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THE DEFENCE OF THE FUTURE: INNOVATION, TECHNOLOGY AND INDUSTRY

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PRESENTATION

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Since the First World War, technological innovation and research have played a key role in national defence strategies. This is what General Beaufre called the Genetic Strategy which seeks to develop new arms systems in order to overcome adversaries. Since the Second World War this technology has been transferred to industry for civil use, with equipment introduced that has a double use, thus making acquisition and development cheaper. Technological innovation and research for military purposes has thus come to play a key role within a strategic framework, making its study and analysis advisable.

For these reasons, the Spanish Institute of Strategic Studies (IEEE), in collaboration with the Directorate-General of Arms and Materiel of the Ministry of Defence dedicates this Strategy Paper to the study of this matter.

This paper has been coordinated by the former Minister of Defence and president of the Spanish Association of Defence, Aeronautical and Space Technological Companies (TEDAE), Julián García Vargas, with the valued assistance and wisdom of Carlos Suárez, Director General of Indra and head of the Defence and Aerospace Department; José Manuel Sanjurjo Jul, the Director of Institutional Relationships at Navantia and academic at the Royal Academy of Engineering; Rear Admiral Manuel Pereira Rueda, the former Assistant Director General of Technology and Innovation at the Ministry of Defence; Manuel García Ruiz, Director Industrial Development Support at Isdefe; Luis Mayo Muñiz, President and Director of Tecnobit and Colonel Arturo Alfonso Meiriño, Assistant Director General of International Relationships at the Ministry of Defence's Directorate-General of Arms and Materiel.

As indeed we might expect this truly excellent cast of contributors has produced a similarly excellent piece of work, one which is rigorous and solid which I am proud to present in its Spanish and English version thanks to the collaboration and assistance of Indra, Isdefe, Navantia and Tecnobit.

IEEE would therefore like to thank the coordinator and authors, as well as the companies that have worked on the translation, for their outstanding work.

INTRODUCTION

THE GENERAL PANORAMA OF TECHNOLOGY AND THE DEFENCE AND SECURITY INDUSTRY

Julián García Vargas

Paraphrasing Adam Smith, technology is the new "wealth of nations". Those that possess it are in an advantageous position in terms of producing goods and services with exclusive characteristics or with price and quality conditions which are superior to their competitors.

The technological skill required to invent and design and to integrate and result in competitive advantages which reduce the importance of other production factors, labour costs and risk capital.

The knowledge that is incorporated within technology fosters greater training of the workforce, quality of employment and the presence of international markets. The advantages offered by R+D and technology become a domestic bastion, even more so where there is an industry producing a marketable product or service.

The power of the state, traditionally based on military capacity and economic weight (without a strong economic base military power cannot be sustained) must now share its space with technology, becoming an essential component in assessing military and economic capabilities. Technology is therefore power, and all states with ambition to play a part on the international stage make great efforts to ensure they are in possession of it.

Since the second half of the 20th century, supremacy founded in a combination of military and economic capability has evolved in favour of economic supremacy. "Military effort killed the Soviet Union", confessed Marshall Grachev, the Russian defence minister, in the 1990s. Over recent decades, economic power has become fractured into industrial power and financial power. Both are closely related although not exactly the same. China is a great industrial might, but still lacks an efficient, internationalised bank that allows it to become, thanks to its vast commercial surplus, a force to be reckoned with in terms of financial services.

Although academic theories regarding the "post-industrial economy" predicted an irreversible loss of the influence of industry in favour of services, which has indeed occurred, the events of the past decade and the current recession has reaffirmed the importance of industry.

The success of Germany and China amidst the economic crisis which began in 2008 demonstrates this. The countries which had opted to abandon industry to focus on other activities, such as Spain, are those most affected by the downturn. The shift in the economic centre of gravity from the North Atlantic to Asia-Pacific is largely due to the transfer of a significant part of the world's industrial capacity to that region.

More recently, technology has joined the classic military and economic influence, combining and associating with these two aspects. The sequence followed seems to be that industry favours economic and technological development whilst all these combined favour the advancement of military power.

In the military field, technology increases capacity and reduces uncertainty. It allows a reduction in troop levels without the corresponding loss in operativeness, which has in turn transformed the nature of modern armies. The technology-military capacity relationship is intrinsic to the existence of armed forces ever since these began to exist in a permanent, organised form. For that reason, the history of humanity is peppered with countless examples of technological leaps forward resulting from armed conflicts. For the most recent generation, this relationship has been further strengthened: nation states do not want numerous armies but rather armies which are highly technological and operational. The digital revolution has transformed modern armies.

Does technology guarantee military supremacy in all kinds of modern conflict? Absolutely not. Modern-day conflicts and threats of conflict, most of which are of an asymmetric nature, are not resolved through technology alone, although they are difficult to win without that technology. The space occupied by virtual integrated combat, modelling through artificial intelligence, connectivity, robotisation, automated and independent platforms and the efficient support are the elements that allow these asymmetric conflicts to be tackled with success.

As a result the Armed Forces seek to maintain their position at the leading edge of technological development. They really need this. This effort is sometimes expressed directly through R+D and on other occasions through the clients and large-scale integrators of R+D resulting from other sectors.

This differentiation has become more acute recently. Over the past decade the defence industry has been surpassed as a source of R+D for other sectors. The ten leading companies in the world in terms of R+D investment have not included a defence contractor in recent years, with a corresponding increase in the presence of companies from the pharmaceutical, digital and even the automobile sector. The reason for this is that Defence Departments no longer have the budgets they used to have and their programmes are not so decisive in terms of advances to R+D, although they are still of great importance in other areas of knowledge.

Ministries of Defence have had to learn to integrate technology created in other sectors, avoiding the costs and corresponding risks associated with being the driving force in new development. They have also learnt to evaluate and detail the available technology in advance as well as improve the acquisition management with better planning, centralisation and handling of relationships between the military administration, the scientific-technical community and industry. The suppliers are controlling the evolution of research and development and its associated costs with greater attention.

In Spain, initiatives such as SOPT (the Spanish acronym for the Observation and Technological Foresight System) and ETID (the Defence Technology and Innovation Strategy), guaranteeing more accurate prior assessment and more detailed planning and execution in terms of future technology acquisition programmes. Such systems will prevent costing and delivery problems which have arisen in the past, which have had important consequences in the present.

The industrial base strategy will determine the technological capabilities which should preferably be developed by companies operating in Spain. Bearing in mind that the majority of future programmes will be multinational, these will be niche technologies that offer the best opportunities for Spanish companies.

The panorama of the defence industry has changed over the past two decades. The budgetary restrictions in place in western countries, which are expected to be maintained, will only serve to accentuate these changes. In fact, in a number of countries, including Spain, there is a risk that these restrictions, which when applied to Defence are always socially more popular, will be extended into the future.

It would be very negative for the industry if this were indeed the case; it would also have unwelcome consequences for employment, innovation, exports and Spanish independence in defence matters. Faced with this pessimistic outlook, industrial experts agree on a number of key aspects.

The *diversification* of activities within the defence industry is essential and not only with regard to domestic security. In this field, the demand for technology has accelerated and appears to be unstoppable, although the programmes here no longer have the quantitative aspect that defence programmes have.

The diversification toward sectors which are of a purely civil nature has proved to be a highly successful strategy for many defence companies. To this end they have taken advantage of R+D acquired in military programmes and the great capacity for combining this with technologies from other sectors. The *integration of systems* is a great advantage in this industry. Also of great importance here is the ongoing modernisation that prolongs the life of systems, within the global concept of support.

In any event this capacity to integrate within the defence industry is not within the scope of all companies, however sophisticated they may be: in order to be industrially capable in matters of defence and security there must also be a profound knowledge of operations and of the operative peculiarities specific to the military and security forces.

The industrial experience in this field guarantees *vertical knowledge* in order to introduce innovation beyond the scope of the sector, combining this with specific R+D and *responding to operational security needs which are often very specific.* Success is difficult without this experience.

As a result of the above, companies should not squander the industrial experience accumulated in this sector and should in fact strive to preserve it. Given the drop in domestic and European demand, the growing competition and the evident surplus capacity there are two possible business responses: specialisation in very specific niches or concentration and growth.

In truth the dilemma is not so clear cut: even where a company opts for *niche specialisation*, there is never true product exclusivity and one should be prepared to gain critical mass in order to be able to access certain projects and customers. Where the company decides to *increase in size,* certain specialisation by area is necessary; nobody can do everything. The response therefore depends on each company, on their shareholders, their financial capacity, their relative position within the sector and their diversification and internationalisation.

Nonetheless, a corporate base of a size which is minimally comparable to that of one's immediate competitors is a guarantee that ensures a share of the market. The largest European countries have favoured the merger of public and private companies to form huge industrial organisations that still have significant numbers of shareholders, although they are quoted on the stock market and are profitable. Competing with these large companies will be very difficult for Spain.

Another option, partly compatible with the above, is to ensure stable participation within large multinational groups which guarantee an industrial presence within the national territory of the state. This is a viable alternative, although one that is not always available, as it depends on the will and international strategy of these groups, as well as the will of the company itself.

The possible options are numerous and flexible, as there are also opportunities for technological, product and market alliances, as well as temporary joint ventures or wider-ranging collaboration.

Internationalisation of this sector drags all companies along with it and all these companies, regardless of their size and area of specialisation, have focussed their business in this direction. In this process, a minimal dimension is essential.

On the other hand, political support for exports and internationalisation is a constant for all important governments. In Spain we should recognise the work that ISDEFE, DGAM and SEDEF have done here.

All analysis of the future of innovation and the defence industry should take into account the close relationship between this sector and its customer, the State. This sector is tied in with sensitive concepts such as sovereignty and national autonomy: no government wishes to overly depend on another in this regard, even though that other government might be a friendly ally. It is therefore currently impossible to leave such matters entirely to the mercy of "market forces" (affected by the State's presence as a shareholder in large competitors) in an attempt to protect local companies at all costs.

The collaboration between companies and the state is obligatory therefore, even in the event that the current fiscal crisis does not allow large-scale programmes to be undertaken. The role of the State can be decisive with regard to internationalisation, exports, the concentration of size, specialisation and a number of other aspects. The State can also have an influence on the international definition of regulations and guidelines and apply them to their acquisitions, orienting R+D and business production; it can influence the orientation of possible international programmes; it participates in the decisions taken by the European Union regarding future R+D; it can decide on the defence and security capacities to be shared with allies and act within the international sphere with positive effects on R+D and domestic industrial capacities.

Domestically, a general R+D policy and definition of strategic sectors and sub-sectors can be maintained, defining the critical capacities that should be conserved as a country, orienting companies with regard to their R+D investment options. Also important here is the essential area of support, with significant opportunities for international projection. At a time of budgetary restrictions this focusing of efforts in certain areas is of greater urgency. Significant industrial policy can also be established without having large budgets available.

Spain has accumulated experience, knowledge and an ability to compete in the field of naval platforms and areas of combat and transport, simulation systems, electronics and optronics, with a high capacity for integration in electronic warfare; in sensors, data mergers and signal treatment: also in the area of domestic security technologies used in the protection of coasts and borders, emergency management, identification, logical security, intelligence, secure communications, cyber security and the protection of infrastructures. Spain is also starting to show capacity in the future area of unmanned platforms and has potential to be highly effective in logistics and support.

Maintaining technological capacities in the area of Defence cannot be a question of direct governmental protection. It is also the result of its own innovation context, based on improved training of engineers and scientists, in the close collaboration between public and private scientific organisations, in the favourable financing and support for all types of leading edge companies, from start-up businesses to mature operations with a consolidated size and range of products.

The technology is included within the European policies contained within the framework of the Common Security and Defence Policy (CSDP). This common policy requires military capabilities supplied by a European technological and industrial base.

This major objective requires the availability of technologies associated with such capabilities, as well as the rationalisation of industry on a continental level. The concern for capabilities and technology is as recent as the CSDP and the Common Foreign and Security Policy, which was introduced during the past decade. The focus on reorganising European industry dates back to the 1990s.

All of this means that security and defence technological and industrial policy is not designed and undertaken exclusively within a domestic context, with the European framework becoming increasingly more important. This requires a more active, less complex presence in European environments, both in terms of the authorities and companies. Both have a long experience acquired through the large-scale programmes that have been overseen by OCCAR (the Organisation for Joint Armament Cooperation) since the 1990s.

The EU has instigated a European Defence Research and Technology (EDRT) strategy defined by member state governments, through the European Defence Agency (EDA) in 2008, which was preceded by the European Defence Technological and Industrial Base (EDTIB) strategy. 22 technological priority areas have also been defined, along with 12 preferential military capacity areas. The combination of both these strategies defines the terrain on which governments and business should focus their R+D efforts. The field thus defined is wide-ranging, providing the margin required in order that each might find the most advantageous niche or area of specialisation.

An additional advantage is the breadth of the EU's approach to R+D. The work undertaken by the EDA in matters of defence and security technology run parallel to that carried out by the European Commission (the Framework Programmes) with regard to civil technology, including so-called "dual" technologies, and those developed by the European Space Agency and Eurocontrol. These are joint areas in which defence companies can operate freely: their diversification is favoured by initiatives which are complementary to these bodies.

More complex is the objective of rationalising the European defence industry, where there is undeniable repetition.

Since the mid-1990s there has been growing awareness of this. In order to tackle the problem the LOI Framework Agreement Treaty was drafted in 1998, as an inter-governmental initiative promoting reflection and discussion among the six European countries in which virtually all defence industry activities are concentrated. The EDA, created in 2004, also has responsibilities for armaments, R+D, industry and markets. In both fields, the progress toward this restructThe European Commission, as a result of the new interpretation of Article 346 of the Treaty on the Functioning of the EU (TFUE), Amsterdam-Lisbon has taken the initiative and set up a process aimed at creating a Single Defence Market through Intra-Community Transfer and Defence and Security Procurement Directives.

As has happened with other industrial sectors in the past, the creation of a single market may lead to a restructuring of the Defence Industry which may have positive effects on some countries to the detriment of others.

Indirectly there is an added consequence of the Commission's initiatives, with the backing of the European Council, with significant implications: the inclusion of the Defence Industry within the single European market represents the evolution of a governmental based approach toward an EC-focused strategy. This industry has traditionally been tied in with the sovereignty and independence of European states and principles such as supply and information security which have been decisive in its activities. This evolution should be expressed as part of Foreign and European Defence Policy and needs to be progressive. It would be a mistake to allow solely market forces to determine *where* industrial capacity is to be located in Europe.

This change is so profound that public opinion in many member states is yet to understand and assimilate it. Its implications are far-reaching in a period in which unemployment is at levels unseen for decades, industry has been strangled by the credit crunch and countries are so fiscally overburdened that they have to reduce all avenue of public expense, including defence.

Under these circumstances it is difficult to explain to public opinion how any investment programme in an area so tied in with the idea of the nation state as is Defence will no longer necessarily create jobs within that country's own industry. Defence programmes, which in periods of social cutbacks are far from popular, are even harder to justify.

We should also add that the Bilateral Agreement between France and the United Kingdom, which covers industrial aspects and constitutes *de facto* Permanent Structured Cooperation within the framework of the European Union. This bilateral agreement may represent something of a common front among the large-scale industrial resources in France and the UK, and may have a significant influence on the European defence equipment market (EDEM). The defence industry in other countries will not have much margin in order to be able to compete with this leviathan.

If we also add the presence of the State as a shareholder in certain large national industrial groups, who will be defended by their respective governments, we must therefore conclude that it will be very difficult to ensure there is real competition in order to *prevent an oligopolistic European market.*

The approach of industrial restructuring, moving toward a Single Defence Market is correct on a formal level; however, political and social realities have always been of great importance in the European Union, in addition to the legal and procedural formalities. On numerous occasions the European Commission has considered them in order to avoid Euro-scepticism and anti-European populist sentiment.

Applying this method, and thus ignoring the wise principle applied to all major construction decisions in the European Union - "nobody gets the lot, nobody gets nothing", is not prudent and governments should ensure it is effective.

Finally, there is an unresolved underlying problem here: the Single Defence Market cannot be considered to be an end in itself. Rather it should be an instrument at the service of a Foreign and European Defence Policy. When faced with the lack of consistency in this regard, governments should not cease to be based on Article 346 of the Treaty on the Functioning of the EU (TFUE), in order to guarantee the participation of their industries in the process of acquiring national capacity.

CHAPTER ONE

INNOVATION AND TECHNOLOGY AS DIFFERENTIATING STRATEGIC FACTORS IN THE 21st CENTURY

Jose Manuel Sanjurjo Jul

ABSTRACT

We are faced with a period of uncertainty and confusion, created by the confluence of simultaneous, profound and exponential global change: we are currently undergoing the greatest scientific and technological transformation of human history, witnessing the evolution of the current unipolar model dominated by a single superpower to a new multipolar model in which power is wider spread. New players have burst onto the international economic, scientific and technological stages, resulting in a process of globalisation that is ever more extensive and irreversible and an imminent transformation of our energy model.

The world we know is changing very quickly and this transformation will not be without upheavals, international instability and confusion of all kinds.

Maintaining a strategic international position this century will mean having both sufficient technological-industrial capacity that ensures a competitive advantage in the marketplace, as well as military muscle. Both aspects should be a logical consequence of scientific and technological development and an innovative forward-thinking business spirit in the country as a whole. In other words, the strategic positioning of the nation will depend this century on a combination of its economic and military influence, whilst these will depend on technological development and a capacity for innovation. The history of the 21st century will be written by technology and innovation.

Key words:

Technology, innovation, position strategic, competitive advantage, defence, 21st century

INTRODUCTION

To compete in an era of change and uncertainty

It is our lot to live in a historic age in which various changes have come together simultaneously. The transition from a unipolar system of international order under the supremacy of the USA to another multipolar system yet to be hatched; economic and cultural globalisation process; profound technological change that propels the transition from the industrial age to the age of information and knowledge; a cycle of deceleration in Western economies (especially those of euro zone countries), and the transformation of the existing energy model. All of this on the planet stressed by an exponential increase in population and subject to climate change whose causes and effects we still do not totally understand. These changes, many of them inextricably linked, will shape the world in which nations will have to compete over the century.

To compete internationally in the 21st century will mean pushing to maintain or improve the position within the dynamics of the international scenario. The foreseeable scenario, in which new players who claim their position in international fora are already vigourously bursting in, will be the result of profound changes in the international economic system that will make for hard fought competition.

From the viewpoint of security, the international panorama under profile will be governed by instability and uncertainty. Because of this, in this century it will continue to be essential to have as much economic as well as military muscle to ensure the international strategic position, and both should be a logical consequence of scientific and technological development and of the nation's spirit of innovation and enterprise. *In other words, the strategic positioning of a nation in this century will depend on a combination of its economic and military influence.*

In the specific case of Spain, to improve or hold on to its current relative position on the international stage will first mean maintaining a cultural, commercial and industrial competitive advantage at home and abroad, and secondly by having the means of defence and security that ensure the achievement of our national objectives and the protection of our own interests, whilst simultaneously enabling us to make an equitable contribution to the military alliances to which we belong or will belong in future.

The Crystal Ball

It would be risky, pretentious and imprudent on my part to attempt to predict the precise evolution of the strategic environment during this century, in both its industrial, economic and technological aspects as well as in matters of defence and security. On the horizon there are too many unknowns, variables and possible points of discontinuity in the process, that depending on the direction of change or fluctuation can lead to completely different scenarios (with the appearance of different centres of power, of new political and commercial relations and new security alliances). There is unanimity in different recently published strategic reports that we are moving into an age of uncertainty and of profound transformations, and if I may be permitted some frivolity, what can be stated without too much of a margin of error, is that the 21st century is going to be anything but boring.[1]

Even though predicting the future is an unscientific and sterile exercise, this is not the case when analysing potential scenarios in line with the appearance of the variables that constrain them, because this enables us to plan for what we consider most probable, and to have contingency strategies ready for those that, even being less probable, or possible; and in both cases endeavouring to prevent and to influence the variables that most influence the result. The analysis of trends continues to be a rational tool for tackling this age of uncertainty.

With the current trends in hand, what we can forecast is that international competition, in the broadest sense of the word, will unfold in a more global, more technicized, more unpredictable with regard to security, more multipolar, with new powers emerging (China, India ...) and others in freefall, and with the growing influence of non-state players such as religious or ethnic groups, organised crime, terrorism etc; a world in which science, technology, engineering and innovation will be the key factors in maintaining a competitive advantage among nations.

Even setting aside the possible points of discontinuity coming from the planet's endemic conflict zones -and that may culminate in wars involving the use of nuclear weapons, which in certain cases could lead to a sudden alteration in the flow of fossil fuels-, the future will be marked by change and the foreseeable shift in the economic centre of gravity and the power towards the South East of the Pacific, a shift that will lead logically to turbulence and instability.

Towards 2025 the population of the planet will have increased by more than 1000 million additional inhabitants, which means considerable additional pressure on the planet's resources. Around that time our existing energy model will foreseeably have entered into crisis. The backdrop of these changes is the irrefutable evidence of their being an increase in the average temperature of the planet, or stated in thermodynamic terms, the internal energy of the atmosphere is increasing with consequences that we still do not completely understand, but that inevitably will have an effect on the production of food,

[1] I would emphasise *Global Trends, A Transformed World* from the National Intelligence Council

on transport and on certain parts of the world becoming uninhabitable, which will lead to massive movements of populations.

This is not a trivial matter, because if we are not capable of maintaining niches of competitive advantage in this new world that is taking shape, we would be endangering our welfare, or standard of life is, our position in the international order and ultimately our freedom.

- **To maintain the competitive advantage individually as a nation and as part of supranational organisations to which we belong will be a matter of survival.**

The guiding thread of my contribution will be first to define the world scenario from the perspective of the economy and of security, to then analyse the technological panorama and its foreseeable evolution in more detail. Subsequently to identify the mechanisms of competitive advantage, paying particular attention to technology and innovation, to then analyse the impact of the foreseeable technological evolution on industrial competition and on defence.

To conclude, the final thesis will be that for Spain the only viable option will be to seek a sustainable competitive advantage in science, technology, engineering and innovation, concentrating on the most favourable areas given the culture, tradition, geographical situation, resources and the social and industrial fabric. And to base competition on technology and innovation were not simply require improvement in the process of generating knowledge, but rather to create and optimise new processes for its integration and exploitation.

THE SCENARIO, INTERPRETING THE TRENDS

The Global Scenario

I believe that a reflection regarding the role that technology and the capacity for innovation will play in maintaining a competitive advantage in this century first[2] requires an understanding of the field in which we will have to play against fierce international competition. As I said in the introduction, it would be pretentious to predict the evolution of the international scenario over the entire century and for this reason the problem we are dealing with is limited to the much shorter period of 2025/2050, a period which is the time reference to approach the majority of analysts usually refer. In this specific period many of the extrapolations that we make based on current trends may still be valid, and this will enable us to analyse the influence that technology and innovation will have when determining -if I may use the football metaphor-that nations will

[2] To avoid confusion I would like to warn the reader that I start with the hypothesis that the strategic weight of a nation is a direct function of its competitive worldwide advantage.

continue playing in the first division, which ones will go up and which ones will be relegated.

- *An Evolving System*

When looking into the crystal ball, as a working hypothesis we assume that the process of evolution that we call the international system will follow a continuous progression -although not linear- i.e. there will be no discontinuities that alter the trajectory of the process in such a way that they make it impossible to make any prognosis. The reader is aware of the fact that unforeseeable events of any kind can occur, natural catastrophes, pandemics, toppling of regimes, high-intensity local wars ... etc. whose probability is low, but when they do occur their consequences in such an interrelated world would be very serious and would invalidate any prediction raced on the hypothesis of continuity.

If we dismiss these potential points of discontinuity -which as I said could lead to unpredictable scenarios- the international system will continue its evolution in line with existing trends, towards a world in which power in all of its aspects, will be more distributed around the new poles of influence, i.e. a multipolar world. Among the new centres of power and influence are the nations known as BRIC[(3)] and from them new technological, economic and military powers arise, China and India, who will have to be taken into account in the future.

Although the first half of the 21st-century will continue being an "American" century, the relative influence of the USA in the new world will lessen, the enormous cost of being the only global power -as has always occurred in history- will have to be paid. But in terms of science, technology and innovation, the leadership of the USA will continue to be irrefutable for decades, although in many fields competitors have already started to close the gap.

Another trend on which all the analysts agree is the growing influence in the international environment that different non-state supranational groups will have, with such diverse aims and objectives such as those of organised crime or terrorist, ecological, religious and "anti-system" groups.

As a consequence of this global process of evolution, it is very likely that at the end of the period 2025/2050 there nothing will remain of the international system designed at the end of World War II.

A predictable discontinuity, I would say an inevitable discontinuity, that will imply enormous political and economic consequences, -in which the role of technology will be determinant- will be the change in our current energy model. Our civilisation is based on the mirage of an uninterrupted supply of petrol at reasonable prices, in which supply and demand automatically come

(3) Brazil, Russia, India and China

into equilibrium. It is evident that it is a question of time for this system to collapse more or less abruptly.

If politically it were decided to seek a technological solution to the problem -which would probably arrive too late for the moment when the demand for oil and gas fossil fuels exceeds supply- and developed economies stop depending on petroleum, the economic and political consequences for the producer companies would be enormous, as they would also be for the international flows of investment capital ... etc. This will be one of the aspects on which technological advancements will have the greatest strategic repercussions in this century.

Change in the Economic System

The major change on the horizon for the period under consideration will be the growing relative weight of BRIC countries on the world economy.[(4)] Towards 2040, the joint GDP of these four nations will equal that of the G-7 nations, and this is a reality that cannot be ignored as it will have important implications for the international economy.

But there is another aspect in the ascent of the BRIC countries that ought to be borne in mind and it is that we Western nations have always advocated an economic system based on the free market and we will have to compete with these countries' hybrid economic systems: State capitalism[(5)]. This is an important matter because to maintain a competitive advantage in these countries' markets will transcend the pure competitiveness of the companies to transfer in some aspects of the completion to the field of governments and states.

Another consideration that we cannot circumvent will be the addition of a good part of the populations of China, India and Brazil in a consumer economy and the growing process of globalisation that is taking place in these countries, which will mean enormous pressure on the resources of raw materials, energy, food and water. (This without taking into account the increase in world population of 1000 million inhabitants for the year 2025).

Evolution of the Defence and Security Scenario

We should not assume that such an extensive and profound evolution is going to be peaceful and free of conflict. A change of this nature in a relatively short period of time will inevitably generate tensions, transitory power vacuums, territorial claims, massive flows of population ... etc. When the Conflict Barometer Report[(6)] is analysed it is not possible to be optimistic with reference

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[(4)] According to *Global Economics Paper No. 99 October 2003.* According to Goldman Sachs, China will surpass the GDP of the USA in 2030 and that of Japan in 2015; India will surpass Japan in 2025

[(5)] «State capitalism», a term used by academics

[(6)] Heidelberg Institute for International Conflict Research to the trend of the future security panorama. According to that report the number of conflicts has not ceased to increase in recent years, and everything seems to indicate that we are not moving towards a more peaceful and stable planet, but rather quite the opposite.

A multipolar system in which diverse nations with interests in competing for their share of international power or in which transnational groups tend to have more power, will inevitably be more unstable and more unpredictable than the unipolar system that we know today. At the same time, areas of the planet where weak states are usually kept under the control and protection of one of the blocks, are gradually falling into the hands of groups of terrorists, traffickers, pirates,[7] etc.

But what is even more worrying than a more confusing international panorama with power being more evenly distributed and less well-defined may lead a nation for political, ideological or religious reasons to fall into the temptation of resorting to confrontation on a large scale, with the possibility of it leading to a conflict with the use of WMD.[8] A conflict of this nature could have unpredictable consequences for international order and the world economy, all the more so because the situation could dramatically affect the normal supply of hydroIf we had to summarise the foreseeable panorama for the period that we are dealing with, we would have to admit that the likelihood of a high intensity confrontation has significantly diminished (if we dismiss the endemic areas of armed conflict that could lead to a war of unforeseeable proportions). But on the contrary, there will be an increase in the number of low-mid level conflicts in which the intervention of non-state groups and the use of home-made weapons with sophisticated technology will be more frequent. Our armed forces will have to be equipped for this kind of hybrid war.

THE TECHNOLOGICAL SCENARIO, IMMERSED IN AN ERA OF CHANGE

Having analysed the foreseeable economic and security panorama, it is now the turn of the scientific and technological scenario, to which, in view of the objective of this paper, we will logically devote special attention.

A World in Technological Evolution

By repeating it so often it is becoming a cliché, but the world is indeed changing and it is not a cliché at all. We find ourselves immersed in the greatest scientific and technical transformation in the history of mankind, an unprecedented

[7] According to the International Maritime Bureau, in 2006 pirates captured a total of 188 hostages, in 2010 the number of hostages captured was 1181
[8] Weapons of Mass Destruction

transformation due to its spread, due to the nature of the changes and the speed at which they are occurring.

A change that is neither linear, nor continuous nor homogenous in all of the scientific disciplines, nor in all the technical areas, nor in all the geographical regions and lesser still, is appearing in the different industrial sectors. Even in developed nations such as our own, there are industrial age production centres currently alongside age of information and knowledge activity centres, and geographical areas that have become focal points of knowledge generation, with others that are based on labour-intensive activities.

The inevitable effect of this unequal change in the industrial and technological fabric is a centrifugal flow of production activities inherited from the Industrial Revolution -which in general are based on the intensive use of low-mid qualified labour- from developed areas to areas with an abundance of available labour and lower salary costs. In the same way, there is a centripetal movement underway in productive activities of the information age towards *areas of knowledge concentration*, which in turn generate an industrial fabric of high-technology and significant added value.

But not even having state-of-the-art research and development centres to ensure the development and creation of employment. If the intention is for technology and innovation to generate jobs for a nation, it is necessary to have a workforce with the appropriate education and training for the new knowledge-based economy.

These phenomena, although eminently social and affect the entirety of a country, have a specific importance in the industrial base of defence, since naval and land-based platforms are in general produced in industrial age centres, whilst airborne platforms and systems are produced in industries of the information age. I will later return to this topic.

In our society technical-scientific transformation affects all areas of human activity. Technology controls or health, or money, or communications, dedicate our children, it takes us around the planet, it feeds us, it occupies our leisure, it has become essential in going about our professional life and safeguards our defence. We now live in a technological civilisation where we depend more and more on machines that will gradually increase their synthetic intelligence and that will communicate directly with one another by means of the network.[9]

The man in the street's perception of the change -which is no more than the tip of the iceberg- comes from the artefacts that are made available to him in the consumer market; the more and more powerful personal computer, connection

[9] The IOT concept, the Internet of Things

to Internet with more and more bandwidth, omnipresent WiFi networks, ... etc., but above all, the mobile phone, which now forms an essential part of our way of life. Many of these innovations provide us with a "connectivity" that was unthinkable just a few years ago, which doesn't just give us wireless communication between persons, but rather also enables us to gain access to information warehouses and planet level knowledge. It is this, the integration of knowledge, that is really changing society.(10) But, if we stop to meditate, what is the real engine of this change?

The Engine of Change

The change that we are witnessing is much more than a spectacular development of information technologies and the possibility of having more or less powerful mobile telephones, iPhones, IPads, TV à la carte, and an entire range of gadgets and similar services. What we are really witnessing is the effect of the exponential accumulation of the Coded Knowledge of Humanity, which in combination with the ease of disseminating it and the possibility of assessing it from any part of the planet -even from a mobile phone- is profoundly transforming our society. This accumulative process and retrofed generation, integration and dissemination of Knowledge has a multiplier effect that will lead to advances, -which although currently not highly visible- will generate far deeper global changes over the century.

Two decades ago it was estimated that human knowledge doubles every 10 years (nowadays it probably doubles a lot more often). Why is the accumulation of Knowledge being made geometrically? The reason is that today we have the technology to store vast quantities of information, to process it in very short periods and to distribute globally almost instantaneously to any part of the planet; in other words we are *digitalising globally***.**

The accumulative and exponential knowledge creation process -with digitalisation at its core- will be what leads to a global technological revolution in the 21st century and will be what really determines the strategic position of nations, depending on their capacity to manage the change. The 21st century will be a digital century.

To understand the true effect of digitalisation, please allow me to cite Nicolas Negroponte(11), who announced in his famous work, "Being Digital", that the philosophical principle of this revolution was simply, *"to change atoms for bits"*. This means transferring to electronic digital format, bits, everything

(10) While I write these reflections on my portable computer I can access the Library of Congress (mankind's biggest coded Knowledge repository) to check references. Isn't this a real cultural Revolution?

(11) Former Director of MIT Media Lab at Massachusetts Institute of Technology. Author of the book, "Being Digital"

that we now handle in physical format, atoms. I do not wish to go to for in this matter, but I believe that it is very obvious that the physical format loses importance in gigantic steps: the newspaper on paper, the CONDITIONS, the printed book, letters, invoices, instruction manuals ... etc. Atoms are losing ground in favour of its. But digitalisation is more than just a change of format, it also transfers functionality that was traditionally carried out with mechanical elements to the world of bits.

Nevertheless, the true revolutionary effect of digitalisation is the impact that the growth of processing power has on the development of numerous disciplines of science and engineering, what we could define as the capacity to generate knowledge by means of bits. Today there is not a single scientific or technical discipline that does not depend on digital techniques for its advance. Remember that without digitalisation on a grand scale it would have been impossible to decipher the human genome or to simulate the physical behaviour of plane, ship, bridge or building design, etc.

Although I would dare to go a step further than Negroponte and announce that this revolution is not limited solely to changing atoms for bits, but rather *"changing neurons for bits"*. That is to say, to transfer human mental functions to digital processors. And here enters one of the fundamental topics of the digital revolution that will have the most profound effect on the changes that we will see in this century, an explosion in the use of *(synthetic) artificial intelligence*. When I deal with the matter of automation and robotisation I will return to the subject in the influence of technology on Defence. And there is still another more worrying step, which I do not believe should come into this paper, -quicksand- which is the land of integration of *neurons and bits.*

Why eactly is the Digital Revolution occurring just now? The answer is simple: Moore's Law. The core of the digital revolution, what really makes it possible, is the microprocessor. This component follows an evolutionary line that goes back to the discovery of the transistor in 1947 which was followed in 1959 with the manufacture of the first transistors using wafer technology, in 1961 with the first circuit integrated on a wafer that marks the start of the manufacture of microprocessors. The evolution of microprocessors from four bits to the current 64 bits has meant a gigantic leap in processing capacity. In 1965 Gordon Moore announced his mythical law in which he predicted that the processing capacity of these components would double every two years. And not only has it grown exponentially, but the price of a MIPS[12] has also fallen exponentially, to the extent of making processing capacity available to the average consumer at reasonable prices, which a decade ago could only be acquired for an official institution.

[12] Million Instructions Per Second

What is surprising is that this law that is still being heeded for microprocessors and is also obeyed by other basic electronic components, sensors, screens, etc., which explains the exponential growth that has come about in turn in diverse fields of science, technolgy and engineering that depended on having the necessary calculation power for their development.[13]

In his empirical law, Moore referred to the growth in the performance of the physical support (hardware), nonetheless the visible part of the capacity of computers is the logical support (software). But can the development of software follow Moore? It was Nathan Myhrvold who came up with the reply to Moore that, "The software grows in size and complexity at a higher speed than Moore's Law." Now we have the hardware and software growing exponentially.

The technologies that will provide the competitive advantage in the 21st century

- *The other Revolutions; The technologies that will change the world*

The reader can consult numerous reliable sources that identify the critical technologies that will have a true impact in this century.[14] The sources are very varied and their focuses are diverse, but in general there is a degree of unanimity when indicating which of them will experience spectacular development, such as for instance biotechnology, renewable energy, biofuels, energy storage technology, robotics, nanotechnology, the new generation of the Internet of Machines and Objects.

It is not my intention, and I believe it would be beyond the scope of these reflections to carry out a systematic and detailed analysis of the individual technologies that will have a determinant in this century, but I do believe that to understand how science and technology will contribute to defining the distribution of power and influence it is necessary to analyse the structure of the different clusters of technology that will be critical when mapping out the future. Because everything indicates that we are entering a totally new phase of technological development of unpredictable consequences that will fundamentally affect the current international order.

(13) Nevertheless, it was Moore himself who warned us that if the microprocessor manufacturing technology were not radically changed then the limits of physics would arrive and that his law could cease to work in approximately 2020 (CRITICAL DISCONTINUITY POINT). Nevertheless, experience shows that the growth of overall technology is exponential and when it dries up and reaches the limit of its possibilities another will take over. In fact in this matter there are already various candidates competing for that fabulous prize.

(14) The reader can check numerous reports regarding future technological trends, to cite one of them, "Disruptive Civil Technologies" from the National Intelligence Council is a good example.

I believe that it has already been made sufficiently clear that digitalisation will continue to be at the core of the great scientific-technological transformation discerned for the coming decades. Internet is evolving and must become a network not just of computers but also of machines and objects, a change whose consequences I dare not foretell.

In a world dominated by technology we should not be surprised that the attributes necessary to maintain a competitive advantage in civil trade are practically the same attributes that, as we will see later on, our digital combatant will need. In civil society the critical factors will be connectivity, automation, robotisation and mobility. Of all of these, the determinant attribute in this century will be connectivity, not as an element to improve the capacity of communication between individuals or to satisfy their leisure needs, rather as a key factor to achieve a global competitive advantage. A society that does not understand this and does not assimilate the dominant value of connectivity in international competition will have lost the game before it starts.

Connectivity in a digital world was in principal and initially, the capacity to transfer the maximum quantity of bits between producers, databases and the different users. But this connection will continue evolving to the extent that they make it, propelled by continuous advances in digitalisation, the concept of sole communication platform, the man-machine interface, the capacity of distributed «on demand» processing and Internet . The other aspect that will influence the evolution of connectivity will be, as is logical, the development of infrastructure in both the terrestrial and space segments. I believe it is unnecessary to underline the fact that taking a position in all the technological clusters relating to connectivity will be a differentiating factor in international competition.

Along with the technologies relating to connectivity, there is a constellation of three inextricably linked technological clusters that will play a determinant role in the global technological revolution of this century: *biotechnology, nanotechnology and the technology of new materials.* The combination of the developmental results of these technological clusters will provide solutions to many of the problems and the growing needs that will be posed for an over-populated planet facing climactic change and a shortage of raw materials and natural resources. But as well as these, innovations that come about in this constellation of technologies will provide a considerable competitive advantage in fields such as energy, manufacturing, etc., i.e. a dominant strategic position in relation to competitors in critical segments.

One area that requires special mention is that of energy in general. The manner in which the technology is managed to bring about the inevitable change in the energy model around 2030 will be determinant for many nations. This will be especially critical for nations such as Spain which has a shortage of fossil fuels and is therefore extremely dependent on imports, the situation of strategic and economic vulnerability. To achieve the optimum equilibrium of the energy sector triad: security of supply, sustainability and competitivity, will demand a technical revolution in intelligent distribution systems, innovation in storage methods and technological development in distributed generation.

TECHNOLOGY AND STRATEGIC POSITION IN THE 21ST CENTURY

The competitive advantage

To understand the role that technology and innovation play in the strategic position of a nation it is necessary to understand their effect on the competitive advantage and on its businesses on the international stage.

I do not believe that nowadays anyone doubts the correlation found between the levels achieved by a nation in science, engineering, technology and the capacity for innovation[15] with its economic growth and industrial development. Nevertheless, this correlation cannot be considered biunivocal and far less linear.

The affirmation that scientific advancement leads to technological development and that this is converted directly into advantage in the market is now simply not held. And even less valid is the hypothesis that technological innovations automatically generate wealth.

[15] Science, engineering and technology are concepts that are not always used rigourously. Speaking in a strict sense, in every rational process of the human mind aimed at resolving a practical problem or at satisfying a tangible need, there are three levels of knowledge, which although interconnected are independent processes.
The first, the scientific plane, is where «know why» lies, i.e. the knowledge base of how nature behaves for the phenomenon in which we are interested. For instance, to design a radar the equations that rule the propagation of electromagnetic waves in the atmosphere, that govern their reflection, reception, those relating to signal treatment ... etc., belong to scientific knowledge. Another different type of knowledge is that which is required to design the different elements that scientific knowledge will bring forth, which is what we class within the field of engineering. One thing is to know the equations of Maxwell and another completely different thing is to design an efficient antenna. This is where the «know what» lies.
Finally, there is the plane of abilities and knowledge that enable us to build, integrate and test a system, this is where practical «know how» lies, which at the end of the day sets the difference in terms of competitivity. It would be impossible for me, and it would also be excessively tedious for the reader, if we were to maintain this differentiation between the different planes throughout this paper, so the reader should be indulgent and excuse me in advance for the lightness with which I will now use the term «technology».

Technological changes are of course one of the determinant factors to increase competitivity and we can confirm that these do indeed generally generate wealth, but not for the entire world. The appearance of new technologies and of technical innovations create opportunities for the appearance of new industries and businesses, but there is also the risk of them failing and of others disappearing, who can't or don't know how to adapt to the pace of change. The total final count, which need not be positive, will depend on many varied factors linked together on a national and international level, which will act differently in each type of industry and in each particular business.

And neither do I believe that anyone doubts that competition in the 21st century is going to centre on knowledge and ideas. I do not wish to seem too Malthusian, but the fact that we live on a finite planet subject to an exponential demand for resources means that any response will have to be made and solutions sought to the enormous problems that this situation will present; problems relating to energy, food, health, accommodation, education and the environment. Is there any other rational alternative other than resorting to science and technology to resolve them? Technology and innovation will be the determinant factors when selecting the winners of the international competition. For a nation to maintain their relative strategic position in the international order, with the changing scenario of this century(16) as the backdrop, this will mean having to maintain a sustained and adaptive, cultural, trade and military industrial competitive advantage on the basis of good management of its most valuable resource: grey matter.

As concerns science and technology, in this century resting on laurels could be fatal. Globalisation and the increasing competition from rapidly developing economies (RDE),(17) will result in modification of the international technological scenario as we know it today. The large centres of knowledge generation have until now been concentrated above all in the USA, Europe and Japan, but in the same way as we are seeing a displacement of the economic centre of gravity towards Asia, we are also seeing a parallel phenomenon for knowledge, will be more distributed around the new focal points. In the future, no nation -not even the USA- will simultaneously be able to be the leader in many fields of science and technology (neither will it be able to sustain a global military hegemony in all of the broad spectrum of possible conflicts).

This means that competition will also be unleashed in the field of knowledge, so that on the national plane it will be necessary to make a coordinated effort of all society in order to maintain a sustainable advantage in certain scientific and technological niches that are considered critical. For a nation, the result of this competition will be that in the end it will determine to a great extent the

(16) The military advantage will be dealt with below

(17) Brazil, India and China

wealth, standard of living of the citizens, its specific weight in the international order and finally its defence capability.

Ensuring a global competitive advantage in certain industrial and military segments will mean being among the winners of the fierce international technology competition. This means in our case that it will determine the place that Spain occupies in the world of the future.

The lessons of history

What does History tell us about winners and losers? Michael Porter started his book, already a classic, «The Competitive Advantage of Nations» asking the fundamental question of why some nations have been successful in international competition and others have not. Although the question that we should now be asking is what the factors will be in a more and more global, interdependent world immersed in the biggest technological change in History that will determine the nations who come out victorious from the international competition and those who fall behind.

Analysis of the past is always a good starting point. Nevertheless, we should be tremendously cautious when extrapolating from reading, because the theories and arguments that are valid for explaining what has happened in a world where the advantage lies in an economy's own factors still dominated by the last phase of the Industrial Revolution is not going to throw much light on a century such as this one, which is characterised by an exponential technological change and is of an essentially different nature to what we have seen in the past.[18]

In general, nations who in the past have known how to adapt, to assimilate more quickly and to manage new technologies better have had more success than those who have been reluctant to take up innovations. But never in the past have we seen such an extensive, profound and rapid change as the current one, and for that reason selected strategies have to be established in order to follow the giddy pace of change.

In an age of change such as ours, on which technologies should we bet? Domestically, success will consist of choosing from those that will propel the following technological revolution and prioritising technological clusters that best adapt to the conditions of the environment and the specific characteristics of each nation, and being sufficiently creative to get ahead and adapt strategies to market changes.

But, it will not only be crucial to get it right in the choice of the appropriate clusters. Another aspect that will have a fundamental effect on competitivity is the capacity of a nation to transform its scientific and technological potential

(18) Unfortunately evolutionary theories are analytical, not predictive, and only provide trends.

into a competitive advantage in the market. At the end of the day the strategic position that a nation holds will depend on the capacity it has to place value on the potential of its scientific-technological fabric.

- *The National Innovation System*

To place value on the technological potential and the domestic capacity to innovate depends on the ease of connecting knowledge producers and idea generators with their consumers, who are those responsible for transferring them to the market in the form of products and services. This capacity is a function of the interaction of numerous factors that form what is known today in the professional literature as the National Innovation System (NIS).[19]

NIS can be conceptually represented as a model in which all the actors -insiders and outsiders- who take part in the innovation process are identified and in which all the interrelations between them are characterised, which enables quantification of their efficiency. To describe a potential model for Spain would exceed the scope of this paper.[20]

More than the a nation's rate of growth, its NIS efficiency index will be the real determinant factor for predicting its potential and its strategic positioning in the future. For example, the result of the bid between the USA, EU, China and India for world leadership in technological development -if we set aside possible discontinuities- will depend on how these nations are capable of optimising their respective NIS and of defining the appropriate development strategies.

There are many factors that determine whether a society is creative and innovative and knows how to place value on this capacity (an efficient NIS), some of them are tangible and others intangible and therefore more difficult to evaluate and quantify. For instance, the *attitude for encouraging creativity* in a society is an intangible factor, but at the same time it is fundamental for generating innovation. It is a factor that depends on cultural and historical aspect deeply rooted in each society, and is often difficult to recreate or to transplant starting from nothing to another place. Why did Michelangelo, Leonardo and Raphael walk the streets of a relatively small city like Florence?

The *receptiveness of governments and administrators to innovative ideas* is another factor that logically has a significant influence on the NIS, not just directly in what refers to the efficacy of public research, but rather because governments, as important consumers of technology -as for example the

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(19) Global Trends 2025. National Intelligence Council

(20) The reader interested in the subject can find a vast amount of information about it by simply serving the Internet with the heading National Innovation System, which is how it is recognised in the professional literature.

defence sector- indirectly determine the direction and vitality of the system with the decisions. For instance, a negative attitude when taking risks in the development of new technologies could be indirectly closing off avenues of innovation. As an example of the negative effect, we have the well- known initial resistance of the Royal Navy to steam propulsion and as a paradigmatic example of rapid receptivity towards an absolutely innovative technology, the Manhattan project.

The ease of *access to finance, the mobility of the workforce and the legal mechanisms of intellectual* property rights are other factors that are normally considered when evaluating the efficiency of the NIS. But the really determinant factors are *the human factor, TIC infrastructure, the organisational infrastructure of R&D, the national research strategy and the national strategy for market penetration.*

The human factor is something that cannot be improvised and although in some cases "brains" can be captured abroad, this is logically something exceptional and at the end of the day the capacity will depend on the nation's own pool of players(21), which in turn is a direct consequence of the efficacy and quality of the education system. If we have come to the conclusion that competition in this century is going to be about knowledge and ideas then it is no exaggeration to state *that the competitive advantage of a nation will depend to a great extent on the efficiency of its education system to train the number of graduates with a quality that the new economy requires.*

A controversial subject is what the role of public Finance should be when establishing and financing the technological effort, because the rules of the game in this regard are also changing. Liberal economists believed until very recently that those who competed in the international field were companies not nations.(22) Nevertheless, most recent experience contradicts -or at least modifies- this affirmation, because what we're seeing is that more and more nations act with global government-industry integrated competitive strategies.(23) It should be remembered that the economies of the BRIC nations have robust public intervention in many sectors and cannot be considered free market economies in every sense of the term. Their systems are what are currently called *state capitalism,* and here is the paradox, how can a private company -even supposing that it is of considerable size- compete in R&D in a sector in which a nation such as China decides that it is strategic and invests enormous amounts of public money? How can a private company compete in the international market with another public one that has all the institutional

(21) Once again I turn to a football metaphor
(22) See Michael Porter in the previously cited work
(23) This phenomenon was started in the defence industry and is now being transferred to other industries

support of a state behind it, mobilising significant political, economic and military influence?

In any case, in the long-term, with a free-market model or with state capitalism, to be competitive overall a nation needs to have competitive businesses, needs public or private firms that are capable of creating value and of being profitable.[24]

The NIS is therefore a useful instrument for evaluating a nation's potential for converting its technological capacity into value, whilst at company level in order to understand the effect of technology on the competitive advantage, the best analytical tool to turn to is analysis of the value chain.[25]

Technology affects the competitive advantage of a company in so far as it contributes to maintaining its position of advantage in the market, in cost and in product differentiation. Put more simply and flatly, as far as it is capable of selling services and products in any more and more competitive market that the result more attractive by the prize, the design, the innovative technology, the singularity or by a combination of some of these attributes. This means that it contributes to maintaining the advantage both by following a strategy of competing by cost as well as by competing in innovative products.

Technology somehow intervenes in practically all the activities of a company's value chain and this is regardless of the technological content of the products it makes or the industrial segment in which it competes. There is no magic recipe to determine how to inject technological advances into the different activities of the value chain, as this will depend precisely on the innovative spirit of the company. But as a general, the more capable an industry is of adapting digital technologies, automation and robotisation to its processes, the greater will be its competitivity.

Technology, energy and competition

The manner in which technology is managed to effect the inevitable change to the energy model that will come about around the year 2030 will be determinant for many nations. This will be especially critical for nations such as Spain which has a shortage of fossil fuels and is therefore extremely dependent on imports, a situation of strategic and economic vulnerability.

I have already previously referred to the potentiality of the cluster formed by biotechnology, nanotechnology and new materials, so from their exploitation and a combination of them, there will be to a great extent a solution to our future energy needs.

[24] What purchasers are willing to pay for what they are being offered
[25] Porter, Michael. *Competitive Advantage.* The Free Press 1985

Cyberspace, connectivity and robotisation

We live in a digital society where the working of government, public services, our businesses, the banking system, the stock exchange and even defence abstractly depend on cyberspace and its most tangible expression, the Internet. Cyberspace will be the backbone of the technological, economic and industrial capability in this century.

At the same time, in a world dominated by technology we should be surprised that the attributes that are necessary to maintain a competitive advantage in the world of civil trade are practically the same attributes that our digital combatants need. In the civil society of this century the critical attributes will be *connectivity, automation and robotisation and mobility* (as we will see, these same attributes will be those of the future combatant).

Of all of these, the determinant attribute in this century will be *connectivity,* not as an element to improve the capacity of communication between individuals or to satisfy their leisure needs, rather as a key factor to achieve a global competitive advantage. A society that does not understand this and does not assimilate the dominant value of connectivity in international competition will have lost the game before it starts.

Connectivity is the most visible expression of the digital revolution, since it really deals with the transfer of the maximum quantity of bits through cyberspace connecting the producers and databases with the different uses. The concept of connectivity will evolve as they evolve, propelled by continuous advances in digitalisation, the concept of salt communication platform, the man-machine interface, the capacity for "on demand" distributed processing and Internet. The other aspect that will influence the evolution of connectivity will be global coverage and the increase in bandwidth, which will logically pass as the development of infrastructure in both the terrestrial and the space segments.

TECHNOLOGY AND STRATEGIC MILITARY POSITION

I believe, I have previously discussed this, but allow me to give an introduction to the section and reaffirm the thesis that for a nation like Spain to maintain its strategic position in this century, on the one hand it will need to achieve a technological-scientific advantage that guarantees its position in the world economic ranking, and on the other to maintain the military capacity that is a logical consequence of its technological, industrial and economic development. So, now that the effect of technology on the competitive advantage of a nation has been analysed the time has come for us to consider how technological revolution will affect the world of defence. I would like to make clear that I would exclude from this section the three technologies previously identified as the driving force of what will be the next great technological revolution. The reason for excluding biotechnology, which was down to play a fundamental role in this century is because in my opinion international agreements regarding the use of biological weapons will prevail. As far as nano technology is concerned it's current state of maturity makes it difficult to predict its impact on defence on a large scale. In consequence I will limit myself almost exclusively to analysing the impact of the digital revolution on the battlefield.

The impact of technology on the battlefield of the 21st century

- *The nature and scale of future conflicts in this century. Fukuyama vs Huntington*[26]

Returning to the thesis of the need for a military component. Unfortunately, in a more and more unpredictable and increasingly unstable world in which international[27] institutions are weaker and weaker, it will not be possible to enjoy international influence without having a degree of military muscle, as in a world with a globalised economy that sustains itself on the increasingly free circulation of goods and services, and on a free cyberspace, it will be essential to maintain order and laws that guarantee this traffic. If transnational organisations and nations become incapable of imposing international laws, -by other means or by force- it would be simply impossible to have normal operations in world trade. International order would slip dangerously towards a more and more chaotic panorama, aggravated by the proliferation of states incapable of exercising their authority over any type of non-state agents (with increasing influence over certain geographical zones).[28]

As I already commented at the start of these reflections, by reading the «Conflict Barometer 2009»[29] report, it is immediately deduced that the trend since 1945 has been towards a constant increase in the number of low and medium level conflicts parallel to a stabilisation in the number of high-level conflicts, for

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(26) In the 1989 Francis Fukuyama published the article «The End of History?» in the magazine International Affairs, which in 1992 became a book entitled «The End of History and the Last Man», in which he argued that following the end of the Cold War, liberal democracy would mark the end of the India logical evolution of mankind.
Samuel P. Huntington is the creator of the theory that following the end of the Cold War, religions and cultural identities will be the major source of conflict. The principles of his theory were published in 1993 in the magazine Foreign Affairs entitled, «The Clash of Civilisations», which also subsequently became a book.

(27) At the time writing these reflections, Tunisia and Egypt are subject to upheavals of popular uprising and Libya is caught up in an internal war.

(28) If we had not been intervening in the Indian Ocean, any maritime activity in the zone would have been interrupted, with the enormous economic consequences that this would have entailed.

(29) Heildelber Institute for International Conflict Research. University of Heidelberg. There are other institutions who prepare reports with similar content.

which it seems we are not going to live on a more and more peaceful planet, but rather quite the contrary. If this trend continues the most foreseeable panorama will be the proliferation of low-level conflicts, and far less likely a high-level confrontation between nations.[30] The optimistic forecasts of a "peace dividend", and Francis Fukuyama's view of the world have been abandoned, and it seems to me that we are closer to the predictions of Huntington. The proliferation of low intensity conflicts obliges us to intervene frequently in areas far from our borders, both for reasons of international law as well as of human rights or simply because of the need to provide humanitarian aid.

But it is not only that the total number of conflicts increases, it is that their very nature is also changing. The type of combat that our combatants will have to face in the future will foreseeably be of a hybrid type, in which on the one hand will be a combination of regular troops, irregulars, paramilitaries, on civilians, etc, in congested scenarios (urban combat, areas of busy maritime traffic etc.), a new fog of war![31] At the same time there will be a concurrence of high-technology and other rustic but efficient threats[32] with increasingly sophisticated individual anti-air missiles; pirates and terrorists armed with anti-ship missiles or unmanned aircraft, land vehicles, surface ships or submarines.

To recapitulate, on the one hand we cannot rule out our combatants having to intervene in a high-intensity conflict and they should consequently be equipped for that possibility, but on the other hand the most likely interventions will be in low-intensity conflicts in which they have to face a range of high-technology weapons and other home-made ones. This equation can only be resolved on the basis of technology, this should be the future combatent's competitive advantage. We will only be able to provide our future combatants with protection, mobility, connectivity, precision and robotisation by means of technological innovation.

In another order of things, within a few decades technology will have spectacularly expanded the dimensions of war as we knew it until recently; the combat that we witnessed in the first phase of the last Iraqi war is a preview of multi-dimensional war, in which action in the three spatial dimensions and in the electromagnetic spectrum dimensions are integrated to produce a simultaneous and devastating effect on the enemy; an effect that an uni-dimensional army with a classical structure and tactics is simply unable to face.

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[30] Nevertheless, we should remember that there are at least three geostrategic zones with chronic cystic conflicts that could at any time turn into a large-scale war in which the use of nuclear weapons cannot be ruled out.

[31] At the time of completing these reflections the outbreak of conflict in Libya is a clear example. In a single theatre of operations which the concurrence of NATO forces, irregular forces, on civilians, regular Libyan forces, mercenaries and probally special operations forces from third countries.

[32] IED roadside bombs are an example

This integrated action is the product of an evolution from the concept of combat focused on platforms (in which what is important was the individual capacity and the number), moving to the concept of networks of platforms (which started to take advantage of the synergy of different platforms' capabilities) and which is now being transformed into the concept of integrated and virtual battlefield, in which all the players share data and their coordinate actions, i.e. a cyberspace subset.

But at the same time as this evolution in the direction of greater integration towards a kind of large virtual organism -technically possible thanks to the digital revolution coming about, consisting of technology extending the battlefield to the three continuum:[33] the ocean continuum, which has until now been the traditional one -that technology opened in the period of discoveries-, space and cyberspace. Any nation that wants to maintain a certain degree of military superiority in the future will have too achieve a competitive advantage in the integrated digital battlefield, in space and in cyberspace.

Nevertheless, we should be cautious and think that potential enemies will not fight a war in classical terms and fight face-to-face where we have overwhelming superiority. Our enemies will consider the fight in asymmetric terms, using low or high technology depending on their convenience, and without doubt if it is possible they will expand the combat to the continua of space and cyberspace were our greatest vulnerability is found.

We tend to consider asymmetric war as a current phenomenon, but I cannot resist remembering that the since David brought down Goliath -a shepherd with a sling and five stones, and a soldier armed with the best technology of the period- asymmetry is always been inbuilt in war.

What role will the technological revolution play in military capability?

Revolutionary changes in military technology, although they have not been very frequent, have neither been something new throughout history. In the past there have been technological transformations that have had a large repercussion, such as for example the massive use of artillery in the battlefield and on-board ships. The impact of this technical innovation was felt in the military field as well as in the political, social and geostrategic -as Carlo Cipolla said,[34] European supremacy in the period of the discoveries and subsequent expansion was due to the combination of sails and cannons. Without going any further, we cannot ignore the fact that the manufacture of the enormous quantity of steel artillery demanded by ships-of-the-line in the 18th century

[33] I take the liberty of using the Latin term continuum to define an environment regulated by international agreements, but in which nations exercise solely a limited sovereignty. In particular I will refer to three continuum: the Ocean, Outer Space and Cyberspace.
[34] See «Guns, Sails and Empires» by the same author.

were a significant inducement for the development of blast furnaces, which in turn was the embryo of the iron and steel industry and the icing on the cake of the Industrial Revolution.[35]

From a purely technical point of view we can consider World War I as the first technological war in history; the war in which for the first time machines were generally and extensively used in the battlefield. This saw the debut of new war machines and the perfection in with other already existing ones. This was the war for the use of military aviation, for the appearance of the battle tank, of the submarine as an oceanic weapon, of the torpedo as a decisive weapon, of artillery fire control, of naval armour plating, the use of the steam turbine and the use of the incipient chemical industry in the military effort. But it was during World War II when we witnessed the systematic use of Knowledge applied to military force. All warring nations turned to mobilising all their scientific, academic and technological resources to try to achieve a competitive advantage over their adversaries.[36]

Now we reach the Cold War, which along with the space race was purely and simply a technological competition, which was fed by a continuous spiral of threats and systems to cancel out threats, until one of the rivals could no longer resist the challenge due to economic exhaustion.

But now, contrary to what happened in the past when immediate operational needs were those that spurred on inventiveness, it is not just the threat that drives the technical transformation of armies. The real driving force is the profound technological change that society in general is experiencing, or to be more precise, the pressure of the civil market for technology. Armies are changing today largely because they are dragged by the tsunami of the digital revolution.

The foreseeable future trend would be that the pressure of demand and the corresponding frequency of technological renovation that it generates mean that the civil market is developing more rapidly than military demand. Not even nations with the volume of defence spending such as the USA can continue maintaining multiple lines of technological development for exclusively military use. If we make the exception of technologies exclusively for use in military applications, armies will, with more or frequency, turn to adapting those developed in the market. This is what has come to be known as COTS components.[37]

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(35) Cast iron artillery substituted bronze artillery aboard ships for simple reasons of economy. The cost of a bronze cannon became prohibitive because of the increasing price of copper.
(36) The Manhattan Project alone mobilised more than 100,000 graduate technicians from official institutions, from private industry and from the universities.
(37) Commercial off-the-shelf

The profound technological change that our society is going through will continue to have profound consequences in the area of defence (traditional consumer of high technology) which can stand aside from the Digital Revolution and will be seen forced to continue the profound review and transformation of the Armed Forces in order to adapt them to combat in the world that looms ahead; basically in a digital world in which nobody should doubt that the competitive advantage of the combatant will be technology.(38)

At last the digital combatant and the integrated battle space

As has already been stressed throughout these reflections, in both high and low-intensity conflicts the competitive advantage of the combatant cannot be based on mass and saturation. It will have to necessarily be in technology, and above all technology that is capable of generating added value from information and knowledge. But the fact that the our combatants' advantage lies in technology is far from meaning that we should persist in the operational concept that came to be known as RMA (Revolution of Military Affairs).(39) A kind of balm from Fierabrás that was going to solve all future battles. Nevertheless, it would be so dangerous to blindly believe in the paradigm of the RMA, like extrapolating current experiences to future hypothetical conflicts and drop the guard with respect to the technology that we use to equip our combatants.

It would be totally unacceptable for us to send a combatant into the battlefield with technology inferior to that used by school children in their videogames or with connectivity inferior to that available to any of our adolescents. I believe that this is worth a reflection.

If there is anything that we can be sure about it is that nobody can precisely predict the nature of the next war. Let us not make the same mistake that we are frequently accused of, of preparing ourselves for the last war!

- *The Virtual Integrated Battle space*

The enormous technological advances that are taking place in the civil world, which is building and evolving cyberspace on a daily basis, are going to drive the massive use in the battlefield of digitalisation techniques and information technologies, easing the implementation of the connectivity paradigms, i.e. that of achieving a truly virtual integrated battle space (virtual because the

(38) Recently there has been a degree of scepticism about the competitive advantage provided by technology, or to be more specific regarding the RMA concept. See for example the recent report from the UK end of the "Future Character of Conflicts". I cannot disagree more with this argument, the only way to maintain security and improve the protection of our combatants will be to go for innovation and an entire series of new technologies.
(39) The Future Character of Conflict, UK MOD

material and logistic support of the system is distributed in a wide geographical area) that has a certain parallel with the cyberspace of the civilian world and could even be considered in some way to form part of it.

Phenomena such as the evolution of the Internet towards an object network are not just of computers, the growing use of virtual recreation of reality in different fields of science and engineering and new concepts such as "cloud computing", adapted to the military world and accelerated even further the establishment of the *Integrated Battle Space* paradigm, since these will ease not only direct communication between every type of machine and components between themselves, but rather the interaction between virtual worlds and the real world, with effects that we still cannot predict.

Returning to the topic that concerns us, on a physical level the concept of integrated battle space will evolve towards a system that integrates all the sensors,[40] all the process nodes, all the platforms (manned or unmanned), all the resources in orbit, all the weapon systems in the theatre and all the combatants by means of a fabric of broadband networks that permit the exchange of high quality information in real time.

In this paradigm, at the information level, any system element will not only be capable of gathering relevant information from the surroundings (directly from the combat operations theatre), but rather will be able to access extensive databases and software applications situated in other information nodes, which will enable it to expand and increase its knowledge of the action scenario, i.e. *amplified reality.* The system component will in turn process the information, it will use it for its mission and will exchange it with other combatants,....., a large virtual system of systems.

At the cognitive level, the combination of human and artificial intelligence will enable real-time "perception" of the exact status of the theatre of operations, and the construction of virtual models that will enable the optimal use of resources at the exact moment and to maintain the initiative over the enemy. To draw up a view of the surroundings using sensorial elements, to process information, to exchange it with other processing centres, and to activate the specific motor responses. Is this not a form of virtual brain?

The simplicity and elegance per se of this conceptual model hides the enormous technical complexity of its implementation and its subsequent evolution. But once a truly virtual integrated battle space is implemented the advantages for the combatants are obvious:

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[40] Sensors that are more and more accessible, better connected, more distributed, weigh less and occupy less volume.

- Achieving a total and integrated view of the operations theatre's surroundings with a same spatial and temporal reference. All the participants will be sharing the same view of reality, where their own forces are, where the enemy is, how they are manoeuvring, which suppose and imminent threat, etc.
- Having a total and instantaneous view of the battle space has the clear advantage of being a step ahead of the opponent in any manoeuvre.
- The reaction time for command and control decisions will be shortened considerably.
- The allocation of the optimal weapon for the most threatening target will be made automatically without having to follow the usual bureaucratic processes.
- Logistics will connect with the force more efficiently.

The dream of every combatant comes true by seeing what is on the other side of the hill! (Liddel Hart) and «the fog of war» (Clausewitz) clears.

This is what is known today as superiority of battle space knowledge.

On the other hand, the growing neutralisation of all digital electronics will ease new developments in the field of intelligent weapons, improving the precision and target discrimination; key characteristics to equip the combatant with greater firepower based on information and not on the concept of saturation.

The technological axes, pillars of the integrated virtual battle space concept, are *connectivity and automation.*

- *Connectivity. Plug and Fight*

Connectivity is the capacity that all the elements of the integrated battle space have that enable the exchange of information, i.e. the ease of connecting to the fabric of networks by means of wireless global access in real-time with broadband. But this concept is evolving rapidly; it is no longer simply the exchange of information. The future combatant -the same as we already do in some way with our iPads and intelligent phones- will exchange software applications and share processing resources as required by the tactical situation. This capacity will be the essence of the future connectivity paradigm, moving towards a digital battle space ecosystem.

To have aglobal range with high bandwidth first means having a consistent infrastructure among other means, in satellite constellations, UAV's and other types of platform that ensure total coverage of the conflict area. And at the same time, in the same way as occurs in the civilian world, the future trend will be towards the bandwidth increasing exponentially. So if we want to take advantage of all the available information and the capacity to share processing resources through all space, the technology of networks, satellite communications and UAV links will have to revolve in that direction. But something more than this, to create a type of connectivity that distributes the information process and software applications do not necessarily reside on the platform or with the individual combatant adds a new level of complexity to the designs.

Think for a moment about a multinational battle space with land, naval and airborne forces, with robots on the ground and unmanned aerial vehicles; the fabric of networks can be really complex and in spite of inter-operability it can be a difficult task to achieve connectivity. The technology will have to ensure that the networks self-configure so that the user only has to do something as simple as *plug and fight*.

I would like to add a final consideration; connectivity in the digital world is a dialogue between machines that exchange their own messages as per their own protocols. For the operators the process is a page and the only thing visible to us is the interface that allows us dialogue with a terminal. Even so, practically the only way in which we can dialogue today with our computers is by using an alphanumeric keyboard or a touch screen. Either of the two solutions keep the operator's hands busy and for a few seconds distract his attention from the surroundings, and this at a critical moment in a combat could be a question of life or death.

In the future the natural form of communication with a machine should be by the spoken word, without ruling out other forms of relating to our body language, like indicating to the machine in which direction we are looking (this type of communication is already being used in weapons systems), or going further, by means of simple mental orders. I am entirely convinced that in the coming decades we will see significant advances in this area.

- *Automation and Robotision*

A requirement of the *integrated battle space* will be the capacity to process vast amounts of information *automatically* in real or almost real time. The trend is that, to the extent that technology allows advances in process automation, the information grows exponentially in volume and complexity.

But process automation will not only be used at the upper level of the systems, it will also be used extensively at the level of platforms, equipment and even individual combatants. In fact, in both civilian life and the military world there will be more and more "intelligent" elements connected to cyberspace.

With the aim of helping the understanding of this matter, I am going to consider three different aspects of its military application:

- The first field of application is in the "nodes" of the *integrated virtual battle space.* What we call nodes time at the same time have the complexity of the combat system of a frigate or of a command and control system. In reality we already have systems operating with this level of automation, as in the case for instance of the combat system on the Álvaro de Bazán Class Frigates.
- The second field of application is what we call platform control. These systems are today extremely complex due to the number of parameters that they have took control, due to the variety of automatic functions that they have to carry out in due to the level of reliability that is required from them. Imagine for example that all existing fighter planes are aerodynamically unstable and could not fly without being fitted with automatic control systems; or that the submerged navigation management and the new system of anaerobic propulsion of our S-80 submarine will be managed by an automatic system.
- The third is the robots, i.e. automation associated with unmanned that forms referring both to the handling of information as well as to platform control.

I believe it is necessary to devote some space to this latter aspect because of the enormous influence that it will have on the future battlefield.

- *Robotisation of the digital battle space*

The battlefield has already started being robotisized. The trend clearly points in the direction of a growing role for robots in the digital battlefield.

During the coming decades we will witness the appearance of new types and new generations of those that already exist, that will live and will operate jointly with manned platforms. This will be an area of enormous development during this century.

The basic principle of military robotisation is to take the operator out of the platform and pass it or control it from an earth station or from another manned platform.

Today we have the technology to implement this concept without any difficulty. To take the operator out of the platform complicates the control link, but at the same time presents clear advantages: the vehicle size is reduced considerably and as a consequence all its design parameters such as the propulsion power, vital operator services, its protection system, etc. If dealing with airborne platforms, the limitations on manoeuvres above certain «g» forces and the duration of missions that the physiology of the pilot imposes will disappear. In the case of submarine robots there will also be a far more intuitive advantage of removing the operator from the vehicle. Robots will enable a considerable reduction in the physical risk and the number of losses of troops.

Analogical Brains in a Digital World

The use of military robots in operations is growing constantly, but their future as an essential element in the composition of armies will be largely constrained by the advances that are achieved in artificial intelligence, in the available processing capacity and in the energy solutions that facilitate their autonomous mobility.

Foreseeably, in this century the evolution of the «brain» capacity of robots will follow a similar guideline as nature followed. For the reader to understand this better I would like to make clear that in all my considerations my starting point is the *digital hypothesis, i.e. any functionality of a biological brain can he emulated by means of digital technology.*

Technology exists today that enables the manufacture of robots with an *instinctive intelligence* equivalent to a reptile; i.e. capable of building an image of the surrounding universe and by integrating its sensors, to discover the threat or the feed and act in consequence, but everything within a very rigid behavioural frame.

The following evolutionary step will be to have a brain capable of superimposing *instinctive intelligence the learning capacity intelligence,* and here we are speaking of the simplest brain of a mammal.

The third step could be taken when there is sufficient calculating power available so that the brain carries out real-time *simulations of the situation,* compares it with previously experienced situations and stores it in its memory and makes predictions that enable it to act.

And so finally the great milestone of humanity, to create an inorganic brain capable of emulating our own. Different estimates indicate that a capacity of 10exp8 MIPS should be sufficient for a digital machine to emulate the fabulous analogical "machine", our brain made up of 100,000 million neurons plus the corresponding synapses; and all of those with a consumption of only 20 Watts.

Supposing Moore's Law continues being complied and that the problem of energy consumption is solved, the calculating power and the necessary memory could be available around 2030 or 2040, in either case before the middle of the century.

But the problem of emulating the human brain with digital technology is not basically a problem of calculation capacity or of memory, it is a programming problem, and here we should be much more cautious.

In any case the enormous financial, scientific and technical efforts that are being devoted to the study of the human brain along with the development of new tools for its observation will bring to us asymptotically closer to a level of knowledge that will enable us by using inverse engineering to have prototypes before the end of the first half of the century. All the same it pains me that I should not go further into this fascinating topic.

Robotisation of the battlefield is an irreversible trend and we will have more and more different types of robots in service, far more «intelligent», that do not need operators in the control link, capable of deciding on what actions to take. The digital combatant will have to learn how to operate in this sophisticated and complex environment, but which offers enormous operational opportunities.

Energy for the digital combatant. Batteries and Petrol Stations

Since World War I, which we can consider the first technological war, petrol has played a crucial role in strategy and in the result of conflagrations since mobility and the capacity of manoeuvre were achieved on the basis of having an uninterrupted global supply of petrol and fuel.

Here History can also teach us some valuable lessons. In the Second World War, contrary to what happened to Japan and Germany, the USA had the supply of petrol assured. The need to assure external sources of petroleum constrained a significant part of the strategy of these two countries.

Napoleon said that armies move on their stomachs, current armies are moved by consuming enormous amounts of fossil fuel. The consumption of fuel in recent conflicts has surpassed any forecast made on the basis of previous experience. In general, expeditionary forces need to move themselves with their own fuel distribution system independently of local distribution networks.

The digital combatant will be a large consumer of bits and kilowatts necessary to operate their systems and to provide them with the tactical mobility that will be required in new scenarios. The first technical problem that arises, taking into account the foreseeable change in the energy model that will inevitably come about during the century, is to provide the energy to feed military platforms (vehicles, planes, ships, submarines, motor vehicles, etc.). To put it in colloquial terms, *"the petrol pump problem"*.

We are facing the dilemma that during this century our armies will consume more and more energy, but at the same time the most elemental strategic principle advises that national security can not be subjected to the vicissitudes of a more and more unpredictable supply of petrol.

How will we drive the platforms of the future?

Every army has a different energy problem. The example, in this century the Spanish Navy will bring between two and three new generations of surface ships into service (the first in the window 2020/2025, the second between 2050/2060 and the third towards the end of the century). Nobody can imagine that the hypothetical frigate «Jorge Juan» that is delivered in 2060 will continue being driven by petrol.

In naval platforms the trend I believe will be on the one hand in the direction of integrating power generation and electrical compulsion as a single system, and on the other the use of superconductor technology in engines and generators, but this does not resolve the fundamental problem of primary fuel (who produces the electricity?). If we rule out the solution of nuclear energy, the only alternatives will probably be to go for biofuel technology and hydrogen.

To have a reference as to what is being done in this regard, an example is that the US Defense Department has launched an ambitious programme, not devoid of controversy,[41] for the development of alternative fuels with the objective of 40% of the fuel consumed by the U.S. Armed Forces coming from this source by 2016.

This is a field in which the contribution of the technological triad that I have previously referred to as the driving force behind the great technological revolution is going to be definitive, both with reference to the cultivation and production of biomass for the production of biofuels, as well as an increase in the efficiency of solar cells, fuel cells or the development of new catalytic converters, etc.

In a way, in Spain we have already started down this road with the development of a propulsion plant for the S-80 submarine based on fuel cells fed with hydrogen produced on board using bioethanol.

Due to the great difference in civil and military demand, the solutions for airborne and land platforms will to a great extent come from those adopted by civil industry, although some of them, for example the electric car, will have to be initially ruled out for military applications. Specifically, in the field of aviation it seems logical to think that it is civil demand that will stimulate the development of new fuels and even new propulsion machines in the long-term.

If we think about the first-line combatant, all his equipment consumes energy: helmet visors with cameras and virtual presentation, night vision goggles, image intensifies, communications equipment, combat PC, telemeters and laser

(41) Alternative Fuels for Military Applications.RAND National Defense Research Institute

designators, GPS,[42] support robots, uniforms with thermal regulators, etc. The digital combatant is also a large consumer of portable energy. The challenge in this case will be to equip him with a lasting and portable individual source of energy: *"the battery problem"***.**

The technology for portable energy systems will follow two different evolutionary paths. On the one hand, going into more depth in battery technology and on the other in the development of fuel cells.

I do not believe that now is the time to go into this topic in further detail, but to summarise, in the area of defence the main option should be the application of technology not just to the axes of connectivity and automation but also to mobility.

Some considerations regarding sustainability engineering in the information age

These reflections would be incomplete if consideration is not given to the less abstract and more mundane aspects that the design and sustaining of weapon systems in the information age will mean for us.

The first aspect that I would like to consider is the practical influence that the laws of Moore and Nathan (Myhrvold) mean in the life-cycles of weapon systems. The current trend is to use COTS (commercial off-the-shelf) hardware and software in electronic weapon systems. The days of military computers that were not replaced throughout the life-cycle of the platform, that were programmed in military language to have become history. This means that for better or for worse we have ended up chained to Moore's Law.

To see the problem more clearly let us say -for example- that the useful life of a ship can be of approximately 30 years. How do we harmonise the cycle of platform renovation with the cycles of technological renovation of the systems? In 30 years 15 generations of microprocessors will have been produced.

Learning to live in a world where the cycles of technological renovation are measured in months is a problem of pure engineering; without going into details the only response to this labyrinth is to establish a strict **systems engineering process**from the first design day and to keep it in place throughout the life-cycle. We have to be conscious of the fact that the systems' design in the information age does not end with delivery. Design is converted into a process that will last throughout the entire life of the system.

[42] Global Positioning System

Technology and the Industrial Base of Defence

- *The scenario*

The international defence industry has suffered a profound transformation since the end of the Cold War. Currently, the international market is dominated by a small number of large industries that arose from a process of consolidation caused by the pressure of the reduction in defence budgets on an almost global scale.[43] This group of companies, with a capacity to generate and integrate military technology and supply complex high-technology weapons systems to the armies of their countries of origin, compete fiercely in the export market.

In the specific case of Spain the panorama is peculiar because two phenomena have occurred simultaneously. On the one hand, the large force renovation programmes that have served to raise the technological level of the industrial base of defence will very soon come to an end, and on the other hand, austerity programmes have reduced defence budgets. This combination of circumstances is leading towards a drastic reduction in internal demand and consequently to a gradual reduction in the workload.

Faced with this panorama, no industry within the fabric of the Spanish defence can consider that its viability can depend exclusively on the national defence budget. The future of the defence industries, both if they are of the information age and if they are of the industrial era, will depend on their capacity to adapt to the new situation, to increase their productivity, to manage technological change and to achieve a competitive advantage which will enable them to position themselves in the export market.

The consequence is clear, if we want our industrial defence base to survive, it will have to export and compete in a market, which as we have seen is dominated by large, internationally well-established companies with a large technological capability. To export in this scenario will require a certain industrial critical mass and opting for technology and innovation.

I already commented at the start of these reflections that in the information age, labour-intensive plants and factories of the industrial era are centrifugal with respect to *areas of knowledge generation and accumulation,* i.e. they tend to move towards geographical areas with lower salaries, whilst the activities of the information age are centripetal with respect to those areas.

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(43) "The last supper" held at the Pentagon in 1993 is already legendary. It was attended by the then Defense Secretary, Les Aspin and 15 top executives from the main defence industries, in which he more or less told the invited group to set in motion a transformation of the defence industry through consolidations or that at the next dinner only a third of them would have survived

This creates a problem for the industrial fabric of defence since the platforms are manufactured at centres of the industrial era (in the case of the shipyards) and the systems in information age industries.

The productive centres of the industrial era require special attention if we wish to ensure their viability. Without going into proposals that would go completely beyond the scope of this work, in my opinion, there is a universal recipe, which consists once again in going for technology.

On the other hand, thinking about the future of our technological and industrial fabric, it is expedient not to lose sight of the fact that armies equipped with more advanced weapons systems cannot be kept operational if they are not sustained by a solid technological industrial base. A base that takes an all the knowledge resources: universities, public and private research centres and industry.

NEW TECHNOLOGIES, NEW THREATS.

In an age such as this of profound technological change, new technologies inevitably mean new threats. At the same time, as I believe is made clear throughout this work, the nature of conflict is also changing in the background, in manner and extension for the simple reason that the world is changing. We are not just witnessing a profound transformation in the way of competing in the international environment, but rather also in the manner in which we have to face security and defence.

Future enemies will endeavour to use the advantage that technology provides them to their own best advantage and we cannot ignore that to a great extent military technology is today based on technology adapted from civil use and therefore is far more accessible to our potential rivals. This causes the paradox that a not necessarily irregular combatant is a combatant equipped with obsolete low technology. On the contrary, there are recent cases in which terrorist organisation have shown a capacity for the use of sophisticated weapons.

Technology has enlarged the battle space from its traditional framework, sea, land, air, the electromagnetic spectrum, and the continuum of cyberspace and outer space. In a future high-intensity conflict it must be foreseen that the battle space will extend to all the continuum.

But returning to our topic, the major and most immediate threat will come from the use of WMD[44] by terrorist groups, by dictatorial extremist states or by the combined action of both. Globalisation and the facilities for the free circulation of information contributing to the transfer of W's technologies

[44] Weapons of Mass Destruction

-more and more difficult to control- and therefore the proliferation of weapons of mass destruction. Especially worrying is the spread of biotechnology and nuclear technology potentially applied to the design of weapons.

The situation is doubly worrying when development programmes of this kind of weapon coincide with programmes to develop short, medium and long-range ballistic missiles. The combination of the two capacities brings a completely different dimension to the threat.

But throughout the century there will be more and more obvious threats to the three aforementioned "continuum": the Ocean, Space or Cyberspace.

Cyberspace, the Digital Pearl Harbor

Recent professional publications are full of references to what is now known as «asymmetric war», a generic term that encompasses a new series of threats relating above all to terrorist actions, which like sadly celebrated roadside bombs seek to overturn the technical advantage of our forces by using low technology.

Even if tactical asymmetric attacks are important because they cause a high number of losses and negatively affect the morale of personnel, what should really worry us is strategic asymmetry.

We are the great digital Goliath, and somewhere there could be a David setting his sling. We have to consider that our potential enemies are also changing patterns for bits and that we would be repeating the error of Goliath if we ignored the fact that it is a question of time for our opponents to have the same range of technologies as we have today. In the future they will be in shape to attack our interests, whilst at the same time avoiding armed confrontation.

In this sense, the worst scenario that we can consider -a «digital Pearl Harbor»-, a massive coordinated computer attack to alter our vital control systems, sanitary system, transport, power generation and energy distribution, revenue, banking and all the services and businesses based on the Web, will be technically viable in the coming years.

Our digital society has become very vulnerable in this regard, which should make us think that we are facing a real possibility of strategic attack that could seriously affect our national security.

This is an example of how technological changes such as those we will live through in this century can demand that we even have to review the future aspects of national defence. Do we have the necessary technology to first defend ourselves and then counter-attack? Do we have a doctrine to lead an attack? Should the cost of computer defence be paid for by the companies? These and many other similar questions are debated in different seminars inside and outside our country.

The topic has recently come to the fore with the appearance of coordinated computer attacks against certain countries coinciding with crisis; such as has been the case in Georgia and in Latvia. But the most alarming has been the use for the first time of a cybernetic weapon, not to refuse the use of servers, but rather to damage part of an installation and disrupt and industrial production process.

As I have indicated previously, the new concept of combat is based on connectivity, and it is not possible to provide global wireless connectivity without having a constellation of civil and military satellites that ensure the operativity of the digital force.

Outer space

This is the digital combatant's Achilles heel. The entire concept of connectivity requires the availability of a spatial segment equipped with diverse constellations of specialised satellites (GPS, intelligencd, communications ... etc.), capable of giving global coverage to the theatre of operations. In a future high intensity conflict an attack on the satellite network could have catastrophic consequences, since all the digital compact space would be seriously limited. Even so, an attack on the scale would require a technology that is only available to a very reduced number of nations. Both the USA and China have carried out anti-satellite system trials.

But the proliferation of medium and long range missile technologies and the coming together of nuclear, biological and chemical weapon development programmes will continue to be the major threat over a significant part of the 21st century.

COROLLARY AND FINAL REFLECTIONS

We are facing an age of uncertainty and confusion, created by the convergence of simultaneous, profound and rapid changes: the biggest scientific and technological transformation in history; the evolution of the current unipolar model dominated by a single superpower, -in turn heir to the bipolar system that prevailed during the Cold War- to a multipolar order in which the distribution of power will be more equitable; these sudden appearance of new actors on the economic, scientific and technological stage; the displacement of the centre of gravity towards the Asian Pacific zone; a more and more widespread, deep and irreversible globalisation process; and the necessary transformation of our existing energy model.

All these changes are taking place with the backdrop of a planet subject to a process of global warming and overpopulation, which to a greater or lesser extent affect us all and generate enormous tensions in the social fabric of many parts of the planet.

The world as we know it is changing very quickly and this transformation will not be devoid of shocks, international instability and all kinds of serious upheavals.(45)

The enormous technological changes that are approaching will radically affect the society that we know today. As the century progresses, science and technology will transform communications, transport, medicine, education, public administration, leisure, etc. The evolution of existing technologies, the maturing of others that are still found in embryonic form, and the appearance of other totally new ones will change the industrial fabric and the productive model of vast areas of this planet, with the subsequent social repercussions. Industries of the information age will tend to group together around areas of knowledge generation, whilst activities of the industrial age will turn to relocate to areas with an abundance of cheap labour that does not require advanced specialised training.

Some of the technological advances, especially in the field of biotechnology, genetics and artificial intelligence, will put many of our principles, our ethical and religious values to the test and indirectly lead to a profound social transformation in wide areas of the planet. It is not science fiction, but thanks to bounces in artificial intelligence, the "machines" play a more and more fundamental role in our society; to what extent they do it will depend on our willingness to combine on the one hand or willingness to seed the power of decision and protagonism to artificial entities and on the other, our new concept of humanism.

The technology that made us a prosperous species -depending on how you look at it, one of the most prosperous of the biosphere- will now make us face enormous dilemmas that even affect the concept of what it means to be human.

Advances such as the capacity to decipher the genome of living beings and to create organisms with modified DNA place us on the threshold of advances that could lead us down the road of Doctor Victor Frankenstein(46), or for resolving the challenges involved in seeking, sheltering and educating 7000

(45) Some of which are already taking place at the time of drafting these reflections
(46) Like the creation of new forms of life is for commercial purposes, which could even reach human cloning.

million human beings and probably inevitably for both. Now more than ever it is necessary -I would say essential- to have calm but in-depth debate about the ethical and moral implications that the foreseeable advances in science and technology will have during this century.

The digital revolution today allows the generation of knowledge, its storage and its distribution in real-time to practically any part of the globe. The total knowledge of mankind doubles every few years and Internet contributes to this knowledge being available to a large number of inhabitants of the planet. Documents and information that only 10 years ago were accessible only to specialists in large libraries around the world can now be consulted while we are waiting for a bus. Although it is hard to predict what the human effects of this phenomenon[47] will be, we are facing a new reality, the exponential accumulation of Knowledge, similar -but of far greater proportion- to that caused in its day by the invention of the printing press.

Until recently knowledge was almost entirely confined to developed countries, but in this new world that is being profiled, the sacred flame of knowledge will not be the sole custody of a select group of nations. The digital revolution has contributed to distributing knowledge on a global scale, and access to new technologies will be for everyone who knows how to interpret and assimilate the change and is willing to adapt to it. The future will not be an inheritance, it will have to be earned.

Foreseeably, in this century the economic centre of gravity and of world political power will be displaced towards the Asia Pacific region and globalisation of markets and of ideas in this geostrategic zone will become accentuated. Growing access by the populations of China and India to the consumer market will necessarily have enormous repercussions above all due to the pressure on raw materials and energy. At the same time it should not be forgotten that these two nations are going down a road to become scientific and technological powers, daily shortening the gap with USA, Europe and Japan.

These profound changes indirectly imply that the redistribution of influence and power will inevitably create instability and uncertainty. In these circumstances it will be a priority to maintain order and international law and although our ethical duty will be to promote peace, military power will be an important factor in maintaining an international strategic position.

If we rule out the previously mentioned points of tension -significant discontinuities that could come about at any time- the likelihood of a high-level location in the medium term is low. Nevertheless, the trend will be a

[47] I note that my fellow traveller on the bus is reading a course from Yale on Roman Architecture on his iPad. Who can predict the cumulative effect of these technologies will have on society?

proliferation of medium and low level conflicts over a wide area of the planet, "the instability belt".

In the area of defence, the competitive advantage of future combatants can only lie in technology in its broadest sense. In the same way as in the field of the international trade competition, developed countries must direct themselves towards innovative products with a high technological content. In future conflicts the advantage of military force cannot be sustained in number and saturation, as it will have to be based on technology.

Strategic and tactical mobility; global connectivity in real-time in an integrated combat space; automation and robotisation; and finally precision weapons, will be the technological axes that will provide our combatants with the definitive advantage in the entire conflict spectrum.

Armies will continue adapting to change, but more than the threat, it will be the profound technological change that society in general is undergoing, or to be more precise, the pressure of the civil technology market that will be the driving force behind the technical transformation of armies. Armies change today to a great extent because they are dragged along by the tsunami of the digital revolution.

The foreseeable future trend will be that the pressure of demand of the population in general, and the consequent frequency of technological renovation that this generates will force the civil market to develop more quickly than the military one, for which reason if we except technologies for the exclusive use in military applications, armies will more and more frequently turn to market solutions (COTS).

The battlefield of the future -to a great extent it already is- will be digitalised and robotisized. The enormous technological advances that are taking place in the civil world, that are building and evolving cyberspace on a daily basis, will be the driving force behind the massive use in the battlefield of digitalisation techniques and information technologies, providing the establishment of the paradigms of perfect connectivity, i.e. that of achieving a truly integrated virtual combat space (virtual because the material and logical support of the system is distributed over a wide geographical area) which stays in parallel with the civil world's cyberspace and could even be considered to be part of it.

As I previously mentioned, the evolution of the Internet towards an object network and not just of computers, the growing use of virtual recreation of reality in different fields of science and engineering and new concepts such as "cloud computing" adapted to the military world, accelerate even more the establishment of the paradigm of a combat cyberspace in which machines and humans communicate directly with one another. Enormous processing capacity will allow the creation of virtual replicas of real scenarios and there will be an interaction between virtual worlds and the real world, with effects that we still cannot discern.

One only has to open the professional defence magazine to discover from the articles devoted to robots in the battlefield that they almost outnumber manned systems. The battlefield is being robotisized and the trend is towards a growing use and role of robot vehicles in conflicts (land, air, naval and submarine).

The proliferation of robots[48] will be constrained by advances in artificial intelligence, but I am not going to return to this because I believe it has been dealt with sufficiently.

But we should not ignore the fact that technology does not only act in our favour, as new technologies will mean the appearance of an entire panoply of new threats to our security. We have to prepare ourselves for combat in the three continuum: space, ocean and cyberspace.

Spain's place in the 21st century

What place should Spain occupy in this new world that is being profiled? Spain is not a power of the first order, and it would be unrealistic to aspire to it being so, but we still occupy a relevant position among the planet's most developed nations and of course we have the potential to stay in the leading group. We have so much in our favour: culture, language, history and geographical situation are assets that are far from insignificant.

If we look with a certain historical perspective at our most recent period, we have to conclude that our achievements in the last few decades have been more than notable from the point of view of economics, social progress and of integration in the international community. For this reason we now have double the responsibility, first to maintain and consolidate our position in the international setting and secondly, to contribute to the European Community with which we are integrated and to whose military alliances we belong, or we decide to belong to the future. Everything involves maintaining economic, industrial, scientific and technological vigour and having a certain military capability.

To keep the position among the leading group of nations necessarily calls for «an acceptable quota» of influence in international fora, where matters that affect our interests are decided and in parallel promote the image of our nation, which in turn is translated as what may be called the «Spanish Brand». This is

[48] I belive it necessary to highlight the fact that when I use the term "robot" I am not absolutely assuming an anthropomorphic appearance. I refer to autonomous and remote vehicles equipped with artificial intelligence.

no more than the abstract expression of how our prestige, our credibility, our solvency and our compromise are perceived abroad, which counts for a lot in the international competition.

But not everything is marketing and image. At the time of writing these reflections we are immersed in a profound crisis -not just Spain, but in our case it has coincided with the end of a cycle of our productive model,- which will require many structural measures to be adopted in order to ride it out. But this is also an opportunity to adopt measures aimed not exclusively at getting out of crisis, but rather to prepare us and to position us for this century. Now we are being offered a great opportunity to change to a productive model based on knowledge and information. Because if we do not understand that the world is changing and how it is doing so, we could be preparing ourselves for yesterday and not for tomorrow. The crisis, although deep, is a cyclical phenomenon, but to preparare us for the 21st century is a medium and long-term strategic planning matter.

I believe that I have tried to transmit in this work that the enormous technological changes that will come about in this century will radically change the productive model of developed countries, and for this reason to set as an objective an increase in growth aimed exclusively at improving productivity and not competitivity is meaningless if in parallel we are not capable of establishing a new framework and productive model that will enable us to maintain a sustained advantage in the future.

Economic growth, the guarantee of our welfare and of freedom, will be our best contribution to the strengthening of supranational organisations to which we belong, but that does not exclude maintaining strength in defence and security similar to that of the nations around us.

I cannot resist mentioning again that to maintain our economic position in this century it is vital to go decidedly for science, technology and innovation as axes to create a new competitive advantage and this necessarily involves radical improvements in the teaching system and revitalisation and renewal of the nation's scientific-technological fabric.

It would be unrealistic to try to set as an objective our conversion into a leading economic or industrial superpower as it would be to pretend to have a military capability capable of intervening in any part of the planet and to support operations for lengthy periods of time with our own logistics resources.[49] Nevertheless, the guarantee of the defence of our interests and security, as well as a contribution to our obligations with our allies, can only lie in modern armies, conveniently equipped for any kind of operation in the future, and the logical consequence of our scientific, technological and defence industry

(49) What is understood today as global force

base. In the current world it would be unthinkable to have Armed Forces with a high degree of readiness that are not sustained on a national technological and industrial base. A principal that the most recent history teaches us is that artificial armies created on the basis of enormous investments without a national industrial base, which are formidable on paper but do not resist the first skirmish with a technologically advanced force.

This last reflection brings us to a conclusion of wider scope. The defence of the 21st century requires a systematic approximation to that which affects the overall quality of our combatants, the technological level of our Armed Forces and the capacity of our industrial base. Would it make sense to have Armed Forces in the information age and an industrial base dating back to the industrial revolution?

Over and above any other factor, competition in this century will be about Knowledge and Ideas. Technology and innovation will be the basic factors that determine which nations come out winners and which ones the losers. Whoever wants to win the future has to win the technological race and in consequence start preparing for it today.

As a final corollary, I do not wish to seem too deterministic, but in this century, technology is going to write History.

CHAPTER TWO

INNOVATION AND ITS IMPLICATIONS FOR DEFENCE PLANNING

Manuel Pereira Rueda

ABSTRACT

The relevance of investing resources in R&D and innovation for defence lies in their capacity for reducing the risks and uncertainties which will characterize future military operations, enabling the Ministry of Defence to become a smarter client and contributing to bringing our industrial base towards a more competitive position.

The outlooks state that military R&D will no longer be a leading driver of many of the new developments and technologies. COTS and MOTS will be common elements in future defence systems. In addition, new strategies for allowing the incorporation of new technologies and tendencies into the defence systems with reduced costs and in shorter periods of time will be necessary. This scenario demands the creation of a centralized organization for managing and coordinating all defence R&D activities. As key tools for assisting and helping to manage R&D activities, the Defence Technology Watch System (SOPT) was created in 2003 and, more recently, in 2010, the Spanish MoD Strategy of Technology and Innovation for Defence (ETID) was launched.

The increasing blurring at the frontiers that separate military, security and civil matters makes it necessary to abandon the term "dual" and introduce a new term: "convergence" which is a better description of the new scenario where defence R&D activities will be included inside a wider frame of collaborative actions, in terms of coordination and financial support, with other domains which are traditionally independent and separate from the defence universe.

Key words:

Research and development, innovation, technology, convergence, forecast, hard sciences, paradigm, planning, change, technological goals, strategy

INTRODUCTION

This work is mostly based on information collected, conferences and interviews during the preparation of the Strategy of Technology and Innovation for Defence; as a result, I would like to thank the Defence Technology Watch System for its help, in particularly the contributions of Germán Vergara Ogando and Guillermo González Muñoz de Morales, who, in addition to helping in this study also provided critical comments.

Throughout this chapter, I will use the terms “defence research and development” and “innovation for defence” interchangeably in order to highlight their close relationship and the fact that such actions should be integrated; the subject of this paper is knowledge and technology applied to defence and its implementation.

The strategic usefulness of defence R&D derives from its contribution to mitigating the risks and uncertainties related to national defence, by developing military capabilities and improving the performance of the armed forces as an intelligent client whilst supporting and encouraging the incorporation of innovation into the nation’s technological and industrial base. Defence R&D is playing an ever more important role in inter-government solutions related to global security in today’s asymmetric world. Nevertheless, these multiple facets often face obstacles as a result of poor recognition of opportunities and possibilities and short-term attitudes in logistics bodies which turn to proven options already on the market. We might state that the existence of an organisational culture focused on knowledge and continuous innovation in defence systems is a critical factor for the integration of R&D into security and defence policies.[1]

One of the roles of defence innovation is to create and maintain armed forces which are at the cutting edge of technological knowledge. The question we need to consider is whether defence bodies should be creators of knowledge or just clients using products already on the market where the R&D was undertaken by suppliers outside the application. The contemporary trend towards the predominance of civil and commercial technology means that even large countries are turning to COTS and MOTS in order to reduce costs and delivery times; this is particularly true in the case of urgent operational needs. Many such countries now rely on private R&D, as Andrew D. James states when describing the capacity of military systems to incorporate technologies and capture the benefits of commercial innovation[2]. This poorly managed process runs a serious risk of converting the armed forces and governments

(1) JERNALAVICES Tomas, *Defence R&D: Lessons from NATO Allies*, ICDS, 2009

(2) JAMES Andrew D., *Transatlantic defence R&T goal: Causes, consequences and controversies, Defence and Peace Economics*, Vol 17(3) (2006)

into “less intelligent clients” which are not capable of adequately appreciate what is on the market and how to use technology and knowledge.

Furthermore, the classic defence R&D paradigm is also affected by the hazy limits between defence and security. From the organisational point of view, current and planned operations include aspects of policing and military and intelligence matters; whilst from the operational point of view they include counter-terrorism operations, peace keeping, protection of critical infrastructure, control of territorial waters, etc. These aspects involve a range of government bodies in which there is a convergence of the technologies used; as a result, we must consider the coordination and finance of R&D programmes related to defence and security from a broader perspective.

On the other hand, the US Department of Defence Government Accountability Office has stated that the technologies are not being sufficiently mature by the time they are needed, resulting in considerable delays in development and, as a result, increased costs. The existence of defence R&D planning and a degree of centralisation, as we will see below, in addition to reducing risk, is of the utmost importance as it facilitates the exchange of knowledge between creators of knowledge, technology suppliers and users, in other words, the triangle of the armed forces, the R&D community and industry.

Strategic sovereignty arguments must play an appropriate role in R&D planning for a country such as Spain, considering that it is a member of a range of collective defence organisations. As a result, it is important to identify the technological niches in which its technological excellence means that it has a valuable role.

This chapter is divided into four sections: in the first we describe the current changing world situation from the technological point of view; in the second, we discuss the need to implement new technology planning and management systems in order to incorporate mature technologies into weapons systems during development; in the third, we give a detailed description of one of the management instruments: the Strategy of Technology and Innovation for Defence; and in the fourth we draw conclusions.

A CHANGING AND UNCERTAIN WORLD

The distribution of political, economic and military power in the world is changing and becoming ever more widely spread. The growth of China, the country with the largest population in the world, and India, the largest democracy in the world, will continue over the coming decades, affecting the balance of the distribution of forces on the international stage. The United States will continue to be the most powerful country on the planet, but it will need more robust strategic alliances with its traditional allies in order to maintain its status. This outlook, whilst complex in itself, will be increasingly threatened by the continuing growth of parties which are outside the control of states, and which can benefit from the inevitable process of globalisation which will be characterised by the crumbling of the barriers which today impede access to technologically advanced products.

As the growth of technological innovation and information flows continues to accelerate, these groups will continue gaining influence and capabilities. The proliferation of weapons of mass destruction will continue to be an increasing threat, undermining global security and hampering peace-keeping efforts. This outlook will be further complicated by a number of other trends: the financial crisis; increasing demand for energy; scarcity of natural resources; rapid urbanisation of coastal areas; climate change; the effects of demographic change, etc. These will result in frequent tensions in international relations which may also result in conflicts which are no longer just local, with their influence expanding in many cases to global dimensions.

As new powers emerge and other non-governmental parties become stronger, it will become ever more important to guarantee the West's access to natural resources and other basic goods. It will be necessary to safeguard the transport of goods around the world, in addition to information flows. A number of recent events have highlighted this increasing threat and the technological challenges arising from attacks in cyberspace; IT piracy; the testing of anti-satellite weapons; and the increasing number of nations with the technological capability to launch spacecraft and space systems. Given the proliferation of sophisticated weapons and technologies, small states and groups will be able to acquire and use highly accurate long-range weapons, making them potential adversaries to be considered in the global balance of forces. Over the coming years, it is expected that armed conflicts will result more frequently from the weakness of states rather than from their strength.

From the operational point of view

As a result of the complex way in which they are developing, conflicts are currently undergoing a profound change. This has direct consequences in the way the military operations in which the armed forces are currently involved are carried out. The lessons learnt in these conflicts tell us that, more than ever, we now need joint and combined forces which are able to operate in a wide range of geographic locations in a wide spectrum of situations involving constant contact with the civilian population and other international partners.

Recently the term "hybrid"(3) has been used to signify the increasing complexity of armed conflicts, the multitude of parties involved and the wide range of categories and intensities of conflicts.

States must be able to anticipate the use of new methods and modes of operations by adversaries, who will use innovative tactics, such as the use of criminal networks and terrorist groups, sophisticated manipulation of information, hindering access to natural resources, etc, to increase uncertainty. It is very difficult today to identify trends and forecast events, meaning that extra effort is required from the armed forces in order to adapt. Achieving a high level of adaptation and a high probability of success in operations, where uncertainty is one of the main ingredients, means that both technological innovation in itself and the capacity to incorporate innovation as an intrinsic part of systems are now key objectives to be achieved by any modern defence organisation.

Operations will continue to change dramatically in the future. We expect such changes to continue over the medium and longer-term. Report 066 by NATO's Research & Technology Organisation (NATO-RTO)(4) on Joint Operations in 2030 concludes that in the future conflicts will be characterised by the following aspects:

- Globalisation of asymmetric threats.
- Increased expeditionary operations outside the Alliance's traditional areas of responsibility.
- Increased integration of independent capabilities into joint action forces.
- Increased multinational interoperability and the development of integrated forces
- Increased alarm and protection systems and methods against weapons of mass destructions
- Improvement and implementation of networks involving military command and control systems which are integrated with those of other government bodies, such as security forces, civil protection bodies, etc. and other multinational institutions.
- The differences between peace and conflict will become blurred and armed forces will be involved in both traditional and non-traditional military missions in areas where threats are constantly present.
- We will move on from traditional sequential operations to distributed and simultaneous operations, with military forces being in frequent contact with civilians, NGOs, etc.
- We will move on from current "*strategy as design*" planning to new, more flexible, adaptable and robust "*strategy as process*" methods.
- Future mission scenarios will demand more rapid and decisive action at all levels of command.

(3) *Quadrennial Defense Review Report*, US Department of Defence, (2010)
(4) *Joint Operations 2030*, SAS 066 NATO RTO, 2010

- Access, development, deployment and use of conventional and non-conventional weapons, including weapons of mass destruction, will spread to small countries, and even to terrorist groups and criminals, etc.

If the critical aspects of future military operations as described by NATO are accurate, then future military conflicts will be very different to those of the past and are certain to require a rapid wide-ranging adaptation by armed forces to new situations and new ways of behaving.

It is also clear that it will be very important in future to have full knowledge of the increasing costs associated with the development and operation of weapons systems. Ever tighter budgets and increasing operating and maintenance costs for military units, systems and personnel will result in vastly reduced force structures. However, national defence planning should not just look to the short term: it is essential that we have a medium and longer-term outlook, taking into account the increasing cost of carrying out operations. In this regard, prospective studies will be very useful for achieving a balance between the effects of technological progress on the improvement of the quality and functional characteristics of defence systems, and those related to the efficiency of production processes which will result in lower long-term production costs; this latter factor is of the utmost importance for any nation which acquires a very limited number of technologically cutting edge military units or systems.

In this complex and fast changing scenario, tools such as technological innovation will become of the utmost importance for the transformation required by the armed forces. Innovation requires a systematic process of reflection which demands many forms of exchange between users, industry, technology centres and universities: in other words, the triangle made up of the armed forces, the R&D community and industry. Users play a strategic role in this process, and their contribution to technological innovation will be of the utmost importance in the identification of problems in the use and preparation of military and technical requirements, and in the assessment of new technology[5]. Defence Ministries are active participants in innovation processes from the moment that new ideas are generated, and contribute to the development and assessment of technological solutions.

The SAS 066 report also reflected this and stated that it will be necessary to develop a number of enabling technologies in a new organisational and functional framework characterised by new relationship architecture which takes into account that traditional human roles and interactions will be supported by information and decision systems backed by artificial intelligence

[5] MERINDOL Valérie, *New approaches for military innovation in knowledge based economics: an inquiry into the new role of defence in innovation processes*, IMRI, Université Paris Dauphine, 2010

and even robots (see table 1). The operational planning cycle, from obtaining information to operations, is optimum when a fair balance is achieved in the interaction between men and weapons systems. This is a challenge which would have been considered science fiction a few years ago, but which is now clearly possible within a relatively short time.

The 10 scientific fields with the greatest number of technological areas of interest for defence in report SAS 066 (2030)	
Scientific field	**Number of technological areas**
Computer science	108
Engineering	65
Systems science	64
Management	49
Pure science	48
Military technology	44
Knowledge science	41
Anthropology	36
Social sciences	29
Psychology	28

One interesting aspect of the table is the increasing importance for defence interests of so-called "*soft sciences*" –sciences related to human and social aspects-, as opposed to traditional "*hard sciences*", such as engineering, physics and maths. This is further evidence of the changes and developments we are facing today: We are heading towards scenarios in which solutions to conflicts will emanate from a holistic approach, where politics, human factors, security and defence all overlap considerably to form a whole with no continuous solution.

From the technological point of view

In the past, the commitment and participation of defence ministries in the conception of complex military systems was very important. However, from the 1980s onwards, the economic and technological background has changed in such a way that we have had to adapt to new scenarios. One clear example of this is the explosion of information technology and its consequences in the appearance of new markets and industrial sectors with enormous opportunities in the commercial world. Today, most advances in technological knowledge are produced without there being any connection to defence projects.

Forecasts suggest that this trend will continue, and become ever more pronounced as a result of reducing defence budgets and, in addition, new and

increasingly important priorities for public spending. By way of example, over the last two decades research subsidised from the US Department of Defence (DoD) budget represented a large share of activities related to total technological innovation in the country. At that time, defence spending was a fundamental factor in technological development and there were many technology transfer activities from defence to commercial activities ("*spin out*"). However, this situation has now reversed: commercial advances are now made incredibly quickly, and business volumes are far greater in the civilian-commercial field than in the military field.
Figure 1 shows that military spending in the USA accounted for almost 1/3 of total R&D spending in the 60s, 70s and 80s. However, since the 90s, military R&D spending has remained stationary in absolute terms, whilst civilian R&D has continued to rise constantly and sustainably to the present, whilst national R&D efforts are mainly focused on civilian and security issues. And today, it is the military which benefits from developments in the civilian field (*spin in*).

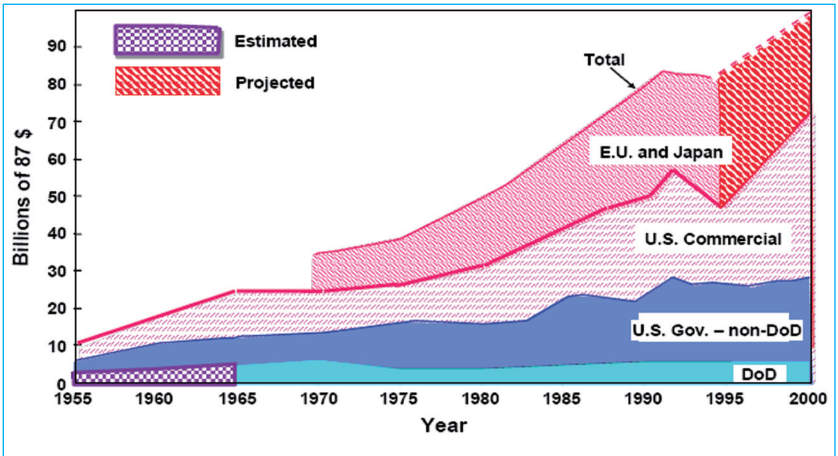

Figure 1.- Innovation spending by different actors over the last 50 years. Spending by the US DoD on innovation has been reducing in relative importance to the very low level of total spending today[6].

We are faced with a paradigm in which the technology itself is blurring the boundaries of its application. In the future, these limits will become even less clearly defined: we will no longer talk about sector specific technologies for the civilian, security, military fields, etc. Everything will be a continuum and different facets of the same thing: technological innovation. This will benefit the parties involved and all areas in different ways. The term "dual" used to describe technology with both military and civilian uses will gradually disappear to be replaced by terms such as "convergence", which perfectly sums up the spirit of new trends.

[6] JAMES Andrew D. *US Defence R&D Spending: An analysis of the impacts, Rapporteur´s report for the EURAB Working Group ERA Scope and Vision*, 2004

When we talk about civil/military technological conversion, we must refer to two initiatives –one European and one Spanish- which sum up the concept as it is currently being implemented perfectly. These are the *European Framework Cooperation for Security and Defence Research* (EFC) from the European Defence Agency (EDA) and Spain's Ministry of Defence's "Cooperation in Scientific Research and the Development of Strategic Technologies", also known as COINCIDENTE.

The EFC initiative, which was signed by EU Defence Ministers in 2009, is an example of future trends. The objective of this new cooperation framework is to share efforts in order to guarantee investments by exploiting complementarity and synergies in security, space and defence R&D. In November 2009, the EDA, together with the European Commission and the European Space Agency (ESA), was given responsibility for establishing all the details of the coordination scheme and for proposing the issues to be covered by the EFC. Unlike other R&D initiatives launched for specific cases in which the civil and defence spheres are also coordinated to achieve synergies –such as SDR capabilities (*Radio Software*), critical space technologies, etc.- the EFC aims to achieve this through systematic synchronisation of investment in the contexts of the three institutions. With regard to technological content, it has already been agreed to examine three areas of particular common interest: CBRN (*Chemical, Biological, Radiological, Nuclear Defence*), UAS (*Unmanned Aerial Systems*) and SA (*Situational Awareness*). These areas are very wide ranging and the actual scope will depend on the technological experts and capabilities. As with other technological activities, the industry and R&D institutions will have a lot to say on this in the technological coordination forums, CapTechs(7).

From the domestic point of view, and in line with the above, we should highlight the Spanish Defence Ministry's "Cooperation in Scientific Research and the Development of Strategic Technologies" (COINCIDENTE) programme. The main objective of this is to take advantage of technologies developed in the civil sphere for defence applications so as to develop the industrial, technological and scientific fabric dedicated to defence, and to give an incentive to companies, universities and public and private bodies to achieve higher technological levels in order to be able to satisfy the military capabilities required by the armed forces.

Ministerial Order DEF/1453/2010(8) regulates the basis for tenders for R&D projects which are susceptible for inclusion under the programme, in order to channel efforts in predefined directions and to ensure that benefits continue

(7) MARTÍNEZ PIQUER Tomás and AGRELO LLAVEROL José, *EFC: European defence R&D cooperation, Boletín de Observación Tecnológica en Defensa – SDG TECIN / N° 28, 2010*

(8) "Ministerial Order DEF/1453/2010, of 25 May, regulating the procedure for holding tenders to select R&D projects of Defence interest within the scope of the COINCIDENTE programme." / Official State Gazette 136, page 48327 / (2010)

over time. A list of preferential technology areas has been established in order to give guidance on the main needs and interests of the Ministry of Defence in annual tenders; however, this does not stop technology providers from proposing their own technological initiatives which they consider to have equal or greater potential in terms of defence applications.

In general, the projects covered are those which tend to develop a demonstration model with military functionality and which represent a significant technological innovation which meets a real or potential need of the Ministry of Defence. One major distinction compared to other civil initiatives is that this is not a subsidy to the technology system; rather, the Ministry of Defence is acquiring rights (use and ownership) based on its contribution, as established in Law 30/2007 on Public Sector Contracting; in other words, this is a public technology purchase.

The preferential technology areas proposed for 2011 are:

- Platforms (Land, Naval, Aerial and Space): Protection materials, energy solutions and unmanned vehicles.
- Personal protection: Combating IEDs, NBQ protection and combatant technology.
- Protection for platforms and facilities: Self-protection systems, facility protection and electronic warfare ESM and ECM systems.
- Information, Communications and Simulation Technology – (ICST): Command and Control (C2), tactical communications, NEC and CIS security.
- ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance): Sensors.

Technological convergence opens up new perspectives from the moment in which it improves and updates weapons systems in much shorter time frames and at more reasonable costs which are affordable for a country such as Spain. In addition, it makes it possible to take greater advantage of resources and to maintain niches of technological excellence based on economies of scale.

- Nevertheless, there are some drawbacks with such convergence; these are described very well by the Spanish Chiefs of Defence Staff in the document "The Joint Forces and the Challenges of the Future"[(9)]. This states that free access to technology will reinforce our adversaries, whether states or non-state actors. This could have serious consequences, such as: advanced countries losing their technological advantage over other actors.
- The military capacity of non-state actors will be reinforced by dual-use commercial technologies.

[(9)] *The Joint Forces and the challenges of the future Preparing for operations up to 2030*, Chiefs of Defence Staff, Ministry of Defence, 2009

- Emerging powers may be able to significantly increase their military capabilities, and therefore use their strengthened Armed Forces as an international political instrument.
- The main areas of development will be space (communications, navigation, command and control, surveillance, guidance and reconnaissance), hypersonic missiles with precision armaments, unmanned systems, naval aviation, amphibian capacity and sophisticated land systems.
- Intensification of the proliferation of weapons of mass destruction and their means of delivery.

Perhaps the most significant contribution in the description of this new paradigm is the conceptualisation of change, understood as the continuous adaptation of methods rather than objectives; change has evolved into being the playing field, and innovation the tool for achieving success. Thus, driven by innovation, change becomes a measure of an organisation's success or failure: the difference between a successful organisation and an organisation in crisis is the ability to take change into account, to manage it and proactively seek it in order to obtain advantages and identify opportunities, modelling the environment using its rules; in other words, managing change effectively.

THE NEED FOR OUR OWN TECHNOLOGICAL CRITERIA: R&D MANAGEMENT IN DEFENCE

All the parts of the technology management system in the defence field –from management of projects financed by the Defence Ministry to the distribution of R&D activities between the Administration and industry- are undergoing radical changes. The transition from the traditional way of managing technology, based on major technology projects associated with and designed to obtain very ambitious weapons systems, is changing our ways of doing things, adapting to a new logic which is much more diffuse and uncertain, in which markets are and will continue to be the key and determining factor. In this regard, changes in the organisations responsible for promoting and coordinating technological innovation in defence will be neither linear nor step-by-step, and the transformation process –which has already begun in Spain and in many other countries in our circle- will be neither easy nor, in some cases, successful.

The case of Britain is a widely recognised example of the difficulties of reorganising defence R&D management. The process of change in its management system has been both long and tortuous, following a process of trial and error which is subject to controversy over the nature of the public-private partnership and is subject to continuous refinements. During the first half of the last decade, this process of trial and error led to the emergence of a new system of mixed governance dictated by a mixture of market forces and the requirements of the knowledge economy. Despite successive reports published by the Defence Ministry (1998, 2002 & 2005) on defence policy and industrial strategies, market mechanisms continued to be prioritised. There were notable inconsistencies in knowledge management and corrective measures were soon needed to re-establish a fairer balance between the competences of government and industry. In 2009, as a result of analysis of the experiences learnt, the British Ministry of Defence decided to centralise its defence R&D in a single body (a "transformed" DSTL), enabling it to combine the supplier base of technological innovation with the activities of the Ministry itself more efficiently[10].

In Spain's case, the most important defence R&D drivers are, mainly, major development and acquisition programmes for weapons systems. The most well-known of these are the A 400M transport aircraft; the Eurofighter combat aircraft; the F100 frigates; the NH90 helicopter; and the Leopard tank. These are all complicated and expensive weapons systems, the financing of which has revealed serious difficulties and resource shortfalls, with extraordinary resources being required in order to fund the programmes. In many cases, the finance system for these "special programmes" has been through reimbursable advances, at no cost on the part of the Industry Ministry to the contractor companies[11].

Delays in the development and incorporation of what are now mature technologies into industrial production patterns etc, due to the complexity of these programmes, most of which are multinational, have resulted in revisions to the programmes to adjust payments to the actual pace of production; such delays have become routine. In many cases, these programmes are subject to considerable delays, with the resulting management and cost overrun problems. This is a serious problem in today's economic environment in which there are continuous budget cuts and there seems to be no end in sight to this in the short term.

This outlook, which is complicated enough in itself, is further aggravated by the changing situations we described in the opening sections of this chapter; and as a result, the need to develop new management and finance tools which avoid or decrease, as far as possible, the delays and cost overruns which are accumulating on many of the Defence Ministry's major weapons acquisitions programmes, is becoming ever more evident.

It is widely recognised that inefficient management of technological innovation is a major cause of these delays in the acquisition of weapons systems. Insufficient investment in prospective studies, technical viability

[10] *"Critical interfaces and structures for the delivery of MoD's Science and Technology" /* Consultative document. UK MoD, 2009

[11] LUNAR BRAVO Vicente, *La Industria y Contratación con Defensa* [The Defence Industry and Contracting] CESEDEN Presentación UIMP 2008

studies and technology demonstrators results in programme delays and cost overruns. Recent analysis(12)(13)(14) has demonstrated that in around half of the projects which needed to have their timescales extended, this has been due to it taking longer than initially expected for key project technologies to mature. In contrast, projects based on mature technologies hardly ever suffer delays or cost overruns. Without mature technologies it is difficult to know when a system in the design and production stage will produce the capabilities desired. In summary, systems which go into development with technologies which are not yet very mature cost more and there is a much higher probability that they will be subject to delays; this establishes the overwhelming need for efficient management of the early stages of the innovation process.

The GAO[12] report shows that programmes based initially on highly mature technologies only overrun initial cost estimates by 2.6%, and delays to completion are usually less than one month. In contrast, programmes which are initially based on technologies which are not very mature have 32.3% cost overruns on average, and are delayed by 20 months on average, with all the associated additional costs of this.

Despite the expression R&D being a single expression and Research and Development always appearing together, in reality they are very different. A few years ago a very suggestive and significant phrase was coined –the "Valley of Death"(15)- to describe the gap between these two phases when it comes to obtaining a military capability. The problems we have been describing in this document and which we are facing at present are the consequence of this. In most cases, finance in technological innovation processes arrives too late in the whole weapons system and equipment acquisition process, resulting in substantial impact on project costs and timetables. All the parties involved in the process of defining and acquiring military capabilities –the Defence Ministry, industry, etc- must be able to close the gap between R and D.

This is no simple undertaking, and efforts must be made by both sides: government bodies and industry. Whilst it is true that during the early stages of technological maturity, Research plays a leading role in the development of new ideas and the acquisition of knowledge, it is also true that industry should take the lead in the process of maturing these developments at earlier stages than they are doing at present. A very early industrial and commercial

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(12) *Defence Acquisitions. Assessment of Selected Weapons Programs*, US Government Accountability Office GAO-07-406SP, 2007

(13) JORDAN Graham and DOWDY John, *Acquisition and Technology: The problem that won´t go away,* RUSI Defence Systems. Vol. 10, 2007

(14) OWDY John, *Predicting Acquisition Performance*, RUSI Defence Systems, 2008

(15) AUERSWALD Philip E. and BRANSCOMB Lewis M., *Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States*, Journal of Technology Transfer, Vol. 28, 227–239, 2003

effort is required to convert ideas into products and systems efficiently[16]. The consequences of this new form of doing things will have a huge impact.

The traditional integration role played by industry in Spain's technological base must change towards models where technological innovation and the creation of added value through knowledge and the development of new technologies are ever greater. Within companies, engineering activities, understood in their traditional sense, must adapt and share common spaces with other branches of technological innovation which are gradually taking on importance due to their high added value. This will require an additional effort from the Spanish defence industry, not just in terms of economic and human resources, but also from the point of view of business organisation and culture. There is no other way to confront the problems we are facing today as a result of a history marked by our limited entrepreneurial spirit with little regard for scientific knowledge, which has resulted in the low competitiveness of our industry in the development of the state of the art, advanced defence systems required by the armed forces of a country such as Spain.

There can be no doubt that all the parties involved must adapt rapidly to these new scenarios. And all parties must begin this change from the inside and based on the conviction that technological innovation will only bear fruit if those who plan, specify, develop and supply weapons systems are able to identify the technological areas where they should focus the greatest effort.

The Ministry of Defence is clear that it will be necessary to advance towards proactive policies which are consistent with sharing future technology training plans in order to increase understanding among supplier networks of future technology capabilities and requirements, and the steps to be taken to achieve these in terms of functionality and costs. In this regard, it must try to focus the domestic technology industry -SMEs, technology centres and universities- on areas of knowledge which are of interest to, and meet the technological needs of, the Spanish Armed Forces. The Defence Ministry must provide a comprehensive vision of where innovation can fit into its systems and equipment.

The outlook: SOPT, DISCOTECH and KETs

- *The Defence Technology Watch System (SOPT)*

As a result of the above, we should highlight the increasingly important role being acquired by bodies both inside and outside Defence Ministries which are dedicated to prospective technology and knowledge management. Within the Spanish Ministry of Defence, in 2003 the Directorate General of Armaments

[16] JORDAN Graham, *The Defence Technology Plan: The mouse Trap and the Elephant*, RUSI Defence Systems, Vol. 6 (June), 2009

and Materiel created a Defence Technology Watch System as a tool for managing defence R&D[17]

This system is involved in constant monitoring and analysis of current and future technologies as they emerge, as a basis for the evaluation and selection of the most promising and interesting projects and the prioritisation of investment in the technologies of the greatest interest. It performs frequent prospective technology exercises in order to analyse the scientific boost from new technological advances and knowledge.

Complementary to this, it also identifies the technological capabilities of domestic industry, research centres and universities and establishes communication channels with them; these serve not simply as a way for companies with innovative projects to access the Ministry, but are also a source of information on domestic technological capabilities and the possibilities and technological risks of various initiatives.

It is common today for the most advanced nations and prestigious supra-national bodies, such as NATO's RTO and the EDA, to publish prospective studies on enabling technologies of interest for defence at the system level and also drilling down to the component level. In this chapter we will discuss two of these because of their importance and impact on the issue we are concerned with: the EDA's DISCOTECH[18] study and the EU study "*Preparing for our future: Developing a common strategy for key enabling technologies*"[19], which is not dedicated specifically to defence technology, but which is important for this as the future trend leads us towards convergent technology.

- *DISCOTECH*

DISCOTECH is the unusual acronym for the EDA's *DISruptive COTS TECHnologies in the Information Technologies Area*. This project analyses possible developments in COTS components, and tries to forecast their development over 10 and 20-year horizons. In this study it is important to highlight that the point of view followed is that most relevant technological advances come from the civil sphere, and that it is necessary to find an appropriate balance between components available in the market and their adaptation to military systems. Reliability, obsolescence and availability will become problems of the utmost importance and all the prospective studies carried out will be essential to helping to identify the best way forward.

(17) RIOLA RODRIGUEZ J. Maria, *The Defence Technology Watch System (SOPT), Boletín de Observación Tecnológica en Defensa – SDG TECIN* / Nº 25 (Special R&D activities in the DGAM), 2009

(18) *Disruptive COTS Technologies in the IT Area (DISCOTECH)*, European Defence Agency Study (CAPTECH IAP 01), 2009

(19) *Preparing for our future: Developing a common strategy for key enabling technologies in the EU*, European Commission, COM(2009) 512, (2009)

DISCOTECH states that the new capabilities and future defence programmes to be carried out at the European level will require sovereign supply chains within the European Defence Technological and Industrial Base (EDTIB) at both the level of systems and of devices with substantial, state-of-the-art technological content, in addition to the development of critical technology and devices. If the European defence industry wishes to be competitive, it must be able to design and manufacture not just systems, but also components, and this will not be possible without entering into supra-national alliances and establishing new forms of mixed finance which correct the ever increasing current imbalances which are undermining the competitiveness of the European defence industry.

The prospective study pays particular attention to the development of "*outsourcing*", which is understood as being an increasingly important way of reducing the costs of military systems. However, it may at the same time be a distorting element which threatens European technological sovereignty; this is not only from the knowledge point of view but also from the point of view of supply of critical components and above all, from the commercial point of view due to ever increasing commercial regulatory restrictions on dual use components and systems. *DISCOTECH identifies the establishment of an optimum balance between outsourcing and technological sovereignty as a particularly urgent and relevant issue for Europe from the point of view of components.*

Another important part of DISCOTECH is the comparative study of expected COTS developments and expected military needs over the medium and longer terms. This identifies the following technological gaps which will need to be filled in the immediate future, and where European defence ministries can contribute to achieving full technological sovereignty in key defence areas:

- Ensuring the competitiveness of the EU in key defence photonic and electronics components.
- Maintaining and promoting a sovereign European supply chain for advanced micro-electronics and photonic devices.
- Analysing the impact of export control regulations.
- Educating and attracting new talent to work in technological innovation for defence.

Once the gaps have been identified, DISCOTECH proposes a number of activities and actions to be carried out immediately to correct these:

- New technologies have a very significant impact on systems such as: Radar, EW (Electronic warfare), ESM (Electronic Security Measures), Missiles, UAV (Unmanned Air Vehicle), Communications and satellite components. Progress should be made in developing critical technologies, such as: OPOE

(Optics, Photonics and Optoelectronics), microwave power, RF, digital processing, integrated and intelligent Tx/Rx modules, etc.

- Some technologies require specific development for defence purposes: Image detectors, high-power DFB (distributed feedback) lasers, VCSEL (vertical cavity surface emitting laser), MEMs (Micro-electro-mechanical systems) and MOEMs (micro-opto-electro-mechanical systems), RF technologies, GaN (galium nitride), SiC (silicon carbide), activators, etc.
- Knowledge must be maintained of the reliability of components and advances in new technologies which adapt COTS for military requirements.
- Access and European sovereignty must be maintained for state of the art devices, such as CMOS (Complementary Metal Oxide Semiconductors), SiGe (silicon germanium) and BiCMOS (Bipolar CMOS).
- The development of technologies deemed to be critical should be shared by EU countries. The free circulation of technological components and devices within the EU should be promoted.
- It is of the utmost importance that work is undertaken on advanced R&D and attracting students (doctoral thesis, etc) and talent towards laboratories and projects.
- From the governmental point of view, greater efforts are required from European institutions in order to finance programmes developing key technologies and components for future defence systems.
- There are fewer and fewer foundries in Europe, and it is ever more difficult for markets which require low production levels, such as the military, to access them. Urgent measures are required to offset the effects of these gaps.

The above list reveals some of the existing gaps and the resulting problems to be resolved if, according to DISCOTECH, Europe wishes to have sovereignty in important technological fields which are of critical interest for future defence activities. It should be noted that these problems are not exclusively technological: other key aspects for the initiatives and activities required if we are to fill the gaps identified include education and the introduction of new legislation at the continental level.

- *Key technologies for the future. KETs (EU)*

In the case of the EU study on key enabling technologies for the future of Europe in the purely civil sphere (KETs), despite the strengths and limits of innovation systems and the various national industries, various EU members have identified technologies which will be relevant for the competitiveness and prosperity of Europe over coming years. The study has a European dimension and makes it possible to identify the most important areas of technology to be developed in the future. Whilst their complexity makes it difficult to achieve a definitive conclusion about which KETs would require greater strategic cooperation in order to achieve improved industrial competitiveness on the continent, the conclusions are sufficiently clear; and it is worth commenting on these in this chapter.

The study finds that leading countries in technology, such as China, Japan, Europe and the United States, are also focusing their attention on identifying the key enabling technologies which will be most important in the future. The lists of these include technologies related to biotechnology, ICT and nanotechnology. In particular, immediate political action is required in specific ICT fields such as micro and nano-electronics, given that the European industry is clearly lagging behind the other most developed countries in this area. Other technologies, such as those related to carbon capture and storage (CCS) are activities in which the report states that the EU has offered cooperation to other partners and for which it recommends making specific efforts.

One of the most important conclusions of the study, based on market trends and research activities at the global level, is that the most important KETs from the strategic point of view, given their economic potential, their contribution to resolving current social questions and their knowledge intensity, are:

- Nanotechnology. This area of technology is of great interest for developing nano and micro-devices and systems which constitute a technological breakthrough in fields of vital interest for society, such as health, energy, the environment and manufacturing.
- Micro and Nano-electronics (including semiconductors). These are essential for all types of goods and services which need intelligent control, in areas as diverse and important as motor vehicles, transport, aeronautics and space. The most advanced industrial control systems will enable a more efficient energy management, generation, storage and distribution.
- Photonics. This is a multidisciplinary technology which includes the generation, management and detection of light. Among other things, this provides the technological base for the conversion of solar light into electricity and many other devices of great interest and widespread use today, such as LEDs, lasers, cameras, displays, etc.
- Advanced materials. The development of these offers substantial advantages in a range of fields such as space, aeronautics, construction, healthcare, etc. It is expected that new materials will help to improve recycling, decrease energy demand and $CO2$ emissions and demand for other materials which are scarce in Europe.
- Biotechnology. This development involves the implementation of alternative industrial processes which are cleaner and more sustainable. This will be of key importance for improving the production of new drugs and foods.

The study finds that the potential of these technologies is enormous, and it adds that technological solutions should be sought for the most important challenges facing society today, such as: guaranteeing access to broadband communications, food supply, caring for the environment, transport, health, the ageing of the population, security and energy. Low carbon technologies which respect the environment will play an essential role in achieving the objectives of climate change policies. Technologies to develop new materials for energy production, transport and storage will play an important role in improving efficiency and, as a result, environmental impact.

Lastly, it highlights the importance of KETs related to advanced manufacturing systems, due to their importance in terms of producing goods with substantial technology content and high added value. By way of an example, it discusses the development of industrial robotics as an area of special interest for industries with complex manufacturing and assembly methods, such as vehicles and aeronautics, etc, involving a wide range of technologies, including simulation, programming and the development of robots, which reduce consumption of energy and materials.

Due to the rapid development of these sciences and research therein, the study concludes that the KETs described above will have a global impact and, therefore, irrespective of who develops them, they will have a major impact on the civilian field; there can be no doubt that their development will have major effects on all areas of society, including defence and security.

Finally, given their importance and relevance, despite having different origins -DISCOTECH is an EDA study, and therefore focuses on defence, whilst the EU study of KETs relates to the civilian sphere- we can state that the results of both of these prospective studies are completely complementary and even coincide in many technical aspects. This is a reliable demonstration that the convergence of military and civil technology is a widely-recognised trend which is sure to play a significant role in the development of the military systems of the future.

Defence planning as a tool of change

The first and most important objective of a defence planning system is to estimate and procure what is necessary for the armed forces to be able to respond rapidly and efficiently to a wide range or contingencies, many of which require different capabilities and operating methods. In practice, it is difficult to be very successful at this. As we have already stated in this chapter, the predominant reality for people involved in defence planning today is uncertainty.

The new Defence Planning regulated by Ministerial Order 37/2005[20] is the response of the Spanish Defence Ministry to minimise the effects of this uncertainty and the changing environments in which defence will be involved

[20] "Ministerial Order 37/2005, of 30 March, regulating Defence Planning", BOD no. 68, page 3579, 2005

in the future. This is capacity planning which introduces a combined overview of the determination, definition and harmonisation of the needs and resources to be employed, and also provides a more rational basis for decisions on procuring weapons, providing a comprehensive solution which covers all needs in one.

This planning system does not seek just to determine the capabilities or resources required for a certain type of conflict or to complete a specific mission; it is much more general than this and aims to obtain the capabilities to handle a broad spectrum of risks. The results will be better and more exact the more precisely the various scenarios have been imagined and the more demanding the operational environments contemplated.

This process is started and guided by the President of the Government by issuing the National Defence Directive, which also establishes the general lines of action and guidelines for Defence Planning. One of the defence policy directives established in National Defence Directive 1/2008 which is particularly relevant to what we are discussing here is "*Promoting research, development and innovation in order to maintain a high technological level in the defence sector, in order to improve the operations of the Armed Forces and to promote continuous development of the industrial and technological defence base so that it is capable of meeting the essential needs of national security and of being integrated into the European defence industry in terms of competitiveness and technological level*". This reveals the importance of technological innovation for planning from the outset.

It is evident that the new planning system is in itself an innovation: in this case of the type of organisation and processes. But, how do we incorporate technological innovation? And how does the Ministry of Defence establish the contribution of R&D to the capabilities of the Armed Forces?

Defence Planning makes it possible to establish guidelines for development of military and, as a result, resource planning over the medium and longer term. Resource planning involves the acquisition and maintenance of the resources to support the military capabilities identified with the budget allocated. This planning includes R&D, acquisition, maintenance and infrastructures.

The Ministry of Defence is therefore incorporating technological development on two inter-related planes: the first, that of R&D aspects of the plans associated with Resource Planning; and the second, the implementation of these plans with the corresponding management and performance of R&D activities for which various instruments are available.

With regard to plans, the planning of material resources is mainly carried out for weapons and materiel by the Armaments and Materiel Master

Plan (PDAM)[21], which defines the Ministry of Defence's R&D Policy; in other words, this contains the objectives and guidelines which should govern R&D activities. In addition, it also identifies the main instruments and mechanisms for its management, which we describe below. There is a public version of the PDAM, which is easily available on the Ministry of Defence website[22].

This Plan establishes that the objective of the R&D policy is to contribute to satisfying military capabilities by providing the Armed Forces with adequate systems through the development of technology, demonstrators and prototypes, and by encouraging competitiveness in the National Defence Industry Technology Base (DTIB).

This objective is pursued through five lines of action, the first of which is aimed at centralising the management of R&D activities in the Sub-Directorate General of Technology and Innovation. The next two are aimed at technology centres and their role within defence R&D; in other words, promoting experimentation and innovation as a support for transformation of the Armed Forces. The final two are related to interaction and joint work with the domestic technological industrial fabric. Specifically, these establish:

- Strengthening technological monitoring and prioritisation mechanisms.
- Improving the integration of the National Defence Industry Technology Base into the national and European R&D base.

In turn, these five lines of action are broken down into twenty guidelines which specify more precisely the actions for implementation of the defence R&D policy. By way of example, these include:

- Promoting and facilitating the participation of the domestic DTIB in cooperation programmes and networks of expert.
- Integrating universities, research centres and SMEs into the domestic DTIB.
- Taking advantage of and applying civil R&D to defence.
- Promoting technological innovation as a means to rapid and flexible development.

Associated with the PDAM, we have the Long-Term Weapons and Materiel Plan (PLP-AM)[23], which identifies technologies which are potentially of long-term interest for the Ministry of Defence.

(21) Armaments and Materiel Master Plan 2008, DGAM-Ministry of Defence, 2008
(22) http://www.mde.es/Galerias/politica/armamento-material/ficheros/DGM_Plan_director_PDAM_2008.pdf
(23) Armaments and Materiel Master Plan 2008, DGAM-Ministry of Defence, 2008

Scope	Integrated vision			Technological Aspect
Military planning	Military Capacity Objectives (MCOs)	Military	Mirado*	Functionalit y
Material resource planning	Material resource objectives (MROs)	Defence systems, armaments and materiel	Production systems. Final prototypes	Mature technologies with demonstrated military applications
Strategy of Technology and Innovation for Defence (ETID)	Technologic al goals	Technological objectives which guide R&D activities to contribute to systems development	Prototypes	Technologies demonstrate their maturity and functionality in the military sphere
Prospectiv	Potentially interesting technologies	Scientific and technological drive	Basic principles and formulation of potential applications	Knowledge of potential future applications

*Mirado= Materiel, Infrastructure, Human Resources, Training, Doctric, Organic

This identification of technology with potential long-term interest is complemented by the Strategy of Technology and Innovation for Defence (ETID)[24], which defines specific technological goals linked to the functionality required for the military capabilities. Despite having this strong link to military capabilities, and therefore military planning, the ETID is not officially part of Defence Planning, although due to its importance it was issued by the Secretary of State for Defence in July 2010 as a general technological framework for defence plans and activities of agents involved in R&D within the Ministry. As a result of its importance, we dedicate a specific section of this chapter to the document on technological defence planning.

Associated with the Defence Planning and the management of defence technology innovation, we can highlight the new instruction[25] which will regulate long-term planning processes and short and medium-term planning for all financial and material resources. This instruction establishes a unified and integrated approach which will lead to more efficient resource assignment and acquisition processes. To this end, it defines the concept of the Material Resource Object (MRO) as an ordered set of components which are interrelated and which all contribute to providing a comprehensive solution in terms of scope and timing for totally or partially achieving a specific military capacity or Defence Department objective. Once the components which make up the

[24] Strategy of Technology and Innovation for Defence – 2010, DGAM-Ministry of Defence, 2010

[25] Instruction 2/2011, of 27 January from the Secretary of State for Defence, regulating the financial and material resource planning process , Official State Gazette, 8 February 2011

MRO have been programmed, they are assigned to programmes so that they can be obtained; one programme can serve to obtain one or more components belonging to one or more MROs.

From the technological point of view, the MROs should consider technologies with a sufficient level of maturity to ensure that the process of obtaining them is executed as planned (in terms of timing and cost) and as expected in terms of functionality and performance (military systems contributing to military capabilities). The table below clearly shows the process for the incorporation of technological innovation into defence planning.

For this reason, it is important, as described at the start of this section, to have available the instruments to enable identification of availability and the risks associated with different technologies (such as the Defence Technology Watch System), whether developed by the Ministry through its own programmes or by incorporating third party developments (such as the COINCIDENTE programme).

- *Instruments*

A set of instruments is required to incorporate technological innovation into the implementation of the objectives and guidelines defined in the Defence Planning and for the management and performance of R&D activities driven by the technological priorities and challenges identified in the Planning and by the ETID. The main instruments are:

- Comprehensive management of the R&D value chain. R&D is a synthesis of a process of value creation which begins with the identification of technological opportunity niches, continues with the establishment of technological objectives related to the capabilities required and the analysis of the possibility of implementing these (undertaking them independently, incorporating proposals from suppliers or jointly with other organisations or countries); and in the event of a positive evaluation, the programme is implemented to create a sample or prototype which must then be tested and assessed. This chain of actions obviously covers an infinite number of variables and details and requires comprehensive management and supervision of the results of each agent involved (technology centres, companies, research groups, international management committees, etc).
- The agreements and institutional relations which make it possible to align defence R&D planning and national technology planning. Defence R&D cannot ignore general R&D; likewise, defence planning cannot ignore national technology planning (State Innovation Strategy, the national R&D&I plan, the technical plans of technology bodies and communities, etc).

- Defence Technology Centres -CEHIPAR, ITM, INTA- as the performers of R&D activities, must perform technological experiments and assess the results thereof. This aspect of assessment and functional experimentation of demonstrators and prototypes goes beyond certification in accordance with standards and regulations and into the realm of the experience of the final user of the system in order to ensure that technological developments meet the functional expectations of military capabilities, which in some cases may go beyond simple assessment and extend into active participation in design and conception of technological progress and systems. This activity, known as CD&E (Concept Development and Experimentation) makes it possible to refine the design and the performance of the systems almost from the outset of the R&D value chain.
- The Defence Technology Watch System (SOPT) is one of the main instruments for this, as it acts as a support for technological priorities and technological aspects of R&D planning. The objective of SOPT is to bring technical criteria to each area of technology of interest to the Ministry of Defence, and to carry out technological monitoring and prioritisation activities. To this end, it performs the following missions:

  – Advising on the strategic planning of R&D activities over the short, medium and longer-term; seeking out, acquiring and processing information on technology of interest to the Ministry of Defence, current and future R&D activities both domestically and internationally, and the national industrial and technological base; and identifying trends, progress and future technological challenges, together with specific military needs and objectives, in order to help to guide future defence R&D efforts. All of this information serves as a basis for supporting Materiel Resources planning through the performance of technology prioritisation activities and the identification of strategic technological capabilities in the domestic technological and industrial base for inclusion in plans and strategies.
  – Advising in the process of obtaining systems with significant technological content, evaluating the technological aspects of R&D project proposals, programmes and activities and the various phases in the process of obtaining systems with significant technological content by the Ministry.
  – Acting as a repository for technological knowledge, managing the technological information available and identifying the knowledge available in the organisation and the technological areas of interest so that this knowledge can be used as a corporate resource with regard to weapons and materiel. Moreover, the SOPT spreads knowledge of technologies of interest to the Ministry of Defence in the organisation and the domestic technological and industrial base, providing guidance on the technological interests and needs of the Ministry.
  – Furthermore, it involves a periodic evaluation of R&D efforts and their results.

As with an orchestra, this set of instruments requires a body to act as a conductor to ensure that everyone is playing from the same score; in this case this involves the Defence Planning (including the Resource Management Planning and the ETID). This body is the Sub-Directorate General of Technology and Innovation (SDG TECIN) of the Directorate General of Armaments and Materiel (DGAM) which gives coherence to defence R&D in terms of armaments and material, based mainly on Defence Technology Centres.

The most recent version of DGAM's Organisational Manual, dated January 2011, identifies the SDG TECIN as "*the management body responsible for coordinating and monitoring defence R&D activities performed by the various R&D centres of this Ministry, establishing, coordinating and evaluating the results obtained by the Departmental bodies which implement the R&D policy established*".

The Strategy of Technology and Innovation for Defence. Importance

In the first two sections of this work we emphasised that uncertainty is an omnipresent aspect of defence planning, and that the rapid pace of scientific and technological progress is both a major opportunity and a major challenge for the Spanish Armed Forces. We also described the main organisational and structural actions which the Ministry of Defence has launched in order achieve adaptability and responsiveness to the uncertain and highly dynamic scenarios faced by the Spanish Armed Forces today. This revealed the need to create and develop appropriate planning mechanisms to minimise and mitigate the possible risks associated with the resolution of conflicts dependent on a large number of variables which make it difficult to predict with reasonable certainty how events will unfold. This reduces the risks related to uncertainty, making it easier to incorporate mature technological solutions at reasonable cost and timing, so that Spanish Armed Forces can undertake the missions entrusted to them with greater guarantees of success.

The Ministry of Defence is a major consumer of technology, but it is also a major generator of technology. As such, it has an organisation which is dedicated to generating and managing technological innovation. The DGAM and its institutes –ITM, CEHIPAR and INTA- are its visible tips, and its increasing activity and dynamism is a demonstration that today it is a mature organisation which is able to promote and coordinate all R&D activities efficiently, placing it on a par with the most advanced countries in our context. There can be no doubt that the Ministry of Defence's R&D management system is a pioneer at the national level in implementing new methodologies and ways of doing things. The Improvement Plans of the Secretary of State, the Defence Technology Watch System (SOPT), the Strategy of Technology and Innovation for Defence and the Master Plans within the Defence Planning are all very interesting initiatives which can be exported in full to other areas and government bodies. It would be difficult to find another R&D management system at the national level which is so mature and which has as much development potential as the current Defence system. Necessity requires this to be the case.

Because of its relevance and impact on the future of the organisation and the management of defence R&D, the last part of this chapter will be dedicated to explaining the content, spirit and philosophy which underlies the most important initiatives recently implemented by the Ministry of Defence in order to improve the coordination and management of technological innovation in the defence sphere: the Strategy of Technology and Innovation for Defence (ETID).

The ETID is important not just because of its content, but also because of what it signifies. With its issue, the Ministry of Defence displayed a proactive attitude towards everything related to technological innovation in the defence field. This is an important qualitative step in the ways in which it sees and does things, and means that it is taking the initiative in some vitally important aspects not just for the Armed Forces but also for advancing towards a better model of domestic output which is more aligned with the current times.

The Strategy of Technology and Innovation for Defence

The ETID is a complement to the Defence Planning which aims to bridge the existing gap between the operational requirements established by the Spanish Armed Forces through the Military Capacity Objectives (MCO) and the future technological solutions associated with these. The area for action is R&D activities and technological innovation for defence, which includes technology which is currently at low Technology Readiness Level (TRL) (not higher than 5 or 6). It does not cover the activities included in the Development

(D) category as these are considered in other sections of the Armaments and Materiel Master Plan.

The ETID is not formally part of Defence Planning but it derives directly from it, developing the technological lines and R&D policy directives declared to be of interest by that document. It is based on the basic principle of defining from a technical point of view the path to follow so that in the future the Armed Forces have available the (mature) technologies they require for developing systems at that time. As part of the initial analysis of the Strategy, it identifies the challenges faced by defence R&D at present related to purely technological issues and to organisational and financial aspects.

Spain is faced by a number of challenges which are common to other similar countries, and the identification and analysis of which are the driving force behind joint studies carried out in international forums. These studies were used as input data in preparing the Strategy and have been integrated into the national defence R&D challenges. Some of the main challenges include:

- Promoting the participation of SMEs, universities and research centres in defence R&D.
- Progressing in the coordination of all defence R&D activities.
- Progressing in coordinating and taking advantage of civil R&D strategies.
- Promoting open innovation.
- Promoting international cooperation.
- Promoting investment by the industry in R&D.
- Accelerating the incorporation of the R&D results obtained into defence systems and equipment.
- Maintaining R&D and innovation capacity in the face of tight budget settlements.

Once the challenges were identified, the Strategy established objectives which are fully in line with the times we are living in, where concepts such as innovation and technological development play a leading role as creators of wealth and drivers of progress in modern societies. It aims to achieve the following objectives:

- Guiding technology providers (industry, technology centres, the academic world) on the technological needs of the Spanish Armed Forces, establishing a public reference point on the R&D and innovation activities which are considered to have the highest priority.
- Promoting cooperation among all the parties involved in R&D (in both the defence and civil sectors), bringing technology suppliers and users together.
- Coordinating all parties involved in defence R&D, taking maximum advantage of all R&D synergies in the civil and military spheres and avoiding duplication of efforts in achieving common objectives.

- Supporting efficient management of resources dedicated to R&D and innovation activities, maximising the return on investment from the technological, industrial, business and social perspectives.

Underlying these objectives is a commitment to improvement through economic use of resources and efficient management. Through this Strategy, Spain is not only trying to achieve a specific technological level, but is also trying to maximise the return on its investment from the technical progress, industrial, economic and social points of view.

These challenges are substantial and the objectives desired cannot be achieved in any old way. Since it was first conceived, the ETID has had to be able to count on the participation and agreement of all those who are in one way or another in direct contact with technological innovation for defence. As a result, it has the virtue of being the result of a totally open process involving all relevant parties -from the user to the provider- in its preparation and throughout the period during which it is implemented. This represents the Ministry of Defence's commitment to innovation, not simply as a way of improving the capabilities of the Armed Forces, but also as a way of improving the competitiveness and productivity of the Spanish economy. Through this, the Defence Ministry is playing a leading role as a driver of scientific and technological knowledge in Spain, in line with national science and technology objectives as established in the State Innovation Strategy (E2I)[(26)], and so promoting synergies and convergence between the civil and military spheres.

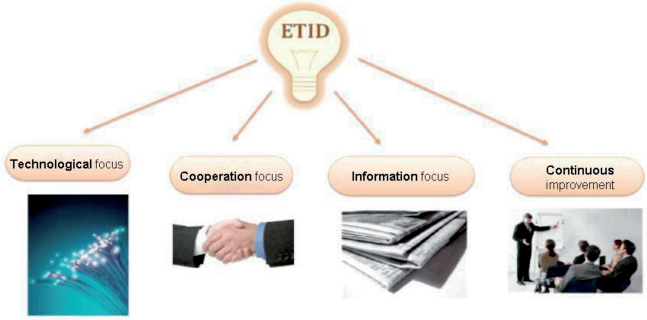
The content of the Strategy

The Strategy will be a highly valuable instrument for the Spanish Ministry of Defence, as it provides specifically designed tools to enable its Armed Forces to have available the most advanced technology and the most innovative solutions for the development of its future weapons systems. In order to respond to the challenges detailed in the previous section, a number of actions are planned which can be grouped into four main areas each with a different focus:

- **Technology focus:** This defines the technological innovation areas and lines of work which are of interest for defence purposes based on a detailed technological analysis culminating in a list of Technological Goals grouped into Functional Action Areas, each with their own route map.

  One of the most characteristic aspects of this is its substantial technological content, which sets it apart from other strategies and similar initiatives by other government bodies. This technological analysis is purely the result of translating the operational needs of our Armed Forces into technology terms. It is, in summary, the result of transposing the Military Capacity

[(26)] State Investment Strategy (E2I), Ministry of Science and Innovation, 2010



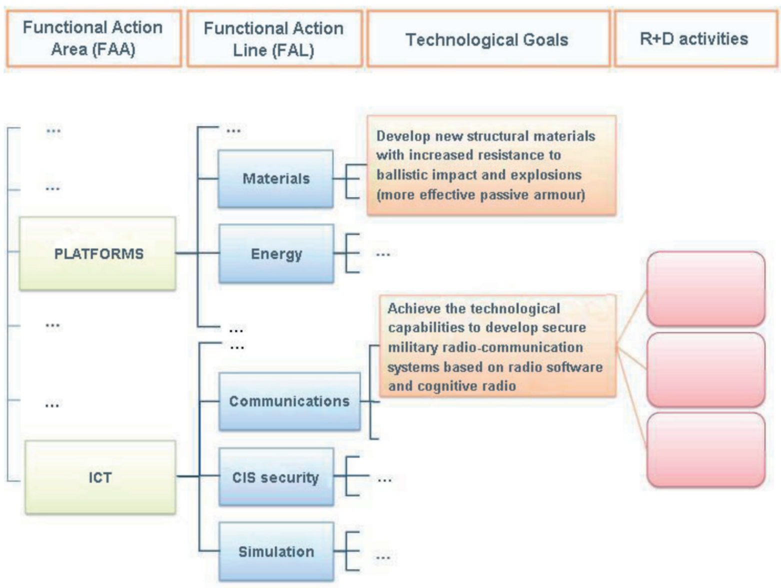
Objectives (MCO) established in the Defence Planning into Technological Goals to be achieved over the coming years. This transposition process has been far from trivial. In fact it has been highly complex, and a consistent methodology had to be designed to divide it into technological areas of interest to defence in six Functional Areas: Armaments, ISTAR, Platforms, Personal Protection, Protection of Platforms and Facilities and ICST. Six groups of experts were then formed (one for each Area) consisting of experts from the Ministry of Defence and the defence industrial and technological base. Each of these groups carried out an exhaustive technological analysis which culminated with the establishment of 33 Functional Action Areas (FAA) and 111 Technological Goals which are stated in the document.

The Goals are based on operating needs and defined an open path to allow space for multiple technological solutions. These are the basic elements on which future defence R&D activities will be established and planned. With regard to technological content, the ETID reflects the Ministry of Defence's vision of the technological horizon over the coming years. This horizon is the intersection of two planes: that of technological innovation, and that of Defence Planning.

- **Cooperation focus:** This is aimed at establishing cooperation agreements and coordination mechanisms to enable defence R&D initiatives to have the support they need. It contains measures aimed at making progress towards centralised and coordinated R&D management in the Ministry of Defence, and the development of cooperation among other domestic and international institutions related to technological innovation. It should be stated that a large part of the work of defence R&D managers will be related to coordination and cooperation in order to enable the most efficient possible management of the resources dedicated to R&D. This work should channel the capabilities and activities of the Ministry and promote the creation of new collaboration channels in order to take advantage of existing synergies with other technological innovation activities in other fields. In the ETID companies and technology centres can find reference points which they can use to guide their technological capabilities towards objectives of interest for defence.

- **Information focus:** This involves initiatives leading to the spread of information and the promotion of mutual knowledge and cooperation among different agents. One of these –perhaps the most important proposed to promote participation and mutual knowledge among agents in the DTIB- is the creation of an internet portal as a communication and knowledge-sharing forum for all parties involved in defence R&D (universities, technology centres, SMEs and large companies). The main objective is to facilitate and accelerate the launch of initiatives; to promote the generation of new ideas; and to have a direct impact on improving the competitiveness of the national defence fabric.

  This portal enables the Ministry of Defence to inform all other domestic and international parties of its interests, capabilities and areas of technological knowledge, thus facilitating the formation of consortia to carry out activities of common interest. SMEs can also use this portal to make large defence companies aware of their capabilities. This improved mutual knowledge among the various DTIB agents facilitates cooperation, increasing the participation of SMEs in domestic and international defence R&D projects. This portal communicates information on defence R&D initiatives and programmes underway and the conditions for taking part in these (tender processes, timescales, documentation required, etc.).



The portal acts as a shop window for both domestic and international initiatives which are of interest to the Ministry of Defence, and news and events related to the sector, including sector meetings, support and aid for the formation of consortia and in the preparation of proposals relating to technological issues of interest to the defence industry, etc.

- **Continuous improvement focus**: This focuses on the assessment and monitoring of returns on R&D activities and the extent to which the objectives set are met. From the point of view of managing the usefulness of the final results of R&D for the end user -such as the defence industry- the full development cycle of the capabilities being acquired must be visible from very early in the process. In order to maximise returns on the investment being made, it is essential to identify all the main parties that may be involved in the lifecycle of the capability –such as users, scientists, technologists, industry, etc- as well as all associated technologies.

Part of the implementation of the ETID is based on detailed technological route maps, which help to attain the capabilities considered to be of the highest priority in military planning. These route maps include a description of the steps to be taken from a purely technical point of view, and also propose timetables and the parties involved.

Throughout the implementation period, metrics are defined to measure the return to the Ministry of Defence on its investment using a number of indicators. However, the usefulness and reliability of these metrics depends to a large extent on the definition of the criteria to be evaluated and the assessment or score assigned to each of these.

These indicators show the contribution of R&D in various areas related to technological and social progress, including:

- **Technological improvement:** This aims to measure the manner in which R&D has improved the technical or functional characteristics of a specific military capability.

- **Economic efficiency**: This relates to the contribution to reducing manufacturing and implementation costs for the products.
- **Improving competitiveness:** This measures the increase in exports of high technology defence products.
- **Economic development of the associated industrial base:** This deals with the way in which externalities have been generated, promoting the development of other related industrial and commercial sectors.
- **The environment:** This measures the contribution of the activities to the reduction of environmental impact from the manufacture and use of the defence systems, helping to achieve sustainable development.

- **Human Resources:** This relates to the impact on activities on improving the quality of human resources and increasing the number of researchers in the industrial base.

The Strategy of Technology and Innovation provides a large number of benefits for various agents involved in R&D in general, and defence R&D in particular. These include:

- Orienting R&D to military needs: The methodology used in preparing the strategy ensures that the activities and the route maps resulting from the objectives are fully aimed at meeting the technological needs of the Spanish Armed Forces, optimising resources and achieving the highest possible returns from the investment made.
- Making it possible to communicate the needs of defence R&D to all parties involved: This eliminates a barrier to participation in defence activities, enabling contributions from a wider knowledge base in obtaining military capabilities.
- Improving industrial competitiveness: The information provided, together with the initiatives considered for implementation, favour and promote rationalisation of investment, efficient resource use and cooperation, facilitating technological innovation and development; all of these factors contribute to improving the competitiveness of the domestic defence industry.
- Supporting the Ministry of Defence's CD&E activities: It is a highly useful tool for guiding institutes and centres on future technological areas of CD&E activity.
- Enabling the transfer of the benefits of defence R&D to society as a whole: This clearly connects the universe of what is considered purely military (capabilities) with the universe of technological innovation (objectives), making it possible to identify areas of knowledge of common interest (civil-military). Therefore enabling us to perceive how defence R&D can contribute to creating a sustainable growth model based on knowledge and innovation, producing qualified and competent professionals, and providing better quality of life and welfare for society as a whole.

In addition to the specific benefits described, and in accordance with the principles and objectives detailed in the National Science and Technology Strategy (ENCYT after its Spanish acronym)[(27)], the ETID makes a clear contribution to the objectives of the National R&D&I Plan 2008-2011[(28)], and is in line with the State Innovation Strategy, promoting research and innovation as attractive investment opportunities, thus boosting economic factors towards a knowledge economy generating a competitive domestic industrial and technological fabric and promoting internationalisation. Progress towards a

[(27)] National Science and Technology Strategy (ENCYT), Inter-Ministry Science and Technology Commission, Ministry of Science and Innovation, 2007
[(28)] National Scientific Research, Development and Technological Innovation Plan 2008-2011, Inter-Ministry Science and Technology Commission, December 2007

knowledge society is, without doubt, progress towards a more modern and fairer society. From this point of view, technological innovation for defence, as a driver of an organisational culture focused on knowledge generation, contributes to achieving a more advanced and sustainable society.

CONCLUSIONS

One word which appears inexorably in all the work and studies carried out recently on the armed conflicts of the future is uncertainty. Part of this uncertainty results from the armed forces having to design operations which are dependent on multiple variables in highly changeable environments and in the worst scenarios possible, with diffuse adversaries, or adversaries hidden among complex webs of interests, and conflicts of varying intensity which are broadcast in real time by the media.

States must be able to anticipate the use of new methods and modes by adversaries who are using ever more innovative and sophisticated tactics. It is very difficult today to identify trends and forecast events; this means that extra effort is required from the armed forces in order to adapt. It is a scenario in which having a high percentage chance of success is dependent upon acquiring high levels of adaptability in operations; where uncertainty is one of the predominant ingredients; and where technological development and innovation are becoming ever more important as differentiating factors which are key to combating and minimising the effects of uncertainty, and are essential for the acquisition of information, decision making and the execution of operations.

Despite this increasing importance of technology and innovation for the armed forces, paradoxically defence R&D is no longer the motor for technological innovation that it was a couple of decades ago. Some of the factors behind this include ever tighter budgets, the driving forces of civil and commercial technology and geopolitical changes. All Western defence organisations have had to adapt to more centralised and proactive R&D management models.

Large defence system development programmes have shown themselves to be useful tools, but at times their efficiency is limited. The technological immaturity of some key components has resulted in setbacks in the development of the system as a whole, resulting in cost overruns and delays which are unacceptable to any economy or army today. Defence ministries need to be able to anticipate future technologies earlier, and to involve all parties –from scientists and technicians to industry and the armed forces- in development from the outset. The industry must evolve towards models where the integration of components is only part of their activity, and they should be involved in the maturing of new technology from early in the development process. This will provide added value and better positioning in the international market with greater competitive advantages than at present.

Spain's Ministry of Defence has started this transformation of its R&D management. Over recent years they have developed towards a more centralised and proactive R&D management policy, in which a single body –the Directorate General of Armaments and Materiel (DGAM)'s Sub-Directorate General of Technology and Innovation (SDG TECIN)- is responsible for the coherence of defence R&D and its coordination with general R&D, particularly that related to security. Two of the first tools to result from these organisational changes which complement Defence Planning and help it to be implemented optimally are: the Defence Technology Watch System (SOPT) and the Strategy of Technology and Innovation for Defence (ETID).

The former, SOPT, is involved in constant monitoring and analysis of current and future technologies as they emerge, as a basis for the evaluation and selection of the most promising and interesting projects and the prioritisation of investment in the technologies of the greatest interest. Complementary to this, it also identifies the technological capabilities of domestic industry, research centres and universities and establishes communication channels with them; these serve not simply as a way for companies with innovative projects to access the Ministry, but are also a source of information on domestic technological capabilities and the possibilities and technological risks of various initiatives.

The ETID fits into the R&D Management Improvement Plan which the Secretary of State for Defence is currently implementing. This is a tool which the Ministry of Defence has incorporated in order to carry out its functions of promoting and coordinating scientific and technical research in areas which affect national defence. Although this is not formally part of defence planning, is does derive from it and is a fundamental part thereof, as it iteratively incorporates R&D into resource programmes and its ultimate purpose is to contribute efficiently to the Spanish Armed Forces being equipped with the most modern military equipment and systems, acting from the early stages of the technology, developing knowledge and supporting the domestic defence technology and industry base.

CHAPTER THREE

RESEARCH AND TECHNOLOGY IN THE CONSTRUCTION OF EUROPEAN DEFENCE

Arturo Alfonso Meiriño

ABSTRACT

As part of the building of the European Union initiated by the signing of the Maastricht Treaty in 1992, and in particular as a result of the progressive application of the Common Security and Defence Policy (CSDP) as an integral part of its foreign and security policy, one of the Union's priority objectives is to identify the military capabilities required to support the CSDP. This was the mission assigned to the European Defence Agency in the Council's 2004(1) Joint Action which created the Agency. This mission was subsequently ratified in the Lisbon Treaty(2) which came into effect on 1 January 2010.

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(1) Council Joint Action 2004/551/CFSP on the establishment of the European Defence Agency (EDA). Article 2 assigns the EDA the mission to "*support the Council and the Member States in their effort to improve the EU's defence capabilities in the field of crisis management, and to sustain the ESDP as it stands now and develops in the future. The Agency's mission shall be without prejudice to the competences of Member States in defence matters*".

(2) Consolidated version of the Treaty of the European Union (TEU), Article 42 (ex article 17 of the TUE) of which states "The Agency in the field of defence capabilities development, research, acquisition and armaments (hereinafter referred to as 'the European Defence Agency') shall identify operational requirements, shall promote measures to satisfy those requirements, shall contribute to identifying and, where appropriate, implementing any measure needed to strengthen the industrial and technological base of the defence sector, shall participate in defining a European capabilities and armaments policy, and shall assist the Council in evaluating the improvement of military capabilities"

European Armed Forces, which have been going through successive and challenging transformations almost since the end of the Cold War, need to have adequate military capabilities to be able to undertake the operations required under the CSDP at present and in the future. Research and technology play an essential role in this transformation process, particularly with regard to identifying gaps in European Union forces for the performance of such operations. In this regard, we should understand research and technology in their widest possible sense, given the ever greater influence of the appearance of dual-use technologies with evident military and security and civil applications. Whilst traditionally technologies deriving from defence research had major applications in civil life, today the relationship is at the least bi-directional. Technologies from the civil field –such as information technology- have a multitude of applications for defence equipment, and this has to be exploited in order to identify synergies between civil and military technology, particularly at a time of budgetary restrictions which are impacting strongly on defence budgets.
The European Defence Research and Technology Strategy is the current reference framework for such actions in the EU to improve the efficiency of investment in research and technology with defence applications through cooperation among Member States, and to promote harmonisation between states at the European level in technological innovation and development efforts, which continue to be fragmented and dispersed.

Key words:
Military Capabilities, Strategy, Security and Defence, Research & Technology, synergies

INTRODUCTION

The relatively prudent formulation adopted by the then 15 Members States of the European Union at Maastricht nearly twenty years ago with regard to the possibility of a European defence policy stated that *"the common foreign and security policy shall include all questions relating to the security of the Union, including a progressive framing of a common defence policy, which might lead to common defence, should the European Council so decide. It shall in that case recommend to the Member States the adoption of such a decision in accordance with their respective constitutional requirements"*. This enabled consensus among those who considered it necessary for there to be an affirmation of European defence identity and those who did not want to renounce an issue as obviously sovereign in nature as defence; they were also concerned not to risk diluting the cooperation established under the Atlantic Alliance.

This vague concept of "common defence" has evolved dramatically over the twenty years since then, with major efforts being made in the desire to progress on the path to a full Union, including the strategic and military dimension. Specifically, the European Security and Defence Policy (ESDP), which has now been replaced by the Common Security and Defence Policy (CSDP) following the entry into effect of the Lisbon Treaty, has been one of the major areas of development in the European Union (EU) over the last ten years.

Europe has been involved in more than twenty operations -both civil and military- over recent years, putting to the test the capabilities provided by the Member States in support of these operations. As the 21st century develops new threats and challenges will demand new roles and missions from our Armed Forces in the context of European Foreign Policy. As established in the document "European Security Strategy: A secure Europe in a better world" –commonly referred to as the "Solana Document" – adopted by the European Union Council on 12 December 2003 under the mandate of Javier Solana as the High Representative for Foreign Policy and Common Security, and subsequently ratified in 2008, "*In an era of globalisation, distant threats may be as much a concern as those near at hand... our traditional concept of self-defence –up to and including the Cold War- was based on the danger of invasion. With the new threats, the first line of defence will often be abroad. The new threats are dynamic*". A good example of this is Operation Atalanta, which was launched in 2010 against piracy around the Horn of Africa.

The operations we are involved in today, and which we will be involved in tomorrow, are and will be dramatically different to those during the Cold War. The change has been so huge because actions today are not based on wielding the maximum destructive power against opposition forces, but on expeditionary forces related to international security, where the opponent is often difficult to identify and isolate, and also has a degree of access to existing technologies, making it difficult to identify the threats.

The capabilities available, and particularly the identification of those military capabilities in which the EU has gaps which make it difficult to adequately perform such operations, are a priority objective under the CSDP. Mobility in the theatre of operations and the fight against IEDs (Improvised Explosive Devices) are examples areas where there are weaknesses in the operations launched by the EU to date.

In order to perform tasks under the CSDP –i.e. peace keeping, prevention of conflicts and strengthening international security in accordance with the UN Charter- the Union's actions are based on civilian and military operating capabilities provided by Member States. Under the Treaty of the European Union, Member States are committed and willing to progressively improve these capabilities. One key factor in this process of improving capabilities is coordinated action among EU Member States on research and technology.

Javier Solana, also the first Director of the European Defence Agency, described the importance of these actions in his opening speech at the first annual EDA conference held in Brussels on 9 February 2006 under the title "Research and Technology: an imperative for European defence": "*We all know that acquiring the right defence capability means many things. We need the right forces, the right doctrine and the right equipment. But we also need to develop our technological base. That is why today's conference is so important. Technology is the key to the transformation of our Armed Forces*".

Furthermore, actions relating to defence and technology research will also have a determining effect on the future European defence industry. As the EDA's National Armaments Directors stated in September 2006 on agreeing the characteristics that the European technology and defence industries should have in the future, the industry must have the necessary levels of competence; providing cutting edge technology on time and competitively; and facilitating exports globally through efficiency. Above all, the European technological and defence industry base should be specifically focused on the military capabilities required by the Armed Forces and by new operating scenarios.

We can debate the types of technology required to achieve adequate levels of military capability which should be generated domestically for reasons of sovereignty and for economic or social reasons. We can also discuss how much of this technology should, or better, has to be generated through international cooperation. Within this category, how much of this technology should be developed through European cooperation or with other allied countries, taking into account limitations on technology transfer with some countries, which are a real barrier to the collaborative development of R&D programmes. Finally, we can also put up for debate how much of this technology should be opened up to the global market, taking into account the security of supply issues this might imply.

We must always take into account a number of aspects in such debates. Firstly, those which affect domestic defence, which also make it necessary to adopt domestic defence technology and industry policies that, through the definition of objectives, and taking into account the many related aspects (strategic, economic, social, international policy, etc), make it possible to define the technological and industrial capability it is considered essential to maintain at the national level, with the corresponding efforts required to achieve this. Such a policy would therefore define the technological and industrial capabilities that we are willing to develop in cooperation with other countries, with associated investment commitments.

Secondly, we need to take into account the reality of current defence budgets, which place a significant limit on our ability to act alone in investing in defence technology, and which therefore impose a degree of realism on our ambitions in this field.

Thirdly, we have to understand the opportunities that might arise from international cooperation, as only through the economies of scale resulting from such cooperation is it possible to develop research and technology associated with major defence programmes.

At the European level, and as a result of Spain's commitments as a European Union Member State, and specifically under the Common Security and Defence Policy, Spain has undertaken to improve its military capabilities; and together with those of other Member States, these military capabilities should enable an adequate degree of autonomy at the European level in implementation of the CSDP, whilst being compatible with national sovereignty.

There is another aspect that we must mention in this analysis of the concept of defence innovation and technology in the European context. Against the current background of economic crisis which we have already mentioned, which has had a particular impact on defence budgets and defence R&D in particular, we need to find innovative ways in which Member States can cooperate and harmonise the efforts of bodies involved in technological developments in order to continue working to achieve the model of an industrial base which is competent and competitive, and able to provide the defence equipment required for military capabilities.

If we want to continue working to improve our defence capabilities, we need to search for synergies between innovation and technology activities in the civil and military fields, enabling harmonisation of work undertaken and increased effectiveness of the efforts of different European institutions in this field, together with the development of "pooling and sharing" approaches which make it possible to share areas of action and costs. At the present times of fiscal tightness, formulas for cooperation at the level of European government bodies to enable maximisation of returns on investment in innovation and technology must be based on dual-use technologies, with uses in both defence equipment and systems to provide the military capability needed to undertake operations under the CSDP and in civil applications.

This chapter aims to describe this vision at the level of European defence research and technology, in which the European Defence Agency's Capability Development Plan and the Strategy of Technology and Innovation, and the interrelations between the two, have a clear role to play. The reference framework is the mission assigned to this Agency as the body designated to perform this mission within the EU, as "*The mission of the European Defence Agency is ……d) to support defence technology research and coordinate and plan joint research activities and the study of technical solutions meeting future operational needs*"([1]).

MILITARY CAPABILITY AS A REFERENCE FRAMEWORK FOR RESEARCH AND TECHNOLOGY IN THE EU.

We have already stated that article 2 of the Joint Action which created the European Defence Agency established that its Mission was to support the Council and Member States in their efforts to improve the EU defence capability for crisis management and to support the Common Security and Defence Policy. The Lisbon Treaty went into further detail, assigning to the EDA the role of contributing to defining the objectives of the military capability of the Member States and to assess compliance with capability commitments made by the Member States.

The improvement in military capability is therefore one of the most important commitments made by the European Union Member States under the Common Security and Defence Policy as contained in the Lisbon Treaty. This is established in Article 42.3 which, in addition to this commitment, also contains that of Member States to make available to the Union under the Common Security and Defence Policy the military and civil capacity needed to contribute to the objectives established by the EU Council.

(1) Article 45(d) of the consolidated version of the Treaty of the European Union

The Lisbon Treaty designates the European Defence Agency and introduces a new structure into the pooling of military capabilities and associated elements through which Member States which meet the most demanding criteria for carrying out missions, and which have signed the most binding commitments in order to make the most demanding missions: **Permanent Structured Cooperation** within the Union. Protocol 10 of the Treaty "On Permanent Structured Cooperation as established in Article 42 of the Treaty of the European Union" assigns the task of contributing to periodic evaluations of the contributions of participating Member States in terms of capability to the European Defence Agency. From my point of view, this important aspect of Permanent Structured Cooperation will have a key role to play in all forms of cooperation between Member States including, of course, cooperation in research and technology.

Analysis of the military capability of the European Union in the Capability Development Plan (CDP) prepared by the European Defence Agency, jointly with its 26 participating member countries (i.e. all EU Member States except Denmark), the EU Military Committee and the EU Chiefs of Staff, is the benchmark document in the process of improving the Union's military capability. The CDP, which was produced in July 2008, and which, because of its nature as a living document, is currently being revised, is the reference framework not just for the national authorities responsible for the development of military capabilities, but also for public and private research centres and defence-related industries, as it sets out the guidelines to be followed in future when rationalising the defence research and technology efforts required to provide the aforementioned military capability.

The CDP provides a body of analysis of military capability requirements, trends and weaknesses to 2025. The CDP does not aim to be a supra-national plan which replaces national military capability plans; rather, it focuses on identifying the areas in which Member States are willing to cooperate on the development and improvement of capabilities, and above all aims to put a stop –whilst keeping in mind aspects related to national sovereignty- to historic European fragmentation and lack of harmonised requirements and shared priorities. In short, it aims to evolve towards a culture based on mutual dependence in the key factors which contribute to the development of capabilities, including factors associated with defence research and technology.

Whilst it is obvious that the future is unpredictable, with the information available at present it is possible to approximate the context of future operations, and as a result we can work on a set of possibilities for military capabilities that might arise. As a result, we cannot analyse the way in which future operations are conducted without considering political, social, cultural and technological aspects. Technological aspects are particularly relevant as in the current technological revolution the search for competitive advantage through the exploitation of new technologies is a top priority in order to maintain a degree of autonomy for EU operations.

What are the potential trends and the characteristics of the future military capabilities that will be required for missions associated with the Common Security and Defence Policy, and which will therefore impact on decisions relating to investment in research and technology and the resulting format of the European technological and industrial defence base?

A joint work coordinated by the EDA involving the Member States, the EU Military Committee and EU's Paris-based Security Studies Institute, entitled "*Long-term vision of the capability and needs of European defence"* presented in October 2006 at the EU Defence Ministers meeting in Levi, Finland, under the Finnish presidency of the European Council, aimed to answer this question.

We will now give a broad-brush analysis of the expected trends in the three families of military capabilities: *Knowledge, Engagement and Manoeuvres* which cover the six areas established, two per family, for the analysis of military capability, i.e. *Information and Command and Control* in the "Knowledge" family, *Protection and Engagement* in the "Engagement" family and *Deployment* and *Sustainability* under the umbrella of the "Manoeuvres" family. These are trends which should set the future course of research and technology for defence application efforts but the origin of which can simply be associated with research and technology.

Knowledge Focus

A key aspect of future operations is that the capacity to plan, prepare and conduct knowledge-based operations will be of crucial importance for ensuring that expeditionary forces are able to execute and achieve the strategic objectives set. This aspect impacts very directly on the first of the families into which the analysis of capabilities is divided. This is **Knowledge**, which in turn includes military information capabilities and Command and Control of operational capabilities, and also includes information management.

The main challenge in this field is to establish adequate architecture related to obtaining and managing IT (Information Technology). Computing power, data storage, bandwidth capacity, connectivity and interoperability will all be key factors, and the NEC (Network Enable Capability) will also be essential for all parties, both in the theatre of operations and in the rearguard command centre, which might be thousands of miles away in the home countries of the expeditionary force. As a result, decision making should be based on adequate surveillance –day and night- from remote locations and over areas to which access is denied. The precision and capacity to select information based on appropriate intelligence architectures which make it possible to fully integrate operations from the strategic level to the tactical level will be key to the performance of such operations.

Future C4ISTAR capabilities (Command, Control, Communications, Computers, Intelligence, Surveillance, Target Acquisition and Reconnaissance) must be developed based on global needs rather than based on platforms. In the future, C4ISTAR capabilities in the theatre of operations must be coordinated by the joint command so that such command can take appropriate decisions about the type of available capacity to use based on the objectives to be achieved at each moment in real time. To achieve this, a powerful network architecture is required to integrate data from all sensors –including those used in civil structures- and provide the necessary intelligence information in real time. In summary, sufficiently robust information management will be required to achieve the desired strategic effects.

In the knowledge area, civil technology will have a dominant importance in the future; this is important when analysing dual-use technology. It will be necessary to increase the power of information systems and to develop software in order to improve the tools which support decision making. This should include “on the ground” simulation capabilities to help in tactical and operational planning; such planning should also require the frequent use of high-resolution sensors to identify the actual situation.

Knowledge of the situation in real time, or nearly real time, through improvements in communications, positioning systems and other types of sensors in the C4ISTAR field is of fundamental importance in analysing the situation of our own forces and those of our adversary, permitting rapid analysis and control of damage and the consequences of combat against such adversaries.

The increase of frequencies and communications bandwidth, together with a reduction in the size of communication equipment (nanotechnology), will facilitate the transfer of data, image and voice, particularly between mobile units, making it possible to establish direct communication between commanders and individual soldiers.

Another technological field which is closely related to the Command and Control of Operations is that of sensors and related information collection and management. There are a number of technological areas in this field which should be developed in order to have a positive impact on the development of the NEC concept. Firstly, an improvement in the characteristics of new generations of sensors –both those transported using “high-end” platforms (such as UAVs - Unmanned Aerial Vehicles) and those transported by troop units and soldiers themselves, in other words, "low-ends". Secondly, technologies which have a positive impact on the proliferation of the number of sensors need to be developed in order to make them simpler and cheaper, enabling them to be used in multiple platforms, vehicles, etc or to be deployed and abandoned, providing information without being recovered. In such cases, the cost of the sensors is essential.

Processing of data from sensors and its subsequent merging will be one of the technologies to be developed in order to support the Knowledge focus from the capabilities point of view. There are two aspects which we need to take into account with regard to the development of sensor technology. Firstly, there is the human factor. The human factor remains a key element in operations, but its ability to assimilate data is limited, as a result of which the merger of data and its presentation to the party taking the decision has to be very selective. Another aspect is the proliferation of data, and therefore the possibility that even in the case of enemies with limited capabilities and sources of supply, they might still have ever greater access to sensors, particularly due to the development of the civilian market. This is the case for example with the electronic-optical sensors used in night vision equipment and even elementary radar constructions. The superiority of our forces in terms of knowledge of the situation is not therefore guaranteed in all situations.

Finally, in support of the knowledge area and networking of military capabilities, stable and lasting power suppliers are required to ensure the continuous functioning of the sensors and communication equipment. In this regard, improvements in batteries and "fuel cells" as sources of power are expected in the civil field, but it will also be necessary to experiment with solar cells and other technologies which permit continuous logistical support from a variety of power sources.

Engagement and Protection

In the Engagement family –which includes military Protection and Engagement capabilities- the general trend is that the platforms used will be more and more networked, i.e. covered by the NEC concept. This signals the need for such platforms to provide information to others and to receive information from others in order to perform their engagement role in accordance with the effects required at the time.

The fact that these platforms operate in different spaces (air, ground, sea surface and submarine) means that there are differences between them in terms of speed, durability and vulnerability to certain threats, and in terms of the possibilities of transporting some sensors and weapons systems. Predicting which types or families of platforms will be the most efficient in future depends on the operating framework, the mission to be achieved and the type of adversary. Therefore, it is difficult to establish beforehand the technological developments and the corresponding investment efforts that might be required more generally with positive impacts on any type of platform or operating framework.

Although in principle all types of platforms will remain relevant in operational planning, from the technological point of view, and apart from the aforementioned networking aspects, the expected trend is towards greater availability and use of unmanned vehicles, including those of reduced dimensions, and an expansion of the tasks entrusted to them. The range of such expansion will depend on future technological developments, mainly relating to the quality and security of communications and data transmission which make it possible to manage and optimise such platforms remotely.

Many of the functions of unmanned vehicles will be executed autonomously as the intelligence elements onboard become more technologically advanced.

Given the differing characteristics of such platforms and the spaces in which they are deployed, the aspects of research and technology associated with them in future will vary slightly.

In the field of land vehicles, the most relevant aspects from the technology point of view relate to their protection and that of the personnel in their crews or transported by them. New materials resulting from new technological developments should increase passive protection, subject to the logical limits of weight which might restrict the operating capacity of the vehicles for which they are planned. This also includes camouflage materials which cover a wide range of forms of protection that significantly reduce the signature of such vehicles for sensors and intelligent weapons. Active protection resources include directed energy weapons such as lasers integrated into the vehicles, which offer certain expectations with respect to certain types of attack, but which currently have limited effectiveness against short-range threats, such as IEDs (Improvised Explosive Devices). This is without taking into account the possible collateral effects of such protection measures which might make it unviable to apply them in urban areas.

Another important aspect related to future technologies affecting land platforms also applies to the Knowledge family: power sources and propulsion. Here once again, the civil sector is in the lead with technological developments based on new fuel forms and hybrid solutions, all of which are being developed as a result of new environmental restrictions which also directly affect the way in which the Armed Forces operate. These new developments are not going to have a direct impact on the military capabilities of land platforms, but are required in order to meet environmental requirements and standards.

The most relevant aspect of research and technology for airborne platforms is the role of these in air-land operations, both from the point of view of the ISTAR spectrum and as of carriers of weapons, whilst always considering their protection from land-based threats. Technological developments should take into account increased use of small UAVs -both those of small size and UCAVs (Unmanned Combat Air Vehicles)- for use in reconnaissance and information gathering and as combat platforms, respectively. The use of stealth technologies -for both manned and unmanned vehicles- to improve the survival of such systems against land-based threats is another fundamental area to be developed for aircraft.

The ISTAR capability in airborne platforms against land targets will be improved through developments in radar technology and electro-optics. Synthetic aperture radars give higher resolution and therefore greater discrimination between different types of objects at the same time as improving monitoring capabilities in all weather conditions. The miniaturisation of radars and electro-optic sensors will permit their installation in small UAVs. Technological developments in the NEC area will enable shorter target location times, and shorter times for preparation and launch of the corresponding weapons from airborne platforms. The improvement in Situational Awareness resulting from sensors will also make it possible to improve the next generation of air to air friend or foe identifiers, and the identification of combatants in air-ground attacks, reducing the risk of friendly-fire casualties.

Perhaps the most relevant aspect with regard to unmanned aircraft will be their use in unsegregated airspace. Their use is currently restricted to airspace not shared with other manned vehicles. The European Union's SESAR (Single European Sky, Air Traffic Management Research) initiative created within the framework of airspace management will also by definition have implications for defence.

Naval platforms will be used mainly in support operations, but also for the protection of logistics bases and maritime communication lines within and around areas where operations are being carried out. Technological developments in this area should also include Unmanned Surface Vehicles (USVs) and Unmanned Underwater Vehicles (UUVs) as reconnaissance platforms and as anti-mine systems at sea (MCM: Maritime Counter Measures). Another priority will be technological advances in countermeasures against submarine threats, which can also be used against naval platforms and civilian shipping.

Although soldiers themselves cannot be considered as being such platforms, there can be no doubt that with developments around the individual soldier –known as the "combatants of the future"- from the technological point of view, they will increasingly take on the role of "platforms". As a result we can establish a certain similarity between the aspects of research and technology related to land vehicles and soldiers in the sense that protection and integration into the network are also the two most important aspects of the technological environment for soldiers, without overlooking other aspects related to training and the need to develop the corresponding simulation technologies.

Nanotechnology will play a leading role in the equipment of the soldiers of the future. We must remember that ICT equipment has to be transported by the soldiers, which places significant limitations on weight in order not to hamper manoeuvrability. Some of the other possible technological improvements in this field include new materials for bulletproof vests which take into account the comfort of the solder using water and air filters, anti-bacterial properties, functional clothing and camouflage equipment.

Most technological developments should be aimed at improving the soldier's operational abilities in urban environments. These developments will include portable radar for detecting mines, vision sensors to detect snipers and their location, etc. As mentioned earlier when discussing command and control, in all of these areas the power sources for the soldier of the future which enable continuity of information and communication systems will be critical.

Weapons systems are a fundamental element of the military capability required in engagement. The most important technological challenges in this area consist of weapons systems associated with sensors and network data transmission, with the objective of producing the desired effects –both destructive and non-destructive- as efficiently as possible.

In terms of destructive effects, this means greater evolution of technological development in the field of Precision Guided Munitions (PGMs). The objective of this would be to achieve greater precision, lower failure rates and better resistance to countermeasures, in order to reduce collateral damage and the effects of friendly fire. New technological developments in the field of the energy of materials will make it possible to improve the explosive capacity of weapons (by around 20-25%); the autonomy of rocket motors (up to 50%); improved performance of submarine weapons (such as torpedoes and mines by up to 25%) and penetrative power.

Without seeking to be exhaustive Directed Energy Weapons (DEWs) are emerging as weapons being used in engagements. Another important field of research and technology related to directed energy weapons is based on High Power Microwaves (HPMs) and laser weapons. Whilst these weapons have the attraction of travelling at the speed of light and not using munitions, their use requires a major power supply, and at present this represents a serious restriction on their operational use.

With respect to threats arising from non-conventional usage, technological developments in the civilian field could increase the adversary's options. This might mainly affect biological weapons, due to rapid advances in biotechnology which could enable adversaries to obtain virulent weapons or agents which could escape effective treatment or conventional detection measures. Whilst technological advances directly related to chemical, radioactive and nuclear threats might appear slower in comparison to biological threats, it is important not to forget that the proliferation of technological knowledge in such cases might result in a large number of potential actors getting their hands on such threats. With respect to protection against chemical and biological attacks, research and technology should focus on improving protection, decontamination and treatment of victims and, above all, detection and improving situational awareness. Here, as in other areas of capability, in the field of the battle against CBRN, sensors, including remote sensors, will provide the information required for knowledge of the situation.

Manoeuvres focus

The deployment and sustaining, as parts of the manoeuvres family of military capabilities is also affected by aspects related to networks and communications. Positioning and monitoring sensors and self-analysis systems which enable auto-repair of materials are the fields for greatest technological development in the future. Likewise, developments associated with healthcare support in the form of telemedicine and remote patient monitoring will be necessary in order to improve the treatment of the injured in the theatre of operations. Developments in biotechnology will enable better treatment of casualties.

In the field of individual support for soldiers, there are interesting options which should continue to be developed, such as the possibilities of biotechnology for improving the capacity of human action through stress and fatigue reduction and improved healthcare. However, it is important not to forget legal and ethical aspects which are certain to play a fundamental role in the development of these technologies and their acceptance for general use in society.

The maintenance and logistics of systems based on new technologies is difficult to predict prior to the development of such systems having progressed to a sufficiently mature stage; however, in principle, sustainability aspects will be decisive for the spread of such systems.

Innovative designs for high-speed boats and high-capacity transport aircraft are others areas being developed related to strategic logistics. However, these designs are more related to engineering considerations for new generations of vehicles than technological advances as such.

In the logistics field -which is that covered by the manoeuvres area in the three families into which military capabilities are divided- whilst science and technology will have a direct impact through some of the developments already mentioned in the other two areas (such as sensors, communications, innovative materials, alternative energy and power sources and propulsion systems) innovative management formulas will have the greatest impact on the efficiency of deployments and sustainability. A clear example of this is management of strategic transport fleets in cooperation with others as a form of improving the cost-effectiveness of logistical support for operations.

Technological developments in this area should always take into account the overriding objectives of deployment and sustainability. In other words, this means ensuring rapid deployment of ground combat forces, and the availability and capacity of sea and air transport (including that for large loads) is crucial for this. The probable increase in the frequency and duration of operations will make careful planning necessary to achieve an appropriate balance between organic logistical support and that provided through contracts with industry.

One of the aspects which is being found to be necessary in the field of logistics –particularly in expeditionary-type operations where presence and mobility in the theatre of operations are very limited for security reasons- is sea-based logistics and the field which this is opening up from the technological point of view is certainly interesting.

THE EUROPEAN DEFENCE RESEARCH AND TECHNOLOGY STRATEGY

Improvements in the effectiveness of defence research and technology in Europe in support of the military capabilities to support missions under the CSDP and as a resource for strengthening the defence technological and industrial base and to promote weapons cooperation is one of the four strategies in which the European Union is involved, through the European Defence Agency.

The Reality of Defence Research and Development in the EU

Investment in research and technology is vital for maintaining defence and industrial capabilities in the future, and for permitting a certain degree of autonomy at the European level when launching operations under the CSDP. The margins for increasing such investment are very limited given the restrictive trends in defence budgets; however, the possibilities for improving such investment collaboratively and for improving synergies between civil and defence investment are highly promising.

According to the latest data prepared by the EDA, total defence spending in participant countries in 2009 amounted to 195 billion euros, having fallen over the four year period in which the Agency had been keeping figures (2006-2009) by 3.48% in nominal terms.

Of this reduction, investment in Research and Development (R&D) fell by 2.3%, and the Technology and Research (T&R) subsector of this fell by 8.07%.(2)

However, perhaps the most interesting data is that in a situation of squeezed budgets in which it is difficult for one country to achieve technological objectives on its own, collaborative spending on T&R compared to total T&R fell by almost 23% between 2008 and 2009. In other words, EU countries are still mostly investing in T&R in a fragmented way, thus missing out on opportunities for economies of scale.

Investing more effectively, and more in collaboration with others, should therefore be a priority objective for EU Member States if they do not want to miss the defence technology train, with the negative impact that this would have on military capabilities.

The European Defence Research and Technology Strategy (EDRT), launched by the Defence Ministers of EDA Member States in November 2008, is an ambitious project which aims to combat the fragmentation in this area at the European level to date. However, it could also be seen as a threat to national industrial and technological defence base. Nevertheless, the reality is that the strategy has been implemented not simply because it was approved by EDA Member States, but because it is supported by many trends.

Firstly, the need to base research and technology planning by Member States at both the national and European levels on military capability planning. Research and technology efforts must be closely related to military capabilities which are required in order to take on operations. It is absolutely crazy in today's world to continue investing in defence systems associated with the Cold War. In the previous section of this chapter we referred to some of the considerations taken into account in the Capability Development Plan which, as previously described, through the catalysing work of the Agency with Member States, established the reference framework for the military capabilities considered priorities to be obtained in the framework of EU operations. There must be total connectivity between the CDP and defence research and technology

(2) In accordance with the definition accepted by EDA participant countries, T+R investment covers the cost of basic research, applied research and technological development for defence purposes (ie. approximately Technical Readiness Level 1 to 6). This does not therefore include costs related to demonstrations and product and systems development for which an acquisition decision has been made and there is a planned date for the item to come into service. T+R is therefore a part of R&D.

planning in order to ensure that required effects are achieved. In other words, the technology demonstrators which eventually arise from research and technology developments should have the objective of being developed into defence equipment which is capable of covering specific areas of military capabilities. Obtaining such capacities has now been set in progress through the aforementioned CDP.

Secondly, the trend –which has definitely stalled over the last couple of years- to the restructuring of the European defence industry and transnational ownership at the level of major integrated industries as well as small and medium sized companies which are part of the wider supply chain for defence equipment. We need to remember that six EDA member countries (Germany, France, Spain, Italy, the UK and Sweden) decided in 1998 to launch a process to facilitate cross-frontier restructuring of the European defence industry, which in principle made the need to cooperate in investing in technology more evident.

Thirdly, the overwhelming need to create synergies between civil and military research and technology activities, including harmonised cooperation at governmental level within the European Union as in the case of the European Commission being responsible for the ESRP (European Security and Research Programme) and the EDA, or in some way related to the European Union, as in the case of the European Space Agency.

The European research and technology strategy takes into account all of the above aspects with the objective of changing the guidelines which have governed European research and technology to date. However, before analysing the content of this strategy, it is important to be realistic and to take the current European situation into account.

According to the latest analysis published by the European Defence Agency relating to 2009 data and the period 2006-2009 (the EDA began to analyse defence data for its member countries in 2006), the twenty-six EDA members invested a total of 8.4 billion euros in Research and Development (R&D) (8.6 billion euros in 2008). This was 4.3% of total defence spending in 2009, very similar in absolute terms to the 2008 level. Two of these twenty-six countries (France and the UK) alone accounted for 78% of the 8.4 billion euros, having assigned 9.45% and 7% of their total defence budgets, respectively, to R&D. 90% of defence R&D by the twenty-six EDA member countries is accounted for when Germany is also included.

With regard to Research and Technology (R&T) as an integral part of R&D (R&T represents 27% of R&D) EDA countries invested 1.17% of total defence spending in 2009. In this case, the three largest investors accounted for 81%, and this rises to 98% of investment in R&T when this group is expanded to eight countries (France, the UK, Germany, Holland, Spain, Sweden, Italy and Finland, listed from highest to lowest) ([3]) (Excluding Denmark, data for which is not included in EDA statistics).

Drilling further into the detail of European defence R&T, 14.8% of the total invested in R&T was related to projects and programmes in collaboration in 2009. Of this percentage, 88% was focused on collaboration at the European level, which means that R&T in collaboration in 2009 accounted for around 13.1% of the total employed in R&T. Compared to 2008 (16.6%) this represented a major decrease in R&T in collaboration; curiously, this occurred at a time of penury in defence budgets, whereas collaboration provides economies of scale and therefore viability for projects which otherwise would be impossible to launch by one country acting alone. Of the seventeen countries which reported involvement in collaborative R&T, seven contributed 94% of the total, and five of these (France, Spain, Italy, Sweden and Holland, from highest to lowest) accounted for 87% of collaboration at the European level.

In general terms, investment in defence was cut by 2.7% in 2009, and R&D, and R&T, in particular, by 3.4% and 8.1%; this latter figure is certainly worrying. When deflators are included to compare 2008 with 2009 in real terms, the fall, particularly in R&T, was 9.2%. Although R&T investment is obviously subject to annual fluctuations related to progress on major projects, in this case the fall was mainly due to cuts in defence budgets. It would be interesting to examine the corresponding figures for 2010 (which will be published by the EDA in the last quarter of 2011) as the real impact on defence budgets in most EU countries was felt in the 2010 figures, and it is highly probable that the downward trend will continue over the coming years.

However, 1.17% of R&T spending in 2009 compared to defence spending, and 13.1% of R&T spending in collaboration compared to total R&T at the European level was well below the levels of 2% and 20%, respectively, set as a target by Defence Ministers at the October 2005 meeting at Hampton Court under the UK presidency of the EU. Whilst it is true that the economic circumstances since 2005 could not have been foreseen, in detail at least, at the time, if we wish to maintain an adequate level of ambition with regard to European sovereignty in defence capabilities, we need to change this dangerous downward trend.

Although the objective of this chapter is the analysis of defence research and technology at the European level, I also consider it necessary to make a brief reference to European R&T figures compared to US figures. Without going

(3) It is important to remember that six of these eight countries -Germany, Spain, France, Italy, the UK and Sweden- constitute what is known as the LoI (Letter of Intent) group of countries. At the 1998 Farnborough air show, these countries signed a letter of intent in which they undertook to facilitate the trans-frontier restructuring of the European defence industry; in 2000 they signed a framework agreement.

into too much detail, the reality of the situation is that the ratio between these is one to six in the favour of the US, and there is a serious risk that this ratio could increase over coming years.

Research and Technology Initiatives by the European Defence Agency

The strategy launched by the European Union through the EDA for the implementation of a European defence research and technology plan had the clear intention of making a major change in the way in which R&T collaboration occurs in Europe. It aimed for convergence of R&T investment by Member States. This convergence will make it possible to improve the coherence of activities related to R&T for capability planners, researchers and technology developers, putting all of these to the service of military capabilities. In summary, it would place the benefits in the hands of the end users -soldiers in the theatre of operations. The European strategy aims to achieve this convergence through three main elements.

Firstly, “Goals” through the identification of the technologies in which Member States should invest in collaboration in order to improve future military capabilities. This identification involves not just fundamental information for defence-related industries, but is also a key element in strengthening the European Defence Technological and Industrial Base (EDTIB). When Defence Ministers adopted the European Defence Technological and Industrial Base Strategy in May 2007, they established that one of the priorities for Governments would be the “clarification of priorities”. The identification of the military capabilities required was a fundamental element in the implementation of the EDTIB, leading in turn to definition of the technologies required. The “Goals” are in other words the technologies in which investment should be made in the framework of the level of ambition agreed by the Member States with regard to improving military capabilities.

Secondly, “Resources”. In other words, the mechanisms, structures and processes which help to increase the effectiveness of investment to achieve the “Goals” through various forms of collaboration, including cooperation with international institutions. A number of “Resources” had to be defined in order to improve collaboration and achieve these “Goals” quickly and efficiently. Those defined in the EDA strategy are:

- Improvement in the integration process for specific defence technology in the framework of general technology. The resources for this are fluid and open dialogue with industry and researchers; in both cases this includes those from civil backgrounds to ensure appropriate coordination with other parties, and bodies and institutions in the European research and technology network, and also includes small and medium-companies that play a key role in the development of new technologies. The objective is to achieve adequate "Security of Supply" by increasing competitiveness and the efficiency of the defence industry by improving the technological base.

- Promotion of technological development as a way of balancing considerations related exclusively to capabilities. We have already stated that one of the most important aspects of defence research and technology is its connection with military capabilities. However, it is also important to carry out joint analysis of emerging technologies in the civil field which might result in an improvement to military applications in order to provide specific military capabilities. We need to pay careful attention to the development of disruptive or emerging technologies which will enable the EU to remain competitive or even take a lead against third-party competitors in order to retain this competitive advantage. The "Resources" included in the European Strategy include improvements in shared technological observation mechanisms, together with the promotion of contacts with the world of civil research and the creation of route maps.
- Improvements in the very limited existing collaboration among EU Member States on research and technology. The sharing of national plans, for those aspects not intrinsically related to national sovereignty and national policies relating to technological and industrial capabilities, is a route to improved use of the scarce existing resources, avoiding duplication of efforts and identifying common aspects which might be developed in collaboration in order to improve military capabilities at the European level.

Finally, technological priorities. In the context of implementation of the R&T Strategy, the EDA and participating Member States and the European Security and Defence Agenda (SDA) have prepared an initial list of specific priority technological areas which now form part of this strategy; the objective of this is to identify how this relates to the results of the Capability Development Plan. This involves 22 technological areas in which the common denominator is that the benefits of collaboration and the information exchange are, in principle, greater than would be possible with individual development, even when the difficulties of multilateral collaboration are taken into account. The fact that no single Member State –not even one of the leaders in research and technology- has the resources required to undertake a major development was one of the factors considered when establishing the list of functional priorities. One part of the connectivity exercise carried out by the EDA consisted of comparing these 22 technological areas with the 12 areas considered to be priorities.

Prior to the creation of the EDA, defence research and technology collaboration projects normally involved cooperation by 3 or 4 Members States with relatively small investment. The exchange of information between projects in order to exploit synergies was extremely limited due to the differing composition of the countries involved in individual projects.

The EDA has changed this outlook by acting as a catalyst for projects, promoting research and technology programmes with a larger number of participants, and enabling the identification of synergies between projects and avoiding duplication of efforts. The first model launched by the EDA consisted of the Joint Investment Programme (JIP), particularly that related to force protection, which brought together 20 member countries of the Agency plus Norway which takes part in various specific EDA projects. This identified 18 technological areas related to 5 military capabilities (collective survival, individual protection, analysis and merger of data, secure tactical communication systems in urban environments and planning and training for missions in asymmetric environments). All of these are related to the concept of force protection, which is critical for EU operations under the CSDP. This project launched in 2007 was followed by another related to innovation and emerging technologies in 2008. Finally the Unmanned Systems Programme for mine counter-measures at sea and other naval applications was launched in 2009.

The capabilities identified in the Capability Development Plan will be crucial for the selection of the JIPs to be developed in future. The four priorities currently being analysed for future projects denominated in Category A are related to the fight against Chemical, Biological, Radioactive and Nuclear weapons; countermeasures against portable air defence systems (Counter MANPADS: Man Portable Air Defence Systems); and countermeasures against Improvised Explosive Devices (IED).

Unlike cooperation in research and technology prior to creation of the EDA, JIPs have a common budget with voluntary contributions; the project is managed by a programme committee consisting of representatives of contributor countries. This model enables participating Member States to maximise their contributions and their industrial returns, and facilitates synergies between projects within a specific programme. Furthermore, one of the selection criteria for these projects which enables the participation of a larger number of countries is that they should promote multinational participation in collaboration with universities, laboratories, research and technology institutes and small and medium-sized companies. Participation in these projects by companies and institutions is dependent on participation and financial contributions by their respective countries. This rule facilitates transnational participation and, therefore, the formation of networks of contacts among those awarded project contracts.

Another form of research and technology collaboration through the EDA consists of projects denominated as being in category B. In these, a group of countries (generally more limited than those in Category A, numbering 3 or 4) decide to launch a particular project which could, under certain conditions, leave the door open to the participation of other of the Agency's Member States (including Norway with special status). The implementation of these projects can be led either by the EDA in the name and representation of the participating countries, or by each of the participant countries for the contracts covering work by companies and laboratories in their country; in other cases, they solely consist of exchanges of information with no financial contributions being involved. On average, category B projects are worth around 5-6 million euros with the average financial contribution being around 1.5 million euros for each participating Member State, with co-financing by industry –which is permitted for such projects- usually accounting for around 30% of each project.

Since the EDA started to collect information on investment in research and technology by Member States through the EDA, there has been a significant increase in the total volume of such investment; this involves both Category A and Category B projects, together with small R&T projects financed through the EDA operating budget. This is demonstrated by the figures for 2009 when these projects were worth €61.5 million, clearly demonstrating the upward trend when compared to the figures for 2008 (37.2 million) and 2007 (30.5 million).

However, the numbers are still very low as there is still significant reticence at the European level to the sharing of defence technology with other Union members, particularly with regard to capacities which are considered to be essential at the national level, and therefore classed in the sovereign category, as still permitted under the EU legal framework.

EUROPEAN DEFENCE RESEARCH: THE SEARCH FOR SYNERGIES.

The defence R&T strategy launched by the EU through the EDA provides the reference framework for the sharing of efforts to improve European technological and industrial -and by extension military- capabilities. However, against the current backdrop budget constraints, the European Union is trying to promote a new form of research and technology cooperation. This relates to cooperation at the European governmental level between two government bodies involved in research and technology in the European Union: the European Defence Agency in the field of defence research and technology and the European Commission in the field of civil technology and security research. The European Space Agency -another body which is not exclusively part of the EU, but which has obvious links to research and high technology in Europe- is also included in this framework.

The European Commission is responsible for implementing the Council's decision to implement what are known as its framework programmes (the seventh of which is currently in place). The Council's Joint Action which created the EDA established that one of its functions was to identify appropriate areas for collaboration with the European Commission in research activities in order to meet future defence and security requirements and to strengthen the defence technological and industrial base.

This mission recognises the existence of areas of dual-use technology applicable to both civil and military uses, and the need to establish an appropriate framework for the coordination of the various activities involved.

The content and form of cooperation between the European Commission and the EDA varies, whilst also aiming to take into account the work carried out by other institutions such as the European Space Agency and Eurocontrol. Working together is not an objective in itself "per se". This cooperation seeks to develop the capabilities required to meet defence and civil security requirements. The Commission and the EDA need to synchronise their projects where common capabilities converge; where requirements are similar; where duplication can be avoided; and where compatibility between defence and security technologies is clear.

The EDA and the Commission are already involved in seeking out synergies in specific projects, such as software defined radios and the introduction of aircraft into regulated airspace and critical space and maritime monitoring technologies.

At a meeting of EDA Defence Ministers on 18 May 2009, the Agency was entrusted with the task of systematically developing specific proposals –together with the Commission and the European Space Agency and based on their individual experiences- in the framework of the EDA's JIPs, the Commission's framework programmes and multinational ESA projects. The objective of this was to synchronise research activities and to share results. However, due to differences between the three bodies involved, they decided against joint finance, with management responsibilities also remaining separate.

Three candidates are currently being examined. Firstly, and as a priority, the struggle against the threat from chemical, biological, radioactive and nuclear weapons. The EDA would make its contribution through the CBRN joint investment programme (JIP). The other two candidates are unmanned aircraft, which the EDA in principle plans to contribute to through a JIP, and Situational Awareness. Most of the technological challenges associated with these projects are as applicable to civil security as they are to defence and the technological and industrial base; these challenges include a range of issues from sensors to management of information and networked command and control.

The cooperation is planned to include research, technology and demonstrators ranging from the concept of systems of systems to support technologies.

New formulas for improving military capabilities.

At a meeting in Ghent in September 2010 under the Belgium presidency, the Defence Ministers of the European Union chose the central topic for discussion as being “challenges in the development of military capabilities in the current economic climate and particularly in the face of deep cuts to defence budgets in European Union countries”; these are issues with clear implications for investment in research and technology. The October 2010 announcement in the UK of 8% cuts in real terms to the defence budget over the next four years is a clear sign of the situation we are in. This announcement is significant in the European context as the UK, together with France, accounts for around 50% of the defence spending of the 26 Members of the European Defence Agency and, as we stated earlier, these two countries account for 78% of investment in defence technology.

The funds assigned to defence nationally in Spain over the coming years will be lower than in recent years, and this will have an impact on defence as a whole, which we need to understand in its widest possible sense. This situation affects both the Armed Forces –as it involves a number of limitations on the development of its military capabilities- and the defence industry, which is highly dependent on government defence equipment policies, as governments are, in many cases, the only customers for such equipment whilst also regulating the industry. Sometimes governments are also the owners.

Furthermore, or perhaps as a consequence of the above, a significant number of European Union countries are involved in a strategic review of their own defence, their armed forces and their equipment policies; this is also having a significant impact on various dimensions of the concept of defence. Once again, I will use the UK as an example and a recent document submitted to the UK parliament relating to its strategic defence review, which has the evocative title: “Securing Britain in an age of uncertainties”

The difficult current situation brings with it a number of challenges at the national level, but also opens up a multitude of opportunities at the European level.

At the Ghent Meeting, the Director of the Agency, Baroness Ashton, underlined the need on one hand to develop strategies which are ever more integrated at the European level, and for greater cooperation as a way of maintaining an adequate level of military capabilities to cope with the ever more demanding actions of the European Union in international crises, which in turn requires increased cooperation in research and technology.

One key aspect which was discussed at Ghent was "*concentrating efforts on priorities agreed by European Union member states through two main lines of actions based on increase political will*":

- On the one hand, increased cooperation in order to make military spending more effective: such cooperation begins with the identification of military capabilities and continues to specific proposals for joint investment in research projects for defence-related technologies.
- And at the same time, better and more coordinated defence equipment procurement strategies through the creation of a real European market in defence equipment and strengthening of the industrial base.

In summary, ideas were floated for pragmatic harmonisation at the European level of operational requirements; the launch of multilateral projects; and improvement in the effectiveness of military spending as established in article 45 of the Lisbon Treaty, which defines the tasks assigned to the European Defence Agency. These would be achieved through analysis of the current situation and continuous dialogue among Member States of the European Union and other important parties such as the European Commission and the European Union's Joint Chiefs of Staff.

As stated previously, work is done in the framework of the European Defence Agency when a limited group of countries decides to launch a specific project. This variable geometry, which has been a reality of the EDA framework since it was established in 2004, is stipulated in article 42.6 of the new Treaty of the European Union. The concept of Permanent Structured Cooperation in Defence is established in protocol 10; and how this will be developed is still under discussion, as shown by the seminars organised on the issue by the first presidency of the European Union following the Treaty coming into effect (the Spanish presidency) and by the Belgian presidency. Reality has demonstrated that this route is already working in the bilateral agreement on defence issues between the UK and France. Such bilateral cooperation, or cooperation between a small number of countries, is an aspect to be monitored closely with an eye to maintaining the Spanish defence technological and industrial base at the cutting edge.

The initiatives launched in Ghent involve an analysis of the "intentions" of each of the member states at the European level with regard to their future military capabilities in order to identify areas for cooperation. To this end, Member States would have to provide information for this exercise in three categories:

- The military capabilities which they wish to maintain at the national level, whether for security reasons or for reasons of industrial capacity.
- A second category would consist of the military capabilities which would be serious candidates for cooperation.
- The final category would be military capabilities for which Member States would be prepared to accept interdependence.

Furthermore, this exercise would analyse the military capabilities that would be affected in each of the European countries as a result of budget cuts. The purpose of this analysis is to identify the military capabilities which, whilst still being necessary, might disappear from European countries as a result of budget restrictions. It would be necessary to act in concert to ensure that funds are available for research and technology to maintain an adequate level of such capabilities.

In summary, the European Union is moving to identify the military capabilities at the European level that we are willing to share, or on which we are prepared to collaborate. In this regard, all Member States need to take into account three indisputable realities. First, the budget restrictions which are forcing governments to seek savings in procurement processes. Second, the economies of scale associated with sharing systems, and related benefits in terms of interoperability and harmonisation resulting from the pooling of resources for acquisition of defence equipment. The question is simple: which defence capabilities are we prepared to share, and which technologies should we therefore develop jointly?

There is a further important aspect which I have already mentioned which needs to be considered in addition to these realities and questions: the national sovereignty and interdependence that we are playing with when we talk about sharing military capabilities; whilst there can be no doubt that military operations are going to become ever more expeditionary, multinational and multidisciplinary, we have to make an effort to strike an acceptable balance between sovereignty and interdependence.

CONCLUSIONS

The future of European military capabilities will necessarily involve strengthening the defence technological and industrial base; in turn, this involves maintaining reasonable and acceptable levels of technology investment, both in terms of defence and dual-use technologies, in both the civil and defence sectors.

The European Union has launched a series of initiatives which will lead on the one had to improved effectiveness of research and technology investment through cooperation and on the other to greater synergies between the various institutions involved in research and technology, whether civil or defence related.

Europe as a whole is plumping for sharing efforts and cooperation as a way of meeting the challenge of constantly changing threats –and what these represent in military terms- and the current critical state of defence budgets, which has a direct impact on research and technology investment.

Paradoxically, this outlook is not always well understood at the national level. This is easily demonstrated when we consider the protectionist measures governments often implement at times of economic crisis. It is obvious that there are important issues of national sovereignty and shared sovereignty when it comes to defence, in addition to issues of national security, security of supply and industrial and economic issues. However, it is also true that we have to be realistic and to try to find a way out of the current crisis, which fragmentation on defence-related issues related would not help at all. Today no country is capable of maintaining acceptable levels of military capabilities to meet all current and future threats, and far less are they able to make the high levels of investment in research and technology required to support such capabilities.

The Lisbon Treaty opens up the possibility of financing research and technology through the Union budget. However, this debate has only just begun. The development of defence technologies is associated with military capabilities and the harmonisation of requirements through very specific and precise specifications which are tightly linked to intellectual property rights which benefit Member States. This supposes, for the moment, that the transfer of defence research, through research programmes, to the Commission's Seventh Framework Programme is excluded, as rules on governability and property rights do not fit the defence case.

However, it is also true that an analysis of civilian-military needs based on operational aspects will help to identify new technological solutions with wide-ranging applications. In this context, efforts need to be made to identify relevant issues which when duly proportioned could be considered for inclusion in the European Commission's future Eighth Framework Programme. This could for example promote disruptive technologies which meet both civil and military needs in the context of dual-use technologies. If the Union's budget is used for defence research and technology, this would reduce R&T at the national level, which would be bound to leave Member States in a position which would be difficult for them to accept given their resulting lack of competences in this field.

Specialisation is another interesting issue to be addressed in the field of military capabilities, and therefore defence research and technology. Would European

Union countries accept interdependence through specialisation? In other words, countries would renounce certain military capabilities at the national level, including associated technological capabilities, on the understanding that such capabilities would be made available by other Member States. Is it reasonable to carry out this analysis of specialisation at the European level, or would it be more reasonable to begin at the bilateral or regional level? Which capabilities could be considered less sensitive for beginning the specialisation process? Perhaps some of these approaches might sound like science fiction, but they are innovative approaches which not only need to be considered, but which are already starting to appear on the agendas of ministerial meetings.

This chapter has aimed to examine aspects of defence research and technology at the European level. The first point to consider in the current situation is that all aspects of defence investment and technology are totally interconnected with military capabilities. This means that there is also full connectivity with the Capability Development Plan launched by the European Defence Agency at both the European and national levels. Secondly, the EU has already established a defence research and technology strategy which, in addition to defining objectives (basically, improving and increasing investment in collaboration) also includes resources and participation models and a set of priority technologies on which to focus current and future R&T efforts. Joint Investment Programmes (JIPs) and Category A programmes, Category B programmes based on variable geometry and small projects financed from EDA operating budgets are already a reality, although they are a long way from reaching the benchmark objectives set by European Defence Ministers in 2005 under the UK presidency of the Union: 2% of defence spending dedicated to research and technology, and 20% as a benchmark for multinational collaboration.

Participation in such programmes and projects by national defence ministries is crucial for facilitating the participation of national companies and institutions. Not participating means exclusion from industrial participation and loss of presence in technological developments which might subsequently result in specific projects to develop demonstrator models and subsequent full-scale production.

It is essential that from hereon we monitor the development of the European Cooperation Framework, which aims to increase the efficiency of research and technology efforts in government and European bodies. In particular, cooperation between the EDA and the Commission, and the possibility that investment in defence R&T might be undertaken within the framework of the Union budget is an issue which needs to be closely followed.

A tangential aspect which will also affect the way in which research and technology develops in Europe is the implementation of European

Commission procurement regulations and regulations on intra-Community transfers of defence goods and services, which comes into effect in July([4]). These Directives, together with monitoring of their application by the European Commission, will be determining factors in the configuration of the future European Defence Market, the objective of which is to achieve greater transparency, competitiveness and integration in the single internal European Union market. Monitoring the development of these issues in Brussels is an obligation for all governments at the official level and at the business level because of the effects this could have on future investment plans and strategies.

In short, Europe is facing up to the need to obtain and maintain the military capabilities required to launch operations under the CSDP. Improvements to the effectiveness of existing resources through the sharing of such resources in the field of research and technology is a clear priority; and a number of official initiatives, multinational cooperation models and cohesion and harmonisation programmes involving a range of institutions are underway to achieve this. This is taking place at a time of unprecedented budget tightness. The idea launched by Javier Solana within the framework of the first annual conference focused on research and technology -"Spend more, spend better and spend more together"- continues to be as relevant today if we wish to maintain the level of ambition defined in the CSDP.

[4] Directive 2009/81/EC of the European Parliament and the Council on the coordination of procedures for the award of certain works contracts, supply contracts and service contracts by contracting authorities or entities in the fields of defence and security, and modifying Directives 2004/17/EC, 2004/18/EC and Directive 2009/43/EC of the European Parliament and the Council simplifying the terms and conditions of transfers of defence-related products within the Community.

CHAPTER FOUR

THE BENEFITS OF INDUSTRIAL COOPERATION. THE PROGRAMMES OF SPAIN'S MINISTRY OF DEFENCE AND THEIR FUTURE.

Manuel García Ruiz

ABSTRACT

We are faced with a period of uncertainty and confusion, created by the confluence of simultaneous, profound and exponential global change: we are currently undergoing the greatest scientific and technological transformation of human history, witnessing the evolution of the current unipolar model dominated by a single superpower to a new multipolar model in which power is wider spread. New players have burst onto the international economic, scientific and technological stages, resulting in a process of globalisation that is ever more extensive and irreversible and an imminent transformation of our energy model.

The world we know is changing very quickly and this transformation will not be without upheavals, international instability and confusion [1] of all kinds. Maintaining a strategic international position this century will mean having both sufficient technological-industrial capacity that ensures a competitive advantage in the marketplace, as well as military muscle. Both aspects should be a logical consequence of scientific and technological development and an innovative forward-thinking business spirit in the country as a whole. In other words, the strategic positioning of the nation will depend this century on a combination of its economic and military influence, whilst these will depend on technological development and a capacity for innovation. The history of the 21st century will be written by technology and innovation.

Key words:

Technology, innovation, position strategic, competitive advantage, defence, 21st century

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[1] Some of these changes are taking place as these reflection are being written.

INTRODUCTION

The history of technology dates back to the early days of homo sapiens and the rudimentary tools and techniques they developed and have been developing ever since; this development will continue in the future.

According to the Dictionary of the Royal Academy of the Spanish Language, technology is the set of knowledge related to a mechanical skill or industrial art. It also defines technology as being the language of a science or art and as the set of industrial instruments and procedures for a particular sector or product.

From my point of view, the most appropriate definition regarding industry is the latter of these, as it covers the widest range of industrial activities and, therefore, technological and industrial sectors and products. As Donald Cardwell says in his "A History of Technology", records of human activity on earth begin with the earliest archaeological evidence of human technologies. The history of technology is therefore the most fundamental and overarching of these.

In summary, technology can be considered to be the material and organisational resources which enable the results of research, development and innovation activities to be applied. Such activities are generally undertaken to find solutions to specific problems or to optimise the application of complex industrial processes in terms of time and cost.

Therefore, technology has always been closely linked to science, and the two have always mutually benefitted each other.

Although the Scientific Revolution took place in the 17th century led by figures such as Descartes and Newton, historians regard the technological era in Spain as having begun at the end of the 18th century during the reign of Carlos III resulting from the spread of the ideas of the Enlightenment from Europe.

To date, this technological era has passed through many stages resulting from its acute sensitivity to global economic and social conditions. Technology can be considered to be an indicator of the state of society due to the influence of technological development on social change.

In the case of Spain, the most rapid period of technological growth began in the mid-1960s, reaching its peak at the end of the century and continuing until the start of the current global economic crisis. At present, Spain has a very high-level, multi-disciplinary, technological and industrial base, which is the result of the implementation and development of R&D&I policies by Spain's Government.

THE MINISTRY OF DEFENCE'S INDUSTRIAL COOPERATION POLICY

Building on this base, in this document we will examine the Industrial Cooperation Policy systematically developed over the last 26 years by Spain's Ministry of Defence for acquisition programmes for defence products and services for Spain's Armed Forces.

This policy initially derived from the National Defence Directive within the Defence Planning cycle which, based on EMAD's (the Chief's Defence Staff) Operation and Force Planning, established the broad outline of Secretary of State for Defence's Resource Planning, in particular with regard to R&D&I, and as specified in the Armaments and Materiel Master Plan (PDAM, after its Spanish acronym).

The Ministry of Defence's Procurement Policy aims to achieve significant returns on investment in terms of the quantity and quality of technological and industrial improvements and developments, thus contributing to the development of an industrial defence fabric which meets criteria of both cost and efficiency; in other words, such investment should be competitive in terms of price, timescale and quality, also providing opportunities for participation in international industrial collaboration programmes.

Spain's technological development policy must focus on achieving the following objectives:

- Improving business competitiveness
- Boosting knowledge
- Increasing the welfare of society

The first of these objectives is related to increasing the R&D&I capabilities of our industries, making investment in these fields more attractive.

The end result of the above is to establish a robust trend towards a stable and sustainable economy which makes an adequate contribution to the welfare of society, based on a solid industrial and technological base consisting of a large number of companies.

In line with the above, and in terms of the aforementioned returns on investment, and particularly the acquisition of goods and services from foreign suppliers, the Ministry of Defence's Procurement Policy focuses on materialising the benefits of economic, industrial and technological activities in our industrial fabric. These benefits are generated by commitments by foreign suppliers with the Ministry of Defence to develop such Industrial Cooperation with

Spain's business fabric, a prior condition for the agreement of corresponding procurement contracts.

These commitments are covered by a contractual document known as an Industrial Cooperation Agreement (ACI after its Spanish acronym), which is specific to each procurement and is signed by the foreign supplier and the Ministry of Defence.

The aforementioned Agreements are associated with a Compliance Plan negotiated with the foreign supplier which lists and details the activities through which the supplier will meet the commitments to generate returns during the life of the agreements.

This practice, which takes place in one way or the other in every country in the world as part of the contracting process, means that the purchasing country, in addition to making up for all or part of the investment required for the procurement, has an additional justification for the purchase of defence systems to taxpayers and public opinion as a result of the resulting domestic benefits of all types. Such benefits become greater when the technological and industrial base of the purchasing country is improved because of the empowering effect of such Industrial Cooperation.

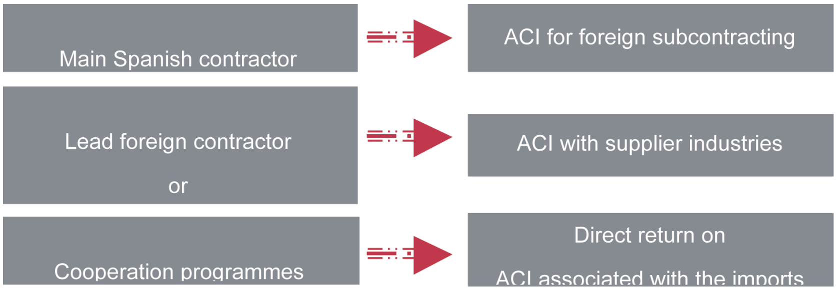
In Spain, Industrial Cooperation associated with procurement of defence products and services is the responsibility of the Ministry of Defence's Directorate General of Armaments and Materiel (DGAM), as established under Royal Decree 1287/2010 article 4.2.c). It is further covered by Instruction 375/2000 from the Defence Secretary.

This practice is outsourced to ISDEFE's Industrial Development Support Department which, under instructions from DGAM, negotiates, monitors and controls ACIs with foreign suppliers for procurement contracts entered into by the Ministry of Defence.

An ACI is negotiated with each foreign company involved in a procurement process.

This practice is also applied to subcontracts which a leading Spanish contractor should establish with all foreign suppliers in order to complete the procurement required under the contract with the Ministry of Defence.

This policy is also applied to foreign suppliers in procurements by Spain's Ministry of Defence carried out under "Government to Government" agreements, such as the USA's FMS (Foreign Military Sales) system.



This Industrial Cooperation policy has three main objectives:

1) To strengthen and consolidate strategic industrial and technological sectors.

2)To achieve an adequate degree of autonomy and self-sufficiency in the development of Integrated Logistical Support activities for defence systems over their lifecycles.

3) To establish a base from which our industry can access international defence markets.

STRENGTHENING AND CONSOLIDATING STRATEGIC INDUSTRIAL AND TECHNOLOGICAL SECTORS.

This is achieved by including commitments from foreign suppliers in the ACIs for procurements that they will generate or complement the capacity to carry out the activity within our industrial fabric.

This may be achieved through specific training and development programmes, technological assistance programmes, both "in situ" and from the suppliers facilities, and through the delivery of knowhow (procedures, standards, plans, diagrams, IT packages, etc), both generally and specifically related to what we want our industries to produce.

Once the production processes have been implemented – ie, when the transfer and development process is complete- they must be assessed, approved and certified by the original manufacturer. In summary, an appropriate Technology and Knowledge Transfer Plan must be developed for the Spanish industry involved in the procurement.

We can give many examples of Spanish companies who, in addition to being involved in supplying our Armed Forces, have become preferential suppliers for foreign suppliers after being approved and accepted by them. In this context we could mention the aeronautical structural components for the F-18 aircraft developed by CASA (now EADS) following training by McDonnell Douglas (now Boeing) and the production of antenna components under licence from Lockheed Martin by the Spanish company RYMSA.

Technology Transfer activities have not always been associated with production programmes and the participation of Spanish industries in supply contracts with foreign suppliers. There have been cases when, driven by the need to cover technological weaknesses, it has been necessary to negotiate Knowhow Transfer programmes in specific fields with foreign contractors which have not had an immediate application and/or resulted in a production or supply programme. However, these have often established the basis for future developments of highly competitive defence products.

What I am trying to say here is that ACIs arising from the Ministry of Defence's procurement policy represent a mechanism for technological modernisation and absorption, underlining the character of the Ministry as a technological and industrial driver.

This practice makes it possible to promote the presence of Spanish industry as a Leading Contractor in the Ministry of Defence's procurements as well as to achieve an adequate share of international industrial collaboration programmes as members in their own right (co-contractors).

The positive effects of this policy have been recognised by Spanish industry in various publications. For example, we could mention the publication by the company formerly known as CASA of "Los primeros 75 años (1923-1998 de CASA" (*The first 75 years 1923-1998*) written by José María Román Arroyo, where the policy pursued by this company is described as being to "put CASA at the forefront of cutting edge technology in the manufacture of combat aircraft structures".

The technological contributions received by Spanish industries through ACIs have enabled Spain to achieve qualitative and quantitative shares in programmes such as the Eurofighter, A400M, the Tiger combat helicopter, the Meteor missile, etc, as many Spanish companies have recognised.

Spanish industries are intensively involved in a number of international industrial collaboration programmes, often being responsible for design and development, and for the production and manufacture of important parts and/ or subsystems for the systems in such international programmes.

ACHIEVING SELF-SUFFICIENCY IN INTEGRATED LOGISTICAL SUPPORT FOR ACQUIRED DEFENCE SYSTEMS.

This capacity -which is largely a consequence of the developments described in the previous section, particularly with regard to promoting increased participation by Spanish companies in procurements under contracts with foreign industries- is also boosted by training and development programmes for Spain's industries and organisations in maintenance and integrated logistical support technologies over the lifecycle of the defence systems acquired being incorporated into ACI compliance plans. This has resulted in the creation of approved Maintenance and Service Centres for the original foreign manufacturers, which may also include capacity to modernise and update the systems acquired.

This is the result of establishing commitments with foreign suppliers when the ACIs and, in particular, their associated Compliance Plans, are negotiated and include the delivery and transfer of technological documentation and knowledge for defence systems related to:

- Systems engineering and the main functional and operational areas of hardware and software.
- Engineering of Integrated Logistical Support in terms of reliability, maintenance, accident repairs, etc.
- Engineering of the operating environment of the system in different environmental conditions.
- Information relating to specific usage for maintenance and support, with particular emphasis on testing requirements for electronic sub-systems.
- Failure modes and analysis.
- Damage tolerance.
- Etc.

Adequate knowledge of these disciplines makes it possible to undertake the maintenance and logistical support of the systems procured with a high degree of autonomy. It also makes it possible to integrate armaments into platforms without foreign assistance of any type. This capacity is hugely important, particularly in the case of weapons based on aerial-delivery systems.

Perhaps the most important synergy arising from such knowledge relates to the power to modernise and update our weapons systems without support and assistance from the original manufacturers.

One example of this is the EF-18 aircraft, the Mid-Life Update (MLU) of which was carried out totally autonomously by the Spanish industry and the

Air Force. Spain is the only user of this system –apart from the United States- to have been able to do this.

The capabilities resident in Spain are also projectable onto the Armed Forces of other allied countries which either do not have such facilities themselves, or which find it more economical to use our facilities as a result of distant deployment from their own countries.

Spain has on a number of occasions been the logistical support and maintenance base for armed forces deployed in the south of Europe and the Mediterranean.

Examples include servicing of over 1800 Phantom F-4 and other aircraft for the USAF, and the signature in the late 1980s of a BOA (Basic Order Agreement) for the maintenance and repair of US Navy aircraft deployed in the Mediterranean.

ACCESS TO INTERNATIONAL DEFENCE MARKETS.

The situations described in the two preceding points demonstrate that export activities have always been associated with the Defence Industry Cooperation Policy. Among other reasons, this is because Spanish industries have been involved in joint production for our own weapons systems and for those sold by the foreign supplier to other countries, in order to capture the largest possible production run through competitive conditions (cost-efficiency), and as a result of having developed capabilities which can be projected beyond our territory.

The technological training and development acquired by Spain's industrial fabric has made it possible for Spain to have a significant participation in International Industrial Collaboration Programmes, as stated earlier, resulting in increased international prestige which makes Spanish companies attractive and viable partners for future international development and production programmes.

As a final point to this section, we can say that, as a result of this Industrial Cooperation Policy, Spain's Ministry of Defence has established long-term commercial relationships and links between our companies and foreign suppliers, based on competitiveness, technological training, quality and production.

The strong performance and reliability of Spanish defence products has captured market share which would have been impossible in the past, and this has been achieved in competition with major and prestigious foreign industries.

VALUATION OF TECHNOLOGY TRANSFER

As previously stated, the Ministry of Defence's Industrial Cooperation Policy for the procurement of goods and services abroad is one of the main vehicles for the technological and industrial development of our country.

The effects of this become more efficient the better we understand the real capacities of our defence industry fabric; the technological trends being shaped by demand for defence goods and services nationally and internationally; and R&D&I&T plans and programmes, at both the domestic and European Union levels, and this is because it makes the negotiation of technology transfer with foreign suppliers much more selective focusing on acquiring new technologies and improving existing technologies. Furthermore, access to certain technological areas is only achieved through this mechanism, as it is the only one which foreign suppliers and their governments will agree to.

We receive technological training under Industrial Cooperation Agreements associated with defence procurement contracts, often at no cost for the Spanish side receiving the technology, and even when there is a cost, it is usually low or below market rates.

In summary, industrial cooperation mechanisms save time and money in obtaining certain technologies, and these savings are an important factor to be considered when evaluating such projects.

A further parameter which should be taken into account is the potential for improving production processes and establishing these from the outset, with the resulting potential for the recipients of such technology to access other markets in future.

This approach and openness to continuous technological improvement in such receiving companies may also help to keep them at the cutting edge of industrial supply as demands change.

In addition to the aforementioned parameters (savings, access to markets, new markets, etc), any such valuation should take into account the efforts by the party transferring the knowhow or industrial processes that we have already mentioned:

– Standard and specific training and development programmes.
– Technical assistance during the technology transfer and during production processes resulting from their application.
– The transfer of wide-ranging and diverse Technical Documentation for support and updates.
– Acceptance, accreditation and certification programmes.

– Free transfer of tools.
– Etc.

All these are always free or at a reduced price for the recipient.

Quantitative aspects

The value of Industrial Cooperation in terms of technology transfer activities to Spanish industries and public bodies between May 1984 and December 2010 amounted to a total of €3,833 million, based on 418 ACIs, of which 136 are still current.

These technologies have played a major part in winning orders placed with our industries with a value in excess of €6,800 million.

Qualitative aspects

The technological returns generated by the ACIs in the period mentioned have enabled our industries to access around 70 technological areas in the following fields:

– Aeronautics.
– Electronics.
– Naval.
– Defence systems.
– Explosives, munitions and missiles.
– Quality control and assessment.
– General Applications.
– Civilian areas and those not related to defence.

Appendix I contains a list of these main technological areas.

It is worth stating at this point that an examination of the aforementioned Appendix might make one think that many of these technologies are well known Whilst this might be true now, this was not the case in the past, or their application was not clear at the time. The objective of the list is to show the evolving and technology-driving character of our Ministry of Defence.

Likewise, as we have already stated, Industrial Cooperation has resulted in over 60 Authorised Maintenance and Service Centres being established for many of our weapons systems and/or their main subsystems. Many of these centres have modernisation, updating and combat and accident damage repair capabilities.

A list of these centres is given in Appendix II.

FUTURE AREAS FOR ACTION

Starting from the demonstrable fact that the Industrial Cooperation policy pursued by the Ministry of Defence over nearly 27 years now has been within the thresholds currently established in the Code of Conduct of the European Defence Agency, the areas for action to be pursued are:

- Encouraging participation by SMEs in order to consolidate their technological and industrial capabilities and to promote the absorption of new technological assets, in line with the policies of the European Defence Agency relating to the European Defence Market and the European Defence Technological and Industrial Base (EDTIB).
- Establishing priorities for updating technology and industry in line with future domestic and European defence needs.
- Promoting initiatives which are in line with the overall Spanish industrial strategy, so that Spain's supply of defence products and services is shaped by the demands of our Armed Forces.
- Ensuring that international industrial collaboration programmes guarantee adequate participation by our industry in design, development, production and integrated logistical support over the whole lifecycle of new systems developed and produced.

QUALITATIVE RESULTS

Spain's experience with Industrial Cooperation agreements has been very positive, achieving tangible results such as the following:

- Significant participation in international industrial collaboration programmes:

Eurofighter	Tiger helicopter
A400M	Taurus
Harrier II+	Meteor
NH90 helicopter	Iris-T

- The establishment of long-term industrial agreements between Spanish industries and foreign suppliers, including:

Lockheed Martin	Raytheon	Rheinmetall	MBDA
General Dynamics	Thales	Rafael	BAE Systems
General Electric	KMW	Northrop Grumann	Etc.

- Consolidation of Spanish Centres of Excellence as authorities in design and production in areas such as:

- Advanced materials.
- Tactical and operational simulations.
- Automatic testing and diagnosis systems.
- Optoelectronics.
- Electronic warfare systems.
- A/E identification systems.
- Missile guidance systems.
- High-precision and high speed mechanisation.
- Naval combat systems.
- Airframes.

Development of a high level of autonomy and self-sufficiency in the weapons system ILS throughout their operational lifecycle. Examples of this include:

- Mid-life updates (MLU) for the F18.
- Simulators and Automatic Testing benches for the most important systems.
- Systems engineering and HW and SW configuration.
- Etc.

Furthermore, important trans-national industries have been based in Spain, such as Eurocopter in the helicopter sector; General Dynamics for armoured vehicles; and Raytheon for missiles and electronics, etc. All of these have a high level of engineering capabilities which are applicable to future programmes and manufacturing capabilities for end products with the possibility of exports to other countries.

- Industrial Cooperation is considered to be a fundamental instrument in the Ministry of Defence's technological and industrial policy.
- This enables the consolidation and boosting of current technological and industrial capabilities, and promotes participation in technological R&D&I programmes at lower cost.
- It generates significant savings for the Armed Forces by promoting self-sufficiency over the system lifecycle, and by optimising the scope of procurement contracts.
- It contributes to the consolidation of a European industrial and technological base in line with the policies of the European Defence Agency and the European Union.
- It contributes additional financial resources and technological assets to our defence fabric.
- It ensures adequate participation by our industries in international development and production programmes.
- It guarantees the supply of systems and autonomy in integrated logistics support over the lifecycle of our weapons systems.

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– Máquinas y Hombres (*Machines and men*)
• Patxi Aldabaldetrecu
– I+D+i en el sector de la Defensa (*R&D&I in the defence sector*)
• Vicente Ortega, Manuel Gamella, Rafael Coomonte, Ainoa Quiñones.

APPENDIX I

MAIN TECHNOLOGICAL AREAS ACQUIRED THROUGH INDUSTRIAL COOPERATION AGREEMENTS

AERONAUTICS AND AEROSPACE

- Chemical milling of titanium parts
- Super-plastic moulding
- Metal spinning
- Ion vapour deposition coating
- Composite materials and "Filament Winding"
- Plasma pulverisation
- Numerically-controlled mechanisation of machines on five axes
- Advanced CAD/CAM systems
- Damage and fatigue tolerance
- Failure modes and analysis.
- Helicopter aerodynamics, engineering and systems integration
- Flutter
- Unmanned Aerial Systems (UASs)
- UAS operations and maintenance doctrine.
- Electron beam welding.
- Calculation and integration of space trajectories
- Ground support equipment.

ELECTRONICS

- Advanced IT languages and operating systems.
- Expert systems.
- Tactical and operational simulation.
- Automatic testing and diagnosis systems.
- Systems integration.
- Production of advanced electronic systems (micro-electronics, hybrid circuits, micro-processors, etc).

NAVAL

- Simulation of on-board aerial defence systems
- Naval propulsion (conventional and electric)
- Anaerobic propulsion systems (AIP)
- Internal combustion engines for propulsion and electricity generation
- Underwater acoustics
- Ocean floor simulation
- Naval communications

- Weapons integration
- IFF systems
- Vertical missile launchers
- Systems engineering
- Combat System
- Weapons systems
- Landing assistance systems
- Control and command console design
- Optronic systems
- Missile/torpedo launch systems
- Auxiliary hydraulic systems

DEFENCE SYSTEMS

- Missile launch systems.
- Fire control systems.
- Weapons stabilisation and activation.
- On-board tower systems on platforms.
- Naval combat command systems.
- Anti-aircraft battery systems.
- Control and command console design
- Three-dimensional radar.
- S band radio systems.
- Optronics
- Electronic Warfare
- C3 I tactical network systems.
- Tactical military communication systems.
- Datalink.
- IFF systems and electronic warfare.
- Automatic target detection algorithms.
- Simulations.
- Synthetic aperture radar
- Satellite antennae and transponders

EXPLOSIVES, MUNITIONS AND MISSILES.

- Laser/GPS guided bombs.
- Guidance systems, actions and cooling
- Missile electronics and mechanisation.
- Missile aerodynamics.
- Proximity fuses.
- Warheads.
- Insensitive munitions.
- Rocket motors.

– Visors.
– Launchers and firing points.
– Design and manufacture of metallic and composite metallic containers.
– Integration of missiles onto aerial platforms.

QUALITY CONTROL AND ASSURANCE

– Receipt or Raw Materials for Production (Rheometrics, Chromatography of solids and liquids, Spectrum analysis, etc.).
– Computer-controlled non-destructive testing (Automatic internal fault detection system using ultrasound and static and dynamic x-ray inspections).
– Simulation of extreme environmental conditions (vibration benches, weather and environmental chambers, etc.).
– Quality control software.
– Automated results resolution.

GENERAL

– Simulation
– Advanced production processes.
– Project management.
– Quality Management.
– Integrated logistical support analysis and management
– Configuration Control.
– Reliability and maintainability.
– Advanced IT languages.
– CAE, CAD, CAM, CALS
– Artificial intelligence and expert systems.
– Military programme management.

CIVIL OR NOT RELATED TO DEFENCE

– Management of major hospital facilities.
– Applied biotechnology.
– Advanced pharmacology.
– Special combustion processes.
– Special chemical treatment processes for metals.
– Production of liquid crystal displays.
– Handling and storage of radioactive waste.

ANNEX II

MAINTENANCE AND SERVICE CENTRES

COMPANY	PROGRAMME	ELECTRONICS, COMMUNICATION AND AVIONICS EQUIPMENT
ARMY/AIR FORCE/NAVY	EF-18 / HARRIER / TIGER/ NH-90	Automatic maintenance system SAMe: Failure detection and loading of software.
AIR FORCE/ARMY	SUPERPUMA/COUGAR	Automatic maintenance system MASH
AMPER PROGRAMAS	COUGAR	Superpuma and Cougar helicopters/Eurocopter
CLOTRA (AIR FORCE)	COMMUNICATIONS HF (HARRIS)	Maintenance of HF equipment (HARRIS)
INDRA	MLU EF-18	Digital data recorder (CARE) / SAAB
INDRA	MLU EF-18	Mission computer (TPAC) / GD-UK
INDRA	RAC 3D RADAR	Maintenance of 3D /TRS radar
INDRA	ARTHUR RADAR	Maintenance of Arthur radar
AMPER PROGRAMAS	RBA	Commutation system/ Thomson
AMPER PROGRAMAS	RBA	Radio-links/ Tadiran
AMPER PROGRAMAS	RBA	Optical line terminals / Marconi
AMPER PROGRAMAS	RBA	Encryption systems / Marconi
AMPER PROGRAMAS	RBA	User terminals / Tadiran
AMPER PROGRAMAS	MODERNISATION OF F-1	Mirage-F-1 aircraft radio-communications.
INDRA	NEPTUNEL	Neptunel system / Electronics
SAES	MODERNISATION OFP-3B	Sonoboy receiver /Flightline
INDRA	MODERNISATION OF P-3B	Maritime search radar / ELTA
AMPER PROGRAMAS	PR4G	Maintenance of PR4G tactical radar installed on various platforms / Thales
AMPER PROGRAMAS	INTERCOMMUNICATORS	Maintenance of inter-communicators installed on platforms / Cobham

AMPER PROGRAMAS	LIGHT RADIO-TELEPHONE	Maintenance of Light Telephone / Elbit
TECNOBIT	LASER DESIGNATOR + FLIR	Maintenance of parts for the PODs / Rafael
SENER	POD RECOGNITION	Maintenance of parts for the PODs / Rafael

COMPANY	PROGRAMME	ARMOURED VEHICLES AND ASSOCIATED SYSTEMS
GDELS-SBS / INDRA	PIZARRO	Turret action systems / Curtiss Wright
GDELS-SBS	PIZARRO	Transmission and final drive / RENK
GDELS-SBS	PIZARRO	Cannon / Rehinmetall W&M
GDELS-SBS/DIS	PIZARRO	Drive train / Diehl
GDELS-SBS	PIZARRO	Climate control system / Ametek
GDELS-SBS	PIZARRO	Anti-explosion and anti-fire system / Spectronix
GDELS-SBS	PIZARRO	Motor / MTU
PEUGEOT	BRIDGE LAUNCHER	Leguan bridge / Man
IVECO ESPAÑA	VANGUARD SUPPORT BRIDGE	Transport vehicle
SAPA	LEOPARD	Transmission / Renk
SAPA	LEOPARD	Differential / ZF
SAPA	LEOPARD	Drive train / Diehl
INDRA	LEOPARD	Combat system / JV INDRA-RHEINMETALL DE
GDELS-SBS	LEOPARD	Cannon / Rheinmetall W&M
NAVANTIA	LEOPARD	Motor / MTU
AMPER PROGRAMAS	LEOPARD	Command and Control / Rheinmetall
CAF	MODERNISATION OF AMPHIBIOUS LVT	AAV / United Defense
TERCIO DE ARMADA	HUMMER	Hummer / AM General
GDELS-SBS	BUSHMASTER FOR BMR	25 mm cannon / Boeing
GDELS-SBS	4 x 4 RG31	4x4 RG31 vehicle / BAE OMC
TECNOBIT	4 x 4 RG31	RCWS MINISAMSON / RAFAEL

SAPA	ANTI-AIRCRAFT CANNON BITUBO 35/90	CANNON / Theinmetall AD
GDELS-SBS	PIRANHA	PIRANHA / GDELS-MOWAG

COMPANY	PROGRAMME	AIRCRAFT
EADS CASA	EF-18	EF-18 / Boeing
EADS CASA	MODERNISATION OF HERCULES	C-130 / Lockheed Martin
EADS CASA	MODERNISATION OFP-3B	P-3 / Lockheed Martin
EADS CASA	HARRIER II PLUS	AV-8B Plus / Boeing

COMPANY	PROGRAMME	HELICOPTERS
ECE	LAMPS	SH-3D Sea King, SH-60 Sea Hawk and S-76 / Sikorsky
ECE	COUGAR	Superpuma and Cougar / Eurocopter
ECE	MODERNISATION OF CHINOOK	Chinook / Boeing
ECE	HH ATTACK TIGER	EC Tiger HAP / HAD

COMPANY	PROGRAMME	UAVs
INDRA	PASI	Searcher MK III / IAI
COMPANY	PROGRAMME	AIRCRAFT MOTORS
ITP	COUGAR	Makila / Turbomeca
ITP	MODERNISATION OF CHINOOK	T53 and T55 / Allied Signal Lycoming
ITP	EF-18 F-404, T-700, CT7-7A/9C, J-85 / General	Electric
ITP	NH-90	CT7-8F5 / General Electric
MAESTRANZA AÉREA SEVILLA	SUPERPUMA	Makila / Turbomeca
MAESTRANZA AÉREA SEVILLA	T56 MOTOR TEST BENCHES	T56 / Allison

COMPANY	PROGRAMME	NAVAL PLATFORMS
INDRA	F-100	Submarine telephone / EDO
FLUIDMECÁNICA	LHD / MCTAGGART (*)	Aircraft lifts
ARIES NAVAL	BAC / HEPBURN	Provisioning at sea

NAVANTIA	BAM	76/62 cannon / OTO MELARA
FLUIDMECÁNICA SUR	S-80	Hydraulic plant / MACTAGGART (*)
INMAPA	S-80	Torpedo launch system / Babcock (*)
MECANIZADOS S.A.	S-80	Acoustic countermeasures / Babcock (*)
INDRA	S-80	Connectors / Ametek (*)
NAVANTIA	S-80	Valves / Truflo (*)

(*) Activity currently underway

COMPANY	PROGRAMME	NAVAL ENGINES AND PROPULSION SYSTEMS
ITP	F-100 / F105 / F-85 TURBINES	LM2500 gas turbine / General Electric
NAVANTIA	BAM	1163, 2000, 396 and 956 motors
NAVANTIA	S-80	396 engines for submarines
NAVANTIA	LCM-1E launches	MAN D25 AND D28 engines / Man
SIEMENS SA	LHD	Propulsion for Pods / Siemens
AIR LIQUIDE ESPAÑA	S-80	SIP system oxygen tank/ Air Liquid
INTA	S-80	AIP system/ Hamilton
NAVANTIA	LPD-2	Naval propulsion train for tugs / Caterpillar
NAVANTIA	LPD-2	Reduction gearing / Renk
NAVANTIA	F-100	Reduction gearing / Schelde Gears
WARTWILA IBERICA	F-100	Propulsion propellers / Wartsila
NAVANTIA	MINE HUNTERS	Remote-controlled submarine vehicle
DETEGASA	F-100 / F-105 / LHD	AA cooling plant, NBQ / Stork
FLUIDMECÁNICA	F-100	Helicopter mooring system/ INDAL (*)
SIEMENS SA	LHD	Propulsion for Pods / Siemens

(*) Activity currently underway

COMPANY	PROGRAMME	MISSILES AND LAUNCHERS
NAVY	STANDARD	Standard missile / Raytheon
GD-SBS	SPIKE LR/ ER	Motor and warhead / Rafael
TECNOBIT	SPIKE LR/ ER	Launcher / Rafael
SENER	METEOR	FAS (Fin Actuator System) / MBDA
INDRA	METEOR	Data Link / MBDA
SENER	TAURUS	FAU (Fin Actuator Unit) / TAURUS
SENER	Iris-T	FAS (Fin Actuator System) / MBDA
ICSA	Iris-T	Logistics container / MBDA
INDRA	MAVERICK	Guidance system / Raytheon
INDRA	ASPIDE	Guidance system / SELEX
NAVY	HARPOON	Missile parts / Boeing
INDRA	HARPOON	Launch and Control / Boeing
INDRA	TOW	Lightened launcher / Raytheon - Indra

COMPANY	PROGRAMME	COMMAND AND CONTROL, SENSORS AND OPTRONIC SYSTEMS
NAVANTIA	F-100 / F-105	AEGIS combat system / Lockheed Martin
NAVANTIA	F-100 / F-105	SPY 1D radar cooling system / Lockheed Martin
Air force/CLOTRA	3D radar	3D radar /SELEX
Air force/INDRA	3D radar	3D radar / BAE SYSTEMS
TECNOBIT	ARPECA	MK 38 cannon optical system / BASE SYSTEMS
INDRA	MINE HUNTERS	SQQ-32 Sonar / Raytheon
INDRA	F-105 frigate	Helmet sonar / Lockheed Martin
INDRA	F-100 frigate	1160 helmet sonar / Raython
NAVANTIA	F-100	Fire control system (F-100/FFG) /Lockheed Martin
INDRA / NAVANTIA	F-100 / F-105	Spy Radar / Raytheon
NAVANTIA	MINE HUNTERS	Submarine control vehicle
INDRA	F-100	Combat system network servers (DIANA) / Lockheed Martin
NAVANTIA	S-80	Periscopes / Kollmorgen (*)
INDRA	S-80	Masts / Calzoni(*)
SAES	S-80	Towed Sonar winch /Atlas UK (*)
SAES	S-80	Covered-hose for towed radar (FRTAS) / Thales (*)

(*) Activity currently underway

CHAPTER FIVE

TECHNOLOGICAL NEEDS IN THE NEW CONFLICT SCENARIOS: SPANISH CAPABILITIES

Luis Mayo Muñiz

ABSTRACT

The demand for technological capacity on the new stages of armed conflict will be profoundly different to that experienced last century. The armed forces in western countries will require greater flexibility in order to adapt to unexpected threats, and will need to incorporate new technologies with more agility than the enemy, whose access to these same technologies will be increasingly easier in a globalised world. Maintaining an advantage represents a shared endeavour in the field of R+D, and mechanisms that allow competitive technological advantages developed in other sectors to be transferred to defence. To this end, the industrial and technological base of European defence cannot depend solely on "national champions" or the large-scale trans-national systems. The development of specialist companies should be facilitated which, accessing the European market, building economies of scale in niches that allow them to compete in the global marketplace with their American and Asian rivals. The role of nations as "early adopters" of new developments, and their willingness to consolidate demand are of fundamental importance.

KEY WORDS

Industrial and technological defence base; globalisation; new threats; national champions; niche specialists; early adopter, consolidation of demand.

INTRODUCTION

The fall of the Soviet block at the early 90's and the surge of the Islamic terrorism with the attack to the World Trade Center in september 2001 have dramatically modified the very nature of the threats that Western countries, and in particular Spain, must consider to sketch their defense policy at the dawn of the XXI century. In the case of Spain, there add on these circumstances, the full integration of our country in the NATO military structure, the more intensive involvement in international mission, as well as the professionalization of our Armed Forces, that has meant a significant reduction of the resources available. Besides, the acceleration of the technological development and, especially, the "democratization" of the access to technology with the Internet boom have substantially modified the strategic planning scenarios:

- The new scenarios are assymetric; there is not any organised and clearly identifiable threat.

- Attacks against civil population and objectives are nowadays part of the terrorist strategy.

- The defense of national interests cannot be limited any more to the homeland: it often requires the intervention beyond the country (or alliance) borders.

- The ability to gather, distribute and act on reliable information is far more critical than the destruction power of weapon systems.

The new scenarios call upon new tools that allowed the Armed Forces to anticipate, assess and respond properly to the emerging threats. Within this context, it turns out necessary to identify those technologies that will become critical in those tools.

Unfortunately, the effort required to sustain the technological advantage over the enemy in the upcoming scenarios is unaffordable for any country at its own, even for military Powers. Nations must decide on which technologies do they want to keep their full technical sovereignty and autonomy, which are they willing to share with other allies and in which they will cover their needs through acquisitions in the international market. The industry in a mid-size European nation like Spain undoubtedly holds technological capabilities most relevant to the Defense market, but maintaining those capabilities is only feasible with the national support in those areas identified as critical for the national Defense policy, or through the specialization in niches where technological excellence provides competitive advantage in the global marketplace.

THE NEW SECURITY SCENARIOS: THE WORLD AFTER SEPTEMBER 11th, 2001

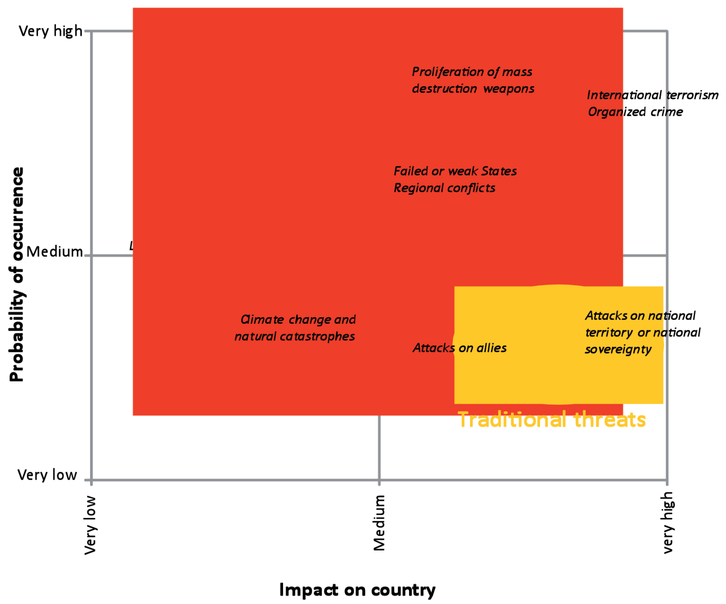
Looking into the past, the last two decades have come up marked by two crucial historical events: the Fall of the Berlin Wall in November 9th, 1989, and the terrorist attack against the New York World Trade Center in September 11th, 2001. It may happen that, as Friedman says in *The World is Flat* (1) "these two dates represent the two competing forms of imagination at work in the world today: the creative imagination of 11/9 and the destructive imagination of 9/11". From the standpoint of the perceived security in Western societies, both two set milestones that have radically changed our view of the threats that lay on our nations, our citizens and our way of life. The first one represented the break up of a bi-polar scenario, that of Cold War, and the emergence of new risks due to the dismembering of the extinct Soviet Union. This caused in turn the proliferation of nations with weak States, prone to failure, but endowed with mass destruction weapons. The second one has asserted the existence of movements, alien to the States, but able to strike globally against the interests of any nation, anywhere in the World, even at their homeland, as Spaniards had the sad occasion to attest with the bombings in Madrid of March 11th, 2004, or Britons with those of July 7th in London, a year later.

On the other hand, the very same technologic development that has fostered the economical and cultural globalization, has enabled the emergence of new vulnerabilities and threats in the last decades of the 20th century, as well as of new conflict scenarios. The importance of communications and of the free flow of goods and people for a globalized economy have rendered the communication and transportation networks, critical assets for the developed societies as ours, susceptible to be attacked with potential catastrophic effects for the country. Meanwhile, the technology enabling this development may also be used to attack those vital infrastructures.

In essence, the risks and scenarios to be considered for the Spanish security and defense – not much different from those concerning other European countries – are those already sketched in the 2003 *Defense Strategic Review* (2). As a matter of fact, the *National Defense Directive 01/2008* (3) scarcely modifies their definition. Figure 1 illustrates the analysis presented in that document:

The traditional threats, that may drive to conventional war scenarios in defense of the integrity and sovereignty over the national territory, or in support of a

(1) FRIEDMAN Thomas L., "11/9 Versus 9/11", en FRIEDMAN Thomas L., *The World is flat*, Londres, Penguin, 2006, pag. 545.
(2) SECRETARÍA GENERAL TÉCNICA. MINISTERIO DE DEFENSA. "Anejo B. Riesgos y Escenarios para la Seguridad y Defensa". AZNAR José María, TRILLO-FIGUEROA Federico et al. Revisión estratégica de la Defensa. Madrid. Ministerio de Defensa. 2003
(3) RODRÍGUEZ José Luis. Directiva de Defensa Nacional 01/2008. Madrid. Consejo de Defensa Nacional. 30/12/2008.



national ally, have not disappeared. But the truth is that this risk is perceived as remote, as a consequence of the low probability of occurrence attributed to those events. The *National Defense Directive* considers as much more eminent risks those derived from new threats such as, to start with, international terrorism, organized crime and proliferation of mass destruction weapons, or even more worrisome, a combination of them all. In a second stage, there appear the risks derived from the collapse of weak states or from regional conflicts that could unleash strong migratory pressures over Europe – and more specifically over the southern European countries, such as Spain – and cause the destruction of infrastructures that may be critical for our countries, even beyond our national territories. In a third stage, the *Directive* considers those risks related to the fight to access to natural resources and to the climate change that, in the longer term, may have similar effects to those of regional conflicts. At last, the *National Defense Directive* shows a clear concern about Cyberterrorism, though it does not specify clearly up to which point it considers feasible a large scale cyber attack that might cause a serious damage to nation critical infrastructures or networks.

This perception does not differ much from that generally existing in other Western countries. For instance, the new United Kingdom national security strategy identifies as the main threats for the next five years [(4)]:

[(4)] HM GOVERNMENT. *A Strong Britain in an Age Uncertainty – The National Security Strategy*. Londres. TSO. Octubre 2010.

- international terrorism, including the potential use of mass destruction weapons;
- cyber attacks, including both those organized by other countries and those coming from organized crime and terrorist groups;
- international military crises and
- accidents and natural catastrophes.

There is also the common view across all the developed countries that globalization has deeply modified the vulnerabilities to be dealt with when establishing the most likely risk scenarios. The strong interrelationship existing between virtually all the countries in the modern economy makes that any threats on infrastructure placed outside their homeland may have a tremendous impact on the wealth and welfare of our citizens. And if, on the one hand, this globalization has undeniable benefits, even in terms of security, for our society[(5)], on the other hand, it forces our countries to consider the convenience of intervention beyond their national borders in defense of their national interests.

Another element originating such a deep evolution of the risks to be considered in terms of vulnerability is the technology boom itself. Nowadays, the welfare, the security and, in the last instance, national sovereignty, depend upon transportation, distribution and communication networks that may be open to terrorist or gang attacks. Just imagine the effect that may have on the country economy the disruption of cellular communications for not more than a day. Certainly, even though this kind of risks is also associated to natural catastrophes that we can hardly avoid, - albeit we can minimize their effects – these infrastructures have become a potential target for the enemies.

Furthermore, it must be noticed that the potential enemies also benefit themselves from the ease of access to technology. By the beginning of the 20th century, "anarchists were limited in their ability to communicate and collaborate with one another, to find sympathizers, and to band together for an operation"[(6)]. Today, Bin-Laden could run an Al-Qaeda cell in Spain from a remote den in the Afghan mountains, using just material that can be easily purchased in a shopping mall worldwide; let alone the potential danger that may have any failed state infiltrated to the point of control by those terrorist or criminal gangs.

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(5) For instance, Friedman formulates in *The World is Flat* what he calls "the Dell Theory of conflict prevention", by which it is extremely unlikely that two countries that are both part of a major global supply chain will ever fight a war against each other. See FRIEDMAN, Thomas L., "The Dell Theory of Conflict Prevention – Old-Time Versus Just-in-Time"", en FRIEDMAN Thomas L., *The World is flat*, Londres, Penguin, 2006, pag. 515-539.
(6) Ibid., pag. 531.

THE NEW PARADIGM OF DEFENSE IN THE XXI CENTURY

As we have seen in the previous paragraph, the national security and defense challenges in the XXI century have to do with a profound change of the threats to be considered:

- From a conflict scenario with an enemy clearly identified, organized and established within a precise territory, world has evolved towards a fuzzy enemy, that can reside anywhere, even at our homeland, and who we cannot isolate in a formal way.
- From the need to shield vulnerable assets within the national territory, to the need to protect critical infrastructures and networks that may lay substantially abroad.
- From a world of clear and straight forward military alliances, to a globalized world where our interests are not just interwoven with those of our direct allies but also with those of other nations, that may fall involved in regional conflicts or fail as states.
- From access to the most advanced weaponry limited to Superpowers to the possibility that crime or terrorist organizations, whether or not sheltered by national states, gain access to weapons of mass destruction, coming from the breakup of the former soviet bloc.
- From an obvious technological superiority of developed nations over those organizations, to a "democratization" of the use of technology that renders feasible an asymmetric confrontation.

A radical transformation of the national defense paradigm becomes undoubtedly necessary at the sight of such deep changes. In the same way that the concepts inspiring the construction of the Maginot Line were superseded by the massive utilization of aerial and mobile means by the German Army during the Second World War, the new reality has overcome the concepts inspiring the defense strategy during the Cold War. Firstly, the dissuasion doctrines – be it "massive retaliation" or "flexible response" – lose all their meaning against an enemy that cannot be clearly isolated. Secondly, it turns out necessary the capability to deploy force and strike against a threat *anywhere around the Globe*. Thirdly, the cooperation and coordination with other nations in the response is indispensable; a singular confrontation scenario is extremely unlikely, and it is possible that any regional conflict easily spreads internationally. Fourthly, we must prepare for attacks making use of sophisticated weaponry, i.e. potentially NBC, against both our armed forces fighting in the field and civilians. Lastly, we must foresee that the enemy will have available information – according to Donald Rumsfeld, an Al-Qaeda's training manual captured in Afghanistan tells its readers that, "Using public sources openly and without resorting to illegal means, it is possible to gather at least 80 percent of all information required about the enemy"[7] – and moreover, he will be able to use the open source technology to fight the propaganda war.

This does not mean that some dissuasion capacity is no longer required. Obviously, in this new scenario we must still consider the possibility that a terrorist group, or a related organization, takes the reins in a failed state and becomes a menace in the most conventional and traditional terms. Let us consider for instance the possibility that the Muslim Brothers manage to gain the power in Egypt. Bearing in mind that organizations such as Hamas or Al-Qaeda itself surged from them, it is sensible to fear that their arrival to the power would impose a radical change in this country attitude towards its neighbor Israel, and that might eventually destabilize the whole region. The possible appearance of governments with an Islamic bias at the Southern Mediterranean shore can be considered a reason to build up sufficient dissuasive military capacity to preempt a direct attack on Spanish or any other ally's territory.

However, it is evident that the rules of the game have changed and that is necessary to review the conflict scenarios and their technological requirements.

NEW TECHNOLOGICAL DEMANDS IN THE CONFLICT SCENARIOS OF THE XXI CENTURY

It is useless to enter in this document in a detailed analysis of the scenarios that the European armed forces will have to face in the coming years. In the case of Spain, this analysis has already been done in depth and with better knowledge by the Ministry of Defense, and the conclusions as concern military capabilities are expressed in the Defense Strategic Review documentation [8]. It is not needed either, to derive from that demand of capabilities the areas that cover "the full spectrum of technologies interesting for Defense", since this has been very properly dealt with by the Sub-Direction General of Technology and Innovation of the Ministry itself [9]. The work performed by this body yields an exhaustive map of the Defense technology needs at the dawn of the 21st century. Similar analyses have been undertaken by other nations

[7] Ibid., pag. 535.

[8] SECRETARÍA GENERAL TÉCNICA. MINISTERIO DE DEFENSA. "Anejo D. Capacidades de las Fuerzas Armadas". AZNAR José María, TRILLO-FIGUEROA Federico et al. Revisión estratégica de la Defensa. Madrid. Ministerio de Defensa. 2003

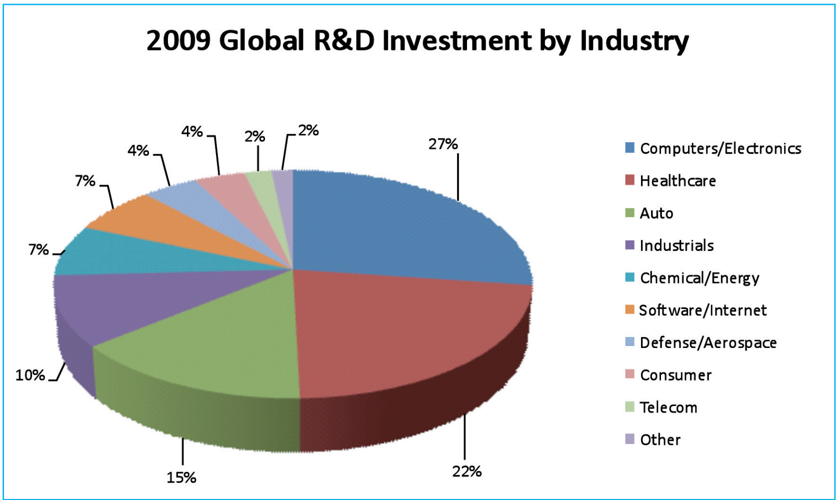
[9] DIRECCIÓN GENERAL DE ARMAMENTO Y MATERIAL. SUBDIRECCIÓN GENERAL DE TECNOLOGÍA Y CENTROS. "Estrategia de Tecnología e Innovación para la Defensa. ETID-2010". Madrid, Ministerio de Defensa, 2010. The Defense Technology and Innovation Strategy 2010 (DTIS-2010) identifies six functional areas of action: weapons; ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance); platforms, personal protection; infrastructure and platform protection; ICST (Information, Communications and Simulation Technologies). For each one of this areas, the DTIS defines lines of functional development and, in turn, for each one of this lines, identifies the key technologies necessary to satisfy the demand of capabilities.

and international Defense organizations. Nevertheless, we should add some considerations to those analyses.

- *Dual use technologies*

To start with, as admitted by the DTIS itself and has often been acknowledged by our defense authorities, it does not make proper sense to speak about defense technologies. Not even about "defense and security" technologies. The convergence of civilian and military technologies is, in most domains, a fact. The consequences may not be self evident, but must be taken into account when defining the strategy of the Ministries of Defense.

The advance in some sectors takes place at such speed that the relevant technologies become obsolete in a few years, causing that the R&D investment amounts flowing into them be much higher than those that can be expected in the defense sector, even under much more favorable conditions. Let us consider for example the case of the OSINT (Open Source Intelligence) technologies: Could we ignore when referring to them the development of Internet search engines ever more efficient, or of data mining or business intelligence applications increasingly sophisticated? Microsoft invest yearly over 9 billion dollars in R&D; Google, over 3. Among the ten top R&D investment companies worldwide, there is not anyone from the defense industry [10].



Fuente: Booz and Company, Inc.

[10] JARUZELSKI, BARRY y DEHOFF, KEVIN." The Global Innovation 1000. How the Top Innovators Keep Winning". Booz & Company, Inc. New York, 2010. Among the top 10 R&D investing companies in 2009, seven were pharmaceutical. Microsoft ranked second.

Since the investment in other industries is massively bigger than the one sustained in the defense sector, a priori, it is more likely that innovation breakthroughs drastically changing the state of the art appear in those domains. The defense sector must keep a constant survey on the achievements made in other industries, to add to its toolset those technologies that may contribute to resolve its problems. The defense companies that are diversified into other industries, either directly or through their affiliates, have an important advantage with respect to other competitors at detecting those opportunities and catching up quickly with the innovations developed elsewhere.

- *International cooperation*

The Spanish Defense Technology and Innovation Strategy lists 111 technology targets that must serve as "a fundamental guide to determine the collection of I&T (Innovation and Technology) actions to be undertaken in the next years"(11). In turn, every one of those technology targets may imply the development of several technologies, which makes the implementation of this strategy an extremely ambitious goal, probably unaffordable for the industrial and academic fabric of any country alone, with maybe a few exceptions. In a similar way, the European Defense Agency (EDA) lists some 274 technology areas in its Technology Taxonomy (12). No nation in our environment plans the development of a new weapon system on its own. The need for international cooperation, within the framework of the appropriate structures (e.g. EDA, RTO), is well beyond any question. A different matter is, though, how to maximize the benefit obtained from this cooperation from different viewpoints: the response to the demands of our armed forces, the creation of technological capabilities that are exclusive or differential for the country or, simply, the national sovereignty. The balance among the different criteria determines, without question, the cooperation model.

- *The purposeful character of the Defense I&T developments*

Even if the basic underlying technologies in any defense product are common to other industries, and if more often than not the technology innovations in the sector come from outsiders, the concrete applications, and consequently the systems in which they are integrated, are defined by the specific requirements of the sector. Let us think for instance of infrared sensors. This is one of the technologies demanded by the Spanish Ministry of Defense, as well as by EDA Cap Techs. This type of sensors can be used in complex ammunition guidance systems, ISTAR systems, terrestrial platforms for indirect visión systems, and many other applications in the military field. But they also have multiple applications in the civilian world,

(11) DIRECCIÓN GENERAL DE ARMAMENTO Y MATERIAL. SUBDIRECCIÓN GENERAL DE TECNOLOGÍA Y CENTROS. "Estrategia de Tecnología e Innovación para la Defensa. ETID-2010". Madrid, Ministerio de Defensa, 2010. Anexo 1, pag. I-1.

(12) EUROPEAN DEFENSE AGENCY. Technology Taxonomy. Available in http://www.eda.europa.eu/webutils/downloadfile.aspx?FileID=249. Date of consultation May 2nd, 2011.

for example, they can be applied to night and all-weather driving assistance systems. What is different in these two scenarios is probably the way in which these components are combined and integrated with others to provide the required functionality. Thus, the auto industry can be more efficient than the defense sector when developing an IR sensor, however, the second will likely better off the first if the objective is to develop a panoramic view system. The difference between the two cases resides in the operational knowledge of the client's demands when integrating the same sensors to satisfy them. In other words, the technological knowledge alone is not enough; it is this, combined with the operational knowledge of the precise application that adds value to the end user.

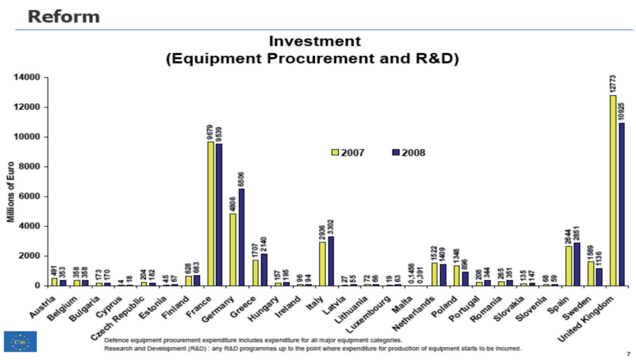
It is somewhat usual to underestimate the importance of "vertical" knowledge against the horizontal technologies. However, in many cases is the vertical knowledge which causes major breakthroughs. It is not easy to imagine a James Watt without a Matthew Boulton. If the wit and thermodynamic knowledge of Watt made it possible the steam engine, it was Boulton's mastering of the textile industry technologies – in the end, his family business – what allowed to transfer the benefits of the basic science to the solution of industrial problems. Whatever could be the technology demands of the new scenarios, the old sectorial knowledge will always be valuable to optimally apply the new technologies to the solution of the new probl

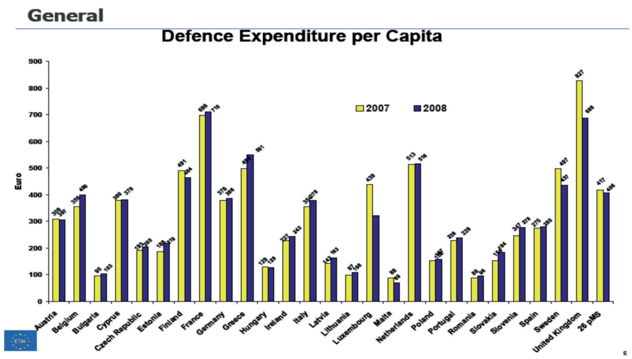
We may hesitate whether the traditional vertical knowledge in the defense sector is adequate to face the new scenarios. It is a fair question. But it would also be fair to doubt if there is any other industry that might have at its disposal an operational know how better fit to the resolution of the new security problems. There is no simple answer. For instance, distribution companies possibly have an operational knowledge about areas such as logistics that does not envy that of the most advanced defense organizations. However, the security companies can learn a lot from the defense industry about perimeter protection. Anyhow, there is no question about the need to preserve and develop the sector specific know how to better confront the present and future challenges of the defense.

SPANISH INDUSTRY CAPABILITIES TO RESPOND TO THE DEFENSE NEEDS OF THE XXI CENTURY

Spain is a mid-size country in the international arena. The national investment in defense technologies and systems ranks fifth among the EDA member states (see graph).

However, in terms of investment per capita, Spain falls to the fourteenth place, approximately at the level of Slovenia. Nevertheless, the effort made by this country to facilitate the participation of its industry in the major European endeavours





Fuente: European Defence Agency (EDA).

for the development of weapon systems, as well as in the modernization of the Spanish armed forces, over the last few decades has allowed its national industry to reach a high competence level in several domains.

Add to this the capabilities existing at different research bodies depending from the Ministry of Defense. The Instituto Tecnológico "La Marañosa" develops technologies in the areas of weapons, electronics, optronics, platforms, acoustics, metrology, human factors, ICST, NBC protection and materials. The Canal de Experiencias Hidrodinámicas de El Pardo (CEHIPAR) specializes in naval techniques. At last, the Instituto Nacional de Técnica Aeroespacial (INTA) focuses in aerospace technologies, covering such diverse areas as aerostructures or exo-biology. Besides this organisms, there exist other public sector entities that contribute to the whole set of defense technological capabilities in Spain, in areas that range from nanotechnology to propulsion. We must admit, though, that leaving aside a few successful exceptions, there is a deep disconnection between the defense industry and the civilian research centres – this obviously does not happen with those belonging to the MoD. This alienation is due to different factors: the reluctance of a large portion of the Spanish society to invest in defense research, especially in weapon systems, the difficulties to arrange effectively the collaboration between university and industry, or the companies' mistrust of research centres that have become competitors rather than supporting technological development organizations. Anyhow, structuring the research system, and in particular, articulating the relations between public research centres and industry, is still an open subject in Spain.

Even if there exists a research and industrial fabric, we must bear in mind that the size of the national demand is small, insufficient to justify almost in all cases the development of new products. As is case for many other European countries, the Spanish industry does not have a domestic market that may yield a fair return on investment for new defense technologies. Therefore, it has managed to stay at the state of the art in those areas where:

- It has been consolidated within international consortia (Eg. Airbus o EADS), but has kept some *centres of excellence* in our country. This has generally happened in those cases where there was some relevant technological capability in the country before the across-border consolidation. For instance, EADS has kept in Spain some centres of excellence in composites, whose origin can be traced back to the capabilities that Construcciones Aeronáuticas S.A. had developed in this field before its integration with the consortium.
- The existence of centres of excellence bound to international consortia has fostered the existence of human resources with experience and know-how in those areas of excellence that, in turn, has eased the appearance of other companies in those niches, and fed the development of new technologies there, thanks to a healthy competition. For example, it is remarkable that almost 10 percent of the member companies in TEDAE, the Spanish association of aerospace and defense industries, produce – among other things – composite aerostructures.
- The demand generated by a prime contractor – eg. an international consortium established in the country – has pulled from a subsidiary industry, that supplies auxiliary or complementary components or technologies. For instance, the existence of composite production centres of excellence calls for the development of companies like MTorres that supply advanced technology machine tools to those, thus contributing to close a virtuous circle that allows to mutually reinforce the competitive advantage of the two types of companies.

- The early incorporation of the national industry to international or multilateral programs for new weapon systems has allowed it to reach the state of the art in certain disciplines. For example, the Spanish participation in the EF-2000 program made it possible for companies like Indra or Tecnobit to develop technologies in areas such as radar or IR target search and tracking (i.e. FLIR/IRST), that have later originated successful business lines for these companies.
- The wise use of offset policies in the procurement of weapon systems, that has brought a technology transfer to the national industry crucial to developing or consolidating its capability in some areas. Offset programs such as the one associated to the FACA program (i.e. the procurement of F-18 aircraft by the Spanish Air Force) have permitted the Spanish industry to develop significant capabilities in areas like flight simulation, where Indra is nowadays a world leader, or automatic test benches. In other cases, these offset plans have not only allowed the acquisition of technology, but also the establishment of strategic alliances of broader scope, as is the case between Navantia and Lockheed Martin for naval systems.
- The country has maintain over the time a relevant participation in international R&D organisms and programs. This has been for instance the case of the space industry, where the sustained contribution to the programs of the European Space Agency over several decades has supported the development in Spain of several leading companies in their respective areas of activity: Sener, in space mechanisms, EADS Astrium – CRISA in power and sequential electronics, GMV in satellite navigation or ground control systems, or Indra Espacio in ground stations.
- The Ministry of Defense has acted as an early adopter, promoting a sophisticated demand that has facilitated to the industry to anticipate to the market demand in other countries. For example, in the case of Navantia, the combination of this factor with a wise choice of international industrial alliances has allowed this company to remain at the leading edge of the naval industry.
- It has been possible to close the gap between basic research and application, thanks to the spinning of new companies off public research organizations, as in the case of photonic technology, where a company like DAS Photonics has capitalized on the investment made by the university in this field.

Ellaborating herein an exhaustive list of the technological capabilities of the Spanish industrial and scientific fabric that can be used to satisfy the present and future demands of the Armed Forces is beyond the scope of this document. We could risk forgetting some of them, either because a lack of knowledge of the potential application of the available technologies, or because of ignoring in the analysis some companies or research organizations not yet present in the defense market, but whose knowledge could be used to satisfy some of the new, or even old, operational needs. Nonetheless, we can draw some general conclusions on those capabilities:

a) The Spanish industrial and academic fabric cannot, on its own and because of the accessible market size, cover the full range of technological capabilities demanded by the Defense scenarios. It is mandatory to maintain the participation of the Spanish industry in international programmes, even assuming the required economic efforts, where the industry may consolidate its leading position in some areas, and rely on the complementary know-how of other international partners to complete the array of techniques needed to satisfy the future demand. The Spanish industry is ready for this international cooperation, and can easily find its place in the multinational consortia that may be created to face the new challenges (the problem of market size is really common to all the European countries and so is the need for cooperation).
b) The Spanish industry has the vertical knowledge required to introduce the technical innovations, developed within or outside the sector, in the design, production and life-cycle support to the future defense systems.
c) Besides, the industry is very competitive in some niches where it can compete globally. To sustain its competitiveness, however, the industry needs that the Ministry of Defense sponsors a sophisticated demand that allowed it to remain at the leading edge of technology.
d) It is necessary an effort to improve the coordination of the research system, in such a way that the industry may efficiently bring to the market the technological achievements of the sector. And this endeavour must not be limited to the industrialization of the developments made by the public research centres, but also of those made by SMEs, or more generally, by the lower tier suppliers of the large system integrators, that often see their innovations dying because of their inability to make them available to the end user.
e) Generally speaking, the Spanish industry outside the defense sector has capabilities that may be applicable to the new operational needs of the Armed Forces. Leaving aside some exceptions, though, and possibly due to the average size of the Spanish companies, the technology transfer from those other sectors to defense is scarce and could be increased. The existence of multisectorial companies in the Spanish defense industry will ease such flows (and will also improve the resilience of the industry, because of the risk diversification and of the possibility to combine countercyclical activities).

These considerations are generally valid for the whole of the European industry. As EDA itself acknowledges [13], Europe, investing in defense R&D a sixth of what USA does, devoting some 35% of a budget that is more than twice as much that of the the European countries combined, can hardly keep an industrial base capable of satisfying the complete demand of technologies required to face the

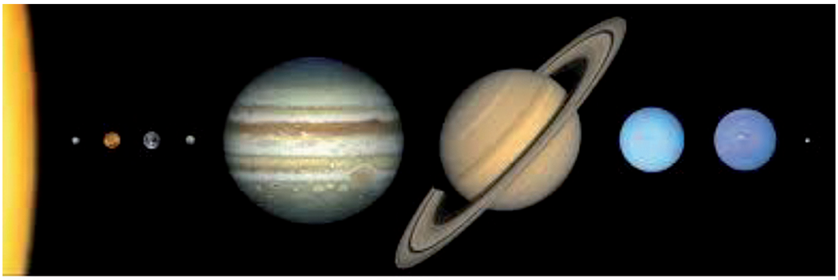
[13] An initial long-term vision for european defence capability and capacity needs, European Defense Agency (EDA), LTV – 3 October 2006 – SB MoDs Levi.

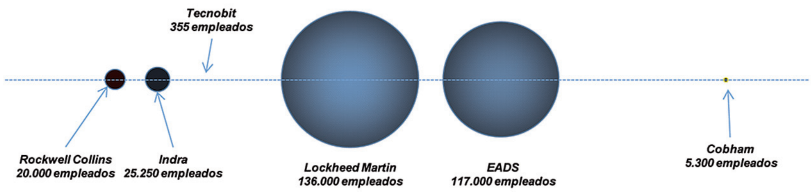
quickly evolving scenarios of the 21st century. Consequently, EDA fears that the European industry falls relegated as niche producers, ever increasingly abided by the American primes, and that the companies funding flows to that market where some of them, as BAe Systems, EADS or Finmeccanica have already made important investments. However, even though it is nearly impossible for the European industry to match the best in every relevant technology, its Defense Technology and Industrial Base (DTIB) is, as a whole, capable enough to be competitive with the American industry and with the increasingly important Far East industry. It also holds the vertical knowledge required to exploit the existing capabilities in other industrial sectors where Europe boasts know-how and resources sufficient to develop innovations in disciplines that may be relevant to satisfy the future defense demands.

INDUSTRIAL RESEARCH, DEVELOPMENT AND INNOVATION STRATEGIES TO FACE THE NEW TECHNOLOGICAL DEMAND

As we have stated before, the Spanish – and more generally, the European – defense industry suffers the limitations due to its size. Leaving aside the national subsidiaries of the large European consortia or of the mutinational companies, even the larger companies are too small when compared to their foreign competitors, as shown in the following figure:

Even ignoring the great sector giants, that are often strongly vertically integrated, making them frequently real competitors even for the smallest companies in the sector, the size of the Spanish companies is much smaller than that of their foreign competitors. It is evident that in these conditions, the industrial strategy must be





carefully assessed to ensure the sustainability of the national competitiveness in a market that, also necessarily, tends at least to be internationalized (if not globalized). The reasoning is also valid for most of the European companies when we carry out the comparison versus their American competitors.

The first question that we can consider is the convenience of a deeper industrial concentration in the sector at national level. The creation of large corporations as Lockheed Martin or EADS has not been the result of organic growth since inception, but the fruit of concentration movements in the sector in their respective countries, in processes that almost every time have taken a long while. Therefore, we may consider this a viable strategy to compete in this inudstry. The truth, however, is that the defense industrial sector in Spain is quite concentrated:

- More than 50% of the defense electronics business is held by a single company. The biggest four in this segment, represent over 75% of a market, that involves some 96 companies.
- Over 75% of the aerospace market, where there are 31 active companies, concentrates in just two of them.
- Something similar happens in the ground vehicles segment, where 2 companies held over 75% of a market that involves 32 companies.

At European scale, the situation is different. The sector has not yet started a transnational consolidation at the level below system contractors, and even at this level, the one existing is pretty much limited. As EDA admits, we must overcome "the notorious fragmentation of the European defense industrial scene, to eliminate wasteful duplications and achieve economically viable scale"[14]. Nevertheless, this consolidation will also require actions on the demand side that are still far from implementation.

The idea of promoting "national champions" that bring together the industry, and of concentrating on them the resources, is attractive for the public sector because of several reasons. In the first place, the investment required for the development of new products and technologies for this market are increasing, and hardly affordable for smaller size companies, except if they have a strong support from the end user. In a scenario of budgetary constraints that will likely last for some more years, the possibility of counting upon the support of private partners large enough to obtain the required funding without recurring to the public sector is very much appealing. In the second place, we must take into account that the defense sector is strongly regulated and controlled. From the end customer's stand point, it is obviously easier to control a "national champion" that bring together the necessary partners and suppliers, local or foreigner, than to deal with a foreign integrator that groups under its leadership several national companies, sometimes with conflicting interests. In the third place, we have

[14] Ibid. pag. 24.

to ponder reasons of national autonomy and sovereignty. The Armed Forces require to have at their disposal local and real integration and life cycle support capabilities, to ensure capacity of response in those cases where the national sovereignty is compromised. And it is sensible to think that those capabilities can be better guaranteed by a national system integrator – though as we will see later this idea can be refuted in the new technological scenarios -. Lastly, it is a proven solution, that has delivered in the past and that performs in other countries, and consequently means lower risks, at least a priori.

But the potential advantages of the "national champion" model can be disputed from different points of view. It is true that the need for increasing investment due to the higher sophistication of the demand favors the idea of concentrating the public resources in a lower number of companies. However, it is not less true that the defense system integration technology is a vertical knowledge hardly applicable to other sectors. While more modest investments in concrete technological areas can be leveraged with funds coming from civil sectors and that search for return of their investment in other markets, it is questionable that the investment necessary to develop a defense system integrator, at least in what concerns technology, may attract funding from other sectors. On the other hand, it is also difficult that companies that invest massively in technological research in other sectors, get interested in the concrete demand of the defense sector if the national strategy comes through the creation of a national champion, at the expense of sacrificing the investment in niches that may be closer to those of their specialization.

Besides, in an environment technologically more sophisticated, and even though it may seem paradoxical, it is disputable that the national sovereignty needs were better protected by a "champion" than by a network of highly specialized companies. A scenario in which the system integration capability were concentrated in the hands of foreign concerns would not be riskier than another in which the national integrator depended upon foreign suppliers to ensure the availability of spares for the critical elements of the weapon systems, and these are more often produced by specialists rather than by system integrators. Moreover, a good deal of the scenarios considered in the *National Defense Directive 01/2008* call for answers that, technologically, do not require large and complex weapon systems that in turn require for their development and maintenance correspondingly large industrial conglomerates. They rather demand specialists able to adapt quickly and respond fast to the changing threats.

The investment required to create and sustain a defense system integrator is huge, as can be clearly seen in some of our fellow countries. Even those having far larger defense budgets, can barely afford to support one or two integrators. In the Spanish case, the national market is not possibly enough to maintain even one, and so the only possibility to implement the "national champion" strategy is that it may compete in the global market, in manifest inferiority conditions with respect to competitors that have a privileged access to much larger domestic markets.

In these conditions, it makes sense to consider as an alternative strategy that of sponsoring niche companies that may specialize in one or more of the relevant technologies and compete globally in those areas. The I&T investment required to stay at the leading edge of niche technology can be affordable within the budget available in a mid size country, and can be much more cost-efficient to establish competitive advantages therein.

This strategy is also compatible with the consolidation of the market at European level, as concerns both its offer and, especially, its demand side. If the European Defense Technology and Industrial Base may only survive in the future competitive scene if considered as a whole, and not as just the addition of the different national capabilities (15), it must be recognized that the European market will hardly feed 26 system contractors – not even the American, six times bigger, allows so – but it will able to support a network of national niche players that will benefit from the economies of scale of a larger addressable market.

It is tempting to think that these niche strategies necessarily correspond to a fabric of small and medium enterprises (SME), but this not necessarily right. We must bear in mind that the SME definition in the European Union(16) is very restrictive, and it does not distinguish between different sectors when establishing the thresholds that set apart large companies and SME. As shown in the next picture, any company with over 250 employees, over 50 million euro turnover, or over 43 million euro balance sheet, must be considered a "large" company. In the USA, the rule is much more flexible and treats differently to the different sectors. For instance, in the electronic equipment industry, only the companies having less than 500 employees can be considered SME, regardless its turnover or assets, and the limit increases to 1,000 people for companies in the computer manufacturing industry.

A good number of the European (and of course Spanish) companies in the defense sector are not SME and, however, are far below the critical size necessary to compete as integrators in this sector. They can compete, though, in some concrete niches where they have adequate technology and capacity. On the other hand, it must be considered the possibility that some large multi-industry conglomerate, specialized in some across-sector technologies, act as niche players in the defense market, capitalizing on their ability to obtain

(15) Ibid. pág. 24.
(16) European Commission Recommendation of 6 May 2003 concerning the definition of micro, small and medium size enterprises (2003/361/EC), published in the Official Bulletin of the European Union on May 20th, 2003.

return of their I&T investment from their different sectors of activity. Thus, the difference between niche players and large integrators is not necessarily size, but specialization. We can conclude that the niche strategy tend to favour "*non-prime"* against the sector integrators ("*prime contractors"*).

The Defense market is far from being "perfect". It is a heavily intervened market, where considerations on national sovereignty and security weight on. The competition is biased towards local integrators that, in general, control access to the end customer. Furthermore, exceptions aside, the primes are strongly integrated vertically, which makes it difficult for the "*non-prime"* innovations to reach the market. How, then, may these companies compete in the market? The *"non-prime"* need to innovate to be present in the defense market. They use to be the *challengers*: they can only break the entry barriers and remain in the sector if they offer relevant innovations with respect to the large integrators. On top of that, the trend to vertical integration in large system contractors forces them to a continuous innovation strategy. They also need to capitalize on their investment by applying their solutions across different sectors, which on the other hand, forces them to keep a permanent surveillance on the technological breakthroughs in sectors other than Defense.

For a *"non-prime",* innovation is only feasible in selected niches: its investment capacity is limited and therefore, they must concentrate its resources. Even if we consider large companies, their advantage to compete in those niches is based upon putting up in them bigger funds than what may devote the large integrators, that have to distribute their investment in a broader range of products, relatively unconnected, or to apply a substantial share to vertical integration technologies. In turn, customer access is only feasible through multidomestic integrators, but this is not necessarily a drawback: the effort required to bring new technologies to the market can be lower if one can establish in this way adequate commercialization channels. The national entry barriers in a multidomestic market as defense are more permeable to niche solutions, because these permit the collaboration with local integrators, and open the possibility of technology transfer to the target country.

For the *"non-prime"*, whether complicated or not, the internationalization of operations is not an option: is a matter of survival. The rising pressure in the domestic market from foreign competitors, and the need to access a market large enough to capitalize their investments in R&D, yield this a vital question. But opposite to the "national champion", the niche player demands less public resources to sustain its technological competitive edge.

In summary, there are at least two different strategic alternatives to ensure the sustainability of the technological development status in a mid-sized

THE NEW THRESHOLDS *(Art. 2)*

Enterprise category	Headcount: Annual Work Unit (AWU)	Annual turnover	or	Annual balance sheet total
Medium-sized	< 250	≤ €50 million (in 1996 € 40 million)	or	≤ €43 million (in 1996 € 27 million)
Small	< 50	≤ €10 million (in 1996 € 7 million)	or	≤ €10 million (in 1996 €5 million)
Micro	< 10	≤ €2 million (previously not defined)	or	≤ €2 million (previously not defined)

Source: European Commission.

country: that of a "national champion" and that of the technology niche specialist. If we opt for the first, we must ensure that a substantial part of the R&D resources and of those applied to the procurement of defense material concentrate on the chosen champion. However, if we adopt the second, we should unavoidably make a choice of the technology areas deemed critical to attend the needs of the future defense scenarios from the national standpoint. But not only that, we should consider how and why commercially viable knowledge and technology are created in this sector. As Michael Porter says: "what underpins the process of national productivity improvement is the result of thousands of efforts to achieve a competitive advantage over foreign rivals in certain sectors and segment, in which products and processes are created and improved"(17). Thus, when choosing in which areas must seek their specialization the country niche competitors in a sector, we should consider the conditions of the domestic demand that largely determine that choice. Though we might consider that in a globalized world the weight of domestic demand has blurred, this is not the case, and much less in such a strongly regulated sector as defense. Following Porter (18), it must be acknowledged that companies gain competitive advantage in those countries

(17) PORTER, Michael, "The competitive advantage of Nations", in PORTER, Michael, *Be competitive. New contributions and conclusions,* Ediciones Deusto, Barcelona, 2003, pag. 169.
(18) Ibid. pag. 182.

where the "domestic demand provides its companies with a sharper or earlier picture of the new needs of the buyers", and where these – in our case, the Armed Forces – "push on the companies to innovate faster and achieve more valuable competitive advantages than those of their foreign rivals. The size of the domestic demand is much less important than the character of such demand". In accordance with this, the more viable market segments will be those where the national buyers are better informed and are more demanding, obviously depending on their own needs. This explains why countries with a size and human and material resources inferior to those that can be deployed by others, have nonetheless a level of industrial development much higher than the latter. A paradigmatic case is that of the Israeli defense industry. But there are others. The Dutch naval industry has a strong weight in the market that is heavily influenced by the sophistication of the demand of their Navy. Conversely, we can hardly expect the Swiss defense industry to have a significant presence in the area of maritime border surveillance.

The second factor to be accounted for in the selection of those areas where to specialize the national industry while implementing a niche strategy is the presence of similar and complementary sectors that are also competitive [(19)]. For example, the existence of a powerful fishing industry can be an asset to promote technologies related to naval construction. There are multiple examples of industrial clusters that have allowed some country industries to build competitive advantages in some segments. In fact, the Spanish ceramic industry has based its international competitiveness on the huge weight that the construction sector has had in the Spanish economy.

The third factor has to deal with the structure of the sector and the domestic rivalry among the companies. The hackneyed argument that promoting domestic competition leads to wasted efforts and prevents achieving economies of scale is, most of the time, false. Domestic rivalry pushes companies to innovate, making them more competitive. But not just that, domestic rivalry eases the development of specialized human resources, and their mobility, contributing to create and spread the technological know-how across all the national industry, making it stronger than its foreign competitors. It also fosters a research and academic network focused on those areas where there is a stronger demand of staff and innovation, closing a virtuous circle that, in the long term, benefit to all the companies in the sector.

The last factor to be considered has to deal with the availability of production factors. But in the knowledge society, this has not much to do with the abundance of human and natural resources, infrastructures or equity referred to by the classical economists. Basic factors such as the availability of manpower or raw materials, do not yield any sustainable competitive advantage in those sectors that make an intensive use of knowledge. The companies can easily

(19) Ibid. pag. 183.

access to them in the global markets, and eventually to manage without them using technology. Even the fact of having available a large percentage of active population with university education does not represent a competitive advantage in a globalized economy. The advantage arises from the specialization of the factors in the specific needs of a sector: the existence for example of research institutions specialized in basic technologies. The national industry can better compete in the international markets in those niches where there are highly specialized resources available in the home market. It is therefore important to align the industrial strategies with those of scientific investigation undertaken in the research centres.

Of course, making an actual choice of those market segments where to concentrate the activity of the defense companies is beyond the reach of this chapter – this is in fact their competence. The intention is just to sketch a general strategy that may result more successful in a country like Spain than the attempt to consolidate its industry around a "national champion". But the public sector plays a critical role in the development of such strategy. This is discussed in the next section.

PRIVATE-PUBLIC PARTNERSHIP IN THE DEVELOPMENT OF THE NATIONAL CAPABILITIES

If the collaboration between private companies and States is a matter of concern in almost every economic sector, in the defense sector this consideration is virtually compulsory. As pointed out before, the defense market is heavily regulated and intervened in every country across the world, because of obvious national sovereignty reasons. Actually, we cannot speak properly about a global defense market; in the best case, we can refer to a *multi-domestic* market. Therefore, if in other sectors the role of the Public Sector is crucial in what concerns to education systems, regulations, basic infrastructures or promotion of an early demand that allow to the local companies the early adoption of new technologies, in the case of the defense sector, this influence is even more important.

The most tempting option to support the development of the national industry, for both the Administration and the companies, is the protectionism of the domestic market. As can be derived from the previous exposition, this is not possible today because of many different reasons:

1) The need to satisfy the demands of the new defense and security scenarios, and the accelerated rate of change of both the technologies and the threats, that make the I&T investment required to remain at the state of the art in the various disciplines involved unaffordable for a country alone.

2) Many of the relevant technologies for this sector are, in itself, dual-use, and restricting the competition in the domestic market in other sectors is simply not possible in today's economy.
3) The international agreements and the participation in multilateral organizations (e.g. LoI, EDA) force member states to open, even if with some constraints, their domestic market to foreign competitors.
4) The access to productive factors, that are seldom sufficiently available within a single country, no doubt requires the mutual opening of domestic markets.
5) The very need to project the action of the armed forces beyond national borders in joint operations with other allies, that call for the interoperability of the different systems.

But not just that: the industrial protectionism pushes companies to settle into easy life and to lose competitiveness and innovative ability.

Nevertheless, it does not make sense either to abandon the defense industry to the quirks of the market "invisible hand". The public sector must undertake a role as catalyst and sponsor that is vital in the defense market. If we further accept that the best strategy to develop the required technological capabilities, at least is not limited to building a "national champion", but also to develop a powerful industrial network of niche players then, having in mind the competitive structure of the sector and the dominant position that the large integrators in the marketplace, the State must undertake an arbitration to level the competitive battlefield.

The first contribution of the public sector to the development of those capabilities is certainly to participate actively in the selection of the technologies to be implemented in the end solutions. The State, in cooperation with the industry, must decide which technologies are critical to respond the present and future needs, and so have to be internally developed, and which may be acquired abroad. Having made this choice, it is important to understand that the cycle of generation of new technologies is a long one. The selection of the technical domains of interest must be publicly known, and perdurable, at least long enough to permit the R&D actions to reach maturity. Furthermore, this selection must be consequently supported by other policies. The armed forces have to act as catalyst of the demand of the technologies of choice, acting as "early adopters" or anchor customers, assuming the risks of pioneering. This is yet one more reason to be extremely restrictive in the promotion of technologies: obviously the public sector cannot undertake risks in all the technological fields.

The selection of sponsoring certain areas must be immediately followed by efforts in the creation of the adequate productive factors. The choice of the niches of specialization in the defense market has to take into account in a broad way the availability of the required resources in the country – for instance, the availability of universities able to produce professionals with the relevant qualifications in those fields – and the power of the Ministries of Defense and of the armed forces to acquire or generate such resources – e.g. by influencing in the offer of university education – is limited. However, they can drive the specialization of the defense research centres in the appropriate direction to generate them. These centres must contribute to the development of the basic science relevant in the selected niches, assuming the burden of the research most apart from the market. The industry will normally tend to focus its investment in the development of technologies and processes closer to the market that allow them some payback in the shortest possible period. And though is certainly fair to ask companies to undertake some research risk, the public sector is usually in a better position to carry on the load of basic scientific research. In the share of tasks between the public and the private sector is, for instance, more sensible to leave up to the first the development of the basic sensor technology, and charge the second with sensor packaging, developing the required proximity electronics, and integrating it within a system with the required functionality.

The public sector also plays a key role in the establishment of procedures and standards. The participation of the defense organisms in the international forum that define and approve standards is fundamental to, on the one hand, defend adequately the interests of the national industry against those of their foreign competitors and, on the other hand, remain at the leading edge of the different technologies, so that they can act as a smart and informed buyer, able to generate with its domestic demand competitive advantages for its companies. One of the key features in the new defense and security scenarios is interoperability, and because of this the ability to influence the new standards and their early adoption can be crucial to allow the industry to build some competitive advantage. For instance, the eager Spanish participation in the development of the NATO tactical communications standard Datalink 22 has permitted a Spanish company as Tecnobit, to lead this technology in the global market.

But we have also highlighted above the arbitration role of the public sector in the national competitive scenario, adopting an anti-monopolistic internal policy. The structure of the defense industry includes large system suppliers, with a strong vertical integration along the value chain, and the Administration must monitor the process of subcontractor selection in the material procurement programs, to avoid an unjustified bias in favor of those large industrial conglomerates. In the same way, it must endorse a R&D policy that, in the broadest terms, involves companies outside those groups and, more specifically, SME. It is fair to acknowledge the role that primes may play as locomotives for the whole national industry, but this has to be defined and closely monitored by the public sector, to ensure that monopolistic practices do not strangle the introduction of technological innovations that may challenge the incumbent position that the large national and foreign industrial groups have in the market.

The private sector has to contribute to the development of national capabilities as well. To start with, the companies must decline the irrational protectionism of their domestic market, and seek eagerly the internationalization of their operations. The industry has to recognize that the national market is insufficient to obtain the desired return of the investment necessary to maintain its competitiveness when attending the demands of the public sector, and must attempt to penetrate in the most exigent markets. Furthermore, the companies have to look, through internationalization, for the exploitation of the selective advantages of other national markets. This is without question one of the pending tasks for the Spanish industry, that if it has often tried to export its products to other markets, has seldom made an effort to completely establish there, and exploit their local resources. It is necessary that the industry thinks of new strategies that result in the local implantation in other markets that would allow them to profit from their scientific know-how or their particular technological advantages. It is unquestionable that the public sector support in this respect is very important, but we must not deny that the initiative in this regard must be taken by the industry.

To reach this objective, both the public and the private sector may promote technological partnerships with foreign companies, but only in selective fashion. It is true that such alliances are useful tools, shortcuts to hit concrete targets, yet it is also true that they impose remarkable costs: imply the coordination of operational centres geographically and culturally separated; require the agreement of their objectives with other independent entity and, often, because of the very nature of the sector, with other Sates; and may imply the creation or the strengthening of a competitor. As Porter says, "establishing alliances as a fundamental part of the strategy will drive the company to mediocrity, not to international leadership" [(20)]. The coordinated action of the public administration and the private sector in the selection of temporal partnerships is the best guarantee to avoid that risk.

The private sector must also cooperate closely with the public sector in the development of early alarm systems that allow spotting new technologies attractive for the sector. Bearing in mind the logical will to protect their potential competitive advantage, the industry cooperation with instruments like the Technology Watch and Prospection System of the Spanish DGAM, exchanging information with the public sector that helps to identify technological or scientific innovations, leading to new processes or products. In the case of the defense sector, the industry must also bear with a big share of the burden in the task of capturing technologies from other industries that can bring new solutions to the defense demands.

[(20)] Ibid. pag. 201.

We cannot ignore a fundamental element in the partnership between public and private sector for the development and maintenance of the technology capabilities of the defense: the support to exports. In a sector as heavily intervened as that of defense, there are two issues that are paramount to ease exportation, that are in turn key for the competitiveness of the industry. The first one is the success in the domestic market. Hardly any foreign defense corps will ever acquire a technological solution that had not previously adopted in its country of origin. The point for the national customer is not just to act as *"early adopter"*, but, all conditions equal, buy in the domestic market. The second issue is the support to export by means of government-to-government sales. It is also a well known fact that, in many occasions, it is easier to access foreign markets under the umbrella of these mechanisms. Sometimes, because they provide ancillary tools (e.g. credit to the purchaser) that make feasible the sale. In other cases, simply for reasons of political lobby.

In summary, there is a lot that the public sector can add to the development of a competitive strategy that allows to the defense sector to acquire and sustain the technological capabilities required to face the challenges of the 21^{st} century, but the private sector has to make a huge effort aiming at this purpose, by adopting an attitude of leadeship in the international context that reduces its dependence with respect to the national market.

CONCLUSIONS

The technological capabilities demanded in the conflict scenarios foreseeable in the next coming years will differ deeply from that of the second half of the last century. The armed forces of the Western countries will require a higher flexibility to adapt to unexpected threats, and will have to adopt the new technologies faster than an enemy whose access to them will be much easier in a globalized world. Yet, to maintain their technology advantage, the European countries as a whole and Spain in particular, will need to sustain a continuous effort in R&D that, necessarily will have to be shared among them. Not only that: they will have to develop the mechanisms that allow quickly import the competitive advantages produced by industries other than defense.

Ensuring the sustainability of a Defense Technology and Industry Base in Europe requires the implementation of an industrial policy that considers not just the development of "national champions" that, on the other hand, would not be viable in many of those countries because of the limited size of the market in each one of them, and even in all together if compared to others. The barriers to the generation and growth of specialist companies must be removed, so that they can access to a larger joint European market and build economies of scale in their niches of activity, that in turn permit them to sustain the innovative effort and compete in the global markets with their American and, ever more often, Asian rivals.

Obviously these specialists must coexist with the large system integrators, who will increasingly be transnational industrial conglomerates that will to a large extent hoard the vertical knowledge of the sector and control the access to the customer. The public sector has to ensure that this oligopoly does not impede to the "*non prime*" to reach the market and to incorporate their innovations to the supply of defense products, by actively participating to the process of selection of suppliers in the large defense procurement programs. In this respect, it is crucial the definition of offset policies that contribute, on the one hand, to ensure the transfer of the technologies required for the operation and maintenance of the systems, but also on the other hand, to avoid that the large system contractors impose the solutions offered by their affiliate companies, detrimentally to others that could be more innovative or effective, or that could help to sustain a viable fabric of specialists.

The public and the private sectors must complement each other in the I&T effort. Generally, the public sector will have to undertake the research needs that are farther from the market, those in which the private sector will hardly make a significant investment, because of both their associated risk and the long payback term. On its side, the industry will bear the responsibility of transferring to the sector all the scientific and technology innovations developed by itself, by the academy or by the public research centres, as well as by other industries than defense. Aiming at this end, it is necessary to maintain a close contact between the two sectors, enhancing the mechanisms that allow the information exchange with the governments not only for the prime contractors, but also involving SME and, broadly, to the complete network of specialist companies.

Last but not least, we must highlight that the Spanish and the European industry have enough technology capabilities to satisfy the operational needs of its armed forces. However, the chance to maintain their competitiveness in the future scenarios depend on its ability to internationalize and compete in the global market, which in turn depends dramatically upon the support of their national governments in such a regulated and intervened sector as defense. The role of the nations as "*early adopters*" of the technology innovations of their industry, their willingness to consolidate their demand to generate a market big enough to reach significant economies of scale, and their institutional support through government to government sales are decisive to achieve that objective.

CHAPTER SIX

PROMOTING INNOVATION. COOPERATION BETWEEN COMPANIES AND THE STATE

Carlos D. Suárez

ABSTRACT

Innovation is a key factor for increasing productivity and hence competitiveness. In today's environment, promoting the economic growth of the country means promoting an innovative industry with a strong technological component and a differentiated offering which is capable of competing in any international market. The Defence Industry fulfils these characteristics, meaning that it is a driving force for other national industries. As a result of its sustained investment in R&D&I, Spain has been able to develop a solid and competitive Defence Industry. Optimising and sustaining this innovative effort in the coming years will be the key to achieving economies of scale and creating synergies, resulting in a more competitive and efficient industry. This promotion of innovation needs to be accompanied by models of public-private collaboration which enable new projects and the emergence of new generators of innovation.

Key words:

consolidation, competitiveness, defence, finance, industry, innovation, internationalisation, technology.

INNOVATION AND COMPETITIVENESS

The recent modernisation of the Armed Forces has allowed the construction of industrial and technological capabilities at the highest level which it is critical to preserve

This is a time of change in which the axes of growth are shifting towards emerging economies, and in which traditionally advanced countries are feeling the need to increase their competitiveness, which translates as becoming more productive.

If we cannot compete by reducing the cost of labour, we can do so with the quality and diversity of our offerings and processes. Productivity increases require increased allocations of technology capital and innovation capacity, with particular importance in Information and Communication Technology (ICT).

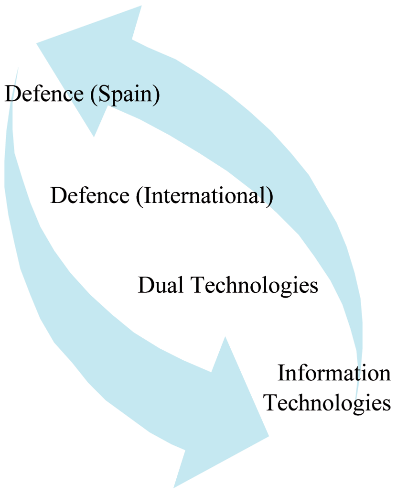
The Spanish Defence Industry, although it has not reached the size of other industrial sectors, stands out as one of the few in which there have been significant levels of R&D&I, product development and marketing at international level, key elements for developing a sustainable economy.

The future of the Defence Industry is based on combining the use of information technology, microelectronics and new materials in order to create more efficient systems. For this reason, the Defence Industry is playing a key role in the development of innovative solutions and systems that enable economic growth. This industry has moved towards a deep knowledge of information and communication technologies and their application to the development of integrated systems of communications, command and control so they can be responsive and effective in dealing with any new threats that may arise.

In this regard, we should point out that the Defence Industry is R&D&I-intensive, with the majority of its technologies being of dual use, that is, with both civil and military applications. Many of these technologies, especially in the area of systems, are also common among the different segments (aerospace, naval, land) as well as many of the resources used by companies as part of different business functions.

On the other hand, technology and civil experience are being incorporated into the defence market, meaning that the separation between these areas is increasingly becoming more blurred. The use of civilian technology allows the reduction of development costs and introduces a new and more competitive dynamic to the defence sector, as well as improved management capacity.

Diversified firms that develop their work in both sectors can adapt their civil solutions to the defence market while always seeking interoperability, flexibility and modularity, as well as anticipating the needs of the Armed Forces. The entrance of these companies into the defence market is a challenge for them since it involves working with a highly demanding client whose needs have high technological content, as well as also being a challenge for the traditional



Technological feedback between sectors. Source: Indra.

companies in this sector who now experience increased competition, which in turn leads to the need to change and innovate.

There are numerous examples of technological advances from which society in general has benefited as a result of innovation in the defence sector. These range from the microwave or GPS technology, to the system of networks that is the Internet, without which the world today would not be as we know it.

That is why sustaining investment in security and defence infrastructure entails many benefits for a country. Firstly, it creates skilled jobs in the Armed Forces themselves and in the companies supplying high-technology systems. Secondly, it promotes research and development in areas that have historically been transferred to civil society. This investment also affects companies from many other sectors which are not strictly defence-related, including the production of raw materials, design and engineering, and research, manufacturing, logistics or service centres. These companies have the opportunity to modernise and develop their structures as a result of increased investment. The figures speak for themselves: in Spain, the Defence Industry brings in EUR 3.6 billion per year, generating 18,000 direct and 50,000 indirect jobs and exporting 40% of its production.

In all advanced countries, the Defence Industry is considered to be strategic for national security reasons, as well as from an economic point of view, so it has always been subject to significant national involvement. This is mainly because it is highly intensive in R&D&I, with high business risks and large economic volumes, as well as being a major exporter and having a pull effect because of the transfer of wealth and knowledge to other sectors in industry and services.

These reasons, as previously mentioned, have led to a consolidation of industries in order to achieve the appropriate technological, trading and financial dimensions both domestically and internationally, and this process has been overseen by states.

The increase in the average size of companies is necessary because of the extensive resources required for development of new products, as well as the need to increase their trade and financial dimensions, given the need to strengthen export markets in order to meet the huge costs involved in developing such products.

Currently, the development of the Defence Industry in the developed nations has led to the creation of large industrial groups in this sector. The appearance of these large groups is not random but is based on the real need to achieve economies of scale and synergies in technology and marketing, with all resources being shared to this end.

These corporations have the challenge of playing a dual role, on the one hand being able to maintain revenues through updates of the platforms and systems which are already in operation, and on the other, to incorporate technologically advanced products into their lines. This area is where cooperation among companies for certain projects coexists with competition in others, demanding ever greater flexibility.

However, this does not mean that other companies in the sector are going to disappear. On the contrary, industry leading companies act as pulling agents for other smaller companies, leading to the formation of technology clusters and knowledge transfer.

While in Spain during the last two decades an industrial policy has been carried out in the field of defence, which either through participation in major international programmes (like the Eurofighter) or through strong support for the acquisition of certain domestic products (as in the case of the shipbuilding industry) has allowed the development of technological and industrial capabilities which were unthinkable just a few years ago, the time has now come, given the changes in our environment, to establish a new long-term strategy for this sector, a strategy of consensus and national dimensions.

The leading companies in the sector not only have to act as benchmarks and cooperate among themselves, they must also seek partnerships with smaller companies and knowledge institutions which because of their flexibility and dedication have become great hotbeds of innovation.

The current budgetary constraints require targeting of investment in critical areas and capabilities

The Defence Industry is facing a difficult situation due to the changing circumstances of the Spanish economy which have led to a reduction in real investment in the Ministry of Defence budget for 2011 of 17.2% over the previous year. These budget constraints make it necessary to target investment in key capabilities and areas and to promote an innovative industry that can adapt itself to the technological needs of our military as well as allowing the industry to grow internationally, by identifying and developing niches of technological excellence and greater specialisation.

In the current environment, where markets are increasingly global, innovation and technology have become the key to the economic growth of countries. Identifying our strengths and the opportunities that arise for Spanish companies abroad is essential in order to focus our efforts and the collaboration between these companies and the Ministry of Defence.

We have extensive experience and technical capacity in the areas of defence and security, and in these areas Spanish industry has major opportunities in niche markets that could contribute to the development of the Spanish economy in a time horizon of 5 to 10 years.

Our platform industry has the capacity to deal with complex projects from design stage to production, with quality and high levels of competitiveness, primarily in the naval and aerial subsectors.

The demand for unmanned platforms is expanding in other countries and not only for military use. According to a report by the Teal Group consultancy, within 10 years investments in UAS (Unmanned Aerial Systems) will increase from nearly EUR 3.5 billion at present to EUR 8 billion, of which 55% will be for purchases and the rest for research programmes. This will entail the manufacture of almost 30,000 units by 2020, half of them in the U.S.

The sector of manned platforms, given the current situation and the long-term investments they require, is the sector facing the most difficulties, however there are still opportunities in the development of programmes to modernise existing systems, as well as in promoting the development of a business model based on outsourcing of services. This alternative means that in the current economic environment, governments with smaller budgets can afford access to essential services for their defence and security.

Another niche market in which Spanish industry contains players which are international benchmarks is that of simulation systems, having high industrial capacity, with knowledge, proven experience and highly qualified personnel. It is therefore important for the industry to maintain this leadership and transfer the experience it has acquired into the civil sector. This opportunity is directly linked to the internationalisation needs described above.

We also have strengths in electronics, optronics and sensors, with a good industrial base featuring a high capacity for integration into electronic warfare systems. Specifically, the development of new systems in multi- and hyperspectral technology has been identified as a possible opportunity for the industry.

These sensors provide a lot of information from a large number of bands (hundreds of spectral channels), and consequently this high number of large-sized images poses a major computational challenge. To do this, it is necessary to take advantage of the extensive experience of national industry in data fusion and signal processing. It is precisely the treatment and processing of signals which is the most critical point in obtaining images with these sensors, and the factor in which the most added value can be obtained.

Spain's experience in combating terrorism, border protection, emergency management, logical security, intelligence and systems of secure identification and communication is combined with technologies developed in the field of defence and significant investments in innovation, which have allowed us to develop a benchmark offering in the world market.

In this sector, Spain's industry features know-how and industrial capability in aspects relating to the detection and deactivation of explosives and nuclear, biological or chemical (NBC) threats; 3D video surveillance systems and critical infrastructure protection.

The Government's interest and investment in the policing of our borders has led to the promotion of the development of a pioneering system like SIVE (Integrated System of External Surveillance in its Spanish initials). The experience gained during its development and operation allows Spanish companies to be placed at the cutting edge in these types of systems and to be benchmarks in the technologies associated with it such as radar sensor networks, optronics systems, acoustic sensors etc., meaning that this system is being exported more for the protection of countries within and outside the European Union.

Development investment has already been made and the technology is well known, and there is the opportunity to seek new business lines to allow additional applications in areas such as the protection of terrestrial and marine resources, vessel traffic management, illegal fishing, piracy, environmental tasks etc.

Innovation is the way to ensure the operational needs of the Armed Forces and to consolidate a sustainable and internationally competitive industrial base

New threats and awareness on the part of society have contributed to the Armed Forces requiring new capabilities based on technological development in order to take on new missions and responsibilities.

These new missions have determined the definition in the European Action Plan of the capabilities identified in the priority areas for action:

- Capabilities to ensure the deployment, mobility and support for combat forces, such as strategic air and sea transport and air-to-air refuelling.
- Those which provide excellence in the field of command and control, communications and information and at the same time provide for the protection of these systems and data integrity.
- Those which ensure the capacity for effective engagement, especially combat support resources, precision munitions and land mine clearance, with a high degree of interoperability between the forces and systems.
- Those which provide protection against nuclear, biological, chemical and radiological attacks.

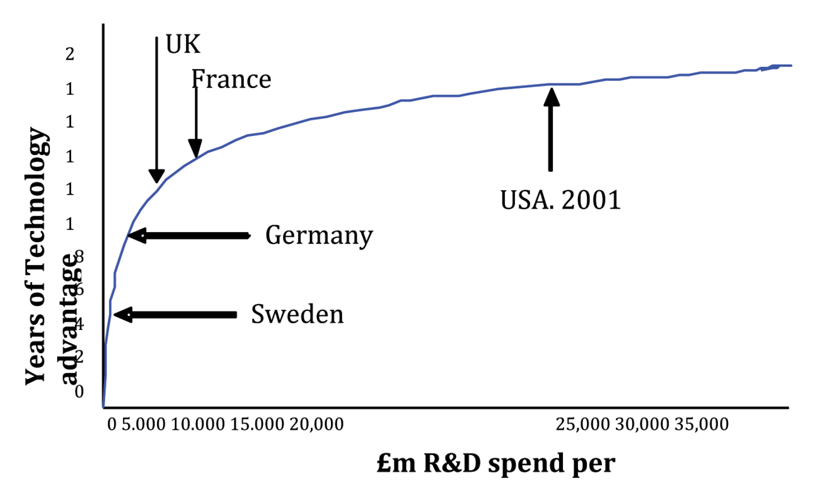
These new requirements mean that the success of military operations is based increasingly on the ability to access, manage and exchange large amounts of information with a maximum level of reliability, security and speed.

This is why innovation is becoming increasingly important to ensure the operational needs of the Armed Forces. The authors Andrew Middleton, Steven Bowns, Keith Hartley and James Reid in their study have demonstrated the close relationship between investment in Defence R&D&I and the functionality and operability of the systems and equipment which are developed. The study examines the relationship between investment in R&D&I in defence and the effectiveness of the equipment of different armies by comparing data from ten countries (USA, UK, Russia, France, Japan, Italy, Germany, Australia, Spain and Sweden) on 69 product lines (not including nuclear weapons), taking into account the investments made in each of these markets since 1951. It presents the results as the years of advantage of the defence equipment of one army compared to the others and highlights the following conclusions:

- The capability of the systems developed for the army depends heavily on the R&D&I investments made in defence during the previous 20 years.
- The improvement in quality resulting from military R&D&I applies similarly to all types of defence equipment.
- The impact of research investment is similar to that of investment in development, suggesting that it is possible to compensate for a lower allocation of resources to basic research with increased investment as the date of commissioning approaches.
- The rate of improvement in the quality of the equipment over time tends to remain constant, which means that if current rates of investment are maintained, the difference in the quality of military equipment between countries will also remain constant.
- Although there are supranational programmes, the quality of military equipment in each European country is best described when considering the individual investment of each state, due to the objectives and requirements imposed by each state on its equipment. It would only be possible to optimise the efficiency of military R&D&I investment in Europe in the event that all states define common objectives and requirements for the equipment.
- The analysis suggests that countries whose military equipment purchases come predominantly from U.S. companies achieve a similar quality in the material to that which they would have achieved in line with the investment they dedicate to military R&D&I. The export restrictions imposed by the U.S. appear to determine effectively what should be exported to offer client states similar technology to that which they would be able to develop for themselves.
- There are no examples of countries that have managed to reduce the latency (the time between the completion of investments in defence and the outcome of improving the quality of the equipment).
- Source: The Effects of Defence R & D on Military Equipment Quality, Middleton, Burns et al., Defence and Peace Economics, April 2006.

As a result we could conclude that a reduction of investment in R&D&I in defence will result, in the medium term, in a significant decline in the relative quality of the equipment of armies and, most likely, in an equally significant reduction of the export capability of the national industry.

Previously we discussed the significant investments made in Spain for the modernisation of the Armed Forces. This effort has allowed us to develop technologies and an industrial sector which are capable of supporting the operational needs of our military and at the same time of competing internationally.

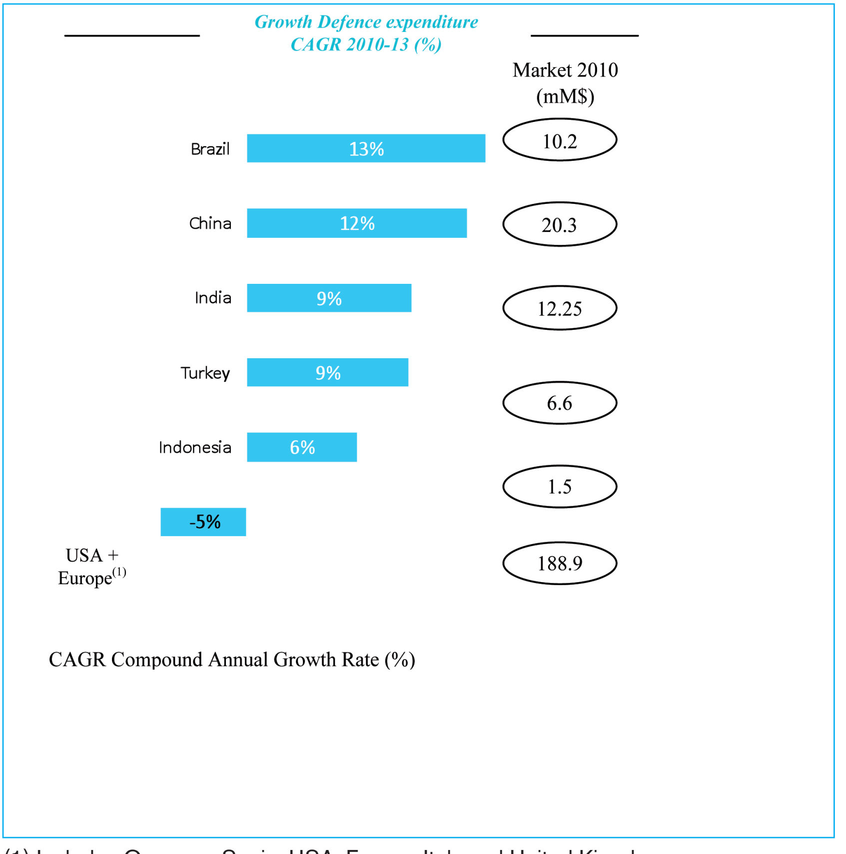


Source: The Effects of Defence R&D on Military Equipment Quality', Middleton, Burns et al., Defence and Peace Economics Apr 2006.

In fact, at present, internationalisation of the Defence Industry is not an option but rather a necessity in which the state and leading companies must work together. Both have to make a clear selection of technologies which are critical to national security, technologies to which we are willing to commit in cooperation programmes, and those niches that we want to develop in order to be able to market products abroad.

The only way to enter new markets or increase the competitiveness of the industry is through investment in R&D&I by both parties, government and business, which needs to be performed with a long-term vision. It is not possible to train professionals and develop innovative projects intermittently, since it takes years to reach optimum levels of innovation in the business solutions and services that are to be exported, as well as ensuring that people develop their talents and gain enough experience to be flexible and adapt themselves to the needs of their situation. Also, it is precisely those countries where we are able today to place our output which are now progressing the most in terms of innovation and technology, whether through their investments in R&D&I, in academic education or in industrial compensation policies such as offset agreements.

Therefore, industry needs to rethink its growth strategy regarding its participation in a highly competitive international market, which involves investment in innovation that will allow companies to develop a more competitive offering that allows them to work abroad, especially in those markets where spending is growing the most, such as the so-called emerging countries.



(1) Includes Germany, Spain, USA, France, Italy and United Kingdom.
Source: Janes (12/2010).

MANAGEMENT OF INNOVATION AND TECHNOLOGY IN A NEW SCENARIO

Requirements for innovation in the current environment

Innovation does not depend solely on the government investing a large volume of resources. Innovation is the transformation of technological expertise into Gross Domestic Product (GDP). As opposed to mere invention, which gives rise to new products and processes, innovation also requires marketing and, therefore, the active participation of companies. Without companies there is no innovation.

Taking advantage of business opportunities in the current environment, in which markets are increasingly global, as we saw earlier, involves the development of innovative processes and products, and this cannot be done without an environment which is conducive to innovation, which in turn requires five principal elements:

- Availability of talent
- Favourable ecosystem
- Flexible corporate structure
- Appropriate institutional framework
- Appropriate funding models

Innovation is talent-intensive. It is people who think, who have knowledge, who find solutions and who transmit the results. This is why talent management and encouragement are essential prerequisites for innovation.

All these changes brought about by innovation in processes and business models produce an understandable uncertainty about what capabilities will be demanded from professionals in the future. For this reason it is essential to pay particular attention to training our students to become flexible professionals who are able to adapt themselves to the future requirements of business and society.

Curricula need to be tailored to the needs of society in general and to business in particular, while it is essential to boost one the strategic vectors of the university: Technology Transfer. Acknowledged technological advances are one facet, the most general, explaining the successful cooperation between the company and the university. However, these technological advances need to have a concrete effect and not to dwell on theory, as well as needing to be translated into improvements in real products, processes and actual services that benefit society.

Another very important aspect derived from cooperation is Collaborative Surveillance Technology, which can be understood as a way of sharing knowledge. The university provides knowledge from basic and pre-competitive research that does not suffer from market pressures. For its part, the company provides the situational awareness of the environment in terms of technological development and marketing opportunities in these markets.

The importance of talent in the innovation process, in particular at universities and research centres, is shown by the results obtained by countries such as Germany and Israel.

Germany spends 2.6% of its GDP on R&D&I, which makes it the country with the third largest expenditure among industrialised nations. The Information and Communication Technology (ICT) sector in Germany represents EUR 140 thousand billion and provides direct employment to more than 800,000 people and 650,000 specialists from other sectors. Of the 1,000 European companies that are investing the most in R&D&I, 206 are from Germany.

Among the measures to promote innovation in Germany, a highlight is the EXIST programme, set up in 1997, whose main objective is to promote the creation of companies, spin-offs, that emerge within the universities. It operates by developing regional networks in which the universities collaborate together with external partners from the scientific, economic and political fields, developing a joint offering.

EXIST was based on a design competition, requiring the joint participation of at least three different partners from the same region, of which one had to be a centre of higher education. The programme has introduced an element of competition among those who can access it, on the one hand forcing the potential candidates to step up their efforts in the design of their proposal and on the other allowing aid to be concentrated in a few regions instead of being dispersed.

The success of this programme is reflected in its figures: in its first phase (five years) more than 1,400 companies were created. 91% of entrepreneurs admitted to having benefited from the programme, mainly from the business advice, and courses and lectures on setting up companies have also been included in the curricula.

Another example of a government sponsoring innovation is Israel. This country is among the world leaders in technological development and in creating globally competitive companies, with more than a third of its industry in high technology sectors. For a small country like Israel, its greatest asset is people, meaning it is one of the countries in the world that invests the most in education; if we add to this the geopolitical circumstances that drive much of their spending towards defence, we can see a country with thriving electronics, aerospace, security systems and biotechnology industries that sells its advanced developments around the world.

A highlight is the scientific and technological system used by Israel, which is characterised by its excellence and the use of research results, exemplified by the Weizmann Institute of Science which is recognised as one of the leading research centres in the world in the field of science, and the Technion, the Israel Institute of Technology, which is the main source of training of scientists and engineers, who represent 70% of the founders and managers of high-tech industries in the country.

New companies which emerge with innovative ideas that are born in research centres and universities are supported by a system of incubators, which have public-private management during the early years and often participate in the ownership of the companies. These incubators also provide advanced management services and, in particular, services in international marketing, contacts, planning and overall business mentality, since they are aware that scientific and technical knowledge is different from business knowledge.

Continuing with the requirements of innovation we need to be aware that companies, countries and economies in general are not isolated entities, but that they coexist with each other and are interrelated. The agents taking part in them also interact with each other, meaning it is not possible to develop innovative organisations if they are not supported by clients, suppliers and governments which are able to embrace change and contribute to their development. Coexisting with demanding customers, high-quality suppliers and top-level competitors, in a suitable institutional framework, is what sustains innovative developments within companies.

In this regard, the development of Technology Centres is of great interest. Technology Centres are public-private non-profit research bodies that have the human and material resources necessary to carry out activities aimed at both the generation of technological knowledge and at facilitating their exploitation either through existing companies or by generating new business initiatives whose success is measured in terms of the improved competitiveness of the companies and their contribution to the economic development of their environment.

Technology Centres are the tool that can assist and promote innovation in the Defence Industry, needing to become the centres of innovation in the sector, as the bidirectional pulling agent between the defence and civil fields, as well as being a space that facilitates public-private collaboration. It would be highly desirable for these Technology Centres to be structured into a network that would allow each centre to specialise in a subject (functional and/or technological) that enables in-depth knowledge and mastery of an area, while also allowing for the establishment of synergies and complementarity between centres.

The structuring of the centres in this manner would allow the loss of knowledge of some capabilities in the defence sector to be solved, as well as optimising resources and budgets, due to the existing dispersion.

Another key element in fostering innovation lies in policies aimed at the protection and promotion of ideas. Protection in the sense of reassuring innovators that their products or processes will not be copied, while they remain aware that it is very difficult in this field to prevent imitation. Promotion in the sense of facilitating administrative procedures, reducing fees for the creation of new companies and rewarding the most innovative among them.

The efficient identification and prioritisation of key skills requires in-depth collaboration between the client and the industrial sector

As outlined above, encouraging innovation and developing greater technological capabilities within our industry depends not only on business or the government; it requires the joint participation of both. In the current scenario, it is necessary for Spain's industries and the defence sector to strengthen their cooperation to establish priorities for technological and industrial adjustment in line with the planning of the future needs of our armed forces, while also being more efficient in the production of solutions and the development of capabilities.

Therefore, the Ministry of Defence (SEDEF) is committed to industrial cooperation as a tool of industrial policy for the benefit of Spanish defence and security companies and has taken the lead in strengthening it by establishing mechanisms which are conducive to this end. The future lines of action of the Ministry of Defence in this respect are focused mainly on promoting the participation of small and medium enterprises, promoting technological initiatives harmonised with Spain's global industrial strategy, and ensuring the participation of Spanish industry in International Industrial Collaboration Programmes, primarily in the activities of design, development, production and integrated logistic support.

In the Comprehensive Plan for Industrial Policy 2020, adopted in December 2010, various initiatives are set out which are aimed at enhancing and developing a national industrial and technological base which is both modern and competitive. These initiatives include:

- Preparation of a Defence Technology and Innovation Strategy (ETID in its Spanish initials) through the Ministry of Defence in order to identify the needs of development and acquisition of future technologies which are a priority and a necessity for the Armed Forces and to establish a long-term public reference regarding the activities of R&D&I as applied to defence.
- Another initiative focuses on providing financing for Technological Innovation Programmes in the defence sector. Given the leading role that the Defence Industry plays in technological development and industrial innovation in general, the Ministry of Industry, Tourism and Trade is working with the Ministry of Defence in the pre-financing of these programmes. The aim is to provide advance funding for development undertaken by the Defence Industry established in Spain for projects of strategic interest because of their innovative content, their technological complexity and/or because they are being carried out in an area of international cooperation.
- Both initiatives are steps in the right direction which have the support of the entire sector and which follow the steps already taken by other countries around us.

A clear illustration of the definition of needs, capabilities and the technologies being adapted to them is the study by the UK Ministry of Defence (MoD) entitled *Defence Technology Strategy for the demands of the 21st century*.

The MoD considered that the threats that hang over the country are increasingly uncertain and changeable, and to be able to address them requires a rapid response capability, in both a tactical and technological sense. This document not only defines which technologies are critical to the emerging needs of the military and the country's sovereignty, but also discusses which of them have to be developed by local industry and which are likely to be imported, as well as the collaborative opportunities which it would be interesting to exploit between industry, the universities and certain allied countries.

The study also recognises the strategic role played by the development and monitoring of policies on R&D&I in ensuring the identification and development of these critical technologies, and the long-term investment in this area by the Government. As shown earlier in the analysis by the authors Andrew Middleton, Steven Bowns, Keith Hartley and James Reid, the MoD is also aware of the correlation between investment in R&D&I and the advantages in the development of advanced equipment to respond to the future needs of defence and national security. In connection with this idea, the challenge is to decide on the appropriate proportion of the MoD budget for investing in R&D&I to be applied between new technologies and the development of defence capabilities based on existing technologies.

As an example of the results of the study, below is an excerpt from the summary of priority technologies identified by the MoD as well as a proposal of what role national industry should play in the development of the technology compared to other non-national industries in order to preserve the strategic interests of the United Kingdom.

EXTRACT FROM THE SUMMARY OF PRIORITY TECHNOLOGIES BY THE MOD

Function	Priority Technologies	Technology Supply Route	
		Sovereign	Collaboration
Marketing, operations, management and planning of missions, management in operation situations.	Calculation, decision support, awareness of the situation, delivery, interface, date of use, risk and asset management tools.	Definition of requirements, customer intelligence, experimental and calculation, data use and fusion, understanding of interfaces and algorithms.	Implementation of algorithms
Concepts, design and integration.	Integration of systems and platforms, computational tools.	Design, guarantees of safety including sea and airworthiness.	Validation of tools, integration.
Simulation, modelling, acceptance, certification and warranty.	TLCM systems (holistic management capability) and synthetic/modelling of environments, guarantee of accessibility, design, interface specifications. Performance modelling, operations support.	Access to capabilities, customer intelligence, methodology.	Exploring collaboration in several areas.
RF processes and technologies including reception and transmission modules.	Advanced processing techniques and technologies including manufacturing capabilities.	Research, design, development, modification, maintenance and evaluation, manufacture and integration of technologies in radar systems.	Technological development/ maturity. RF compact loads for tactical survival.
Electro-optical sensors and others. EO protective measures and countermeasures.	High performance detectors, protective equipment, maximisation of innovation to generate new approaches to use.	Ability to design, evaluation, manufacturing and systems integration.	Beam control technologies and access to the UK.

Source: *Defence Technology Strategy for the demand of the 21st century*. UK Ministry of Defence

PUBLIC SUPPORT FOR INNOVATION AND NEW FINANCING MODELS

As mentioned earlier, the development of the Defence Technology and Innovation Strategy (ETID) allows for the setting of priority areas in a long-term technological horizon. This strategy needs to be viewed as being supported by the implementation of new policies for public support for innovation identified in the strategy for a sustainable economy and in the Comprehensive Plan for Industrial Policy 2020.

The Government of Spain in December 2009 took a step forward when it assumed the lead role in the promotion of innovation, by adopting the Strategy for a Sustainable Economy which rests on the conviction that it is necessary to accelerate the transformation of the production model and contains a wide range of economic policies, both macroeconomic and microeconomic, as well as environmental and social aspects, which together form a new environment for the development of innovative activities.

The Law of Science, Technology and Innovation developed the new regulatory framework for the promotion and coordination of scientific and technical research and the promotion of innovation. The text addresses three major challenges: the design of a meritocratic, stable and predictable scientific career; the need for a more efficient and effective system of R&D&I; and the development of a true knowledge society and the promotion of a sustainable economy.

The Law sanctions the existence of the National Innovation Strategy and provides the legal backing for its development. The Strategy is defined as the multi-annual benchmark framework that will define the elements and instruments available for the change of the production model, with the aim of transforming the Spanish economy into an economy based on innovation.

The bill enhances the transfer of the results of research activity, making it easier to transfer knowledge from research centres to the private sector and promoting cooperation among public and private stakeholders through participation in innovative technology-based companies. Furthermore, it promotes the creation of mechanisms that allow for preferential processing of patent applications relating to the objectives of sustainability referred to in the Law and the establishment of an 18 percent reduction over three years of various industrial property taxes. In fiscal terms, there is an increase from 8 to 12 percent in the deduction for technological innovation activities in corporate income tax.

While it is true that tax policies are necessary for the development of entrepreneurial projects, it is also imperative to add the demand for technological innovation opportunities in different spheres of government so that projects of sufficient size and scale can arise to serve as a stimulus to business investment in innovation projects.

New R&D&I financing models.

As discussed above, the current circumstances have little to do with those of only a few years ago. The defence sector between 1996 and 2007 reached a level of investment of EUR 4 billion per year, 50% of it funded with credit from the Ministry of Industry, which generated unprecedented growth and a significant deficit for defence. For this reason the Defence Industry must find new funding models to maintain the required operational and innovation standards. Among the new financing models, we can highlight four:

- *Innovative Public Procurement (IPP)*

The Spanish public sector, like those in the rest of the world, faces significant challenges, both economic and social. Society demands new public services, better quality in existing services and all with a more efficient use of available resources. These challenges require appropriate responses by governments and, in many cases, the actions needed to address these challenges are more demanding from the standpoint of science and technology, which require significant investments in R&D&I.

The public sector can play a very prominent role in the increase in national R&D&I and in business competitiveness by adopting public procurement strategies of innovative technology (also called pre-commercial procurement), to encourage and complement public support programmes for business R&D&I aimed at R&D&I services that seek to develop new applications and innovative solutions which are not yet commercially available.

However, despite the flexibility that legislation has provided in public procurement since 2007, the fact is that Spain still does not take enough advantage of these kinds of purchases.

In the National Innovation Strategy of the Ministry of Science and Innovation, innovative public procurement will focus on markets identified as priority or unique.

- The economics of healthcare, the care economy and all the technological and innovative deployment it involves,
- Green economics for the environment, for energy, as well as all the technological and research needs they encompass.
- The science industry

- The modernisation of public administration as a key element that needs to contribute to the changing of the production model.
- Information and Communication Technologies, Tourism and Defence, which also have specific R&D&I programmes.

Likewise, the National Innovation Strategy states that it will encourage purchases by placing a special emphasis on innovative small and medium enterprises. These Public Procurement projects with an innovative component accounted for a budget of EUR 1.7 billion in 2010.

The MoD has always promoted innovative components in its tenders with the aim of creating, strengthening and creating an ecosystem of innovative companies in the sector. This model of tenders promoting innovation has been one of the sources on which the civil service has modelled the definition of the IPP.

- *Outsourcing*

In Spain, companies in the sector have opened expectations of new business opportunities since the enactment of the Strategic Defence Review, which stated clearly as one of its objectives "in order to optimise the performance of military personnel in the dedication to their specific professional responsibilities, they will be freed from those tasks which can be effectively carried out by specialised companies, through outsourcing", which these days and despite various efforts and implanted cases, have not materialised in reality to the extent that was expected. Specifically for the Armed Forces, the objective should aim towards optimising human resources by outsourcing services, releasing operational staff from tasks that can be performed by specialised companies.

There is no doubt that progress has been made in the outsourcing of certain services or logistical support to the Armed Forces as part of the administration, initiating this process with the outsourcing of transportation, food, infrastructure maintenance, security of facilities, health, etc. with quite satisfactory results.

No time is favourable for outsourcing for improved know-how since the Ministry through the Maintenance Directions for the armed forces effectively maintains the available resources at the level which the budgets allow, while the armed forces are also capable of responding to any situation with a certain immediacy. However, in the current situation and in the near future, the existing problems of costs, staffing and new systems/technologies mean that they need to consider outsourcing as a priority in the short, medium and long term.

This requirement of outsourcing in the maintenance of weapons systems is therefore influenced by the acceleration of the evolution and higher costs of the systems which make it increasingly difficult for the Armed Forces to maintain the technological autonomy necessary to ensure adequate support for them, together with the limited resources available in the military.

Other improvements that appear intuitively are those relating to maintenance capabilities that are doubled or in some cases tripled between manufacturing industries, companies carrying out maintenance tasks and the Armed Forces themselves. It would be logical to think that the concentration of activities in specialised companies will improve business management, and, one would imagine, cost savings if these capabilities can also be used outside of the stated area and are offered to other customers who need them.

We all assume that maintenance activities are one of the potential business areas within outsourcing, nevertheless several factors and elements should be taken into account to gauge the possible application of outsourcing to maintenance.

The reasons that lead to this conclusion are repeated and are known as: professionalisation, participation in international operations, reduced manpower that needs to be dedicated to the hard core of activity of the Armed Forces, the existence of rapidly renewing technologies, etc.

That is to say, the defence industrial sector has sufficient authority and the necessary technological capability to successfully deal with an outsourcing process involving Logistics Support for Armed Forces Weapons Systems. It is clear that the participation of companies from the defence sector in the development and production of the principal weapons systems for our armed forces and their demonstrated capabilities in the maintenance of practically all the weapons systems currently in service, convincingly shows the sector's ability to take on the role of providing industrial support to the life cycle of the weapons systems.

- *Risk Financing*

The positive effects of risk financing companies are supported by several studies, with figures that conclude that the level of venture capital activity in an industry significantly increases the number of patented products.

Risk financing is an important instrument to support technological innovation in the defence sector.

It involves repayable contributions from the Government to companies in the defence sector for the development of skilled industrial R&D&I projects relating to Defence Acquisition Programmes. Contractors begin to repay the loan based on their fulfilment of the forecast business plan. This financing system is the most open and flexible in application and therefore is the one that requires most control by the government, to ensure that the results remain aligned with the direction and objectives established at the time when the resources were awarded.

- *Public Private Partnership (PPP)*

Innovation is the result of shared knowledge, making it convenient to adopt measures to create collaborative innovation clusters so as to coordinate the transfer mechanisms between the public and private sectors, encouraging the participation of researchers in business projects. It is also important to facilitate international cooperation and technology transfer, which requires global solutions and stronger international cooperation.

The Sustainable Economy Act promotes cooperation between public officials with the private sector through participation in technology-based companies, and equity holdings in privately-owned corporations by Public Research Bodies.

On the other hand, through collaborative initiatives, the public sector can use the private sector to provide services beyond outsourcing or the purchase of equipment.

The Ministry of Defence, in order to exploit the efficiency gains of the private sector and transfer the risk of its operations, and in so doing embark on large innovative projects, regularly pays private companies for extended period services that require investment in infrastructure subsidised by the company. The supplier company is sometimes made up of the union of several different companies that exploit their advantages.

An example of this type of agreement is the one which has been reached between the Air Force and Indra to co-manage the commercial exploitation of its Skydiving Simulation Centre in Alcantarilla (CESIPAL) in Murcia, using the so-called Public Private Partnership model. The Air Force thus takes advantage of the unused hours to market them to foreign military forces and professional skydivers, in order to promote skydiving in the civilian world. Indra contributes its extensive sales network and business skills.

Also, in relation to the creation and consolidation of new Technology-Based Companies (TBC) in Spain, it is worth highlighting the NEOTEC initiative at the Centre for Industrial Technological Development (CDTI in its Spanish initials).

A Technology-Based Company is a company whose business is focused on the marketing of products or services that require the use of technology or knowledge developed from research activities. The TBCs base their business strategies or activities on their intensive command of scientific and technical knowledge.

The NEOTEC grants are aimed at new Technology-Based Companies in the category of small businesses which are less than six years old. These grants meet the requirements of aid to young innovative enterprises from the EU framework on state aid for research and development and innovation.

CONCLUSIONS

Throughout the chapter we have discussed the importance of the innovation work that the defence sector is carrying out. This work not only supports the operational needs of the Armed Forces but is also an engine for improving the competitiveness of the industry and, due to its significant pulling effect, the Spanish economy as a whole.

It is undeniable that the economic situation and budgetary constraints in the field of defence force us to focus our efforts on key areas and optimise public-private partnerships in order to optimise the investment effort. These reasons have also forced a consolidation of the industries in the sector to achieve the appropriate technological, trading and financial dimensions to allow them to compete internationally.

We have seen that, at present, internationalisation of the Defence Industry is not an option but rather a necessity in which the state and leading companies must work together. For this process it is necessary to make a clear selection of technologies which are critical to national security, technologies to which we are willing to commit in cooperation programmes, and those niche products that we want to develop in order to be able to market them abroad.

It is necessary for Spain's industry and defence sector to strengthen their cooperation in order to establish priorities for technological and industrial adjustment in line with planning for the future needs of our armed forces, while also being more efficient in the production of solutions and the development of capabilities. For this reason the Defence Industry must find new funding models to maintain the required operational and innovation standards.

On the one hand the public sector can play a very prominent role in the increase in national R&D&I and in business competitiveness by adopting procurement strategies of innovative technology.

On the other hand, the Armed Forces need to aim towards optimising human resources by outsourcing services, releasing operational staff from tasks that can be performed by specialised companies.

Another of the models to be adopted is that of risk financing as an important instrument to support technological innovation in the defence sector.

Insofar as innovation is the result of shared knowledge, it is convenient to adopt measures to allow the creation of collaborative innovation clusters so as to coordinate the transfer mechanisms between the public and private sectors, encouraging the participation of researchers in business projects.

The collaborative models presented suggest options that are not mutually exclusive but rather complementary to the strategy of maintaining an adequate level of investment effort and increasing the efficiency of spending. These are models that, to a greater or lesser extent, have already begun to be implemented and to bear fruit but whose use needs to be developed and strengthened for the good of our Armed Forces, the Spanish Defence Industry and the Spanish economy.

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