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REPORT

From: To:	European Commission Friends of the Presidency Group on the European Defence Fund (EDF)
Subject:	External study contracted by the European Commission on the magnitude of the cost structure of defence research and development programmes

Delegations will find attached an external study contracted by the European Commission on the magnitude of the cost structure of 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.

Magnitude of the Cost Structure of Defence Research and Development Programmes and Optimal EU Intervention to Incentivize Cooperation

EUROPEAN COMMISSION

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Disclaimer:

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Introduction

The objective of the European Defence Fund (EDF) initiative, launched on 7th June 2017, is to provide the incentives to develop cooperative defence projects and to contribute to greater efficiency in national defence spending in line with the global objective of European strategic autonomy. The European Defence Fund will support investment in joint research and development of defence equipment.

Nonetheless, defence cooperation is complex, and it is essential to define what the best way may be to use the EDF to incentivize cooperation. The European Commission therefore has to define a robust methodology, for the allocation of funds dedicated to EDF.

The first aim is the definition of a methodology to map the costs and risks corresponding to the different phases of an armament programme, particularly in the R&D phase. This means that the assessment of the magnitude of the costs of different types of armament programme, the magnitude of the cost of the R&D phase and of the different actions in the R&D phase is highlighted, along with ratios of research and development costs to unit production costs and acquisition costs. Also, the assessment of risk levels associated with each phase in the cycle will be identified.

The second objective is to outline the methodology of the decision-support system, related to the targeted objectives. This methodology should be a tool for determining the optimal rates and level of EU funding in relation to the different stages of the research and development cycle.

1. Mapping the Costs and Risks of Defence Research and Development Programmes

The first task is to indicate the magnitude of costs of different defence research and development programmes, both past programme estimates and future programmes estimates. This means trying to identify the typical distribution of costs over the main stage of a programme, as well as providing ratios of R&D investment to unit production costs and acquisition costs. The above information will be even more precisely specified in terms of the particular phases of an armament programme—that is to say, at what stage particular investments must be made. The risk issue within an armament programme is a clear one that needs to be highlighted, depending on the particular fields of technology, categories of defence equipment, levels of performance required and the different stages of the programme.

1.1. Estimating the Magnitude of the Costs of Defence Research and Development Programmes

The methodology of the research is based on the available information, which includes public sources, information obtained from representatives of defence companies and information provided by OCCAr.

1.1.1. Methodology

The sources

We use sources that describe the cost of defence programmes and specify these costs in the different phases of the armament programmes, from the R&D to the production phase.

Within this scope, we have used the following sources:

As open sources we have used:

- Several reports from *le Comité des prix de revient des fabrication d'armement* (CPRA), which is a French public authority involving the Ministry of Defence and Members of Parliament in France who oversee the costs of armament programmes;
- Reports from the National Comptroller and Auditor in France (the *Cour des comptes*), and from the National Audit Office (NAO) in the UK;
- Reports from the Government Accountability Office (GAO) in the United States;
- Reports from national parliaments on defence acquisition;
- Various studies on arms procurement issues in national and cooperative programmes.

As non-open sources we received:

- information from OCCAr;
- information provided by defence industries on the general question of the assessment of the costs of an armament programme, and also on the costs of specific programmes with the detailed distribution of costs at the different stages of the R&D.

Further to this, a number of reports from the Government Accountability Office (GAO) on open sources provide another credible source regarding American programmes, even if it is necessary to note that these programmes may not have the same order of magnitude compared to European programmes in terms of the defence equipment quantities produced, as well as total programme costs.

We also sent questionnaires to armaments directorates and defence industry actors, in order to make a better assessment of the costs of armament programmes during the different phases of a programme. In this regard, it appears that it is difficult to get more precise data than we obtain from open sources on national reports. It also seems that industry definitely holds more precise information, and we have acquired some, but it is a little reluctant to provide this data. This is presumably due to the fact that industry has to re-format this data before making it public and transmitting it to private entities like think tanks.

The more precise and systematic data (different types of equipment and numbers of programmes listed) come from the US GAO report. But we have to be careful not to directly re-apply the analysis from American programmes to European programmes for two reasons:

- The quantities of defence equipment which are produced are slightly higher than in European countries: 2,500 F-35s which are 5th generation combat aircraft, when there are no more than 1,200 units of 4th generation combat aircraft in Europe with Rafale, Typhoon and Gripen. For this reason, the ratio of R&D costs compared to the total programme cost is lower in the USA than in Europe;
- On the other hand, the level of performance required in the USA and the Cost+ contracts used for R&D explain the fact that the R&D costs might be higher for a US programme than for a similar EU programme.

Ultimately, however, the magnitude of costs of acquisition programmes is similar in the US and the EU if we take into account the different types of programme. For example, the total costs of a combat aircraft can be 10 to 15 times more than the cost of an armoured vehicle.

This methodology is also intended to bring out the magnitude of costs where a number of armament programmes and different types of defence equipment are concerned (armoured vehicles, combat aircraft, frigates, satellites etc.), as well as whether the armaments programme is carried out nationally, bilaterally or collaboratively. Finally, where possible, these elements are presented in the form of diagrams or tables setting out the various costs; distinct levels of technological readiness (TRL) depending on the R&T phase or Development phase; a distinction between different costs for all the steps within the Development phase related to the taxonomy of the EDIDP; and the relative costs of an armament programme within a dedicated timeline.

1.1.2. The Need Precisely to Define a Methodology of R&D Investment: Averting Financial and Technical Risks

The complexity of armament programmes, both in terms of financial investment and technical requirements, can cause delays with regard to the delivery of capabilities, but also technical complications and cost overruns. All these circumstances are inherent risks which must be clearly anticipated during the assessment and development phases. Several key issues need to be emphasized:

- In order to avoid unnecessary cost overruns during the development phase, technical risks must be overcome during the assessment phase (TRL 5 and 6). If this is not done, cost overruns ensue at the development phase. With Atlantique2 French MPA, for example, the lack of de-risk feasibility studies led too quickly to the development phase of Atlantique2 French MPA and to underestimating the technical development issues. In that case, the cost overruns amounted to 25% of the development phase.
- the second question concerns the level of performance required by procurement entities. From our interviews, it appears that if the level of performance required exceeds a reasonable level of technical requirement, the costs of the assessment phase and development phase increase greatly. In this case, the financial risk associated with the technical risk becomes unpredictable, with resultant large cost overruns and delays. In both these cases, the cost predictions set at the beginning of the programme became unrealistic, leading eventually to its cancellation. This was the case with the MPA Nimrod MRA4 in 2010 in the UK and, to take an example of a cooperative programme, it was one of the causes of the cancellation of the Trigat MP anti-tank missile in 2002.

For companies, the level of financial risk is linked to three criteria:

- the general level of technology involved in the programme (a complex platform like a combat aircraft uses several key core technologies);
- the level of performance required, to the point where new technologies have to be developed to achieve the performance required by the customer;
- the procurement contract used by the customer.

Though the 'Cost +' contract limits the financial risk to the defence companies, it may lead to massive development costs being paid by the procurement entity, particularly if the performance required is very high. By contrast, if fixed-price contracts are used, industry must take into account the risks from the beginning during the contract negotiation, negotiate a reasonable risk margin and, even more importantly, put in place the right industrial organization during the development phase to limit and manage the risks which may appear.

- Finally, it seems difficult to define a ratio of risk for the different programmes, as this must be done on a case-by-case basis, taking account of the three criteria identified above. All that one can state with certainty is that, due to the technological risks, the assessment phase and the development phase—'Death Valley'—are the key phases where financial risk in respect of these technological risks has to be taken into account.

- Moreover, it must be emphasized that a cooperative project involving several countries needs to be precisely defined at the beginning of the programme, to avert all the financial risks relating to the complex management of a project. These cost overruns on cooperative programmes are particularly high when there is a lack of integrated public management of the programme or a lack of a single prime contractor at the industrial level, as was the case with former cooperative projects such as the Eurofighter combat aircraft or the NH 90 helicopter[1].
- Normally, if the cooperative programme is managed rationally, its cost overruns compared to a national programme will be limited, which means great savings for the participating nations, as they share the development costs and the production costs are reduced due to the higher quantities of equipment produced.

1.2. R&D Financial Costs and the Magnitude of Costs Depending on the Type of Programme

In order to better determine the optimal rates and levels of EU funding, it is necessary to determine both global magnitudes of costs and distribution of costs over the distinct phases.

In our proposal we define 7 types of equipment programmes that are representative of different financing needs, whether in respect of the total programme cost or of the costs of the R&D phase: fighting land vehicles; combat aircraft; fighting sea-surface platforms; tactical missiles; unmanned aerial vehicles; attack helicopters and multi-role helicopters. Results and developments are based on the sources listed in the paragraph on methodology.

It appears that both ratios and magnitude of costs will vary, depending on the type of programme. Therefore, it appears more pertinent to discuss magnitude of costs and ratio of R&D separately for each type of defence equipment.

1.2.1. Combat Aircraft Programmes

Regarding the total cost of programmes within this capability, the minimum current cost of a combat aircraft programme ranges from EUR 40 billion to EUR 60 billion. For the US F-35 combat aircraft, it will rise to more than EUR 200 billion, but the number of units produced is also significantly higher: 2,500 for this 5th generation combat aircraft, as compared with the 1,100 4th generation European combat aircraft that were produced.[2] Within these programmes,

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[1] Patrick Bellouard, Antonio Fonfria, 'The relationship between prime contractors and SMEs, how to best manage and fund cooperative programmes', ARES n°24, http://www.iris-france.org/wp-content/uploads/2018/01/Ares-24-Policy-Paper-SME.pdf

[2] We take account here of the domestic market with 620 Eurofighter, 286 Rafale and 200 Gripen aircraft.

research and development costs for the EU member states are close to EUR 12 billion and EUR 15 billion, being between 25% and 30% of the cost acquisition programme (*see annex 9 p 32 for more details on combat aircraft programmes*). With regard to the American F-35 combat aircraft programme and its high level of performance causing financial and technical difficulties, the percentage of development costs is quite similar to European programmes (Rafale, Eurofighter-Typhoon), but R&D costs are significantly higher—four times more, which greatly exceeds the financial capability of the EU member states.

We expect that future aerial platforms could be significantly different from current ones. They consist of several specialised subsystems. These subsystems will be able to interact with each other and it should be less expensive to acquire capabilities, as future platforms will permit of easier modifications from one generation to another.

1.2.2. Fighting Land Vehicles

With regard to this capability (medium armoured land vehicles, with about 750—1,000 produced units in EU member states, several thousand in the USA), the overall cost of a programme ranges from EUR 2 billion to EUR 4 billion. Within this programme, the ratio of R&D cost to total cost stands at approximately 10% (which is around EUR 200—250 million) and 15% for the new programme which involves complex systems. This is the sector where there is least cooperation in the EU, the NL/GE armoured personnel carrier (APC) Boxer apparently being the only example of cooperation (Lithuania has recently joined this programme).

1.2.3. Fighting Sea-Surface Platforms

The total cost of a fighting sea-surface platform programme ranges between EUR 5 billion and EUR 10 billion for 10 to 15 produced units (here we take as our example the FREMM frigate, a Franco-Italian cooperative project, which is a surface vessel with a displacement of around 5,000 tonnes). The ratio of R&D costs to total programme costs is between 15% and 20%. In this kind of programme, one platform costs somewhere between EUR 400 and 600 million.

1.2.4. Combat Helicopters and Multi-Role Helicopters

Where this form of defence equipment is concerned, the overall cost of a programme is EUR 10 billion for a production of 150 units. The R&D ratio for combat helicopters and multi-role helicopter programmes is akin to the ratio for combat aircraft programmes, being 25% to 30% of the total cost.

1.2.5. *Unmanned Air Vehicles*

In the case of MALE UAV drones, production remains very limited due to the small market—around 50 for the whole of the EU member states—and to export control rules, since a MALE UAV falls under the Missile Technology Control Regime (MTCR). The entire cost of a programme in which 50 units are developed approximates to EUR 5 billion. The R&D cost can reach 40% of the total cost on account of the limited number of units.

1.2.6. *Surveillance and Navigation Satellites*

In the case of this capability, the R&D cost is 60% of the total satellite cost, which is higher than other defence assets due to the limited number of units produced (for example, 3 units for the Helios 3 observation satellite). This may change in the future, as the trend is to develop a constellation of smaller satellites orbiting at lower altitude.[3]

1.2.7. *Tactical Missiles*

The number of tactical missiles produced varies with the type of missile. The cost of production itself is lower than for complex systems like combat aircraft helicopters and even fighting sea-surface platforms. The performance of the missile is the key. Consequently, the ratio of R&D to the total cost of a missile is high, even if there is a long product run; it may, in fact be as high as one third of total programme costs.

[3] Mary E. (Becky) Cudzilo; Christopher DeMay; Jolyon D. Thurgood, Ph.D.; and Darrel L. Williams, Ph.D. 'Small satellites, the future is brighter than ever', United States Geospatial Foundation, 17 May 2017. https://medium.com/the-state-and-future-of-geoint-2017-report/small-satellites-the-future-is-brighter-than-ever-11fcc79b4b2d

Magnitude of costs of armament programme

The following chart lays out the magnitude of costs and R&D ratios for each form of defence equipment.	Total programme Cost	R&D cost	Ratios R&D / total programme cost	Quantities
Combat Aircraft	Between EUR 40 billion and EUR 60 billion for several hundred units	Between EUR 12 billion and EUR 15 billion for EU programme, more than EUR 60 billion for F-35	Between25% and 30%	Eurofighter-Typhoon: 620 Rafale: 286 Gripen : 200 F-35: 2,500
Fighting Land Vehicles	Between EUR 2 billion and EUR 3 billion (EU programme)	Around EUR 200-250 million	Between 10% and 15% (for most recent complex systems)	Between 600 and 1000 units
Fighting Sea Surface Platform	Between EUR 5 billion and EUR 10 billion	Between EUR 1 billion and EUR 2 billion	Approximately 15%-20%	Between 10 and 15 units
Combat Helicopters and Multi-Role Helicopters	Between EUR 6 billion and EUR 10 billion	EUR 2 billion	Approximately 25%-30%	Between 100 and 160 units
Unmanned Air Vehicles	Close to EUR 5 billion	Approximately between EUR 1.5 billion and EUR 2 billion	Approximately 40%	Around 50 units
Surveillance and Navigation Satellites	N/A	N/A	Approximately 60%	Few units
Tactical Missiles	Around EUR 2 billion	Between EUR 600 million and EUR 700 million	Approximately30%	Around 1,000 units

1.3. Timeline of an armament programme

The following timeline itemizes the general stages of an armament programme with a timescale

Phases	Phases 1			Phase 2			Phase 3		Phase 4
	Initial maturation of new technologies			**Maturation of concepts**			**Development**		**Operational capability**
Actions	Feasibility studies			Demonstrations and risk studies			Development of the programme		
TRL	1	2	3	4	5	6	7	8	9
EU action	Research window EDF						Capability window EDF		

Dual-use technologies

'Death Valley'
Military development of basic technologies

based on the TRL scope:

A strong European DTIB will make it possible to implement core technologies required by future programmes. These research efforts are based on upstream funding in order to help mature required new technologies to TRL3. At that stage, technologies are often dual-use.

The stages from TRL3 to 6 need a high level of technical and contractual flexibility between procurement agencies and industries. During this phase, it is essential to have close dialogue between industry and procurement agencies, even if this is grant-funded, due to the fact that procurement bodies have sometimes to choose between different technological solutions developed in this research phase. Even if the projects were wholly funded by the EU Commission at this stage, the national procurement agencies of interested nations should be involved.

Regarding all TRL areas, the timeline of the beginning of the initial phase (TRL 1-3) as well as the concept phase (TRL 3-6) is difficult to estimate. Between TRL 1 and 3, an armament programme is not actually launched. Between TRL 3 and 6, countries are considering possibly launching a programme, but this does not always happen, as we have seen in the past with the nEUROn UCAV demonstrator. Generally, a defence programme is officially launched at the beginning of the development phase (see Annex 11 - Timeline board of an armament programme for each form of defence equipment).

A combat aircraft programme takes place over a long-time scale, with an assessment phase, a development phase and the actual production. This breaks down into 5-6 years for the assessment or risk-reduction phase, around 10-15 years for the development phase and at least 30 to 40 years between the beginning of the production and the end of the programme. During the last period, new development may occur, as is the case with the Rafale where the 'F3 version' was developed and implemented 15 years after the first delivery, and the F4 version will be under development in coming years. The F4 version can be considered a significant mid-life update, as is often the case with combat aircraft, and with other military systems that have a lifetime exceeding 30 years.[4]

A fighting land vehicle programme is rather shorter than a combat aircraft programme, with a timeline of around 5-7 years between the development and production phases and another 5-6 years for the production.

Where fighting sea-surface platforms are concerned, the period of time between concept phase and development phase is around 5-6 years, while the timespan between start of production and operational capability is about 5 years. A long time is needed on feasibility studies and the end of the development phase (around 10 years in the case of the French HORIZON programme).

In combat or multi-role helicopter programmes, the development phase is around 10 years, leading to another 10-15 years of production with the possibility of introducing new developments during the life-cycle, as in the case of combat aircraft.

With satellite capability, the development phase ranges between 5 and 10 years, with a limited time for production and launching of the few assets—1 to 3 years—and an approximate life-cycle of more than 10 years.

With tactical missile programmes, the development phase is around 5 years, with an initial limited time of production of some years, and a life-cycle that depends on the development of the new generation. Taking into account the limited life of a missile, stocks are often not very high and new production can be launched during the life-cycle of a particular type of missile.

[4] 'Vers le Rafale F-4', *air et cosmos*, 5 July 2017. http://www.air-cosmos.com/vers-le-rafale-f4-97283

Timeline board of armament programme

	General overview	Assessment phase	Development phase	Production phase
Combat aircrafts	Long-time scale (40-50 years)	Around 5-6 years	Around 10-15 years	Around 30-40 years from the beginning of production to end of the programme
Fighting Land Vehicles	Middle-time scale (10-15 years)	Around 5-7 years		Around 5-6 years
Fighting Sea Surface platforms	Middle-time scale (10-15 years)	Around 10 years on feasibility studies and the end of the development phase		Around 5 years
Combat and multirole helicopters	Middle-time scale (around 20 years)	N/A	Around 10 years	Around 10-15 years
Surveillance and Navigation Satellites	Middle-time scale (around 10 years)	Between 5-10 years		Around 1-3 years (limited time of production)
Tactical Missiles	Short-time scale (5-10 years)	N/A	Around 5 years	Limited time of production

1.4. Determining the costs of the different actions which can be eligible for the capability window of the EDF

It seems difficult to define with precision the different costs associated with the R&D phase. We received precise data for a missile programme only, and it appears that the proportional costs of the prototyping account for only 30% of the R&D phase. The proportional cost certainly differs from one type of programme to another, but we are not able to give even a small degree of precision. For example, the cost of certification and qualification may be high for a military aircraft.

2. Defining Criteria to Optimize the Level of the EU Funding Rate

To define criteria to optimize the level of the EU funding rate, various aims may be considered:

- European Strategic Autonomy implies a competitive and advanced industry. The European Defence Fund could provide an incentive to develop innovative technologies in areas where the developments costs are too high to be financed by a single European nation;

- As innovation and threats are changing faster than ever, armament programmes must become increasingly agile. Consequently, equipment may be designed to shorten the duration of R&D phases and be more easily upgraded.
- As cooperation may reduce the duplication and waste of human, financial and technical resources, the Fund's allocation methodology needs to incorporate incentives for cooperation;
- Cooperation may also foster a better exploitation of the results of defence research, innovation and technological development. It must therefore apply when a European member state cannot take on the development of a technology or a type of equipment alone, because of its lack of domestic technological solutions or expertise;
- Projects have been launched within the PeSCo - Permanent Structured Cooperation. Depending on their relevance with regard to the goal of European strategic autonomy, they might be able to have access to European funds in most cases, knowing that the current EDIDP plans to allow *'an additional 10 percentage points'* to beneficiaries developing a project in the context of the PeSCo; [5]
- The next Capability Development plan, which will be released in late spring of 2018, defines capability priorities jointly agreed by member states. These priorities should be financed by the European Defence Fund (EDF) within collaborative programmes.

From the mapping of the costs and risks proposed in the first part of this study, a typology of armament programs can be developed, and some criteria defined that should make it possible to optimize the use of European Defence Fund monies.

2.1. Defining R&D as a Fixed Cost to Establish a Typology of Programmes

The cost of an armament programme that is devoted to the R&D phase is a fixed cost. This means that these costs are not dependent on the quantities of produced units, as the purpose of the development of equipment is to fulfil technical and operational requirements that the first produced units should satisfy (these requirements may be sometimes demonstrated and implemented in an incremental way, with retrofits of the first produced units). Consequently, this total cost of R&D is not directly connected to the number of units ordered in an armament contract.

[5] European Commission, Article 11, 'Proposal of 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', 7th June 2017.

Therefore, the greater the number of units produced, the lower the fixed cost per unit and the total cost of the programme. Consequently, longer product-runs boost economies of scale.

In this framework, two elements are essential to assess the costs and risks of R&D phases: the magnitude of costs and the number of produced units. Four distinct situations can be identified, depending on these two elements, as shown in the table below.

R&D total cost / Produced units	Moderate costs	Substantial costs
Large number	Case 1	Case 2
Small number	Case 3	Case 4

(1) Case 1 refers to a programme whose R&D investments remain moderate, while the number of produced units is large. These programmes are relatively affordable for most EU countries. In this case, the impetus to work together may be slight. Nevertheless, European funds could be invested in this kind of armament programme, in order to develop common equipment to reduce duplication, limit multiple national programmes, increase interoperability and promote consolidation of the sector. For example, in the land-system sector, there are 17 main battle tanks in service in Europe, whereas only one is in service in the US.[6] This can also be a way to finance disruptive technologies or enable ITAR-free ones to be developed.

(2) Case 2 refers to an armament programme in which both R&D costs and the number of produced units are high. In this case, the cost of development is an obstacle to developing this kind of programme. The high amplitude of R&D costs can be shared where there is cooperation and the increasing number of units reduce the ratio of R&D to the total programme and consequently the cost per unit. However, the high magnitude of costs resulting from the multiple and high-level technologies of this kind of programme increase the risk during the assessment and development phases. Limiting that risk requires the programme specification to be correctly defined, a process which probably involves, first, states participating in the cooperation and the selected prime contractor.

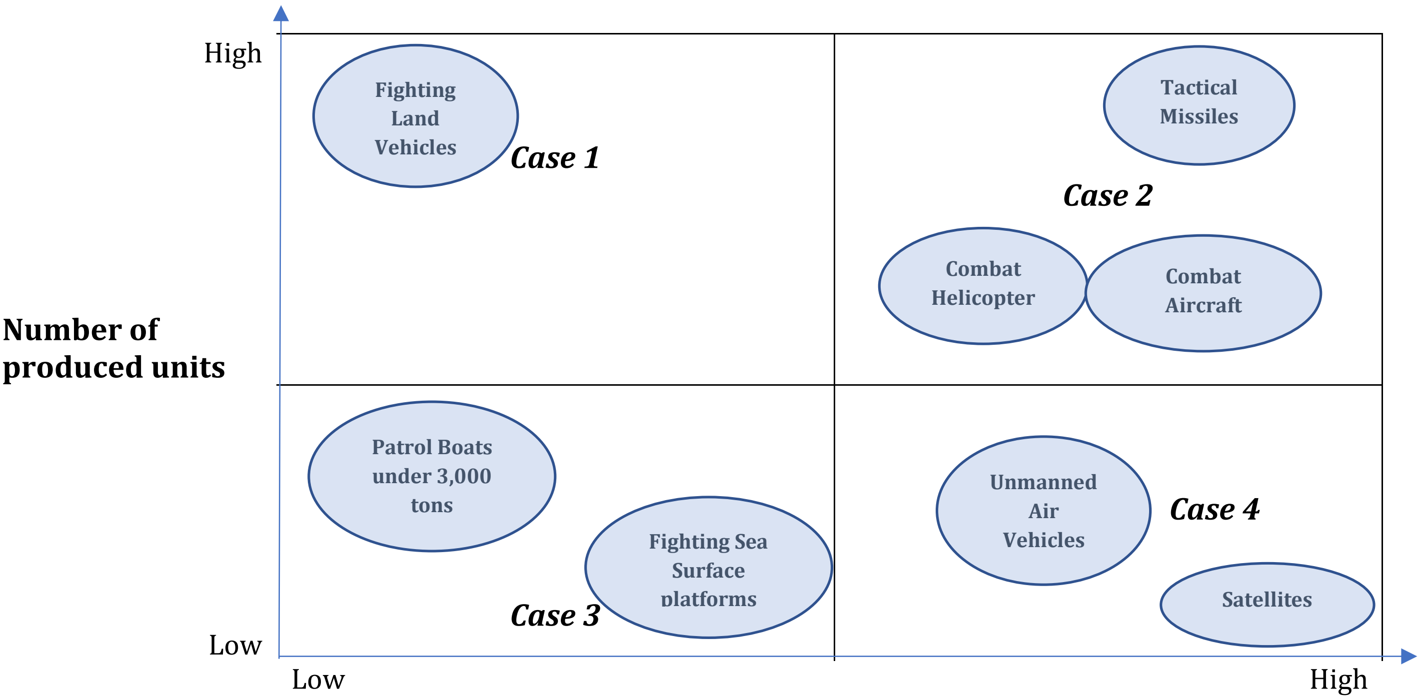
Supporting R&D will, in this case, have two objectives: to develop industrial know-how in high-level technologies and encourage EU members to launch cooperative programmes.

[6] McKinsey & Company Munich Security Conference 2018, 'More European, More Connected and More Capable: Building the European Armed Forces of the Future'.

(3) Case 3 concerns an armament programme characterized by relatively moderate R&D investment and a small number of units produced. In this case, even if the total R&D cost seems to be affordable for most countries, the cost per unit remains high. This is the main incentive for cooperation, as the collaborative approach is the only solution to boost the number of units and thus permit economies of scale. This applies specifically to less well-armed military vessels such as patrol boats under 3,000 tons (corvettes) at the lower end of the scale and more well-armed military ships at the upper end.

(4) By comparison with the other cases, case 4 corresponds to the most complex situation, because of the high level of R&D investment and small number of units produced. In this case, a collaborative approach is particularly relevant and may be the only guarantee of developing such a programme, as the magnitude of R&D investment means high financial and technical risks. The involvement of several countries compensates for the inability of a single country to bear all these risks alone. However, management of the technical risk will be essential to ensure the success of the project.

The 4 cases identified enable us to establish a typology of armament programmes, as shown in the figure below.



Magnitude of R&D costs

2.2. Criteria to Optimize EU Funding

First, there is general remark to be made. Over the last 30 years, countries have simply had difficulties finding the budgets for, and reaching an agreement on, launching new programmes: this has been an obstacle to the launching of cooperative programmes. The co-funding of the EU will, therefore, in itself be an incentive to launch such co-operative programmes. We have also to bear in mind that the cost overruns and delays of national and cooperative programmes were often due to these budgetary constraints, Rafale and Eurofighter programmes being emblematic of this case.

2.2.1. Which system to fund?

Finally, taking into account the cost mapping and risks corresponding to the different stages of defence research and development projects, we have identified several priorities for setting the optimal rates and levels of EU funding in relation to the different stages of the research-and-development cycle:

- We must prioritize the most expensive programmes—mainly those which represent the higher ratio of R&D to total cost: combat aircraft, combat or multi-role helicopters. In this field, no European state currently has the financial capability to conduct such a programme alone, even if it still has the technical capability to do so. This is also the case with MALE UAVs, where European needs are small (no more than 50 units) and export opportunities are limited by MTCR rules. In this last case, the share of R&D will remain significantly high in the total cost of the programme. The level of EU funding may be high for this type of programme. For now, it is difficult to define what could be the R&D cost as well as the production cost of a future programme because we do not know if it will be an air combat system with several platforms or simply a future combat aircraft. If we just make an incremental evolution, the R&D cost of next generation aircraft will probably amount to a range of EUR 25/30 billion, while the whole cost will amount around EUR 100/120 billion regarding a set around less than 1000 aircrafts. For the capability window of the EDF, 20% of a combat aircraft programme could represent around EUR 5/6 billion over 10 years (around EUR 500/600 million/year) for the next generation of future combat air systems, with an acceleration of the development phase that is currently too long for this type of programme due to financial constraints (around 15 years for Rafale and Eurofighter). The main reason for development delays on the Eurofighter and Rafale programmes has been budgetary constraints. It will certainly be a decisive incentive, as member states will undoubtedly have difficulties finding the budget required for the future replacement of the current combat aircraft in service.

- For the research window, it might be useful to fund demonstrators at the 5 or 6 TRL which are not earmarked to a future programme. But, due to the complexity of the technical concept and the need to test different technological concepts, it might be necessary to involve national procurement agencies in the loop and thus have co-funding, which is not currently the case with the EDRP.
- In the case of land equipment, states may be able to finance some programmes nationally. However, EU funding may facilitate cooperation and support European industrial consolidation. It may contribute to the improvement of interoperability and to greater efficiency in defence and security in Europe and stronger European strategic autonomy. It may be a promising idea to begin to fund the most expensive systems (future fighting land vehicles) and/or the most innovative ones (land UAV). Moreover, it might be useful to show that the capabilities most frequently employed during combat in EU operations are also the ones supported by EU funding. In this case, the magnitude of costs for what could be the development of a future main battle combat system seems to be around tens of millions of euros each year over some 5 years.
- The same argument may be applied to the naval field, particularly concerning surface vessels, where the total programme cost and R&D rates are not sufficient incentive to encourage states to cooperate, except for huge or sophisticated vessels where the number of units produced remains low (fewer than 10 units). In this case, it is important to underline that the core system is constituted by the different combat systems of the military vessel, not by the vessel itself. Two types of cooperation can be considered. First, cooperation to develop common platforms, customized by individual states involved in the cooperation (this option can help promote the consolidation of shipyards in Europe); second, cooperation on combat systems (antimissile defence, anti-submarine combat). This may improve interoperability and European Defence efficiency and may also lead to industrial consolidation. In this case, EU funding may be useful for the vessel itself, to encourage consolidation of the shipyards, or for the different combat systems, due to the magnitude of R&D costs.
- In the field of space, the units are very limited in number (3 units, for example, for MUSIS/CSO) and the R&D ratios are very high. EU funding may provide a genuine stimulus to launch new cooperative programmes. However, the current rules for

obtaining funds in the EDIDP regulations can be poorly suited to cooperation in the field of observation satellites. Indeed, cooperation is currently organized around a distribution of capabilities (optical observation for France, radar observation for Germany and Italy). The situation is more open with communication satellites. 100% EU funding may be possible in the future for communication satellites, as this may interest all the member states, as was the case with the Galileo programme.

- In the field of missiles, taking account of the high ratio of R&D to total cost, and the limited total cost of a programme compared to large complex systems, it might be useful to co-fund R&D with the aim of increasing the performance of the system above the basic specification. This would require funding by the research window of the EDF and the capability window of the EDF.
- Finally, taken overall, whatever the field concerned, the EU Defence Fund may finance programmes and projects each time a capability gap is identified and needs to be filled, and/or there is a need to support the development of strategic autonomy when states may not be able to meet those needs or may have difficulty meeting them. Capability gaps may exist, at times, in coherence programs that are not necessarily technically important but may have a marked detrimental impact on operations (examples of in-flight refuelling or small land systems coherence programmes). Some cases of technological dependencies can also exist and may lead to denial of use or supply disruptions. This may concern knowledge and anticipation programmes as much as combat and commitment ones and may ultimately bring to light a capability gap. In these cases, EU funding will clearly provide an incentive, even if the total cost of the programme or of the R&D are not high.

2.2.2. The research window of the EDF

It has been difficult to obtain precise data on national and cooperative programmes for the costs of the R&T phase preceding the development phase. Due to this lack of precise data, the only valuable information comes from general data provided by EDA through 'EDA Collective and National Defence Data 2005-2014' which shows that the R&T budget accounts for 22% of the total R&D (R&T+D) budget for the EU member states.

In this connection, we have to stress two points, which it seems important to point out due to the scope of the R&T phase.

The research covered by the EDRP has to be divided into two classifications:

Between TRL1 and TRL3, when it is basic R&T.

Between TRL 4 and TRL 5, when it is R&T dedicated to precise applications.

R&T between TRL 1 and TRL 3 is dual-use by nature. The technologies developed during this stage could be used for civil, security or military applications. Consequently, we might imagine that co-funding from industry is possible at this stage, but we have to have in mind that the cost of this basic research is a tiny part of the total R&D phase, but also of the R&T phase. The most important point in this regard is to finance breakthrough technologies or those where we lag behind the USA and China. This does not specifically concern the military field, but technologies that are dual-use, such as AI, deep learning and quantum technology.

Between TRL 4 and TRL 5, the research is directed to military purposes. This research cannot be used for civil applications. For example, the basic technology inertial unit of the commercial aircraft A 350 comes from the Mirage 2000 combat aircraft, but new development, beginning at TRL 4, has to be carried out to develop the civil inertial unit using the technology involved in the military asset. So we cannot envisage co-funding from industry at this stage, which is not the case with the EDRP, as research projects would be fully funded by the European Union. And industry's refusal to co-finance is even more evident in the R&D phase, given that this possibility of co-financing is available to it there, which is not the case with the R&T phase.

Another point is that the EU fund has to cover the whole costs of the research when it deals with military R&T at TRL 4 and above. As there is no certainty of gaining markets other than in the countries paying for the development of the programme, defence companies will not take any risks co-funding defence technology, particularly in the case of private companies that are in competition with all other industrial sectors to attract investors. So it appears necessary to better assess the indirect costs that have to be covered by the grants provided by the European Commission through the EDRP.

As a second consequence, even if there are no equipment programme launches during the TRL4/5 R&T phase, the technologies developed are directly geared towards the future programme. This is often the case where national procurement agencies try out several technological concepts, in order to choose the most promising one for the future programme. For this reason, it is certainly useful to involve national procurement agencies at this stage and even to envisage nations co-funding, which is not the case at the moment with EDRP.

2.2.3. *The different actions funded by the 'capability window' aspect of the EDF*

As we point out in the first part of this study, it was very difficult to identify the costs of the different actions listed in the Proposal for a Regulation Establishing the EDIDP as a proportion of the entire R&D costs of a programme. We have received only one precise set of data on these different actions from a company on an equipment programme. It shows that the distribution of costs does not indicate that the prototyping phase represents such a proportion of R&D costs as to justify prototyping costs being financed to the tune of 20% and the other actions at 100%. It seems more valuable not to distinguish all these actions but to have maximum financial assistance coming from EU funding greater than 20% (see 2.1.4).

2.2.4. The Magnitude of the Capability Window of the EDF Regarding Current Cooperative Defence Programmes

Following our conclusions on the difficulties of assessing the proportional costs of the different actions listed in the Proposal for a Regulation Establishing the EDIDP, we elaborate a projection of the magnitude of financial assistance that the capability window of the EDF can offer, taking into account the current level of cooperation and the current level of R&D expenditure.[7] We make some projections on the basis of a single percentage for the financing of the different actions of the R&D phase, not a differentiated rate as in the Proposal for a Regulation Establishing the EDIDP. Our projection takes as a basis three levels of cooperation. The current level of cooperative programmes, which is 16.5%, the objective of the EU global strategy which is 35%, and a projection beyond the future MFF in 2030, which is 50% of cooperative programmes. All these projections are made on the basis of the current situation, in which the UK is still an EU member state with the EDA 27 format. We also make two hypotheses of a single ratio of EU funding for the capability window: a 30% ratio and a 40% ratio.

Level of Cooperation Studied

- Perimeter: EDA 27
- Scope: Development expenditure calculated by defence R&D expenditure – defence R&T expenditure: EUR 6,794 billion (2014) with EDA data sources[8]
- Level of cooperation: we used the level of cooperative programme given by EDA data and not the level of cooperative R&D. We can assume that there is no slight difference between the two ratios as the "D"phase is the first phase of a programme. However the level of current cooperative D could me less than 16,5% as there are no significant cooperative programme launched during the last years.

Level of cooperation	**% of cooperation**
Current level of cooperation	16.5
Objective of the EU global strategy	35

[7] European Defence Agency, *EDA Collective and National Defence Data 2005-2014*, 2014, https://www.eda.europa.eu/info-hub/defence-data-portal
[8] European Defence Agency, *EDA Collective and National Defence Data 2005-2014*, 2014, https://www.eda.europa.eu/info-hub/defence-data-portal

Objective for 2030 (?)	50

Hypothesis 1: Flat Budget (EDA27)

Case A: 30% EDF

	A1	A2	A3
% of cooperation	16.5%	35%	50%
Cooperation (EDA 27)	1.12 billion €	2.4 billion €	3.4 billion €
EDF	30%	30%	30%
Total per year	**0.335 billion €**	**0.720 billion €**	**1.02 billion €**

Case B: 40% EDF

	B1	B2	B3
% of cooperation	16.5%	35%	50%
Cooperation (EDA 27)	1.12 billion €	2.4 billion €	3.4 billion €
EDF	40%	40%	40%
Total per year	**0.448 billion €**	**0.960 billion €**	**1.360 billion €**

Hypothesis 2: Defence Budget Flat between 2015 to 2017. After this period growing defence budget between 2018 and 2020 with +3% trend during 3 years: 9%. In this case in 2021 R&D-R&T amount is around 7.8 billion euro (EDA 27)

Case C: 30% EDF

	C1	C2	C3
% of cooperation	16.5%	35%	50%
Cooperation	1.28 billion €	2.75 billion €	3.9 billion €
FED	30%	30%	30%
Total per year	**0.384 billion €**	**0.825 billion €**	**1.17 billion €**

Case D: 40% EDF

	D1	D2	D3
% of cooperation	16.5%	35%	50%
Cooperation	1.28 billion €	2.75 billion €	3.9 billion €
FED	40%	40%	40%
Total per year	**0.512 billion €**	**1.1 billion €**	**1.56 billion €**

If we take it as a reasonable hypothesis that we do not achieve 35% cooperation before the end of the next MFF, this shows clearly that an overall ratio of 40% appears to be a minimum, with the objective of EUR 1 billion/year for the capability window.

Annex 1 - Multiplicity of European Platforms

The multiplicity of different platforms in Europe is a clear issue because it is becoming more and more complicated to develop interoperability where there are too many different types of equipment. This situation also clearly contributes to the fragmentation of the European defence industry. Indeed, the number of system lines in production in Europe is 36, as against 11 in the US.[9] The ratio is 17:2 where land systems are concerned.[10] Another example shows us that, while the United States uses around 30 types of major weapon systems, EU member states use 178 types[11] (*see annex 10 p 33 for more details regarding each area of capabilities*). The other example of duplication is that three types of combat aircraft are currently employed in the European Union (the Eurofighter/Typhoon, the Rafale and the Gripen). Data on United States programmes is provided here on an indicative basis, to show that the percentage of R&D costs depends on the number of aircraft produced. The higher the number of units in production and/or the higher the number of participants, the lower is the cost of defence R&D compared to the total cost of a programme.

[9] European Commission, 'Proposal for a Regulation of the European Parliament and The Council establishing the European Defence Industrial Development Programme aiming at supporting the competitiveness and innovative capacity of the EU defence industry', Commission Staff Working document, 7 June 2017, p. 15.

[10] European Commission, 'Proposal for a Regulation of the European Parliament and The Council establishing the European Defence Industrial Development Programme aiming at supporting the competitiveness and innovative capacity of the EU defence industry', Commission Staff Working document, 7 June 2017, p. 14.

[11] McKinsey & Company, Munich Security Conference, 'More European, More Connected and More Capable: Building the European Armed Forces of the Future', Report 2017, p. 11.

Annex 2 - Fighting Land Vehicles

For this type of equipment, we have taken data from one French programme and two US programmes. With regard to fighting land vehicles, the available data shows that the development phase represents approximately between 9% - for the American program Armored Multi-Purpose Vehicle (AMPV)[12] as well as the French programme 'Véhicule Blindé de combat d'infanterie' (VBCI)[13] - and 15% in the case of the American program M109A7.[14] The investment is lower than other equipment programmes, but total quantities are higher than armament programmes in other areas.

Programme	Total cost of programme	Development cost (R&D)	Procurement cost	Total quantities	In service
VBCI (FRA) [15]	EUR 2.490 billion	EUR 220 million (9%)	EUR 2.27 billion (81%)	630	2008
M109A7 (USA)[16]	EUR 5.997 billion	EUR 930 million (15%)	EUR 5.067 billion (85%)	570	2018 (forecast)
Armored Multi-Purpose Vehicle (AMPV) (USA)[17]	EUR 9.017 billion	EUR 849 million (9.4%)	EUR 8.168 billion (90,6%)	2936	2022 (forecast)

[12] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 67.
[13] Cour des comptes, 'La conduite des programmes d'armement', *Rapport public annuel 2010*, p. 68.
[14] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 167.
[15] Cour des comptes, 'La conduite des programmes d'armement', *Rapport public annuel 2010*, p. 68.
[16] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 79.
[17] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 67.

Annex 3 – Tactical Missiles

Armament programmes launched to develop this capability show a higher investment in the development phase than other areas. According to available data, between 17%[18] (in the US 'Joint Air-to-Ground Missile' - JAGM - programme) and 31%[19] (in the French air-air missile programme 'MICA') of the total programme costs are invested in the R&D phase. Total quantities vary depending on weapons-system programmes.

Programme	Total cost of programme	Development cost (R&D)	Procurement cost	Total quantities	In service
Joint Air-to-Ground Missile (JAGM) (US)[20]	EUR 4.763 billion	EUR 810.63 million (17%)	EUR 3.953 billion (83%)	26,437	2019 (forecast)
Missile MICA (FRA)	EUR 2.008 billion	EUR 635 million (31.6%)	EUR 1.2037 billion (68.4%)	1,300	1996
SCALP -EG (FRA)	Around EUR 2 billion	Around 33%	Around 67%	Between 1,000 and 1,500	1998

[18] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 153.
[19] Comité des Prix de revient des fabrications d'armement : 'Compte-rendu sur les missiles MICA', 143rd session, 13 October 2011, p. 3.
[20] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 75.

Annex 4 – UAV Programmes

Investments in R&D on UAV capability are higher than in other areas. In the case of American UAV programmes, development costs range between 33% of the total cost[21] (for the US MQ-4C Triton) and 42.5%[22] (for the US MQ-8 Fire Scout programme). At the moment, it is impossible to compare this with EU programmes, since there are none, though the Harfang used by France was a re-development of the Israeli Heron.

It is also necessary to develop European programmes, not national ones, within this capability because of the high investment required in the Development phase, while the proportion of produced units is low. The more countries that invest in European programmes, the lower the costs of the development phase will be for each participating country and the higher the number of units produced. Moreover, many EU member states are considering UAV and UUV as a future key capability with regard to ISR maritime capabilities and also data and imagery collection.

Programme	Total Cost of Programme	Development Cost	Procurement Cost	Total quantities	In service
MQ-4C Triton (US) [23]	EUR 10.653 billion	EUR 3.553 billion (33%)	EUR 7.1 billion (67%)	70	2021
MQ-8 Fire Scout (US)[24]	EUR 2.384 billion	EUR 1.012 billion (42.5%)	EUR 1.372 billion (47.5%)	70	2018

[21] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 109.
[22] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 111.
[23] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 109.
[24] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 111.

Annex 5 – Maritime Patrol Aircraft Programmes

It ought to be possible to produce this capability within European programmes. On the basis of current programs and available data, the development phase ranges between 19%[25] of total cost in the case of the European Atlantique2 programme[26] and 25%[27] in the case of the American Poseidon P-8 programme.

Programme	Total Cost of Programme	Development Cost (R&D)	Procurement Cost	Total quantities	In service
Poseidon P-8 (US)[28]	EUR 25.63 billion	EUR 6.33 billion (24.7%)	EUR 19.3 billion (75.3%)	122	2013
Atlantique 2 (international programme)	EUR 4.790 billion	EUR 927 million (19.35%)[29]	EUR 3.863 billion (80.65%)	22 units	1989

[25] Comité des prix de revient des fabrications d'armement, '35ème rapport d'ensemble', September 2013, pp. 7-8.
[26] 'Comité des prix de revient des fabrications d'armement : compte-rendu sur l'avion de patrouille maritime ATL2', 147th session, 12 April 2012, p. 4.
[27] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2011, p. 109.
[28] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2011, p. 109.
[29] Comité des prix de revient des fabrications d'armement, '35ème rapport d'ensemble', September 2013, pp. 7-8.

Annex 6 – Surveillance and Navigation Satellites

On this capability we have obtained precise data from a US programme only, but interviews conducted and less precise data from a number of parliamentary reports show that the scale of R&D costs is similar to the US programme.

To judge by the two available full data-sets on surveillance and navigation satellites, this specific area exhibits one of the highest percentages of investment in the R&D phase because of the technicality of the systems, though available US sources show that production is quite low. Indeed, the development phase represents 55%[30] of total cost in the case of the US Global Positioning System III (GPS III) programme. This concerns the development of a new generation of satellites to supplement the current GPS satellites and perhaps replace them.

Programme	Total cost of programme	Development Cost (R&D)	Procurement cost	Total quantities	In service
Global Positioning System III (GPS III) (USA)[31]	EUR 4.647 billion	EUR 2.612 billion (56%)	EUR 2.035 billion (44%)	10	After 2017 (but no precise information available)
Family of Advanced Beyond-Line-of-Sight Terminals Command Post Terminals (FAB-T CPT) (USA)[32]	EUR 1.467 billion	EUR 951 million (64.9%)	EUR 516 million (35.1%)	109	2019

[30] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p.145.
[31] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 145.
[32] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 143.

Annex 7 - Fighting Sea-Surface Platform Programmes

In this case, we took two programmes—one from the US and one from a Franco-Italian cooperative project. The weapons system programmes dedicated to fighting sea-surface platforms are based on a low quantity of units (approximately 5-15 units per programme). According to available data, between 9.6%[33] of the total programme cost (in the case of the US Navy Frigate programme) and 22%[34] (in the case of the French 'Frégates FREMM' Programme) are allocated to the R&D development phase. Where the R&D cost and procurement costs of the European programme are concerned, since the data is taken from the French national audit report, the reference is to the R&D costs paid by France.

Programme	Total Cost of Programme	Development Cost (R&D)	Procurement Cost	Total quantities	In service
Programme FREMM (France/Italy)	EUR 7.818 billion[35]	EUR 1.766 billion[36] (22.6%)	EUR 6.052 billion[37] (77.4%)	11	On-going programme since 2010
DDG 51 flight III destroyer[38]	EUR 38.6 billion	EUR 3.6 billion (9.6%)	EUR 35 billion (90.4%)	22	Up-coming programme

[33] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 124.

[34] Comité des prix de revient des fabrications d'armement, '36ème rapport d'ensemble', October 2014, pp. 17-18.

[35] Cour des comptes, 'La conduite des programmes d'armement', *Rapport public annuel 2010*, p. 68.

[36] The R&D cost has been calculated by the following method: The unit cost totals EUR 710.7 million, of which EUR 550.2 million is devoted to the production phase. As a consequence, EUR 160.5 million per unit is assumed to be devoted to the R&D phase. It is necessary to multiply by 11 units, and the result comes to EUR 1.766 billion dedicated to the R&D phase within the programme as a whole. The document base is the following: Cour des comptes, « La conduite des programmes d'armement » (2010).

[37] The production cost has been calculated by the following method: The unit cost total EUR 710.7 million, of which EUR 550.2 million is devoted to the production phase. As a consequence, it is necessary to multiply by 11 units, and the result comes to EUR 6.052 billion dedicated to the production phase within the programme as a whole. The document base is the following: Cour des comptes, « La conduite des programmes d'armement » (2010).

[38] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 124.

Annex 8 – Attack Helicopters and Multi-Role Programmes

In this case, we consider one US and two European programmes.

With regard to attack helicopter programmes, available data shows that R&D phase investment ranges between 20% for the European NH90 programme and 31% for the Tigre programme, while the R&D phase for the US 'CH-53K Heavy Lift Replacement Helicopter' is about 26.3%. Quantities are quite high, and the figure could change depending on the programme. Total costs for European programmes are those for French procurement. Where the R&D costs are concerned, since the data is taken from the French national audit report, the reference is to the R&D costs paid by France.

Programme	Total Cost of Programme	Development Cost (R&D)	Procurement Cost	Total quantities	In service
Tigre Helicopter (France)	EUR 5.898 billion[39]	EUR 1.832 billion[40] (31.06%)	EUR 4.066 billion[41] (68.94%)	80	2005
NH90	EUR 7.759 billion[42]	EUR 1.584 billion[43] (20.4%)	EUR 6.175 billion[44] (79.6%)	160	2010
CH-53K Heavy Lift Replacement Helicopter[45]	EUR 21.3 billion	EUR 5.6 billion (26.3%)	EUR 15.7 billion (73.7%)	200	2019

[39] Cour des comptes, 'La conduite des programmes d'armement', *Rapport public annuel 2010,* p. 68.

[40] The R&D cost has been calculated by the following method: The unit cost totals EUR 73.7million, of which EUR 50.8 million is devoted to the production phase. As a consequence, EUR 22.9 million per unit is assumed to be devoted to the R&D phase. It is necessary to multiply by 80 units, and the result comes to EUR 1.832 billion dedicated to the R&D phase within the programme as a whole. The document base is the following: Cour des comptes, 'La conduite des programmes d'armement' (2010).

[41] The production cost has been calculated by the following method: The unit cost totals EUR 73.7 million, of which EUR 50.8 million are devoted to the production phase. As a consequence, it is necessary to multiply by 80 units, and the result comes to EUR 4.066 billion dedicated to the production phase within the programme as a whole. The document base is the following: Cour des comptes, 'La conduite des programmes d'armement' (2010).

[42] Cour des comptes, 'La conduite des programmes d'armement', *Rapport public annuel 2010,* p. 68.

[43] The R&D cost has been calculated by the following method: The unit cost totals EUR 48.5 million, of which EUR 38.6 million is devoted to the production phase. As a consequence, EUR 9.9 million per unit is assumed to be devoted to the R&D phase. It is necessary to multiply by 160 units, and the result comes to EUR 1.584 billion dedicated to the R&D phase within the programme as a whole. The document base is the following: Cour des comptes, 'La conduite des programmes d'armement' (2010).

[44] The production cost has been calculated by the following method: The unit cost totals EUR 48.5 million, of which EUR 38.6 million is devoted to the production phase. As a consequence, it is necessary to multiply by 160 units, and the result comes to EUR 6.175 billion dedicated to the production phase within the programme as a whole. The document base is the following: Cour des comptes, 'La conduite des programmes d'armement' (2010).

[45] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 93.

Annex 9 – Combat Aircraft Programmes

In this case, we consider four programmes: the French Rafale combat aircraft and the Typhoon Eurofighter; a US combat aircraft, the F-18, of the same generation as the European Rafale and Eurofighter programme; a modern combat aircraft: the 5th generation F-35.

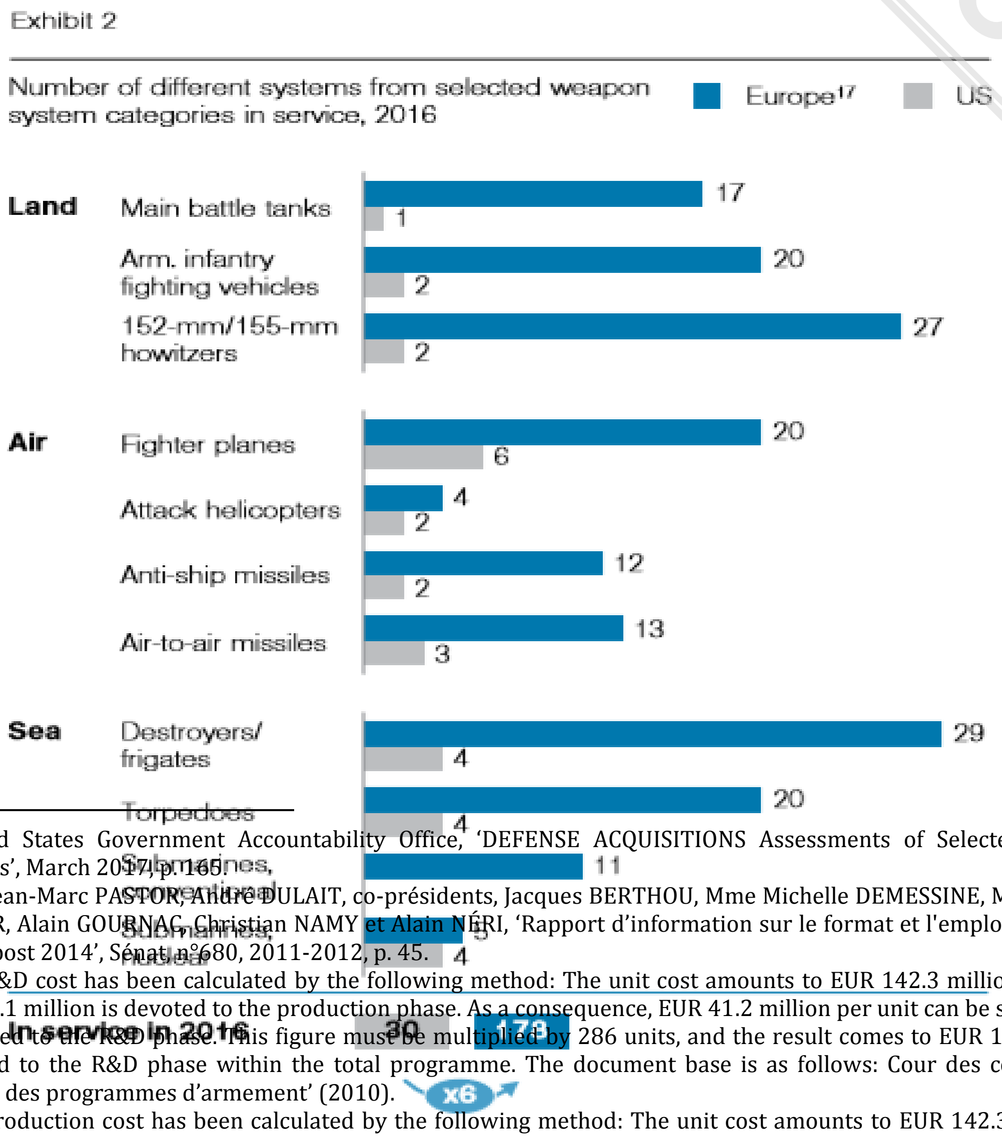
These programmes show both how very large the total programme costs are—around EU 40 billion in Europe and more than EUR 200 billion for the US F-35—and the high ratio of R&D expenditure to total cost. With regard to combat aircraft capability, we can see that investment in the R&D phase ranges between 13.9%[46] - for the US 'F/A-18E/F' aircraft programme – and 28.95%[47] in the case of the French Rafale programme. Moreover, we should note that the US Joint Strike Fighter aircraft programme devotes 20% of the total cost to the development phase (see Annex 8 for more details on these three programmes).

Programme	Total Cost of Programme	Development Cost	Procurement Cost	Total quantities	In service
F/A-18E/F	Around EUR 28.5 billion[48]	EUR 3.96 billion[49] (13.9%)	EUR 24.54 million (86.1%)	548[50]	1998
Joint Strike	EUR 273 billion	EUR 53 billion	EUR 219 billion (80%)	2,457	2018

[46] United States General Accounting Office, 'NAVY AVIATION F/A-18E/F Development and Production Issues', March, 1998, https://www.gao.gov/assets/230/225392.pdf, p. 11.
[47] Cour des comptes, 'La conduite des programmes d'armement', *Rapport public annuel 2010*, p. 68.
[48] The total cost has been calculated by the following method: The unit cost totals $64 million. As a consequence, it is necessary to multiply by 548 units, and the result comes to $ 35,072, which is around EUR 28.5 billion. The document base is the following: United States General Accounting Office, 'NAVY AVIATION F/A-18E/F Development and Production Issues' (1998).
[49] United States General Accounting Office, 'NAVY AVIATION F/A-18E/F Development and Production Issues', March, 1998, https://www.gao.gov/assets/230/225392.pdf, p. 11
[50] United States General Accounting Office, 'NAVY AVIATION F/A-18E/F Development and Production Issues', March, 1998, https://www.gao.gov/assets/230/225392.pdf – p.12.

Fighter[51]		(20%)			
Rafale	EUR 40.69 billion (as in 2009)[52]	EUR 11.78 billion[53] (28.95%)	EUR 28.91 billion (71.05%)[54]	286[55]	2001
Eurofighter Typhoon	EUR 42.5 billion	Around EUR 20 billion[56]	N/A	473	2003

Annex 10 – Number of Different Systems from Selected Weapon System Categories in Service, 2016



[51] United States Government Accountability Office, 'DEFENSE ACQUISITIONS Assessments of Selected Weapon Programs', March 2017, p. 165.

[52] MM. Jean-Marc PASTOR, André DULAIT, co-présidents, Jacques BERTHOU, Mme Michelle DEMESSINE, MM. Jacques GAUTIER, Alain GOURNAC, Christian NAMY et Alain NÉRI, 'Rapport d'information sur le format et l'emploi des forces armées post 2014', Sénat, n°680, 2011-2012, p. 45.

[53] The R&D cost has been calculated by the following method: The unit cost amounts to EUR 142.3 million, of which EUR 101.1 million is devoted to the production phase. As a consequence, EUR 41.2 million per unit can be supposed to be devoted to the R&D phase. This figure must be multiplied by 286 units, and the result comes to EUR 11.78 billion dedicated to the R&D phase within the total programme. The document base is as follows: Cour des comptes, 'La conduite des programmes d'armement' (2010).

[54] The production cost has been calculated by the following method: The unit cost amounts to EUR 142.3 million, of which EUR 101,1 million is devoted to the production phase. This figure must therefore be multiplied by 286 units, and the result comes to EUR 28.91 billion. Cour des comptes, 'La conduite des programmes d'armement' (2010).

[55] Cour des comptes, 'La conduite des programmes d'armement', *Rapport public annuel 2010*, p. 68.

[56] There are several sources available on the R&D cost of Eurofighter

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Hartley, K ; the industrial and economic benefits of Eurofighter Typhoon, University of York, York, 2008 : EUR 18 billion (p 9)

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Annex 11 – Timeline board of armament programmes

	General overview	Assessment phase	Development phase	Production phase
Combat aircrafts	Long-time scale (40-50 years)	Around 5-6 years	Around 10-15 years	Around 30-40 years from the beginning of production to end of the programme
Fighting Land Vehicles	Middle-time scale (10-15 years)	Around 5-7 years		Around 5-6 years
Fighting Sea Surface platforms	Middle-time scale (10-15 years)	Around 10 years on feasibility studies and the end of the development phase		Around 5 years
Combat and multirole helicopters	Middle-time scale (around 20 years)	N/A	Around 10 years	Around 10-15 years
Surveillance and Navigation Satellites	Middle-time scale (around 10 years)	Between 5-10 years		Around 1-3 years (limited time of production)
Tactical Missiles	Short-time scale (5-10 years)	N/A	Around 5 years	Limited time of production

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Interviews conducted

This study has been produced also with the help of several interviews conducted by our team. Different personalities coming from the area of the armament policy have accepted to respond to our questions:

- Senior officers national armament directorate, French MoD
- European affairs and R&T senior executive Defence industry
- Meeting with French defence industry associations CIDEF/GIFAS, 23 february
- Markus Neckenig, Head of Programme Management Support Division, OCCAR

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