# From ESPRIT to H2020: The Evolution of ICT in the European Research Framework Programmes

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**Abstract.** The European Research Framework Programmes have been around since 1984. The Framework Programmes have suffered many changes through the years and saw several increases in budget and impact. The area of information and communications technologies was triggered with ESPRIT in 1982 and has been financed up until Horizon 2020. This paper presents that evolution focusing in the Information and Communication Technologies area.

## 1 Introduction

In 2014, the European Union commemorated the 30 years of the European Union Research Framework Programmes. It is the right time to have a look on how the Framework Programme has evolved both in terms of budget and areas as well as impact. Figure 1 presents the budget allocated to the Framework Programmes over the years, since 1984 to 2014 (including the correction for EUR) [1].

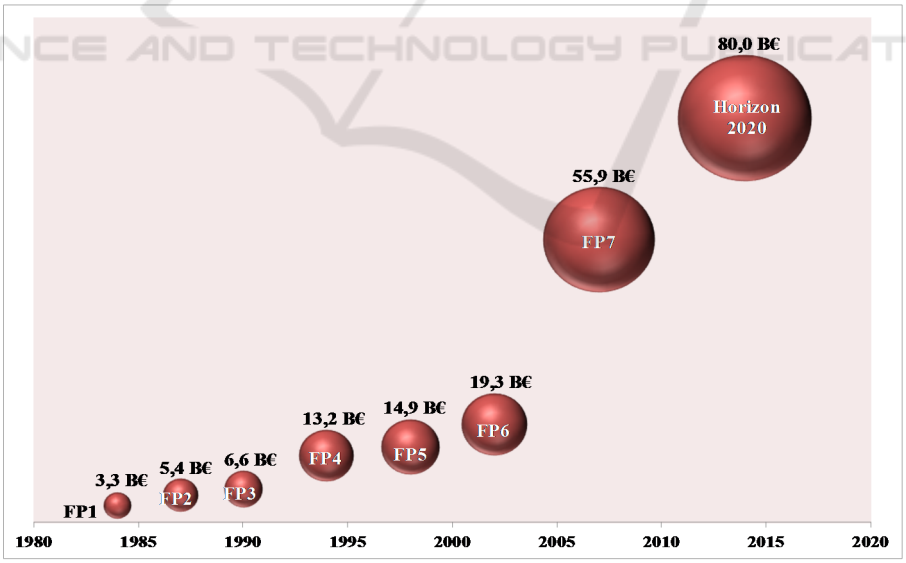


**Fig. 1.** Evolution of the Framework Programmes over the years and their budget (including the correction for EUR) [1].



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Not trying to be exhaustive, this paper focus on the evolution of the loosely called Information and Communication Technologies (ICT) area, which represents several scientific disciplines stressing the study of the technology used to handle information and aid communication. I.e., the role of unified communications and the integration of telecommunications (telephone lines and wireless signals), computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information. The term ICT is also used to refer to the convergence of audio-visual and telephone networks with computer networks through a single cabling or link system.

## 2 Leading to ESPRIT

### 2.1 Before ESPRIT

The European research programme is closely linked with the establishment of European Union, a couple years after the Second World War. During the 1950s, interest in scientific and technological research sprang from the requirements of two different groups. On the one hand, governments saw the control of energy sources as the key to political stability and industrial development. Political attention was focused on two sources of energy: coal, the traditional source, and nuclear energy, which was regarded as the energy source of the future. On the other hand, the European scientific community, with the support of some of those responsible for policy making in this area, asked national governments to provide new structures for research which would enable Western Europe to regain the ground which it had lost to the superpowers, and to the United States in particular.

The interests of scientists and politicians converged, and during the 1950s this led to the birth of several organisations with certain supra-national characteristics, such as the European Coal and Steel Community (ECSC), in 1951;and the European Atomic Energy Community (EURATOM), in 1957, by 6 European countries: Belgium, France, Italy, Luxembourg, Netherlands and West Germany.

From the beginning, science and technology were essential to the work of the EURATOM. The choice of nuclear physics as the priority area in which to concentrate European scientific research also reflects the spirit of the time.It was profoundly influenced by the myth of the atom, the new symbol of progress, power and prestige. Leading to this choice was a report made by Louis Armand, Franz Etzel and Francesco Giordani, known as “the 3 wise-man”, where it was noted that “the nuclear energy has emerged from the scientists laboratory and passed onto the engineers drawing board ... and has now reached the industrial phase”.

Article 4 of the EURATOM Treaty gave the Commission, the executive arm of the and European Economic Community (EEC), the task to integrate nuclear research through the implementation of the Community’s research and training programme with the objectives to avoid duplication, to coordinate national contributions and to cover the gap in national programmes, through the creation of a Joint Research Centre (JRC).

Article 215 of the EURATOM Treaty setup an initial programme for research and

training for the next 5 years (1958 to 1962) with a budget of up to 215 million UA[1], divided in 2 parts:

- A Joint Research Centre (JRC) – where research was performed by direct means
- External contractors – research performed by indirect means

In the next 5 years (1963 to 1967), the EURATOM Treaty doubled the budget to 425 million UA and in 1964 increased it even further to 430.5 millionUA.

EURATOM gave a kick start to research programmes. As a consequence, a working group was set up in 1965, to examine scientific research and technology policies (the PREST or Marechal group, from the name of its president, who was also director of the French agency for science policy). Its mission was to "examine the problems involved in developing a coordinated or common policy for scientific and technological research; and to propose measures enabling such a policy to be set up, bearing in mind the eventual possibility of cooperation with non-member countries"[2].

In 1968, the Aigrain Report (named after the new president of PREST) presented 47 proposals for research to be undertaken in the seven areas: high-performance computer; standardisation of software; electronic aids for motor traffic; gas turbine engine for trains; a giant hovercraft; development and standardisation of meteorological instruments; and numerous suggestions for the battle against air and water pollution.

The first idea for the European Scientific Area appeared in 1973/74 leading to the approval by the European Council on the 14th of January of 1974 of 4 resolutions in the field of science and technology:

- Coordination of national policies and definition of projects of Community's interest in the area of science and technology;
- Establishment of the European Science Foundation (ESF);
- Create the Community's science and technology policy;
- A preliminary science and technology programme to last 1 year.

In 1977, the Commission presented the Community's involvement in six great areas: energy; resources; environment; living conditions; services and infrastructure; and industry; and how it intended to develop these areas in the future. The Community's research activities during this period assumed three forms, which have remained practically unchanged until today (there has been a change in terminology but not in concept): direct action, indirect action, and concerted action. The first two derived from those used during the EURATOM research; the third represents a new departure. Research by direct action was carried out by the JRC and was totally financed from the general budget of the Community. Indirect action referred to research activities contracted out to public research centres or private laboratories in Member States, for these the Community generally paid about 50% of the cost (this percentage has changed over the years and can be in some cases 100% of the cost). In concerted actions, the Community guaranteed and financed only the coordination of the research (reimbursing travel expenses, meetings, etc) and the circulation of the results of the research. This last type of financing also provided an opportunity to evaluate the usefulness of individual projects which might subsequently be the object of indirect action, where this seemed to be in the Community's interests.

[1] Unit of Account (UA): In 1971, 1 UA was 0.88 grams of gold or 1 US dollar.

In the area of information technology, the 1970s saw many interventions on the part of European governments to defend their national industries, threatened by the increase of large American companies. Between 1966 and 1980, France launched three successive plans for the development of the information technology industry, and national semiconductor industries that were heavily subsidised by the state. Similar programmes were also launched in Germany and Great Britain. As well as subsidising research and development programmes, governments became actively involved in encouraging mergers between national companies in the sector. However, the history of attempts to come to agreements between the national companies is a one of failure:

- In 1969, a consortium called Eurodata was formed between ICL from Great Britain, CII from France, Philips from the Netherlands, AEG-Telefunken from Germany, Saab from Sweden and Olivetti form Italy to supply computers to the European Space Research Organisation (ESRO), but the initiative petered out in the face of German resistance.
- In 1973, Siemens from Germany, Philips from the Netherlands and CII from France decided to launch a joint venture, Unidata, to produce a new line of computers, but this attempt was also soon to be abandoned because of the difficulties of working together.

After these failures, the Commission presented a first Action Plan for the information technology (IT) sector in 1976. Presented once again, with minor modifications, in 1978, the programme was approved by the Council in September 1979. It was a programme for the years 1979-1983, with a planned maximum expenditure, over four years, of 25 million UA.



## 2.2 ESPRIT I

In February 1980, the Commission decided to call a meeting of senior executives from ten companies to discuss the future of information technology in Europe. At the end of 1981, the first “Round Table” meeting took place, attended by the 12 largest European Information Technology companies: ICL, GEC and Plessey from Great Britain; AEG, Nixdorf and Siemens from Germany; Thomson, Bull and CGE from France; Olivetti and STET from Italy; and Philips from the Netherlands[2]. The problems of the IT sector were discussed in June 1982, where the Commission presented the Council with a proposal for the pilot phase of the ESPRIT programme, which the Council approved in December that year.

The kind of research which the ESPRIT programme was intended to finance was called “precompetitive”. It was a kind of no-man's land between basic and industrial research. It was industrial research, but sufficiently distant from the market: its results would not be products ready for commercial exploitation. The choice of “precompetition” arose from a complex search for an equilibrium between the various interests involved. In practice, precompetitive research was the research which industries, at the time when ESPRIT was set up, would agree to undertake together. The uncertainties and the caution of both companies and governments were such that the Council's decision of 21 December 1982 was to set up a pilot phase to last only one year initially.

[2] This group would become known as the Big Twelve.

The Council identified 16 pilot projects, belonging to three areas of Information Technology development (micro-electronics, software, and advanced data processing); two kinds of applications (office systems and factory automation); and systems and infrastructure for the dissemination and exchange of information. The Community's contribution to these projects was 11.5 million ECU[3], equal to 50% of the entire cost of the research, while the remaining 50% was provided by the participants in the programme. Each individual project was obliged to have at least two companies from different Member States. Participation on behalf of universities or public and private research centres was not compulsory, but it was encouraged.

In February 1983, the invitation to tender was published; about 600 companies and research bodies responded, putting forward a total of 145 proposals. Expert groups evaluated the proposals in each area of research, and in May the first contracts were signed, for 36 specific R&D projects, corresponding to an acceptance rate of 24.8%. Predictably, the Big Twelve were represented in 70% of the projects approved. The running of the research consortium was entrusted to a project leader, while the Commission maintained the power of control and monitoring of management and results. The latter were to be owned jointly by all the participants in a single project, and companies involved in other ESPRIT projects would have privileged access to these results.

Given that the response of industry, the universities and research institutions to the pilot phase had been of high quality and have shown a high level of interest, the Council approved the first phase of ESPRIT (called ESPRIT I) for the years 1984-1987, assigning it 750 million ECU (corresponding to 50% of the cost of ESPRIT I). To give some idea of the scale of the programme, the Review Board estimated that the entire 1500 million ECU to be spent on ESPRIT I represented 6% of total Community investment by industry in R&D for Information Technology [3].



## 3 From ESPRIT I to ESPRIT III

ESPRIT I main focus was unchanged with respect to the pilot phase (although the sector relating to an infrastructure for the exchange of information was eliminated) but the specific areas had grown from 16 to 27 in 1984 and to 30 in 1985. This meant that the programme became much more open and flexible: almost all areas of IT were covered [4].

- Advanced microelectronics: To provide the technological capability to design, manufacture and test very high-speed and very large-scale integrated circuits (VLSICs);
- Software technologies: To provide the techniques and criteria for organising, managing and optimising all elements of software application technology and the software industrial production process;
- Advanced information processing: To create an industrial exploitation basis for the transition from data processing systems to knowledge processing systems which is the key to the next computer generation;

[3] European Currency Unit (ECU): The value of the ECU is based on a "basket" of currencies of Member States. In January 1979, one ECU was worth 1.388 US dollars;

- Office systems: To carry out research on the information systems that will support the wide range of non-routine tasks performed by humans in the office environment;
- Computer integrated manufacture: To establish the technology base for progressive introduction of IT to all phases of the manufacturing cycle leading ultimately to fully integrated production systems. The main emphasis is placed on manufacturing elements as they are needed for discrete batch manufacturing.
- The infrastructure activities included:
  - the coordination of Community and Member States' research and development programmes and the acquisition and dissemination of information, both within the ESPRIT programme and from the world at large;
  - the coordination and documentation of standards within the ESPRIT programme and their relationship to national and international standards;
  - providing an information exchange system backing for R&D projects.

Between the beginning of 1984 and the end of 1986 there were three invitations to tender: 226 projects were approved, involving 240 companies (57% of which belonged to the category of small and medium-sized enterprises) and 210 research bodies. Around one in five of the proposals made to the Commission received financial aid. Table 1 presents the division of budget per subarea.

**Table 1.** Budget allocation per area of ESPRIT I [4].

| Subprogramme | Year of Call for Proposals (MECU) | | Total | % total |
|---|---|---|---|---|
| | 1983/84 | 1985 | | |
| 1. Microelectronics | 91.8 | 74.4 | 166.2 | 24.5% |
| 2. Software Technology | 72.8 | 54.1 | 126.9 | 18.7% |
| 3. Advanced Information Processing | 89.5 | 60.9 | 150.4 | 22.2% |
| 4. Office Systems | 94.9 | 48.7 | 143.6 | 21.2% |
| 5. Computer Integrated Manufacturing | 49.0 | 41.6 | 90.6 | 13.4% |
| **Total** | **398.0** | **279.7** | **677.7** | **100.0%** |

Despite the “precompetitive” clause, with the passing of time, cooperation crept closer to the market: the percentage of projects resulting in the manufacturing of prototypes went up from 13% in 1983 to an average of 20% in 1984-1985. Further, many ESPRIT I projects were involved in the setting of standards (“pre-normative” research), which had a direct influence on the commercial potential of a product. Still others led to products and processes which stood a good chance of coming onto the market within a year or two of the end of the project. As to the type of participation, 11.6% of ESPRIT I projects involved only companies from the Big Twelve; 50.7% involved Big Twelve companies together with some smaller firms; and the remaining 37.7% of projects were undertaken only by companies other than the Big Twelve. Research bodies took part in 71% of ESPRIT I projects.

When the Council set up ESPRIT I, it was decided that the first evaluation of the programme should take place after two and a half years, or when 60% of the funding had been spent: The very positive response of industry and the scientific world to the

first two invitations to put forward proposals in 1984 and 1985 meant that the projects already chosen on the basis of these invitations would use up almost the entire allocation of funds for the first five year period of the programme. Figure 2 presents the number of participations of ESPRIT I per country.

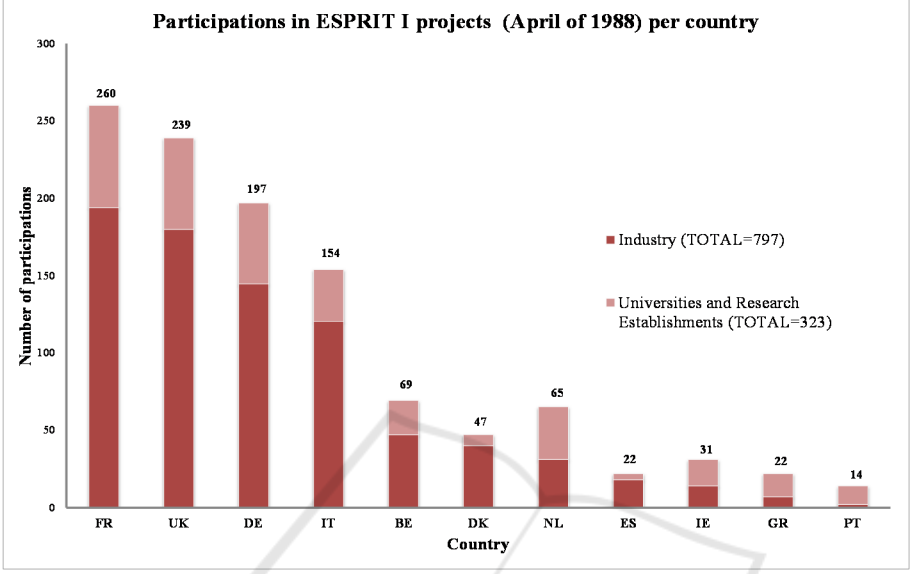


**Fig. 2.** Number of participations (same institution participates in several projects) of ESPRIT I per country and type of establishment, as of April of 1988 [3].

For this reason, the ESPRIT I Review Board was set up and their task was to evaluate the advancement of the programme, and, in particular, to assess the objectives, the management of the programme, the means of communication between the participants, the spread of information and relationships with national programmes. The results of the Review Board were clear: the cooperation between firms, universities and research bodies was considered very profitable, and there were the first signs of a willingness to pursue joint research and development even outside ESPRIT I. The projects regarding standardisation, which were contributing to growing European influence in international negotiations on standards, proved particularly useful. The report recommended that ESPRIT I should pass on to its second phase, perhaps with greater finance, in order to support finalised demonstration projects, to set up stable centres of excellence for research and development, and so that the programme might be more widely publicised.

The money made available for the second phase of ESPRIT (ESPRIT II), for the period 1987-1991, was twice the amount allowed in the first phase, reaching 1600 million ECU; and the programme also saw some changes along the lines suggested by the Mid-Term Review Board. There was a shift in research towards the market: the number of projects for the development of prototypes continued to grow, reaching 30% of the total for 1989. And greater attention was paid to market demands, with an increase in research on applied technologies. Small and medium-sized firms were represented in a larger number of projects, and received a higher proportion of the

overall budget. More ambitious projects, consortia with fewer participants, and a better flow of information were other objectives which the programme established.

ESPRIT II was part of the FP2 (1987-1991) under subactivity 2.1.: "Information technologies"; and included research and development projects, complementary basic research and accompanying measures. There were three research and development areas [4]:

- Microelectronics and peripheral electronics: To enable the Community's microelectronics industry to supply the IT sector with the necessary state-of-the-art semi-conductor technology to provide complete IT systems;
- Information processing systems: To combine software and hardware into the high-quality complex systems required in the nineties;
- IT application technologies: To enhance the integration of IT in a broad range of applications, including computer-integrated manufacturing and office, home and business systems.

The programme also covered basic research in selected areas, which complement the proposed R&D projects, including:

- Molecular electronics;
- Artificial intelligence and cognitive science;
- Application of solid state physics to IT;
- Advanced System Design.

It also had accompanying measures that were aimed at providing the framework necessary to make optimum industrial use of R&D activities undertaken under the ESPRIT programme as well as providing synergy between ESPRIT and related programmes.

The new programme was different from ESPRIT I in that it allowed the possibility of financing 100% of the costs of universities and research centre participation; the programme was enlarged to include all the countries involved in COST; and a review of the question of the ownership of the results of research, based on a less rigorous interpretation of the “precompetion” principle whereby only partners directly financing a project could benefit from its results.

The third phase of ESPRIT (1990-1994) had a Community budget of 1532 million ECU to be distributed over five areas [6]:

- Micro-electronics: To contribute to the strengthening of a European technology base on which future manufacturing capability of a broad range of leading edge ICs can be based (strategic work on very advanced submicron CMOS technologies will be carried out in synergy with the Joint European Submicron Silicon project - JESSI); to strengthen the capabilities in the Community with respect to the chain of designing manufacturing, testing and applying advanced and reliable integrated circuits; and to draw on all the resources available, ensuring wide participation of the largest number of potential actors (large and small industries, both producers and users, universities and research centres) in the Community. Emphasis was on application-specific integrated circuits (ASICs).
- Information processing systems and software: To exploit potential technological breakthroughs in concurrent architectures, to provide better interfaces to satisfy the needs of end-users, and to promote the take up of new software production technologies;

- Advanced business and home systems; peripherals: To establish function integration in the business environment as well as in and with the home environment, easing the use of systems. An especially high priority was given to prenormative work. Distributed computing, including database management, and also the corresponding workstations and microprocessor systems and technologies were of major concern throughout the activities. Two complementary areas were addressed: R&D activities concerning intelligent homes and intelligent buildings and R&D work on integrated business systems;
- Computer-integrated manufacturing and engineering: To provide the technology base for open systems, multivendor systems and distributed operations in engineering and manufacturing environments as well as to contribute to better integration of advanced IT systems components in engineering industries. The work will focus on new generations of basic CIM technologies and on demonstrating their applicability in selected manufacturing and other engineering domains;
- Basic research: To maintain and to expand the knowledge and expertise which underpin the scientific basis of European Information Technology. Areas that such actions support were selected on the grounds of:
    - Their potential to produce future breakthroughs or important advances even if they have no immediately visible application. Particular emphasis was given to topics which are expected to have long-term industrial potential;
    - Their ability to benefit from the added value which cooperation on a European scale provides;
    - Their positioning clearly upstream of R&D efforts, while contributing to the overall aims of the programme;
    - The reinforcement of interdisciplinary links.

The programme comprised research and technological development (RTD) projects, accompanying measures and concerted action projects. The concerted action projects consisted of action by the Community to coordinate the individual research activities carried out in the Member States. They may benefit from funding of up to 100% of coordinating expenditure. The accompanying measures consisted of:

- The organization of seminars, workshops and scientific conferences;
- Internal coordination, by the creation of integrating groups;
- Advanced technology training programmes;
- An information exchange system;
- Promotion of the exploitation of results;
- Independent scientific and strategic evaluation of the operation of the research projects and the programme.

It was the first programme explicitly allocating funds (ECU 15.32 million) to a centralized scheme for the dissemination and exploitation of results of the programme. Specific information on projects was to be provided in close cooperation with CORDIS (Community R&D Information Service). Between 2 and 5% of the total appropriation was to be spent on the training of research workers and engineers. The minimum of two partners independent each other and established in different Member States, should normally be industrial undertakings, except in the case of projects relating to basic research.

Project proposals were submitted by over 1650 companies and 720 universities and

research institutes throughout the European Community and the EFTA countries in response to the 1st call for proposals (August 1991) made by ESPRIT III.

By April 1992, a number of ESPRIT clubs had been set up to further disseminate information on the ESPRIT programme. Founded and managed by the individual countries involved, the groups have various structures and titles. They are established in all EC Member States with the exceptions of Belgium and Portugal. The clubs provided information on a range of subjects including calls for proposals, the ESPRIT conference and publications, associated events, technology transfer from ESPRIT results, and also helped with specific requests for information concerning matters such as the analysis of requirements, choice of themes and partner selection. These clubs later became the National Contact Points of the Framework Programmes, supporting the community in all areas of the Framework Programmes.

By December 1995, there were four calls for proposals under the ESPRIT programme. Over 1,700 proposals were received in the first two calls, of which 430 were selected for funding. The total budget allocated to these is about 500 million ECU. Over 500 proposals were received for the third call for proposals which was published on the 15 June 1995. Users were playing a major role and nearly 38% of all participants were user industries. A new edition of the programme was presented early in 1996.

ESPRIT has had three main beneficial effects on the European information technology industry and its development. Above all, the Community programme has in many cases allowed research to reach the "critical mass" held to be indispensable for the profitability of research and development. This came about thanks to the demolition of a series of traditional barriers separating the various disciplines, which stood in the way of contacts between firms, research centres and universities, and made it hard for researchers in different countries to communicate with each other. Secondly, in an industry characterised by rapid change, ESPRIT has led to a reduction in uncertainties for firms, because it has allowed a more rational sharing of risks, and because cooperation has at least in part modelled the development of the market. Finally, thanks to the creation of links between different sectors, ESPRIT has extended considerably the range of applications of information technology in both traditional and innovative areas. The electronics companies have increased their contacts not just among themselves but also with companies and organisations belonging to very different sectors which also use information technology: telephonic and aeronautic companies, car manufacturers, firms in robotics, mechanics, and chemicals, as well as banks, insurance firms, health centres and other enterprises in the service sector.

The economic side effects of the ESPRIT programme are difficult to quantify, if we exclude the direct financing of half of every project by the Community, but it is unquestionable that the response of industry was unfailingly positive, and that as time passed the programme drew closer to the market. Furthermore, such criticism takes no account of the fact that "precompetion" in itself ruled out very little, and that whenever companies wanted to work together at other levels they were always able to find a way to do so, either within or, more easily, outside ESPRIT. Nevertheless, much of the statistical evidence suggests that more than a decade after the launch of ESPRIT, the European information technology industry was not much more competitive than before. While some believe that its own structure left ESPRIT unable to give adequate support to the development of industry in the sector, others defend the programme,

pointing out that inadequate funds were made available given the size of the problems it was supposed to tackle.

Overall, there was little doubt that ESPRIT and the other Community programmes in the area of technological innovation have created a more open, less diffident atmosphere in which European firms and that they have discovered that cooperation and competition are equally necessary and possible in the field of high technology.

## 4 ICT Evolution within the Framework Programmes

### 4.1 From FP1 to FP4

ESPRIT started before First Framework Programme [7], with the pilot phase of ESPRIT (1982-1983), but it was only with ESPRIT II (1987-1991) it was integrated in the Second Framework Programme, under subactivity 2.1: “Information technologies”[8]. In FP2, we could also find other smaller (budget wise) programmes in the ICT areas.

In the area of telecommunications, the definition phase of the programme RACE, between 1985 and 1986, allocated a budget of 22.1 million ECU and intended to focus particularly on the introduction of Integrated Broadband Communication (IBC) in the Member States. Only in FP2, RACE was included under the subactivity 2.2: "Telecommunications" with a budget significantly higher of 550 million ECU.

Table 2 presents the years and the budget allocated to each programme.

**Table 2.** Years and budget allocated to each programme.

| Years | Budget (MEUR) | Programme |
|---|---|---|
| 1982-1983 | 23* | ESPRIT 0 |
| 1984-1988 | 750* | ESPRIT 1 |
| 1985-1986 | 22,1* | RACE 0 |
| 1987-1991 | 1 600* | FP2 - ESPRIT |
| 1987-1991 | 550* | FP2 - RACE |
| 1990-1994 | 1 532* | FP3 - ESPRIT |
| 1990-1994 | 380* | FP3 - TELEMATICS |
| 1990-1994 | 489* | FP3 - RACE |
| 1994-1998 | 2 057 | FP4 - ESPRIT |
| 1994-1998 | 898 | FP4 - TELEMATICS |
| 1994-1998 | 671 | FP4 - ACTS |
| 1998-2002 | 3 600 | FP5 - IST |
| 2002-2006 | 3 984 | FP6 - IST |
| 2007-2013 | 9 050 | FP7 - ICT |
| 2014-2020 | 16 000 | H2020 - ICT |

*Budget in ECU

FP3 included another ICT area not included in the previous Framework Programmes: the subactivity 2.3: “Development of telematic systems of general interest”, with a budget of 380 million ECU [9]. The programme sought to contribute to the successful completion of the single market, improving the performance of large public services facing the new technological and social challenges implied by European integration. The areas cover were: Support for the establishment of trans-European networks between administrations; transport services; health care; flexible and distance learn-

ing; libraries; linguistic research and engineering; telematic systems for rural areas [10].

In response to public calls for proposals issued in June-August 1991 [11] with regard to specific RTD programmes in the fields of communications technology (RACE) and of telematics, close to 800 proposals have been submitted for consideration, involving a total of more than 7,000 organizations from all Member States, from EFTA countries, and from countries in Central and Eastern Europe, Japan and the USA.RACE received 183 proposals and the specific RTD programme in telematics systems of general interest received 541. The EC funding requested by the proposers totalled ECU 2.9 billion, the total funding available being limited to ECU 869 million.

The Fourth Framework Programme (1994-1998) saw a huge increase in scientific areas and budget [12]. With a budget of 11 879 million ECU it was divided in "Information and communications technologies", "Industrial technologies", "Environment", "Life sciences and technologies", "Non-nuclear energy", "Transport" and "Targeted socio-economic research". It was under FP4 that the JRC started to progressively compete for the funds available under the activities of the framework programme, other than direct action.

Under the research, technological development and demonstration programme (RTD) of "Information and communications technologies", there were 3 specific programmes: "advanced communications technologies and services (ACTS, formerly RACE), "telematic applications of common interest" (TELEMATICS) and "information technologies" (ESPRIT). The budget division of the programme information and communications technologies was the following:

- Communication technologies (671 million ECU);
- Telematics (898 million ECU);
- Information technologies (2 057 million ECU);

The activities within all three programmes were closely coordinated and would collectively contribute to the establishment of a European information infrastructure, which was the priority of ICT research under the Fourth Framework Programme. On the 1st of January 1995, all the 3 programmes saw their budget increased due to the accession of three new Member States. ACTS and ESPRIT budgets were further increased on the 1st of December 1997.

RTD activities under the ACTS programme [13] built on the achievements of both phases of the RACE programme and contributed to the further success of European actions in the area of advanced communications technologies. In particular, there was a stronger focus on stimulating the "innovative use" and closing the gap between the potential of technology and the reality of applications. The programme promoted a multi-disciplinary approach and contained measures to strengthen collaboration between users of advanced communications applications, in both the public and private sectors.

The specific programme on telematics [14] intended to contribute to the development of a European information infrastructure. The activities carried out in the field of telematics under FP4 were redirected in three new ways to reflect the new priorities of Information and Communications Technologies in the Community. Firstly, the emphasis has shifted from data telematics to the new "multimedia telematics", which covered all distributed and interactive multimedia applications. Secondly, research

would be more user-oriented and focused on market needs. Thirdly, particular attention was placed on finding cost-effective and affordable solutions.

The specific programme on Information Technology [15] established under the Fourth Framework Programme built on the achievements of ESPRIT and proposes new approaches and orientations to meet the requirements of the 1990's. To facilitate the development of the emerging information structure, the specific IT programme moves away from the "technology push" policies of previous framework programmes and contained new orientations both in terms of implementation and technical content. Figure 3 presents an abstract of the scientific areas of the ICT programmes under FP4.

| ACTS Scientific Areas |
| --- |
| - Interactive digital multimedia services: Development of new services ranging from specialized telework and professional tools to entertainment services for the general public, with a view to the wide-spread introduction of European interactive digital multimedia communication services from the year 2000. RTD work will focus in particular on the interoperability of broadband services with existing digital switched public services (ISDN and GSM) and the development of advanced image compression systems (e.g. 3D-video communication and "Virtual Presence");<br>- Photonic technologies: Introduction of integrated photonic systems, to include the development of the technological basis necessary for the deployment of fully optical networks ("Transparent Highways") in Europe by the year 2000. RTD covers the development of technology to enable the use of optics throughout the network, for both switching and transmission, and methods to avoid unnecessary conversions between photonics and electronics;<br>- High-speed networking: Provision of integrated high-speed multi-gigabit networks for leading-edge users in European industry and research organizations. RTD will support broadband services (e.g. videophones and teleworking) and cover customer premises networks, public networks and corporate networks;<br>- Mobility and personal communications networks: RTD covers mobile broadband systems and services (including miniaturisation and component integration techniques for low-power portable transceivers) and the development of a "Personal Communications Space" (personal authentication, security and privacy through voice recognition schemes and smart card techniques);<br>- Intelligence in networks and service engineering: To equip communication networks with the built-in features required for real-time communications, including networks, services and user access. RTD will provide the basis for cheaper, quicker and more responsive network services;<br>- Quality, security and safety of communication services and systems: Development of new technologies providing economically viable and operationally satisfactory solutions for services and systems. RTD includes investigations, demonstrations, experiments and trials of integrated systems. |
| **TELEMATICS Scientific Areas** |
| - Telematics for services of public interest: Develop telematics applications facilitating the exchange of information between administrations, such as image transfer and video-conferencing and develop applications to improve the management of all modes of transport, in particular road, air and multimodal transport, whilst facilitating the safety and comfort of users;<br>- Telematics for Knowledge: Research focuses on the development of new methods of access, sharing and up-dating of knowledge; use of large computer networks which require high-throughput communication services; development of distributed multimedia services to support cooperative research; methods for selecting, searching and presenting S&T information; development of a new generation of multimedia distance teaching and group training services, via broad-band networks or satellites, which are adaptable to different user requirements; new techniques for personalized training and learning; facilitating access to library resources and promoting the interconnection of libraries, both directly with other libraries and within the European infrastructure;<br>- Telematics for improving employment and the quality of life: Telematic systems and services to improve employment and the quality of life by promoting better use of land, by raising the degree of autonomy of the less favoured social groups, such as the elderly and the handicapped, and by permitting more effective protection of the environment. |
| **ESPRIT Scientific Areas** |
| produce reliable, correct, efficient and user-friendly software;<br>- Technologies for IT components and subsystems: To provide European industry with the technologies and capabilities to design and produce components and subsystems in semiconductors, microsystems and peripherals;<br>- Multimedia systems: To support strategic RTD in generic information technologies which underpin multimedia end-user systems and applications. Activities will concentrate on the technologies needed for the creation, manipulation, display and storage of multimedia information. Specific work will be undertaken on technologies for integrated personal systems;<br>- Open microprocessor systems initiative (OMI): To coordinate efforts in microprocessor systems RTD throughout the Community in order to develop the standards and technologies necessary to enable European industry to compete effectively world-wide (to cover the provision of components for use in embedded systems applications and advanced RTD in both hardware and software);<br>- High performance computing and networking (HPCN): To exploit the opportunities and expand the application potential of high performance computer networking (activities include the development of software to promote the next generation of HPCN, the creation of a pan-European HPCN infrastructure and measures to demonstrate the economic viability of HPCN);<br>- Technologies for business processes: Integration of enterprises into the information infrastructure so as to increase the contribution of IT to the effectiveness of organizations by, first, improving the level of understanding of best practice in the use of IT business processes, and second, to develop the underlying technologies that will support new organizational developments. |

**Fig. 3.** Scientific areas of ACTS, TELEMATICS and ESPRIT Programmes under FP4 [13], [14], [15].4.2 From FP5 to H2020.

The Fifth Framework Programme (FP5) was executed for the period 1998-2002 and it had two distinct parts: the European Community framework programme covering research, technological development and demonstration activities; and the Euratom framework programme covering research and training activities in the nuclear sector [16]. FP5 differed considerably from its predecessors. It was conceived to help solve problems and to respond to the major socio-economic challenges facing Europe. To maximise its impact, it focused on a limited number of research areas combining technological, industrial, economic, social and cultural aspects. Management procedures were also streamlined with an emphasis on simplifying procedures and systematically involving key players in research.

FP5 had a simplified, multi-theme structure, consisting of seven 'Specific Programmes': four Thematic Programmes and three Horizontal Programmes. Within the Thematic Programmes, there was only one covering Information and Communication Technologies: user-friendly information society (IST) with a budget of 3 600 million EUR [17]. The objective of IST was to realise the benefits of the information society for Europe both by accelerating its emergence and by ensuring that the needs of individuals and enterprises were met. I.e., the transformation from an industrial society to an information society where European industrial competitiveness, jobs, quality of life and the sustainability of growth and cohesion depends on it being at the leading edge of the development and take-up of information society technologies.

The specific objectives were:

- Novelty of the approach. Community-funded research in information and communication technologies and applications was integral to the overall strategy of the European Union for the information society. This was defined by the Action Plan 'Europe's way towards the information society' and revised in the Action Plan adopted in November 1996. The Information Society Technologies (IST) Programme introduced a new approach to the information society theme of the Framework Programme.
    - Single and integrated programme consisting of complementary activities particularly concerning the key issues of usability, dependability, interoperability and affordability. Each key action had, as appropriate, a balance of the complete range of RTD activities from basic research to demonstration and take-up actions;
    - Coordination and integration of the activities through a single work programme using clustering and concertation. Integrated application platforms provided a seamless interaction between citizens, businesses and administrations. This allowed a "theme" to be addressed coherently in more than one activity. Activities were also appropriately coordinated with other key actions and initiatives in the Structural Funds;
    - Single rolling flexible work programme responding to changes in industrial and societal need and the technological context;
- Socio economic needs. Targeting the quantitative and qualitative benefits that information society technologies offer in all industrial and societal activities Socio-economic research, together with the results of other Community initiatives that identify needs for information society technologies. Particular attention was paid to ensuring that the "innovation dimension" is actively addressed, and to stimulating and supporting the participation of SMEs;

- European added value. Collaborative research and technological development was needed to create both the critical efforts and the interoperability necessary to ensure the full potential of the information society is realised in Europe. Pan-European research was also needed.
- European Competitiveness. To be competitive in the global market place Europe needs to master both the supply and use of information society technologies. The programme integrated actions to stimulate the take-up of information society technologies with the research and technological developments to ensure that the conditions and requirements for their use could be met. Actions to stimulate the development and diffusion of the skills necessary to take-up research and development results.

The programme was structured around four key actions and two research actions:

- Key actions:
  - Systems and services for the citizen;
  - New methods of work and electronic commerce;
  - Multimedia content and tools;
  - Essential technologies and infrastructures;
- Research and Technological Development Activities of a Generic Nature:
  - Future and emerging technologies - the open domain and proactive initiatives
- Support for Research Infrastructures:
  - Research networking - broadband interconnection of national research and education networks;
  - Advanced European experimental testbeds.

Between 2002 and 2006, the Multiannual Framework Programme of the European Community for research, technological development and demonstration activities aimed at contributing towards the creation of the European Research Area - FP6.FP6 had a budget of 17 883 million EUR [18] and the main objective was to contribute to the creation of a genuine European Research Area (ERA), with the ultimate goal to integrate the EU's research at local, regional, national and international level.

The Information Society Technologies (IST) [19] thematic priority aimed to increase innovation and competitiveness in European businesses and industry and to help all European citizens so that they can fully benefit from the development of the knowledge-based society. It fell under the "Focusing and Integrating Community Research" title of the programme in "Integrating and strengthening the European research area". The strategic objectives of the IST thematic priority are updated regularly. The objectives were defined in a changing environment for undertaking research in Information and Communication Technologies (ICT):

- ICT research was increasingly organised on an international scale, as firms seek to relocate their R&D activities in the face of accelerating competition in global markets;
- innovation processes were more open, with wider and faster exchange of ideas, people and resources;
- technology chains were increasingly complex, making it more difficult for any single player to establish industrial leadership in any ICT field;
- new promising fields were emerging at the cross-over between ICT and other disciplines such as biotechnologies, materials and cognitive sciences.

At the same time, ICT was becoming more pervasive. New ways of using ICT were at the origin of innovations in most products, services and processes. For the economy, ICT are central for boosting productivity and improving the competitiveness of all businesses and industries. The ICT industry itself is one of Europe's largest economic sectors, and ICT innovations underpin progress in all other major science fields. In the public sector, ICT enable services to be delivered more efficiently, as well as new services that correspond to people's evolving needs. For society at large, ICT offer new solutions to meet societal demands. Research activities carried out under IST addressed the following aspects:

1. Strategic objectives
   a. Applied IST research addressing major societal and economic challenges: aimed to extend the scope and efficiency of IST-based solutions addressing major societal and economic challenges, and to make them accessible in the most trusted and natural way to citizens, businesses and organisations.
   b. Communication, computing and software technologies: aimed to consolidate and further develop European strengths in areas such as mobile communications, consumer electronics and embedded software and systems. It also aimed to improve the performance, cost-efficiency, functionality and adaptive capabilities of communications and computing technologies. Work was also set to lead to the next version of the Internet Protocol.
   c. Components and Microsystems.
   d. Knowledge and interface technologies: aimed to improve the usability of IST applications and services and access to the knowledge they embody in order to encourage their wider adoption and faster deployment.
2. Future and emerging technologies (FET)
   a. FET open scheme.
   b. FET proactive scheme.

In 2006, it was decided by the Council a new Framework Programme, with another big increase in budget 50 521 million EUR [20]. The objective until 2013 was to build upon the achievements of FP6 towards the creation of the 'European Research Area' and carrying them further towards the development of a knowledge-based economy and society in Europe. The objectives of FP7 were the following:

- support transnational cooperation on every scale across the EU;
- enhance investigator-driven basic research based on excellence;
- strengthen human potential in research and technology in Europe, both quantitatively and qualitatively;
- develop and enhance the excellence of European research institutions and universities.

FP7 would promote excellence in scientific and technological research, development and demonstration through four programmes: Cooperation, Ideas, People and Capacities. Under the Cooperation programme, we could find the “Information and communication technologies” theme with a budget of 9 050 million EUR [21]. The objective of FP7-ICT theme was:

- To improve the competitiveness of European industry and enable Europe to master and shape the future developments of 'Information and communication technologies' (ICT) so that the demands of its society and economy are met.

- To strengthen Europe's scientific and technology base and ensure its global leadership in ICT, to drive and stimulate innovation and creativity through ICT use and ensure that ICT progress is rapidly transformed into benefits for Europe's citizens, businesses, industry and governments.

The FP7-ICT theme was organised in the following:

1. ICT technology pillars:
   - Nano-electronics, photonics and integrated micro/nano-systems
   - Ubiquitous and unlimited capacity communication networks
   - Embedded systems, computing and control
   - Software, grids, security and dependability
   - Knowledge, cognitive and learning systems
   - Simulation, visualisation, interaction and mixed realities
   - New perspectives in ICT drawing on other science and technology disciplines
2. Integration of technologies in:
   - Personal environments
   - Home environments
   - Robotic systems
   - Intelligent infrastructures
3. Applications research:
   - ICT meeting societal challenges
   - For health
   - For governments at all levels
   - For inclusion
   - For mobility
   - In support of the environment, risk management and sustainable development
   - ICT for content, creativity and personal development
   - ICT supporting businesses and industry
   - ICT for trust and confidence

A 'Future and Emerging Technologies' activity was to attract and foster trans-disciplinary research excellence in emerging ICT-related research domains. Focuses included: exploring the new miniaturisation and computing frontiers including for example the exploitation of quantum effects; harnessing the complexity of networked computing and communication systems including software; exploring new concepts of and experimenting with intelligent systems for new personalised products and services.

From 2014 on (and expected to finish in 2020), the current framework programme, that this time has a name, is Horizon 2020 (H2020) and has 80 billion EUR budget [22]. Horizon 2020 will tackle societal challenges by helping to bridge the gap between research and the market by, for example, helping innovative enterprise to develop their technological breakthroughs into viable products with real commercial potential. This market-driven approach will include creating partnerships with the private sector and Member States to bring together the resources needed.

Under the Industrial Leadership pillar of H2020, we can find the Information and Communication Technologies (ICT) programme with a expected budget of 16 000 million EUR. However, ICT activities nowadays are transversal (as ICT can be appli-

cable to almost all areas of knowledge), so we can find ICT activities spread out H2020 programme, in all the different pillars and even on the horizontal programmes.

Actually, the first ideas on what would be the configuration of H2020 did not include a specific programme for ICT. Some experts argued that the ICT area was multidisciplinary and did not make sense to have a specific programme for that. On the other hand, others argued that there is still a need to develop the technologies that make ICT and that there should be funding for research. As we have an ICT programme is easy to see who won that discussion.

## 5 From ESPRIT I to H2020-ICT

As curiosity, we present the number of participations on the 1st call of H2020-ICT in 2014 per country, in Figure 4.

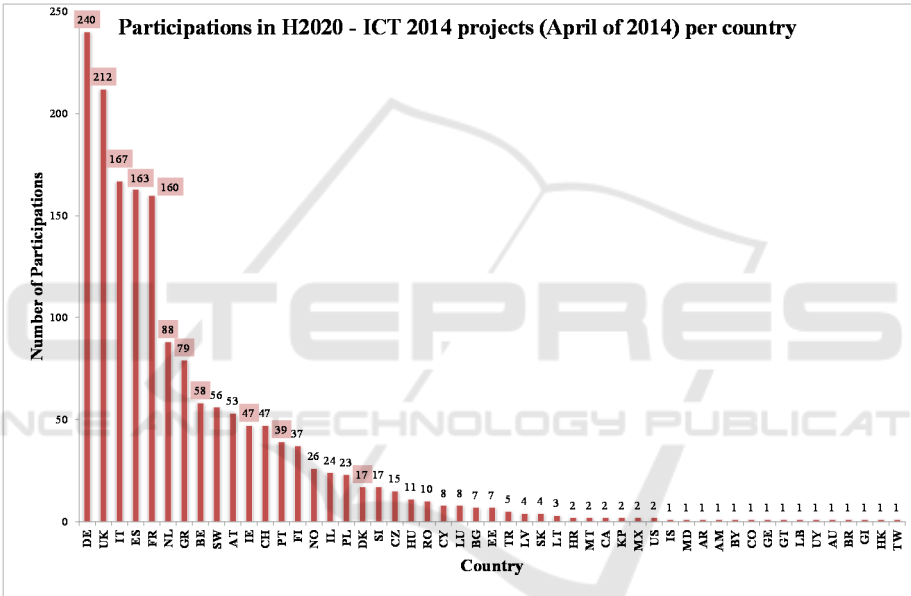


**Fig. 4.** Number of participations (same institution participates in several projects) of H2020-ICT 2014 per country, as of April of 2014 [23].

Comparing the results of Figure 4 with Figure 2, it is clear that the 1st call of ICT in H2020 had more participation (1662) than the whole ESPRIT I programme (1120) that lasted for 4 years. Moreover, there was an increase in number of participating countries, from 11 in 1988 to 51 in 2014 (4.6 times more countries), including a considerable number of countries outside of the European Union, showing that the Framework Programmes have become a truly global programme for research, technological development and demonstration activities[4].

[4] Several other indicators could be used to analyse this impact, however the objective of this paper is to present the evolution of ICT area throughout the framework programmes and not to focus on its impact. That can be the object of another very interesting article.

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