34.48		February 1974	August 1978	58
F-18 E/F Super Hornet	72.81	88.65	November 1995	November 1999	137
F-22 Raport	165.11	315	September 1997	December 2005	
F-35 JSF	109.79	128.96	December 2006		298

Source: Data from Europe Economics (2013) and Defense Areospace (2006)

Lessons learnt

While critics like to point out the delays and cost overruns of the programme, a quick comparison with similar programmes (F-22 or JSF) reveals that these are fairly common, and that the Typhoon is no worse than the others.[119] On the other hand, the literature seems to agree that **such a programme could not have been carried out within the same scope on a purely national level.**

The programme has delivered tangible benefits to the European industry, for instance in employment, but also in spin-offs and spillovers. In addition, it also contributed greatly to maintaining the EDTIB, and thus Europe's technological and strategic independence. Moreover, there are also import-saving and export benefits attached to the programme.

The industrial setup and the work share arrangements have been criticised for their inefficiencies. Critics point to the fact that there is no one prime contractor with financial responsibility and sufficient authority. MBDA has been suggested as a potential model for the future. Another – and similar – issue is on the demand side: there is no one single customer. The four nations can all do their lobbying, can change requirements and national agendas. Therefore, it can be concluded that the consensus-based decision making model of the Typhoon led to significant delays, even with only four participating nations. **Broader cooperative programmes involving several nations would need to be managed differently (e.g. prime contractor and one single customer) to be carried out effectively and efficiently.**

Delays in decision making that lead to a break in the production have an adverse effect on the learning process, and can lead to additional costs and delays through the need to hire and train

[118] Europe Economics (2013), p. 54-55
[119] With an estimated 14% cost escalation and 33% delay, it even compares favourably to the F-22's 127% and 101%. Source: Hartley (2006b) p.23

new staff. Therefore, it is vital to establish a sound planning and to prevent such breaks from occurring.

In addition, the **Typhoon's upgrade programmes are hampered by the differing national priorities and requirements.** Even though these were originally intended to be funded and developed collaboratively, this setup eventually failed.

The principle of *juste retour* has also been subject to criticism, claiming that it leads to inefficiencies. In the case of the Eurofighter, the work share arrangements apply to the first two tiers of companies (the prime contractors and first tier suppliers). However, as shown above, most of the inefficiencies in the production of the Typhoon come at the final assembly stage, which only makes up some 5% of the overall production unit cost.

An interesting consideration of the setup of collaborative programme is related to exports and the **transfer of technology**. One of the reasons the Eurofighter lost out on a massive tender to produce aircraft for the Indian air force was that securing an agreement with a consortium of four countries on a transfer of technology package could have been far more complicated than with just one (i.e. France – Rafale won the contract).[120]

2. Gripen

Description

The JAS 39 Gripen is considered the most advanced development project of the Swedish industry. Gripen is a Swedish single-seat, single-engine, multi-purpose lightweight fighter aircraft. The initial development on the Gripen started in June 1980. The contract, which was awarded in June 1982, specified the aircraft's performance characteristics (e.g. short-term take-off and landing, simple maintenance requirements, rapid turn-around between missions, multi-role etc.), costs and delivery schedules with the consortium partners guaranteeing the contract.

Unlike previous Swedish defence contracts, which were cost-plus contracts, the Gripen contract was for a fixed price with variation of price clauses (with the Swedish procurement agency accepting the foreign exchange risk). Saab was the prime contractor and systems integrator for the Gripen, and major sub-contractors included Volvo Aero for the engine; Ericsson for the radar and flight control system; BAE Systems for the fuselage and wing; Martin Baker (UK) for the ejector seat; and other French, UK and US firms also acted as sub-contractors.[121]

Sweden ordered a total of 204 aircrafts with the final aircraft delivered in November 2008. Currently, the Swedish Air Force operates 100 Gripen C/D and in 2012 the Swedish government has ordered 60 new Gripen E. The new Gripen aircrafts, scheduled to be delivered between 2019 and 2026, will replace the currently used Gripen C/D[122]. In addition to sales in Sweden, Gripen has been exported to South Africa (26) and Thailand (12) and it has been leased to Hungary (14) and Czech Republic (14). Recently the export order from Saab to Brazil was agreed for 36 Gripen E/F to be delivered between 2019 to 2024.

In relation to the contract, the first generation of Gripen aircrafts was delivered ahead of time and at a lower cost than estimated, which is unusual for major defence projects typically characterised by substantial cost overruns and delays in delivery. Various estimates suggests that the total

[120] More information in Heinrich (2015)
[121] Europe Economics (2013)
[122] https://saab.com/air/support-solutions-and-services/airborne-platform-support-solutions/gripen-support/

development costs were between €2.4 bn to €10.42 bn while the unit production costs are estimated at €62.6 m at 2018 prices[123]. Compared to Rafale and F-18 E/F, Gripen has a similar unit production cost, however it is the least costly military aircraft among the three when it comes to life-cycle costs (it is roughly 37 per cent less costly – see Eurofighter case study)[124]. However, in terms of international competitiveness, Rafale has achieved higher total exports and a higher ratio of exports to total output.

Impacts

The macro-economic benefits of the Gripen programme in Sweden are deemed considerable. The combination of technological spin-offs, increased export revenue and the investment in training and education are believed to have generated **substantial revenues for Sweden and to have added 3,000 jobs**[125]. Such benefits would have been lost if Sweden had purchased its aircraft fighters off-the-shelf.

Additionally, some argue that the capacity to develop a military aircraft is an extremely rare industrial capacity (available to a handful of countries), which provides Sweden with independence and an ability to develop a highly sophisticated defence system suited for its demands.

From a military capability perspective, it is argued that a domestic development capability is beneficial for Sweden's long-term development capabilities. From a security perspective, the domestic capability strengthens Sweden's military capability. From and industrial policy perspective, programmes like the Gripen create sophisticated engineering industry that engage many people (thus boosting high-skilled employment) and serve as the industrial backbone and welfare creator for advanced economies such as Sweden[126]. As a result, advanced public procurement, such as Gripen programme, can be considered as an act of effective industrial policy. Furthermore, defence exports can create beneficial security links and revenues to Swedish companies and defence authorities, co-financing of capability development and longer production series.

In addition, the aircraft industry in Sweden is viewed as "an advanced technical university that provides research, education and training services free of charge to other firms and related industries"[127]. Advanced R&D intensive production such as Gripen programme is surrounded by "cloud of technology" available for free in proportion to the local entrepreneurs' ability to identify, capture and commercialise it.[128] Thus, large and technologically advanced company, such as Saab, is considered to operate as an advanced engineering institute through all of its projects and all of its interactions with other companies and networks. Thereby there is a technology and know-how flow which will create positive effects along the permeable boundaries of the project.

Table: Conclusions from Advanced Public Procurement as Industrial Policy (2010) related to spillover and industrial policy

Spillovers	Industrial Policy
• Gripen is a **broad-based technology driver** that has generated a flow of technology spillovers • The social value created around Gripen development and production is potentially substantial with a **multiplier of 2.6**	• The quality of the product depends on the **competence of the customer** and his willingness to pay for it. Advanced customers are a competitive advantage of a national economy • Advanced public procurement as an act of **effective industrial policy**

[123] Data from Europe Economics (2013) was converted to 2018 €.
[124] No consideration is made for operational performance in relation to military requirements.
[125] Saab (2012): Face of success https://saabgroup.com/media/news-press/news/2012-06/the-face-of-success/ accessed 15 April 2018
[126] Eliasson (2010), Advanced public procurement as industrial policy: The Aircraft Industry as a Technical University
[127] Europe Economics (2013) p. 43
[128] Eliasson (2010) p.7

Spillovers	Industrial Policy
• Spillovers mainly originate during product development phase • Spillovers become available to other industries in proportion to the local entrepreneurial capacity to identify and commercialise them. • **Property rights and tradability in intangible assets are critical** for commercialisation competence – an important part of competitive national advantage and long-term growth • **Government is a double customer** – it receives the demanded military aircraft but it is also the biggest beneficiary of spillovers	• Aircraft industry's role as an **advanced technical university for engineering industry** should not be underestimated • Considerable underinvestment in private R&D means that advanced public procurement can **restart an economy in the event of a crisis or stagnation** • Advanced public procurement should not be considered an example of R&D subsidies

Source: Eliasson (2010)

Specific **technological spillovers** from the Gripen programme are well documented and cover the following technologies: general engineering; critical software; systems integration; development of lightweight structure technologies; medical spin-offs; unmanned aircraft; space –e.g. cheap satellites; maintenance of advanced Swedish producers of civilian aircraft and aircraft engine subsystems for international markets (Saab and Volvo); as well as contributions to telephone systems, civil security, heavy trucks, engines and automobiles[129].

More specifically, companies like Bofors and Hägglunds (since 2004 and 2005 parts of BAE Systems) have received considerable technology spillover regarding subsystems or technologies in Gripen. Moreover, production efficiency and quality control in military aircraft development has created spillover effects to Saab's role as supplier of subsystems produced for Airbus and Boeing. Saab's aircraft development is primarily performed in the city of Linköping. Consequently. Linköping has experienced a **development of a technology cloud that creates SME's more or less closely related to the Gripen programme.**

Regarding the **quantification of spillover effects** from the Gripen programme, the most widespread source is Eliasson's publications (1996, 2008, 2010, 2012). Elliason estimated that the **spillover multiplier** (defined as additional returns to society of over and above the value of the product being developed as a multiple of the original investment) from defence R&T development initiatives for the Gripen programme to the Swedish economy and **society has been 2.6**. In other words, a euro invested in defence R&T would therefore benefit/contribute to the technology development more than twice as much.

However, the evidence provided by Eliasson is not fully convincing, as the explanation on how he arrives at the 2.6 multiplier is not fully apparent. The economists who reviewed Eliasson's findings consider **them too normative and too optimistic**. The calculations and econometrics are not sufficiently convincing as they **rely on too many assumptions** in order to arrive at the 2.6 value of the multiplier. Secondly, given that the multiplier and the spillover effect are dependent upon many different factors, providing a range for the spillover multiplier lying somewhere between 1.1 to 2.6 would be more credible. Thirdly, the author's conclusion **rely on the infrastructure around the company and the unit that does the development being receptive and sufficiently absorptive** to what comes out of the project. In other words, there must be entrepreneurs in the company or its surrounding, however not all defence R&T projects have such conditions. Fourthly, Gripen programme had firm support from government and received large financing over long time, which allowed for materialisation of important spillover effects. However **not all government development and research programmes receive such support**. Finally, large R&D programmes in military

[129] Europe Economics (2013)

technology involve **substantial risks** – technological and financial and it is likely that some projects fail, with should decrease average spillover effects.

Another factor that could cast some doubt on the methodology is the fact that some of the Gripen spillover research was funded by Saab company. Moreover, the alternative effects of the state allocating public finances to other high technology initiatives might have created equal or larger spillover effects.

On the other hand, conclusions drawn with regard to the institutional and infrastructural conditions put forward in twelve conclusions (summarised in Table 1) remain valid. Given a sufficient **institutional and infrastructural breadth and sophistication**, the absorptive capacity of a nation is in place for maximising the potential spillover effects.

Lessons learnt

Despite the uncertainty over the exact value of the spillover multiplier, the Gripen programme appears to have generated **tangible benefits for the Swedish economy** and allowed it to develop a highly sophisticated defence system suited for its demands.

Particularly interesting is the consideration of the military aircraft industry as an advanced technical university for engineering industry, which forms part of **nation's industrial and innovation policy.** To maximise the economic potential of technological innovations from military R&D, the policy design, including institutional arrangements, should enhance the absorptive capacity of a nation. In that respect, the lessons drawn from the Gripen case emphasize the role of **customer competence** in raising the quality of innovation supply and that of **entrepreneurship and industrially competent firms** for commercialising spillovers.

3. DARPA's Portfolio Approach

Description

The Defense Advanced Research Projects Agency[130] (DARPA), was founded in 1958 as a part of the US Department of Defense. DARPA's mission, "*to make the pivotal early technology investments that create or prevent strategic surprise for U.S. national security*"[131], has led to the development of significant breakthrough technologies during its 60 years of operation.

DARPA employs approximately 220 government employees, including nearly 100 programme managers, who together oversee about **250 research and development programs**.[132] DARPA does not conduct its own research but funds research activities through 2000 contracts, grants and other agreements with industry, universities, the US Department of Defense, and other laboratories, who the agency refers to as "performers". These activities are implemented under six thematic areas which are reflected in DARPA's technical offices[133]:

[130] Until 1972 the agency was called Advanced Research Projects Agency (ARPA), then "defense" was added to the name to emphasize its mission.
[131] DARPA (2017a), "Creating breakthrough technologies for national security", available at: https://www.darpa.mil/attachments/DARPA_Fact_Sheet_1_07-25-17.pdf
[132] See: https://www.darpa.mil/about-us/about-darpa
[133] For more information on current and future portfolios of each office please visit DARPA's website: https://www.darpa.mil/about-us/offices .

- **Biological Technologies Office**, which invests in developing capabilities embracing biological properties, such as the ability to counter novel bioterrorism.
- **Defense Sciences Office,** which invests in projects of physical and social sciences (including engineering, mathematics and modelling, human-machine systems and social systems). It pursues initiatives, such as sensing technologies for detection and interdiction of nuclear threats.
- **Information Innovation Office,** which sponsors basic and applied information science research in three areas: cyber, analytics and symbiosis (human-machine).
- **Microsystems Technology Office,** which invests in compact microelectronic components such as microprocessors, microelectromechanical systems, and photonic devices.
- **Strategic Technology Office,** which invests in technologies that enable fighting as a network to increase military effectiveness, cost leverage, and adaptability. These technologies include battle management, command and control; communications and networks; intelligence, surveillance, and reconnaissance; electronic warfare; positioning, navigation, and timing; and foundational strategic technologies and systems.
- **Tactical Technology Office,** which invests in new platforms in ground systems, ground, maritime (surface and undersea), air, and space systems.

On top of those, DARPA operates the **Adaptive Execution Office** which connects DARPA with the US Department of Defense and ensures that new technologies are transitioned into defence capabilities as well as two support offices. DARPA also sets temporary offices (such as the currently operating **Aerospace Projects Office** in order to achieve an accelerated development or deployment of advanced capabilities.

Under the thematic areas of the aforementioned offices DARPA's **programmes** are selected and funded by programme managers and implemented by performers. Typically, programmes last for a few years, have a concrete objective of developing a new technology or capability that will be applicable in the "real-world". Programme ideas may be initiated by programme managers (bottom-up approach) or by DARPA's management (top-down approach), but in both cases programme managers are playing a core role in the initiation of a programme.[134]

A key element of DARPA's success quoted by DARPA as well as other sources are the **programme managers.**[135] Apart from the recruitment process which is essential in identifying and recruiting top experts from academia, industry and government agencies, their limited tenure (typically three to five years) gives them an urge to create an impact in less time than in a conventional setting. Programme managers' responsibilities include, creating and "selling" their projects, reaching out to potential applicants and shaping teams, judging quality and picking winners (peer review is not necessary), saying in touch, enforcing milestones and marking changes if needed. This is considered as a unique degree of autonomy, flexibility, and authority among counterparts in other U.S. research agencies.[136] The role of programme managers is not over with the successful completion of a programme, as they are also in charge of transitioning the outcome(s) of a programme into military or civilian capabilities.

DARPA's R&D focuses on revolutionary advances, thus it is investing in **high-risk, high-impact technologies** aiming to develop and promote the early-adoption of novel capabilities. Programmes selection depends to a large extent on programme managers passions and ideas, however they must be in line with the strategic priorities as specified in the DARPA's distribution statement[137] and summarised in the box below.

DARPA's Strategic priorities

[134] DARPA (2016a), "Innovation at DARPA", Available at: https://www.darpa.mil/attachments/DARPA_Innovation_2016.pdf
[135] DARPA (2016a)
[136] Mervis J.(2016), What Makes DARPA Tick?
[137] DARPA (2015), *"Breakthrough technologies for national security"*

DARPA's strategic priorities are influenced from global developments and aim to place US military capabilities on the top by taking advantage or creating state-of-the-art technology. These priorities are the basis for evaluating new programme proposals and can be grouped within four main areas as follows:

1. Rethink complex military systems

- Assuring dominance of the electromagnetic spectrum
- Improving position, navigation and timing without GPS
- Maintaining air superiority in contested environments
- Leading the world in advanced hypersonics
- Assessing a robust capability in space
- Enhancing maritime agility
- Exerting control on the ground
- Augmenting defence against terrorism

2. Harness biology as technology

- Accelerating progress in synthetic biology
- Outpacing infectious diseases
- Mastering new neurotechnologies

3. Expand the technological frontier

- Applying deep mathematics
- Inventing new chemistries, processes and materials
- Harnessing quantum physics

4. Master the information explosion

- Deriving meaning from big data
- Building trust into information systems

On top the strategic priorities a number of processes are in place for the **evaluation and selection of potential programmes**. These processes are there to avoid duplications, anticipate risks and support the selection of programmes that are sufficiently risky and ambitious but within the realm of possible.[138] For instance, DARPA engages in a number of activities (conferences, requests for information, competitions to seek innovative ideas etc.) aiming to keep its staff up to date regarding the latest developments in the industry and academic world, and in close contact with innovators' communities. Additionally, an appointed selection board conducts a technical evaluation including a risk assessment on potential programmes. Moreover, a long preparation period is foreseen before presenting a potential programme for the management's approval. [139] This presentation requires close cooperation between the programme manager and performers and aims to give a comprehensive overview of the programme and respond to key questions, such as the ones developed by George Heilmeier, ARPA's director in the mid-1970s, known as the Heilmeier Catechism.[140]

The Heilmeier Catechism

- What are you trying to do? Articulate your objectives using absolutely no jargon.
- How is it done today, and what are the limits of current practice?
- What is new in your approach and why do you think it will be successful?
- Who cares? If you are successful, what difference will it make?
- What are the risks?
- How much will it cost?
- How long will it take?
- What are the mid-term and final "exams" to check for success?

An analysis of DARPA's portfolio during the financial year 2016 by the Congressional Research Service,[141] shows the receiving performers of DARPA's funding. Approximately, 70% of activities were performed by industries, followed by universities and colleges (13.6%) and intramural

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[138] DARPA (2016a)

[139] For a full list of DARPA's evaluation and selection processes see: DARPA (2016), "DARPA guide to Broad Agency Announcements and Research Announcements)", available at: https://www.darpa.mil/attachments/DARPAGuideBAARA.pdf

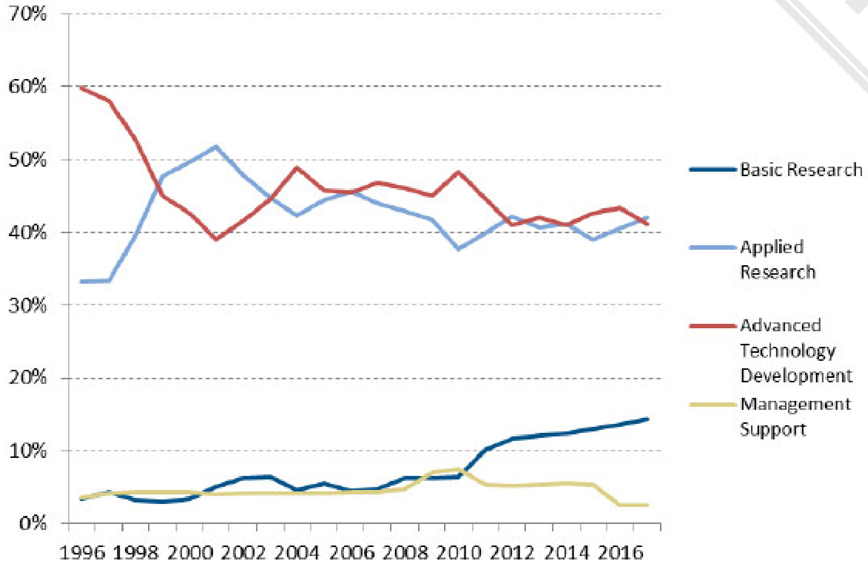
[140] See: https://www.darpa.mil/work-with-us/heilmeier-catechism

[141] Gallo (2018), " *DARPA: Overview and issues for congress*" for the Congressional Research Service, available at: https://fas.org/sgp/crs/natsec/R45088.pdf

performers (e.g. federal laboratories) by 7.7%, the remainder funding went to non-profits and other research centres. Lastly foreign entities received less than 1% of DARPA's funding.

In line with the aforementioned strategic objectives, regarding distribution of funding among different types of programmes, the Congressional Research Service analysis[142] shows that in financial year 2017 **more than 80%** of funding went to **applied research and advanced technology development**, almost 15% (up from 3.4% in financial year 1996) to basic research and less than 2.5% (after reaching 7% in financial year 2009) to management support. The proportions of applied research and advanced technology development have fluctuated since 1996, as there seems to be an exchange of resources allocation between the two throughout the years.

Figure: Share of DARPA funding by character of work (Financial year 1996- financial year 2017)

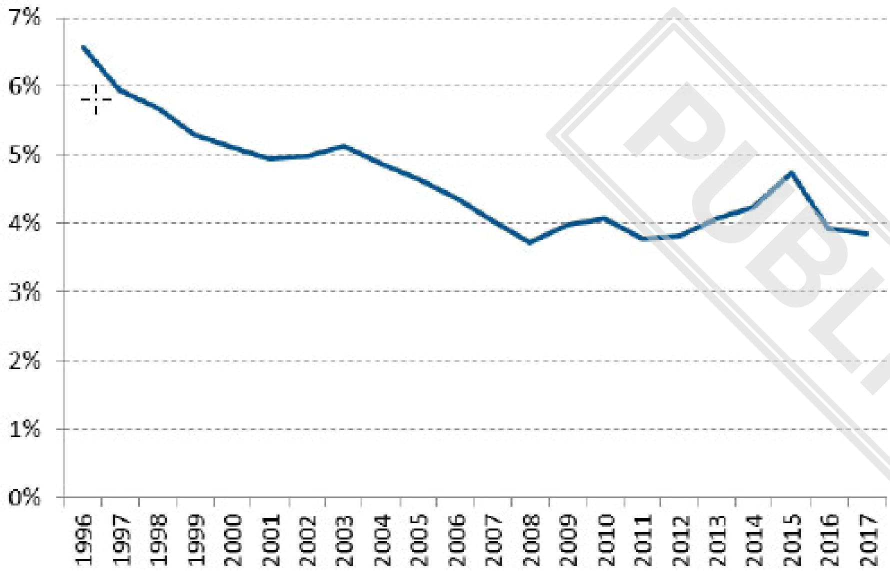


Source: Congressional Research Service

The same study[143] also indicates that in absolute terms the overall funding for DARPA has increased by 22% from $2.3 bn (€1.9 bn) in financial tear 1996 to $2.9 bn (€2.4 bn) in financial year 2017, a compound annual growth rate (CAGR) of 1.2%. The latest budget request for financial year 2019 is $3.44 bn (€2.8 bn) while for financial year 2018 it was $3.17 bn (€2.6 bn). However, the proportion of the total RDT&E funding has almost halved from 6.6% in 1996 to 3.8% in 2017 as indicated in the figure below.[144]

[142] Idem.
[143] Gallo (2018)
[144] Amounts are adjusted for inflation to 2016 dollars

Figure: DARPA funding as a share of US Department of Defense RDT&E funding (percentage of obligational authorities)



Source: Congressional Research Service

Regarding the funding models used by DARPA, they are linked with the purpose of the investment as well as the type of solicitation. The main types of solicitation used by DARPA are presented below:[145]

- **Broad Agency Announcements**: Most DARPA solicitations are accomplished through BAAs which are tied to specific areas of R&D (each DARPA office maintains its own BAA) but rather general in nature (e.g. they do not request the development of a specific system or hardware). Proposals submitted in response to a BAA may be awarded as procurement contracts, grants, cooperative agreements or other transactions (e.g. for prototype, research or technology investment agreements).[146]
- **Research Announcements**: Research Announcements are quite similar to Broad Agency Announcements but they do not use procurement contracts as a funding instrument.
- **Request for Proposals**: These are used less often than Broad Agency Announcements and RAs, and constitute formal competitive tenders in response to government requirements for supplies and services. Request for Proposals lead to procurement contracts.
- Other solicitation types include the Small Business Innovation Research topics and Small Business Technology Transfer Research topics.

Regarding Intellectual Property (e.g. of technical data, software, patents, copyrights, trademarks, and trade secrets) the Office of the Secretary of Defense guide on IP[147] is applicable to DARPA procurement contracts. It is noted that DARPA normally does not acquire IP rights that will impede commercialisation of technology.[148]

Impacts

With a budget of approximately $3 bn per year (approximately €2.4 bn)[149], DARPA has a tracked record in generating or playing a role in the development of breakthrough innovations, to name a few: the Internet, synthetic biology, carbon nanotubes, stealth aircraft, pilotless drones, the chipsets enabling mobile communications, stealth, night vision, laser guided weapons, nurturing the materials

[145] For more information see: https://www.darpa.mil/work-with-us/contract-management#UnsolicitedProposals
[146] DARPA (2016b)
[147] Secretary of Defense (2001) "Intellectual Property: Navigating Through Commercial Waters", available at: www.acq.osd.mil/dpap/Docs/intelprop.pdf
[148] DARPA (2012), "Doing business with DARPA", available at: http://www.acqnotes.com/Attachments/DoingBusinesswithDARPA2012.pdf
[149] Budget request for FY2019 is $3.44 bn (approximately €2.8 bn) and for FY2018 it was $3.17 bn (approximately €2.6 bn).

science and computer science communities.[150] DARPA is widely recognised in academia and within U.S. administration as a successful agency and attempts to copy DARPA's model have been made by other agencies (e.g. the Intelligence Advanced Research Projects Activity and the Advanced Research Projects Agency–Energy) and countries.

In its 2015 publication "Breakthrough technologies for national security"[151] DARPA presents several success stories throughout the agency's history and how these provided solutions to existing problems and generated impact. One example is DARPA's funding on Artificial Intelligence R&D which has led to the development of a number of impactful applications. For instance, the Dynamic Analysis and Replanning Tool (DART), a problem-solving aid using automated reasoning. DART has helped to successfully generate deployment plans with improved logistics and other planning functions and reduce the time devoted to these tasks. DARPA's Speech Understanding Research program led to the creation of automated speech transcription systems (one of which was commercialised). The personalised assistant learns programme developed by DARPA's funding, has improved capabilities of cognitive computing systems which support military decision making. DARPA is working on refined personalised assistant learns prototypes for operational use. Artificial Intelligence R&D was also critical to the development of driverless cars. The publication also mentions current and future areas of DARPA's research in AI, such as the cyber grand challenge competition aiming to create automated cyber defence systems.

However, DARPA's risk taking approach has also led to numerous failed programmes as well. An example is the Falcon Hypersonic Technology Vehicle 2 which exploded during the planned test flight, the programme was terminated later the same year. Despite that DARPA's approach to failure has been quoted as a success factor, the use of resources in failed programmes may also be perceived as a negative impact. Also, in some occasions developments in R&D and technology can raise ethical, legal, and societal concerns. Even-though, DARPA has in place a processes to ensure such issues are considered in their portfolio (starting already during the programme formulation stage, these concerns may persist regarding certain technology uses.

Lessons learnt

DARPA's structure, funding models and strategy is a valuable source of information for EDF. A number of success factors are indicated by DARPA[152], previous staff[153], academics and others that reviewed DARPA's case.[154] Some success factors could also be useful as an inspiration for the development of EDF's structure, governance and design, these are presented below.

1. Risk-taking and tolerance of failure: Creating high-risk and high-impact projects is in the heart of DARPA's mission and an essential factor of its success. Their approach to risk and failure is reflected on the selection of the programmes (i.e. the experts may decide to carry on with a project and not follow the technical risk assessment and advice of the selection board). It is also reflected in the evaluation processes which recognise and reward valuable work even if not successful. A milestones evaluation approach is followed to ensure genuine progress and justify continuation of funding.[155] However, a high risk programmes portfolio entails risks for inefficient allocation of money to programmes with low or no impact. To mitigate costs of failed programmes, projects are only funded for a limited time and either funds from underperforming programmes are reallocated, or performers' are reassigned new work.[156]

[150] For more, see DARPA's timeline, available at: https://www.darpa.mil/Timeline/index.html
[151] DARPA (2017a)
[152] DARPA (2016a) & DARPA(2017b)
[153]i.e. Mervis (2016), Dugan & Gabriel (2013), "Special Forces, Innovation: How DARPA attacks Problems"
[154] i.e. Gallo (2018), Biercuk (2017), Singh (2014)
[155] For more information see: Schlenoff, Weiss & Steves (2010), "Lessons learned in evaluating DARPA advanced military technologies"
[156] Dugan & Gabriel (2013)

2. Limited tenure and urgency: Lack of continuity and stability can be perceived as a disadvantage in many organisations, but in the case of DARPA, key staff (programme managers) are only hired for periods of 4-5 years. According to DARPA's management as reflected in the "Innovation at DARPA" publication[157] this practice urges them to maintain a risk-taking attitude and take actions to achieve ambitious goals within the short period of their mandate. Clear hire criteria and terms of hire are essential in making limited tenure a success factor. However, limited tenure also entails risks DARPA identifies duplication of efforts due to lack of institutional memory. DARPA takes actions to keep programme managers updated with the latest developments in their respective areas (see description section) and also focuses on internal communication practices. The 2018 report from the Congressional Research Service[158] indicates that limited tenure may be linked with gender imbalance in the agency and selection of individuals from similar networks. These drawbacks may be counter-productive as they could hamper access to new innovative ideas.

3. Trust and autonomy: Programme managers are trusted with a significant role as mentioned in the description section, including initiating the creation, selection and termination of programmes. This bottom-up approach and sense of autonomy has been a source of creative ideas coming from passionate and committed project managers. There are of course limits to the autonomy as the approval process described in the description section must be followed.

4. A sense of mission: Despite the short length of tenure, DARPA's mission is paramount as it is linked with national security as well as success and safety of the military. This is a driving factor for many of its staff for being part of DARPA as well as a source of motivation to lead successful programmes and develop cross-cutting technologies that provide solutions to existing problems or prevent surprises from other countries.

5. Anticipated transition of results: DARPA's mission is not limited to the development of programmes, but it also ensures that successful programmes are transitioned into military or civilian use cases. This impacts the development of programmes from the conception phase and urges them to conduct ambitious yet realistic and practical R&D. Programme managers are responsible to lead this transitioning process. In some cases transition of capabilities also depends on technology or geopolitical developments, thus may not be possible in the short-term.[159]

6. Anti-Bureaucracy: The 'flatness' of DARPA's structure helps eliminating slow bureaucratic procedures (e.g. multiple levels of permissions). The limited programme timeframes and tenure of programme managers, urges for fast and flexible procedures that speed-up processes. DARPA considers their focus on impacts rather than processes to be an extraordinary catalyst for innovation.[160]

Other elements of DARPA's structure and design are also identified as factors contributing to its success. For instance, Dugan & Gabriel (2013) indicate that the **ambitious goals** in combination with the urgent need for an application are an essential element. The mention specifically that "problems must be sufficiently challenging that they cannot be solved without pushing or catalysing the science".[161]

[157] DARPA (2016a)
[158] Gallo (2018)
[159] For more information on transitioning practices for different programmes, see: DARPA(2017a), "Changing how we win: DARPA technologies that are making a difference today", Available at: https://www.darpa.mil/attachments/DARPA_ChangingHowWeWin.pdf
[160] DARPA (2016a)
[161] Dugan & Gabriel (2013), "Special Forces, Innovation: How DARPA attacks Problems"

The sole fact that DARPA does not conduct any R&D but maintains an **outward focus** is perceived as an essential advantage by Biercuk (2017).[162] He specifically indicates that at least 90% of such an agency's budget should be made available to "performers" (industries, academics etc.). He also mentions DARPA's forward looking portfolio which is distinct from the current operational needs as an additional success factor.

Moreover, Singh (2014) emphasises the importance of the recruitment of programme managers as key in the agency's success as well as the strong links DARPA is creating and maintaining with other organisations including other agencies as well as industries, academia etc.[163] Lastly, DARPA's ability to offer various contracting options and recognise which one is best fit for each performer based on their goals and distinct characteristics of their programmes, is another important quality.[164]

4. Macroeconomic benefits of investment in defence - Oxford Economics (2009) and Europe Economics (2013) studies compared

Description

The study commissioned by the Defence Industries Council and carried out by Oxford Economics (2009)[165] investigated the economic impact of increasing investment in the UK defence sector in the economic recession environment. The approach adopted in this study looked at eight measures (GDP multiplier, taxation revenue, number of jobs created or supported, share of high-skilled employment, R&D intensity, export intensity, capacity and capital intensity) and compared the metrics for the defence sector with other sectors. While the defence industry does not rank first in any of the above listed measures, it performs very well (above the median) in all of them. Overall, the study found that the **defence industry forms a major part of the UK economy with strong linkages to the rest of the economy**, strong job creation characteristics, high capital intensity, large capacity to expand and the ability to bring future benefits to the UK economy.

The finding of Oxford Economics can be compared to the study carried out by Europe Economics (2013)[166], which was commissioned by EDA. The latter study looked at the EU as a whole and compared the short- to medium macroeconomic impacts of a hypothetical investment of €100 m in major areas of government spending (transport, education, health and defence). It found that **at the EU level**, the impacts of investing €100m in the four sectors on GDP, tax and employment would be extremely similar. However, it also argued that the overall **benefits to the economy** from investing in defence sector would be greater than if the investment was done in other sectors because of the defence sector's **contribution to skilled employment** and to the future economic growth thanks to the **significant impact that such investments have on R&D.**

Findings comparison

Oxford Economics (2009)

The defence industry was found to have a **GDP multiplier of 2.3** (above the median of the 27 sectors considered in the study) whereby £100 (€116.5) m investment in the defence industry (no distinction is made between defence R&D and defence procurement) would generate an increase in the gross output equal to £227 (€264.5) m. Such investment would also have direct, indirect and induced employment effects leading to the **creation of 1,885 additional jobs** (726 jobs in defence industry, 589 jobs throughout the defence industry's supply chain and 570 jobs in the rest of the economy). Finally, it would also bring **£11.5 (€13.4) m in tax receipts**. Interestingly, the study also looked at

[162] Biercuk (2017), "Next steps for Australia's defence innovation: lessons from DARPA"
[163] Singh (2014), "Study of the US Darpa Model and its Applicability to the Indian Defence Research and Development System
[164] DARPA (2016) "Innovation at DARPA"
[165] Oxford Economics (2009)
[166] Europe Economics (2013)

potential losses related to the recession and concluded that if the defence industry was to "suffer significant damage as a result of recession", it would lead to a permanent loss of UK's economy productive capacity. Moreover, due to the defence sector's spare capacity (84% of all defence companies reported operating below capacity), the study concluded it would be **most able to absorb an additional demand** if the government increased its procurement, thus giving an economy an immediate boost. Finally, Oxford Economics analysis also considered long-term benefits of higher spending on defence industry. It has found that supporting the UK defence industry would bring relatively more benefits to the UK economy when compared to other sectors, due to the **relatively high export (22%) and R&D (4%) intensity levels** in that sector.

Europe Economics (2013)

Using input-output analysis,[167] Europe Economics study estimated that €100 m investment[168] in defence would generate a short-term increase in GDP equivalent to €156 m (which implies that the **EU GDP multiplier is equal to 1.56**). The estimated multipliers for individual Member States differed significantly however (due to different savings and import propensities) which implies that **the benefits from the increased defence investment would very across Member States.** The study also assumed the division of €100 m between the Member States according to the actual current relative defence spending of each of them, thus the increase in GDP as a result of it would mainly be concentrated among the current biggest spenders – France, the UK and Germany. As for the other macroeconomic benefits, the study found that (taking induced effects into account) a €100 m investment in the EU defence sector would lead to **an increase in total tax receipts by €42 m** and it would generate **2,870 new jobs across the EU economy** (with the distribution skewed towards the biggest spenders). Finally, €100 increase in defence investment in the EU would also generate **additional export revenue of €16.6 m.**

Table: Main results from the two studies

Indicator	€100 m defence investment in the EU	£100 m (€116.5 m) defence investment in the UK
GDP multiplier	1.6	2.3
Tax revenues	€42 m	£11.5 m (€ 13.4 m)
Jobs created	2,870	1,885
Skilled jobs created	760	283[169]
Exports revenue	€16.6 m	NA

Source: Data from Europe Economics (2013) and Oxford Economics (2009)

The two **studies yield similar results, which are however not exactly the same** due to a number of factors. Firstly, the GDP multiplier in the UK is considerably bigger than that found for the EU. This can be explained by the fact that the estimation done for the UK case was done in the context of economic recession where multipliers are usually higher than during normal economic times. The second reason for the difference in multipliers is that the defence industry in the UK has strong linkages to the rest of the economy (compared to the EU average) so that an additional investment in defence would have a larger impact on the economy as a whole in the case of UK.

As for the tax revenues generated, the multiplier for the EU is markedly larger than in the UK, which can be explained by the fact that some EU countries have high tax rates. On the other hand, Europe

[167] Input-output (I-O) analysis is a model of general equilibrium, which links various sectors in the economy through fixed linear relationships between the output of a sector and the inputs it requires from other sectors. There are however two limitations of the I-O model: it is essentially a short run approximation, thus not suitable for capturing long-term effects and secondly, if the economy is close to full employment, the effects of an increase in final demand (due to investment) may be greatly exaggerated.

[168] It is assumed that the €100m investment would be broken down between the following expenditure categories: equipment procurement; non-R&T R&D; R&T and infrastructure.

[169] This value is estimated based on the following data provided by the study: 39% of all defence jobs are high skilled and direct defence jobs created were estimated at 726.

Economics (2013) also estimated the tax multiplier for the UK alone and found it to be equal to 0.34, which is roughly twice as high as the Oxford Economics estimate.

There are also some differences in job creation capacity where an investment in defence in the EU as a whole would generate roughly 1,000 more jobs than if an investment of similar size was done in the UK. The rationale behind this difference stem most likely from the fact that some EU countries (e.g. Poland, Romania) have relatively low productivity levels and therefore disproportionately high number of jobs would be created in such countries. Interestingly, for the UK, the Europe Economics (2013) study found that the employment multiplier was equal to 18.9, which is almost identical to the Oxford Economics estimates of 18.8.

Critique and Lessons learnt

The two studies looked at a large number of important macroeconomic indicators and considered both short-term and long-term (Oxford Economics) implications when assessing the impact of an increased investment in defence. While such a holistic approach is praiseworthy, the Oxford Economics study lacks in depth and there is no methodology section outlining how values such as GDP multiplier or a number of jobs created were derived. Europe Economics study on the other hand has a methodology section where it outlines the limitations of its estimation technique (see footnote 3). **The shortcoming on the two studies** is also that they do not consider different TRL levels nor different sectors within the defence industry as the benefits are expected to vary according to different spending category. Moreover, neither of the two studies looked at the conditions that would need to be in place to realise the benefits (see Gripen case study). Finally, Oxford Economics study was funded by defence industry while the Europe Economics study by EDA, which can cast some doubt on the very optimistic results the two studies obtained.

Based on the two discussed studies, some **extrapolation of the potential return and/or economic impact** of the EU defence R&D investment (EDF) can be made. Such estimates should however be treated with caution as the discussed studies did not differentiate between the overall defence spending and the expenditure on defence R&D. Moreover, the results obtained by the Europe Economics study apply solely in the short-term, however R&D activities tend to take decades before their full impact on the economy materialises.

With respect to the impact on GDP, the positive spillovers from the EDF to the GDP are likely to be smaller than the ones estimated in the Oxford study given that the growth recovery in the EU economy as a whole has been under way since 2014, and are thus likely to be closer to the Europe Economics estimates. At the same time, the **distribution of economic benefits will depend on how the EDF investment is divided** among the Member States as the GDP multipliers vary from country to country. Extrapolating from the findings of the two studies, the EDF spending is also expected to generate **positive employment effects,** which will however vary from country to country. The cost of defence R&D funded by EDF is likely to be somewhat offset by **extra tax and export revenues.**

Finally, the issue of the **opportunity cost** should be considered. The two studies compare the impact of spending on defence with spending on other sectors (education, health, and transport in case of Europe Economics study) and conclude that investing in the military sector would be most beneficial in terms of (long-term) macroeconomic benefits. However, the reason behind such results is based on the assumption that the **investment in military sector will have a significant impact on R&D[170].** While this may be the case, it is in no way guaranteed given that large military projects sometimes fail to deliver the expected outcomes and the studies do not specify how much of the envisioned investment will be dedicated to R&D/T activities. However, given that the EDF spending will go solely

[170] According to R&D models of endogenous growth, R&D and technological innovation are the drivers of economic growth.

to R&D/T activities may imply that the latter criticism is no longer valid. At the same time, the effectiveness and efficiency of the EDF spending cannot be determined a priori.

5. Literature review on externalities and other economic benefits of defence R&D investment

Publicly funded defence R&D is the single most important component of total government R&D spending in the US, the UK and France[171] and thus it constitutes an important part of public policy. While a vast literature exists on defence spending externalities, including spending on defence R&D, there is still **no consensus on its actual economic impact**.

A number of channels by which military R&D expenditure can affect the wider economy have been identified. Firstly, defence R&D is considered to have a positive impact on other sectors through **'spin-off' – a technology transfer from defence to the commercial sector.** Proponents of the benefits of defence R&D point to the commercial success of major innovations such as jet engines, computers, radars, nuclear power, semiconductors, the GPS and the Internet as evidence that military R&D has been a crucial source of technological development with civilian applications[172].

Ruttan (2006) stressed that *military and defence related research, development and procurement have been major sources of technology development across a broad spectrum of industries that account for an important share of United States industrial production*. Similarly, Hartley (2006) performed a qualitative evaluation of Typhoon's technology benefits and identified the following spin-offs: carbon fibre technology, super plastic forming and fusion bonding, aero-engine technology, pin-offs to civil aircraft, to motor car industries and to supply chains, power generation engines for civil work from EJ200 engine. At the same time, **the monetary valuation of some of the spin offs can be difficult to estimate.**

Macro-economic benefits of defence R&D are another often-discussed example of a positive externality. A number of studies estimated that spending on defence sector have significant positive multiplier effects on GDP, tax and employment[173]. EDA commissioned a study with an aim of providing a robust quantitative analysis on the European defence industry's impact on Europe's economy. The study looked at the EU as a whole (while the previous studies focused on the national level) and compared the short- to medium macroeconomic impacts of a hypothetical investment of €100 m in major areas of government spending (transport, education, health and defence). The study contractor, Europe Economics, estimated that each €100 m cut from EU defence expenditure would imply €150 m fall in EU GDP, €40 m fall in EU tax revenues, 2 870 jobs lost; and 760 skilled jobs lost. Similar results were found by Oxford Economics (2009) (see the case study on macroeconomic benefits). Moreover, investment in defence R&D should theoretically improve **industrial productivity** by transferring resources to highly productive activities and consequently boost economic growth as well as have positive effects on SMEs which are involved in defence development programmes through the supply chains of the main system integrators [174].

Nevertheless, **not all empirical studies report equally positive results[175], while others point out to the number of problems** related to such estimations, including huge problems of data,

[171] Moretti et al (2016) The intellectual spoils of war? Defense R&D, productivity and spillovers
[172] Moretti et al (2016)
[173] Oxford Economics (2009), Europe Economics (2013)
[174] EC (2017d)
[175] Dunne and Braddon (2008) carried and an extensive literature review and they concluded that "we feel confident in concluding that military R&D is not an important factor for economic growth"

measurement, identification and estimation[176]. As a result, studies focusing on the link between defence R&D and growth are few in numbers and ***those studies that have been undertaken provide little support for any significant positive effect of military R&D on the economy***[177].

Other critics argue that, in addition to the positive externalities, defence R&D can also **create negative externalities by crowding-out of private or public R&D in the civil sector** (also known as resource diversion effect). Moreover, **inherent secrecy surrounding defence R&D** can effectively limit the scope of positive spillovers to the civilian sector[178]. The empirical studies investigating crowding-out hypothesis show mixed results. Gullec and van Pottelsberghe (2003) analysed a group of OECD countries and found that defence R&D has a crowding-out effect on civilian R&D partly due to the increase in cost of research generated by government expenditure (it raises the prices of resources and wages of qualified scientists and researchers). Moretti et al (2016), on the other hand, found a strong evidence of *crowding in* rather than crowding out (increases in government funded R&D result in significant increases in private sector R&D - a 10% increase in government financed R&D generates about 3% more privately funded R&D).

Enhanced investment in defence R&D is also expected to bring **benefits with regard to jobs, skills and remuneration.** Hartley (2006) has found that the Eurofighter programme supports between 66,500 and 100,000 jobs across Europe. A study analysing a scenario of the potential Europeanisation of the European Land armament industry has found, on the other hand, potential negative effects on employment[179]. While overall Europeanisation of the European Land is expected to generate a list of positive outcomes, ***negative short-run effects on employment*** *and* ***loss of skills/knowhow*** *in countries/enterprises which are not sector leaders, and coupled with possible employment surpluses resulting from the creation of the "European champions".*[180]

Finally, some researchers even claim that military R&D does not (any longer) drive civil technological innovation but that, rather, the opposite is true. The nature of defence technology has changed since the cold war with the rise in new industries, such as information technology and communications that are less rigid in their civil-military distinctions than the old industry. Consequently, more and more often, **the technology developed during civil projects is ''spinning in''[181] to defence sector** as producers of military equipment are turning to civilian technology that they can then adapt for military applications[182]. In the case of US, changes in the structure of the economy and of the defense industrial base, particularly consolidation in the defence industries led Ruttan (2006) to argue that *defense and defense related research, development and procurement is unlikely to represent an important source of new general purpose technologies over the next several decades*.[183]

To conclude, **whether the net effects of defence R&D spending on the economy are positive, negative or neutral is an empirical question and it is likely to differ across countries**[184]. Even if there are negative externalities related to crowding out, the positive externalities coming from direct spin-off impacts can outweigh the former leading to the overall net effect of higher defence R&D spending to be innovation- and growth-enhancing. On the other hand, **recent recognition of a change in civil-military technology interactions** has led to a shift in focus towards 'spin-in' from

[176] Dunne and Braddon (2008), Herrera and Gentilucci (2013), Military spending, technical progress, and economic growth: a critical overview on mainstream defense economics
[177] Dunne and Braddon (2008)
[178] Moretti et al (2016)
[179] Duran (2012)
[180] The author however concludes that these negative employment prospects, which tend to be a key worry for national Member States, could be diminished if the consolidation process is done in an orderly manner.
[181] Spin in - civil R&D produces inventions that are used in arms production by the military sector
[182] Dunne and Braddon (2008)
[183] Ruttan (2006) Is war necessary for economic growth?: military procurement and technology development p. 29
[184] Ram (2003) Defence Expenditure and Economic Growth: Evidence from Recent Cross-Country Panel Data

civil to military sectors, which suggests that the military **technological spin-offs may be less important in the future** thus reducing positive externalities of defence R&D.

It is likely that in the **future R&D environment, the defence R&D will largely be a minority actor**, while the driving forces for **innovation will be increasingly found in the commercial sector**.[185] To take full advantage of this change, RAND Europe (2013) recommends Ministries of Defence (MOD) or Defence Agencies to: adopt some **good practices from the commercial world** to leverage commercial technologies (such as greater willingness to take risks; identify key parts of the value chain and innovate/invest there; transition to a networked, decentralised structure), **facilitate connections** and culture as key enabling factors, better target **its engagement with its supply chain**, assess how it currently **prioritises its investments.**[186]

185 Penny et al (2013)
186 Penny et al (2013) p. xi-xii.

Rue Belliard 12
B-1040 Brussels
Belgium

T +32 (0)2 743 89 49
F +32 (0)2 732 71 11
E brussels@ecorys.com
RPR Brussels no.01 736 434

W www.ecorys.eu

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