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Key Questions for the Study of European RTD

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Introduction

There are two main elements in the composition of Work Package 1:

- Task 1, Basic Measurements, is an attempt at collecting material for measuring national military innovation systems, with particular reference to identifying recent trends
- Tasks 2-4 provide a discussion of the key institution shaping the different national military innovation systems.

Therefore the Work Package includes two distinct, although interrelated elements: (1) measuring, and (2) mapping national "defence innovation systems". The measuring element could be construed as a cornerstone for further analysis. Particularly, cross-national comparisons and longitudinal analysis are made difficult because of the lack of a common set of comparable data. For some time the CREDIT network has tried to develop a solid data gathering and analysis element into its research projects. This is widely recognised as an important task. The "Frascati manual" states that "the distinction between military and civil R&D is considered one of the most important functional breakdowns of national R&D efforts" (Organisation for Economic Co-operation and Development 1994, p.25). However, progress in the quality and quantity of data available to the researcher has been scarce and, as we will see, the definitions of defence R&D on which the OECD bases its statistical work are not as clear as one would wish..

The information collected in our first set of working papers confirms the continuing disparity of nationally-based data sets, and the difficulties of building reliable series of defence innovation indicators covering a number of countries. This is an area in which information is lacking and still needed. Despite the reduction in defence expenditures, and the lower profile granted to defence-industrial issues after the end of the Cold War, our first set of papers shows that effort invested in defence related research and development (R&D) continues to be very significant. This is particularly true in countries at the forefront of military technology development (United States, France and Britain).

This discussion paper focuses therefore on the shortcomings of present measuring tools and the difficulties inherent in improving data collection. Many of the problems have been known for decades. Yet, despite recurring discussion within academia, defence agencies and international organisations, improvements in data collection, when they have occurred, have usually been implemented only at the national level. The OECD 1993 "Frascati Manual" paid special attention to the issue of defence R&D with a whole annex devoted to problems of measuring in defence and aerospace sector (Organisation for Economic Co-operation and Development 1994). However, the basic definitions of "defence R&D" remained by and large the same as in previous editions. Besides, improving definitions would only solve part of the problem. Present changes in the structure of military production may make it even more difficult for reliable estimates to be produced in the near future. New problems may be generated if the present dual-use policies pursued by several countries meet with any degree of success. As efforts are made to improve the exploitation, both in the military and civilian fronts, of R&D efforts regardless of funding sources, military and civilian research and production activities may become more integrated. The problems of defining and confining variables like “defence R&D” are bound to become more difficult.

This discussion paper presents some of these measuring problems referring to the papers prepared for this workshop by the different national contributions. The analysis calls for a systematic approach to the international collection of defence R&D data. We provide a summary of the different ways of defining of defence R&D, and suggest the type of approach that could prove more productive in the future. We also present a brief summary of the most apparent trends in the evolution of defence R&D analysed by the different national contributions.

This paper does not provide an analysis and integration of the sections dealing with mapping of the institutional structures of the various national defence innovation systems represented in the METDAC network. This type of analysis, more qualitative in its approach, can feed directly into the Work Packages in our Programme that deal with the definition and study of national systems of defence innovation.

Measuring defence R&D: the problems

There are several reasons why the analysis and international comparison of defence research efforts is difficult. First, there is no single and widely accepted source of international data on defence R&D, and countries have different arrangements for controlling and accounting for military research. The different ways in which R&D is defined, broken down and funded in different countries can easily lead to data being misinterpreted. This section summarises some of the main problems encountered.

Definition of R&D and the content of defence R&D

Defining R&D

The main indicator used to describe the effort invested in improving the state of knowledge and generating innovations is the efforts invested in Research and Development (R&D), both in terms of funds and of personnel involved. This “input” measure has been a preferred indicator for more than 30 years, since the OECD established in its “Frascati Manual” the main parameters for defining, collecting and presenting innovation data. The “Frascati manual”, in its various editions, has since become the work of reference when generating and analysing comparable international series of R&D data.

Frascati manual definition

The OECD has published various versions of the "Frascati manual" to assist in the collection of data on the "human and financial resources devoted to Research and Experimental Development". According to the Frascati definition

> "Research and experimental development comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications".

Three categories of R&D are distinguished:

- basic research
- applied research
- experimental development

Although the main definitions of R&D and its components are clear, there are a number of grey areas in which the classification of an activity as R&D might be in doubt. Significantly, Frascati recognises that "possibly the greatest source of error in measuring R&D lies in the difficulty of locating the cut-off point between experimental development and the related activities required during the realisation of an innovation" (Organisation for Economic Co-operation and Development 1994, p.20-21). Experimental development and associated activities like manufacturing design, prototyping, tooling-up, pre-production series, and troubleshooting absorb a very large percentage of the innovative efforts in the defence industries. The costs of these activities are very high, and many of them, although part of the innovation process, are not always defined as a constituent of the R&D effort.

The Frascati manual defines in some detail the conditions under which activities like prototyping, trials and engineering follow-through can be considered part of experimental development. For instance, the production and testing of prototypes will fall within the scope of R&D as long as their primary objective is to make further improvements. Once the necessary modifications to a prototype have been introduced the R&D stage is over:

> "The construction of several copies of a prototype to meet a temporary commercial, military or medical need after successful testing of the original, even if undertaken by R&D staff, is not part of R&D."[1]

The general rule of thumb, in this as well as other borderline activities like trial production and tooling up, is to exclude them from R&D when they involve preparation for manufacturing without requiring the resolution of additional scientific or technical uncertainties. Yet, the point in which a prototype has been "successfully tested" and all technical and scientific problems have been solved is not sharply

[1] Similarly for trial production, the recommendation is to include it when it implies full-scale testing and subsequent further design and engineering, but exclude all other associated activities.

delimited. Consequently, whether a borderline activity should or should not be considered R&D is often a matter of interpretation.[2]

This generates a set of difficulties in the evaluation of R&D expenditures that are particularly intense in the case of complex defence systems.[3] Defence procurement stages do not usually fit with the stages of research, experimental development and other innovative activities as defined by the Frascati manual. Tasks like operational studies, engineering development, and user demonstration, which should not be considered part of R&D according to Frascati, will often be included within the development stages of the weapon procurement process.[4] The analysis of budget aggregates may therefore provide misleading estimates of R&D expenditures.

In sectors like defence and aerospace, where the construction and testing of prototypes absorbs a considerable share of development funds, different interpretations on the nature of R&D may result in radically different estimates of research effort. For instance, defence R&D in Spain revolves around a single project, Eurofighter, which accounts for well over 50% of all government expenditure in defence R&D (Molas-Gallart and Farrero METDAC paper). Eurofighter is a very important element of the whole R&D expenditure in Spain. Yet, the largest Eurofighter investment over the past few years has been linked to the production and manufacture of its prototypes, an unit of which has been assembled in Spain. Although R&D estimates have always included these expenditures among Spain's R&D effort, a strict interpretation of the Frascati rules may recommend the exclusion of much of the Eurofighter-related expenditure from the R&D statistics. This would completely change the profile and trends displayed by Spanish defence (and total) R&D.

It is widely acknowledged that the definitions that government agencies use to compile their research budgets do not necessarily comply with the Frascati definition. In France, for instance, there are three different indicators of defence R&D released by the Ministry of Defence and a further one released by the Ministry of Research which attempts to present data in alignment with the Frascati definition. (Serfati METDAC paper).[5]

[2] A lax interpretation of the meaning of "success" would bring most of the prototyping activities outside R&D. It can be argued that the long and complex process of proving that an aircraft design is satisfactory (a staged approach to confirm the performance and safety of the vehicle and identifying faults) would not be part of R&D. However, it could also be argued that during this process of testing and validation, the prototype has not yet been "successfully" tested, then the activity would be part of R&D.

[3] The OECD has recognised this point, devoting a whole annex of the latest Frascati manual to the provision of guidelines to decide which project tasks in the defence and aerospace sectors should and should not be included in the R&D statistics.

[4] For instance, it has been argued that in the case of the European Fighter Aircraft, much of its new technologies had been demonstrated in its British precursor prototype, the Experimental Aircraft Programme (EAP). Consequently, a sizeable portion of the work carried out to produce the development batch of EF2000 would, in strict sense, fall outside R&D (Stewart 1989).

[5] Differences between these two sets of data have fallen over the years to a relatively small 5-10% gap.

In Britain, the Department of Trade and Industry and the Office of Science and Technology publish statistics, including data on defence R&D, conforming to the Frascati manual definitions, in their publication *Forward Look of Government-funded Science, Engineering and Technology.* Traditionally, the British MoD R&D data had not conformed to Frascati conventions. After much debate about their quality MoD published in 1993 the results of a major review of the basis on which these statistics were collected, and attempted to reconcile previous practice with that of the Frascati convention (Gummett and James, METDAC paper). So far, however, this reconciliation is done only for MoD's intramural R&D expenditure.[6] The official figures presented by the MoD in the annual *Statement on the Defence Estimates* remain being built under different criteria, although for most purposes the differences are not important. The main difficulties seem to arise not over the definitions of R&D but over differing procedures within MoD and OECD for including (or not) VAT and pension costs in the R&D calculations (Gummett and James, METDAC paper).

A final general problem, derived mainly from the general difficulties in the definition of R&D, is the differences between government R&D support to industry as reported by public agencies and as reported by its industrial receivers. Hagelin and Reppy have noted that these differences are particularly important (and growing) in the defence and aerospace sectors. It appears that government agencies see as R&D spending the funding of activities that would not be labelled as such by industry, particularly in the case of large extramural contracts were R&D and production are mixed. In the United States, the differences are particularly apparent in areas like missiles and aerospace (Hagelin and Reppy METDAC paper). The latest "Frascati manual" states that the flow of R&D funds should be based on the responses of the R&D performers and not on those of the funding sources (Organisation for Economic Co-operation and Development 1994, p.23).

Defining defence R&D

The difficulties underlined so far refer to problems derived from the general definition of R&D. There is however another important problem, this one peculiar to the assessment of defence R&D: when can a R&D activity be defined as defence and when is it civil? There are two main ways of answering this question: one can discriminate between defence and civilian R&D according to (a)the goal of the research, or (b) the funding source. We summarise here the approaches taken by the two the most important organisations that collect or have collected international statistical data in this field: OECD, and SIPRI. Significantly, each takes a different alternative although balanced by a number of exceptions that reflect the difficulty of giving an easy answer to this problem.

The Frascati manual defines defence R&D as including:

[6] For internal purposes the British MoD distinguishes between *research* and *development* in a way that differs from the standard Frascati distinction. In MoD terms, work is 'development' if it is directly linked to a specific equipment project. It is 'research' if it is of a more general nature, not related to the current procurement of any specific item of equipment.

> "all R&D programmes undertaken primarily for defence reasons regardless of their contents or whether they have secondary civil applications. Thus the criterion is not the nature of the product or subject *(or who is funding the programme)* but the objective". (Organisation for Economic Co-operation and Development 1994, p. 77-the underline is mine-)

The definition includes nuclear and space R&D undertaken for military purposes, regardless of who is funding it, and does not include civil R&D in areas like meteorology or telecommunications, financed by ministries of defence. Therefore, according to Frascati rules, who is funding the programme is not the consideration when distinguishing between defence and civilian R&D. In principle this seems to make sense. We know that not all defence research is supported by defence agencies and that, at times, defence agencies support research that appears to pursue civilian objectives.[7]

In the early 1970s SIPRI started to publish with certain regularity military R&D estimates in its Yearbooks. According to SIPRI "military research and development" included:

1. all R&D financed through the budget expenditures of a country's defence department (or comparable administrative unit); and
2. all other R&D, financed by national government departments and agencies, which is officially identified as being conducted for military, defence, or civil defence purposes, or concerned mainly with weapons. (1972)

This definition revolves around *who* carries the research, rather than trying to define its objectives, like in the case of the OECD approach. To account for the cases in which substantial defence R&D was funded outside the defence agencies (like the case of nuclear weapons research in the US) SIPRI added to its estimates any other R&D regardless of sources that had been *officially* identified as being conducted for military purposes.

Both approaches face their difficulties. The SIPRI definition refers only to Government expenditure, and leads to the issue of whether defence R&D can be assessed only on the basis of government expenditure. The OECD definition relies on the ability of the analyst to decide whether research is being conducted *"primarily"* for military or for civilian goals, and is faced with the problem of dual-use research (ie research that can be applied to both military and civilian goals). We deal with these two problems in turn.

"Government R&D"

Defence is typically a function of Central Government; therefore when trying to assess defence R&D expenditure at a national basis it is common to focus on the central government budget. However, not all "public" funding is generated by central

[7] In the US, for instance, nuclear weapons research has always been funded by the Department of Energy. In Britain, in the days of the ministries of Aviation and of Technology in the 1960s, the main defence-related research establishments were outside the scope of the Ministry of Defence.

government. In many countries, regional and local authorities are responsible for R&D investments that are not registered in central government budgets. In Germany, for instance, very substantial funding for R&D is provided by regional Landers in addition to that from Federal Government (Stewart 1989); some of this may be defence-related. In Spain, regional governments in Andalucia and the Basque Country have supported the activities of defence-related firms, this funding has not been taken into account by any estimate of defence-related expenditure, let alone of defence R&D.

Even if we were able to take into account the defence R&D investments from all public agencies, there is still the R&D carried out independently by private firms. It has been argued that in countries with large military R&D efforts, privately financed defence R&D is only a fraction of government-funded efforts. In contrast, in countries with smaller government defence R&D programmes (like Switzerland and Japan) private R&D may account for a substantial share of total defence R&D (1972). This situation may be changing with the decline in defence budgets and the new types of relationship being established between defence customers and producers. As shown by the national contributions to this Work Package, the structure of defence R&D activities is shifting. Defence agencies are trying to move a growing number of responsibilities to their suppliers. They would like to see a growing role for the private enterprise funding of defence-related R&D. The firms more able to pick up this challenge will be the top defence producers in countries like the US, UK, and France.[8]

Changes in the structure of industry may also affect the volume of industrial funding of defence R&D. Hagelin and Reppy argue that the effects of the changes in the structure of the defence industry on independent R&D are still unclear (Hagelin and Reppy METDAC paper)

Defence vs. civilian R&D and the problem of dual-use

The results of much R&D, regardless of funding sources, can often be applied to military as well as civilian goals; in other words, R&D activities regularly generate dual-use outputs. Within large diversified firms, for instance in the aerospace sector, much R&D work is conducted for *both* military and civil goals (Stewart 1989). Besides, the constantly changing nature of technology prevents the development of stable criteria defining boundaries for the types of technology with potential military applications (Cuthbertson 1983). This creates a long-recognised problem for the definition and evaluation of defence R&D.

Particularly affected by this problem are the definitions of defence R&D based on the nature of research or, like the Frascati manual, on its objectives. The OECD approach falls further into problems when attempting to deal with basic research, which by definition is *primarily* undertaken to acquire new knowledge. Strictly speaking,

[8] It must be noted also that independent defence R&D investment by firms is often recovered at least in part through the overhead payments included in government cost-based contracts.

OECD's definition of defence R&D and basic R&D are incompatible, and should result in the exclusion of any basic research, even if funded by defence agencies, from defence R&D statistics. Basic research can yield results with potential application in a range of areas (military or civilian), or no practical results at all. However, the military, particularly in the US, has over the years supported basic research in areas that are felt may feed later into technical developments of interest. As shown by research (for instance project HINDSIGHT) the results of fundamental research funded by the Pentagon resulted, over time and after complex diffusion processes, in substantial military innovations.

Technology that has no other conceivable application than a military one is the exception rather than the rule. General fundamental research may feed innovations used in both military and civilian fields, and the same can be said of research in most applied experimental fields (materials research, structures, electronics, propulsion research, aerodynamics, communications, etc.). The US Department of Defense (DoD) continues to be heavily involved in the funding of basic and applied research in a variety of scientific fields. Hagelin and Reppy METDAC study of the US RDT innovative system shows that the DoD support 68% of all federally-funded research in social psychology, 60% of research in mathematics and computer sciences, and 40% in psychology. DoD fundamental research programmes during the decades before 1986 resulted in 20 Nobel prices, and military policies for manpower training, revitalisation of university instrumentation and facilities have led the way of similar federal policies in these areas.

The OECD acknowledges that "where is pressure to 'spin off' defence R&D to civil uses, or *vice versa*, the blurring of the objectives can become substantial. In such cases, only the organisation funding the R&D may be able to decide on its objective - and thus its classification as either defence or civil R&D"(Organisation for Economic Co-operation and Development 1994, p.77). This is not a very clear statement, but appears to insert an exception to the OECD procedure of defining the military nature of R&D by its objective rather than its funding source.

It follows from this discussion that trying to estimate defence R&D on the basis of the potential application of the research conducted or its primary goals is fraught with problems and often subjected to judgements that may not be correct in the long run. Taking into consideration the dual-use potential of much R&D a safer approach to the definition of defence R&D should return to an adaptation of the original SIPRI definition. This included all R&D funded by defence agencies plus other R&D expenditures *officially* identified as being conducted for military purposes although funded by other public organisations.

Meanwhile, the dual-use nature of much research has the potential of further confusing the interpretation of government R&D budgets. In France, a new budgetary line has appeared during the 1990s called "dual research", whose objectives remain unclear. Also since 1997, research funds earmarked for "dual-use objectives" are not included in the defence R&D budget, but in the procurement budget (Serfati METDAC paper). Our discussion in this chapter suggests that such functional definition of research as “dual-use” is bound to be subjective in the extreme, and that, in fact, most research efforts can be labelled as dual-use. The separation of budget entries on the basis of alleged dual-use nature of the research component is likely to further obscure the nature of the research and its objectives.

Globalisation of R&D

A further problem in accounting for R&D is created by the handling of R&D contributions to work carried out in another country. Payments like licence fees and levies contribute to R&D but are included within the cost of a product rather than a research expenditure (Stewart 1989). Formally, Defence GERD (Gross Expenditure in R&D) should exclude R&D performed in foreign territory and include R&D performed in national territory financed by foreign sources (National Group of Experts on Science and Technology Indicators 1986). Instead, if data is based on funding sources (like funding from defence agencies) R&D performed abroad and funded nationally would be included in the defence R&D indicators, while R&D performed at home but funded from abroad would be excluded. The volume of these discrepancies is bound to grow as defence R&D activities become more internationalised.

International comparisons

International comparisons of defence R&D are also subjected to the common problems affecting the comparability of any national-based financial data: the translation of national currencies into a common denomination. The basis on which the exchange rates are calculated (average commercial exchange rates, industrial prices, implicit GDP price index, purchasing power parity) and the ways in which inflation is taken account of; can affect substantially the final resulting data.[9] It is not uncommon for differences of over 40% among estimates to be derived solely from the application of different exchange rates.

Measuring R&D: Sources of data

An examination of the national studies elaborated under the first Work Package of the METDAC network reveals the deficiencies in existing R&D data. Three main sources of defence R&D data can be identified:

- International estimates aiming at comparability across countries. The main source is the OECD (OECD *Main Science and Technology Indicators*).
- Estimates assembled by central national authorities like central statistical offices.

[9] The “Frascati manual” recommends the use of purchasing power parities and implicit GDP price index for use with R&D statistics.

- Estimates contained in the national budgets and other documents of individual government departments and agencies.

International estimates aim at offering comparable data; but nationally-based data often provide more detail and the possibility of identifying with some degree of accuracy the application of the funds, and the changing trends in the structure of defence R&D programmes.

OECD data is based on a survey of official budget and expenditure data. OECD analysts assess when funds are applied to military use even when the government organisations involved are not defence agencies.[10] The main difficulties with the OECD approach have been discussed in the previous section. The OECD data is subjected to its analysts' interpretation of what is and what is not defence research, and the existence of a broad area of research with dual-use application makes such decision problematic.

In fact, the basis for the OECD decisions has not always been clear, and in some cases the "allocation" of such grey areas can cause sizeable variance in the final estimates. The report on Spain provides one such example. The main government research establishment under the direction of the Ministry of Defence is the INTA, the national aerospace laboratory. The Ministry of Defence R&D expenditure in INTA is considered by OECD to be space research and not defence; even when the Ministry of Defence controls the establishment and provides most of its funding. As the main defence GRE, the evolution of INTA funding provides a main indicator of the shifting Ministry of Defence preferences between "intramural" and "extramural" research (Molas-Gallart 1992). Following OECD data, shifts towards "intramural" research would be presented as shifts from defence to space research.

A final problem with OECD data is that it does not include private defence-related investment in R&D carried out by firms independently from government-granted R&D contracts. A brief discussion of this problem has been presented above. Because the volume of private non-reimbursable defence-related R&D effort is likely to vary from country to country, and also from year to year the OECD data may include systematic biases.

For non-OECD countries like Switzerland and Eastern European countries a source of data is the UN. Since 1980 the UN has compiled a register of military expenditure based on data supplied by national governments. In some cases, this information has included data on defence R&D, but this has proven to be the exception rather than the rule (Arnett 1998).

In its latest yearbooks SIPRI has been using a combination of OECD and UN data to provide global statistics for defence R&D. In doing so, SIPRI is distancing itself from its own previous practice of considering all defence-funded R&D as military R&D.

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[10] It must be noted that, traditionally, the United States "Science Indicators" reports defined "civil R&D as excluding both defence and civil space R&D", while the OECD defines it as total R&D less defence R&D, therefore including civil space (National Group of Experts on Science and Technology Indicators 1986).

At the national level many governments provide defence R&D data; yet the quality of these official sources varies. For many countries information is fragmented and at times incomplete. In these cases, the elaboration of defence R&D estimates would require careful independent analysis and monitoring of public spending across a variety of areas. In summary, although world-wide reporting of R&D data has improved (Arnett 1996), the quality of defence R&D data is often lacking and does not provide a solid foundation for comparative and longitudinal analysis.

Other measures: innovation output and the use of patent analysis

This paper has concentrated on the availability of defence R&D data. When available, this data can be used in international analysis and to assess the evolution of expenditures over time. In the cases when detailed data is available, studies of the sectoral distribution of innovation efforts may also be possible. Yet, defence R&D data can be combined with other indicators to provide a fuller picture of the characteristics of the innovation system in the defence industries. For instance, Serfati and his colleagues at the *Observatoire des Sciences et des Techniques* (OST) have combined official data on the firms receiving R&D contracts from the French Ministry of Defence and other government departments, with patent data to analyse the technological performance and innovative characteristics of defence-related firms (Serfati, Carpentier et al. 1997). This example shows how a broader set of indicators can provide useful analytical tools. In particular, the use of patents can provide information on the innovative patterns of defence-related firms, and their evolution across time. The application of this methodology is particularly suited to large firms operating close to their technological frontier. For smaller firms and/or less technologically advanced companies their patent portfolio is bound to be too small to provide reliable indications of changing patterns in company focus. It is common for the R&D and other innovative activities of such firms to focus in the adoption and adaptation of technological developments generated elsewhere. The result would be low patenting performance, which is not necessarily indicative of low innovative activity.

Comparing existing data: a summary of Work Package 1 results

Because of all the difficulties summarised in this paper, any comparison of the preliminary results of Work Package 1 has to be of a qualitative nature. A systematic data analysis of R&D trends is not possible.

Data structure

Because of the different national systems to fund, conduct, and account for defence R&D, not all the data definition and collection problems addressed in this paper are equally relevant in all countries. The table below is based on the national contributions to Work Package 1 and summarises the types of statistical difficulties underlined in this paper that are more significant in the different countries covered by the METDAC network.

Table. *National defence R&D data structure: summary of difficulties*

Types of difficulties	Germany	France	Italy	Netherl.	Spain	United Kingdom	United States
Data Sources							
Regional funding	✓				✓		
Differences between industrial and government reporting							✓
Research Objectives							
Weight of experimental development & associated tasks over total R&D	✓	✓	✓	✓	✓	✓	✓
Defence agencies involved in civilian-oriented R&D (or vice versa)	✓			✓	✓		✓
Accounting problems							
Domestically funded R&D carried out abroad						✓	✓

The table outlines where specific problems are more relevant, although all countries can experience to some degree all the difficulties listed. If a problem is not outlined against a specific country, it does not necessarily mean that the problem is completely absent. Yet, the table provides a first approximation to some national characters of the defence R&D systems.

Trends

In most countries under study defence R&D has either remained stagnant or fallen significantly over the past decade. The decline may not always be as substantial as it may first appear. Hagelin and Reppy analysis of the US case shows that, despite the closure of 62 government defence research facilities, there is still 35% excess capacity in its laboratories. The laboratories are trying to adapt by redefining their missions, and DoD outlays in R&D have oscillated in current terms around a stable trend.

In Japan the research budgets of the Defence Agency have remained stable, with small yearly increases in current terms, only interrupted in 1998 when for the first time over many years current expenditure in R&D suffered a decline albeit of a small magnitude. Overall stability is also the trend in the Netherlands, with R&D accounting for about 1% of the total defence budget, and remaining stable (Smit METDAC paper).

In Spain Defence R&D budgets over the past years have oscillated around Ptas40 billion, in current terms. The highest point in the defence R&D budget was reached in 1992, with a total of Ptas60 billion. This year marked the summit of rapid growing trend that had been initiated in the mid-1980s, when Spanish defence R&D budgets were almost negligible. It is likely that from 1998 defence RDT&E will return to the upward trend that characterised the late 1980s (Molas-Gallart and Farrero METDAC paper).

In contrast, military public R&D expenditures have been falling dramatically in France. Since 1990 there has been a fall of one third in defence R&D expenditure, and the total levels have returned to those of the mid 1980s (Serfati METDAC paper). Similarly British MoD expenditures in R&D have fallen considerably over the last decade, both in absolute terms and in their share of total government expenditure in R&D (Gummett and James, METDAC paper).

Sectoral distribution

Areas like aerospace, missiles, and electronics continue to focus much of the defence research activity. In the US prime contract awards for RDT&E during 1996 and 1997 show that the largest number of contracts were in the fields of “aircraft” and “missiles and space systems”, while the most rapid growth took place in electronics (Hagelin and Reppy, METDAC paper).

Although the US data underestimates the importance of electronics and does not include intramural research, it is much better than in most other countries in our study. Britain is the only other country where data is available on the distribution of defence R&D funds across product groups. Although the British MoD does not give a detailed breakdown of research expenditure, and for development only distinguishes between sea systems, land systems, air systems and general support, other sources offer information on intramural expenditure on R&D performed in UK businesses, and its civilian or defence character. Although this data reflects only part of the total defence R&D effort, it provides a valuable indication of the industrial sectors with more active participation in defence-related research. The greatest concentration of defence R&D activity lies in aerospace, followed by electrical machinery and apparatus, “other” machinery, and radio, television and communication equipment. Defence makes a critical contribution to the total R&D in aerospace, where over 60% of the R&D performed by British firms is in the defence field (Gummett and James, METDAC papers).

Conclusion: key questions for the study of defence R&D

This paper has stressed the continuing shortcomings in the availability of basic data for the study of the defence innovation system. Although the more general trends in the evolution of defence R&D can be derived from existing data, interpretation is not always straightforward, and data lacks the detail and homogeneity necessary for in-depth long-term and cross-national analysis.

Given the difficulties of defining defence R&D and particularly of using definitions based on the objectives of the research activity, we suggest that the main focus of data gathering should be placed on the R&D spending patterns of defence agencies, and public programmes officially earmarked for defence purposes. It is also important to monitor the independent R&D investments of corporations involved in defence production. This would require a co-ordinated analytical effort bringing together a systematic international study and data gathering exercise based on definitions and approaches adapted to the present circumstances.

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