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ANNEX 1

Aggregated entities

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Executive summary

The I2_Tech proposal was presented by the Universidad Politécnica de Madrid (UPM) to support the development of the University Campus of Montegancedo within the Spanish government's International Campus of Excellence program. After the international evaluation process carried out by the Government, the I2_Tech proposal was awarded with the formal recognition of Montegancedo as an International Campus of Excellence (CEI) in 2010. This document corresponds to the “final report” as requested by the Ministry of Education, Culture and Sports (MECD).

This document describes the main objectives, activities, infrastructures, results and milestones that occurred during the development of the CEI Montegancedo until September 2015; even then, it is not only a summary of actions but a common reflection of the role played by the Campus, its positive evolution and the consolidation of its major components for the benefit of the whole UPM. This final report is complemented by additional detailed information which is being loaded onto the Web page of the Campus of Montegancedo (see http://www.upm.es/Montegancedo)

Even if five years is a short period of time to be able to observe how dramatic changes in the structure or governance of universities are consolidated, some trends can be clearly identified. The main inter-related trends for the evolution of universities are as follows:

- “Science-driven innovation”. It reflects the view that technological breakthroughs are more feasible when they emerge from a close interaction between science and innovation.
- “Open innovation”. It is widely recognised that both public and private institutions need to cooperate with other entities and to share knowledge mutually. As a consequence, the creation of strategic partnerships became a fundamental tool for all types of entities. The concept of “aggregation” firmly embedded into the ministerial Spanish CEI program fulfils this view of strategic partnerships;
- “The powerful role of information and communications technologies (ICT) as an enabling tool”. The last five years have seen the dramatic acceleration in the emergence of innovative products and services where ITC have become a key driving factor in innovation-based competitiveness.
- “Exploitation of research results”. All public universities (as well as public research centres) are under considerable pressure from public administrations to develop specific internal mechanisms to exploit the results of R&D projects funded by government programs.
- Contribution to the European Research Area (ERA)”. The construction of ERA is a major milestone in the EU research and innovation strategy. All
community-based R&D programs\textsuperscript{1} were aligned with this objective which also affects the evolution of knowledge policies within Member States and their regions.

Within the aforementioned trends, the \textbf{main driver for the development of CEI Montegancedo} in the period 2010-2015 was its consideration as a catalyst of international impact through the creation of an \textit{open innovation ecosystem}.

Figure 1 depicts this conceptual view of the \textit{“CEI Montegancedo ecosystem”} in which a number of agreements with aggregated entities and spin-offs and start-ups were established.

\begin{center}
\textbf{Figure 1.}
\end{center}

The evolution in the number of aggregated entities (evolution from 2009-2015) has been very large. Figure 1 represents the situation in 2015 and additional efforts are under way in order to increase the number of aggregated entities and the relationship with them. Emphasis will be also placed on improving the interaction with spin-offs and start-ups.

\textsuperscript{1} The period covered by the development of the CEI Montegancedo reported in this document corresponds to the EU FP7 and H2020 framework programmes.
The success of this ecosystem will depend on the UPM’s capability to sustain and enrich this ecosystem in the future by attracting international talent, strategic partners, firms and investments.

Main milestones since 2010

The document describes in detail how the dimensions of the Campus in research, education, innovation, territorial development have evolved in the last five years. This evolution is made visible though the values of KPIs.

- **From research** (projects and large equipment) in all units located in Montegancedo. All research centres have made a great effort to consolidate their role at the international level by participating in international research projects, advanced scientific equipment and human resources. Some of these aspects are as follows:
  - **CBGP**: Automated green-houses, metabolomics and proteomic platforms, controlled plant culture chambers, fermenters, participation in the Spanish National Plan and H2020 projects (several ERC starting grants)
  - **CTB**: Advanced equipment: MEG, Crossbeam microscopy, animal facility, Nanomedicine. Participation in large research projects such as HBP (H2020), Blue Brain, EIT Health.
  - **CEDINT**: Virtual cave 5 walls, energy efficiency pilots with industry, photovoltaic modules.
• **School of Computer Engineering**: Fixed and mobile broadband communications, cognitive software facilities, remote operation of telescopes.

• **IMDEA Software**: hosting of CLC EIT Digital, management of the Redimadrid academic broadband network.

• **CIDA**: Large equipment such as wind tunnels (ACLA-16), facilities for satellite integration and testing, clean room for ISS experiments. Participation in ESA, H2020 space projects, industrial tests.

• **COM**: Living lab Future banking, open projects with industrial partners.

• **CCS**: Creation of a new research centre. Participation in national and regional research projects by using supercomputers.

• **From education**

  The CEI Montegancedo has experimented an integrated view of education with research and innovations activities. Then, all units located in the Campus have pushed education (mainly at the graduate level) as a key asset for the Campus evolution. Main issues addressed in the period 2010-2015 were:

  o Curricula adaptation to EHEA principles has been completed with profound changes in structure and learning methods (mainly blended approaches with e-learning and project-based learning).

  o New degrees
    - CBGP: Biotechnology
    - CTB: Biomedical Technology
    - School of Computer Engineering: DS Master (associated to EIT Digital)

  o Virtualisation of laboratories as a new service.

  o Non-regular courses in entrepreneurship and the commercialisation of technology oriented to UPM researchers and students.

• **From innovation**

  Innovation constitutes a key dimension in the CEI Montegancedo. Many units participate in innovation activities, deeply connected to education and research.

  o **CAIT**: pre-incubation facilities, living labs, consultancy.
    - Actúaupm
      - Spin-off and start-up creation
    - Innovatech_UPM
      - Technology intelligence
      - Licenses from the UPM IP
    - Living labs
      - TV 3D, Smart spaces, Future banking

  o **Technology demonstrators** located in the campus
    - Green labs (CEDINT, CBGP)
• Smart lighting
• Smart renewable grid (PV solar, wind)
• Business incubator
  o CESVIMA: Supercomputing services provided by the Magerit supercomputer;

• Territorial development
  CEI Montegancedo has increased the interaction with the local authorities and it has also increased its visibility in the territory.
  o Deployment of a high-speed communications (RedIris - RediMadrid node) and outside wireless communications
  o Events and Summer Schools
    ▪ Interaction with students (high schools and pre-graduate from other engineering schools)
    ▪ Multiple visits to Campus facilities
  o Services
    ▪ Supercomputing
    ▪ 3D manufacture
    ▪ Support to foreign researchers and students

Key figures in relation to KPIs (2010-2015)
  o Global investments in the CEI Montegancedo were over 120 M€. In the period 2010-2015 40 M€
  o Evolution of students (from abroad)
  o Evolution of human resources
  o Spin-offs and start-ups: 183 companies have been created. 90 of them in the period covered by the report.
  o Technologies identified. 100 UPM technologies were identified as potential assets for commercialisation.

Ideas for the future: Montegancedo 2020

The effort made up to 2015 should serve as a basis for sustainable development in the near future. Taking 2020 as the time horizon, several scenarios have been proposed to reason on the feasible evolution of Montegancedo.

These scenarios start from some general assumptions on the socioeconomic Spanish evolution and, more specifically, the evolution of Spanish budgets for science, technology and education.

More specifically, in the case of the UPM, the possible evolution of the CEI Montegancedo will be framed within three different internal UPM policy scenarios which belong to a number of institutional alternatives where the pressure towards addressing institutional reforms differ greatly:

• Scenario 1: “Business as usual”. The internal situation at the UPM will remain stable and no relevant changes in CEI Montegancedo are envisaged.
• **Scenario 2**: “Empowerment of campuses”. The UPM develops an institutional strategy based on the strengthening of campuses. Then, the two campuses of excellence (Moncloa and Montegancedo) will constitute key factors for ensuring the UPM’s international competitiveness.

• **Scenario 3**: “Dilution of campus identity”. The UPM will develop its activities on the basis of the engineering schools, and campuses will not be the main focus of global activities. Then, CEI Montegancedo is not understood as a driver in itself and research centres will work as separate units.

From the aforementioned scenarios a set of drivers were identified:

1. To empower the development of **multidisciplinary projects** (involving several units located on the Campus) as a key strategy for increasing the impact of the CEI Montegancedo in a broad range of thematic areas of science and technology. The experience gained in I2_Tech is a good starting point to fulfil it.

2. To deepen the principle of **open innovation** as a distinctive feature of the Campus by opening up the activities to a larger number of external entities in all types of activities (from education to innovation).

3. To increase the **internationalisation** of the centres located on the Campus in terms of projects, students, researchers and positioning in other countries (through partnerships or antenna in selected areas where the UPM can offer added value).

4. To promote the **creation of additional joint units** (from joint labs to joint centres) from education, research, services or sharing infrastructures supported by private or public entities.

5. To push an **integrated view on education, research and innovation** within the paradigm of the “knowledge triangle” looking at maximising the potential synergy.

6. To empower the **deployment of generic and advanced common services** in the Campus to improve the quality of life for the Montegancedo community (e.g. in terms of transportation, accommodation, sports, or cultural activities).
**In memoriam**

Prof. José Meseguer passed away in Madrid on the 1st March 2015 at the age of 66. He was the first director of the Instituto de Microgravedad “Ignacio da Riva” of the Universidad Politécnica de Madrid (UPM). This research group, which brings together some 30 people especially professors, technicians, research students and auxiliary staff, has recently reached its 40th anniversary.

![Prof. Jose Meseguer with Carlos Conde Rector of the UPM](image)

Let us highlight the contributions of José Meseguer in the context of the IDR development milestones. The activity of the group started with Ignacio Da Riva, full professor of Aerodynamics at the Escuela Técnica Superior de Ingenieros Aeronáuticos (ETSIA) of UPM, who formed and led a research group, known as LAMF/ETSIA, which quickly achieved renowned prestige in the field of aerospace. This group, after Prof. Da Riva’s death in 1991, was led by José Meseguer and organized itself as an “Instituto Universitario” within the UPM in 1997, adopting the name of his late mentor.

The activity of the group started with the preparation of a spacecraft thermal design handbook under a contract for the European Space Agency (ESA), which was first published in 1975, is periodically updated, and is currently an ESA official handbook denoted as ECSS-E-HB-31-01. This activity offered a great opportunity to a wide number of students in their last years at ETSIA and to achieve hands-on experience in space technology, among them Meseguer at that time, who later also took on the management of this project.
In parallel with this activity, a new line of research was opened up concerning the behavior of liquids under microgravity conditions, following Da Riva’s proposal to an ESA call for ideas on experiments to be performed in the first mission of the European Space Laboratory (Spacelab) to be flown in the early Shuttle missions. In this line of research into the fluid mechanics of a liquid column bridging two solid supports (the so-called liquid bridge configuration), Meseguer largely contributed with theoretical, numerical and experimental works, participating in experimental campaigns on board space platforms such as Spacelab (1983), Spacelab D-1 (1985), Spacelab D-2 (1993), sounding rockets TEXUS (6 flights), Spanish satellites (UPM Sat, Minisat-01), parabolic flights and drop towers. The results of this line of research have been published in more than 10 PhD dissertations, a number of conference proceedings, and more than 100 scientific papers.

As a consequence of the experience obtained from the contribution to the space experiments and the design of experimental facilities for space platforms, the door was opened to participate in more technological projects for ESA, as the study of a Fluid Science Laboratory for Columbus, and the development of a facility to perform experiments with liquid bridges under simulated microgravity conditions on earth using the neutral buoyancy technique, with the aim of training the astronauts to prepare the activities to be carried out in the international space station, in the so-called tele-science operation mode.

As a follow-on to these aforementioned activities, the UPM-Sat project was initiated in 1990 aiming at the development of this microsatellite, which was designed, built, tested and operated by a team including professors, students and staff of UPM, started under the guidance of Da Riva, and continued by Prof. Meseguer. After overcoming a number of difficulties, UPM-Sat 1 was launched into
orbit the 7th July 1995 by an Ariane 4 launcher from the European Space Port (French Guiana).

This experience allowed IDR to consolidate its position as a technology partner in several consortiums of European and American institutions responsible for scientific instruments for some of the more relevant missions for astrophysics and solar system exploration research, amongst them Rosetta, Sunrise, Solar Orbiter, Exo Mars, JEM-EUSO, etc. from several space agencies such as ESA, JAXA and NASA.

IDR is also developing the UPMSat-2, a university satellite devoted to demonstrating technology, with a strong support from STRAST team (Sistemas en Tiempo Real y Arquitectura de Servicios Telemáticos (Systems in Real Time and Telematic Service Architecture), UPM) and the collaboration of several space firms (TECNOBIT, Airbus, etc.), to be launched in 2016. At the same time, a centre with specific facilities for 50-kg-class satellite development is being developed at IDR premises in the Parque Tecnológico of UPM (UPM Technology Park) in the CEI de Montegancedo, including a laboratory to test space environment conditions (LEAE, Laboratorio de Ensayos en Ambiente Espacial (The Laboratory for Trials in a Space Environment)), started in 2013, and a Concurrent Design Facility (CDF) set-up in 2012.

After some successful contacts, a new project has recently been initiated in collaboration with Beihang University to build a university satellite, with characteristics similar to UPMSat-2, to be launched in 2018.

Also, under Prof. Meseguer’s leadership, the development process of the Spanish User Support and Operations Centre (E-USOC) started in 1999, with the help of financial support from the MCT (Ministerio de Ciencia y Tecnología (Ministry of Science and Technology)).

All these IDR activities have been complemented by an active policy of student incorporation into the projects with a suitable educational content. In fact, Prof. Meseguer, aiming at giving these space activities an educational character, promoted the process that led to the approval and the initiation in 2014 of an Official Masters’ Degree in space systems (MUSE, Máster Universitario en Sistemas Espaciales (University Masters’ Degree in Space Systems)). A number of final degree projects, PhD works, and student stages, related to lines of IDR research, taking place regularly every year, using the IDR facilities.

As regards the field of aerodynamics, on the IDR premises at CEI Montegancedo (CIDA), several wind tunnels have been built and commissioned, thus widening the activities that were being carried out at the Moncloa campus. Prof. Meseguer personally took on the management of the CIDA facilities development. The CIDA building construction started in 2003, and finished one year later, being the first building of the CEI at the time devoted to R&D.

The biggest wind tunnel (ACLA16) started development in 2004 and was finished in 2009, initiating exploitation in 2010 after a commissioning phase. Since then, more than 20 test campaigns have been carried out in this wind tunnel in support of several industrial sectors (transport, energy, construction, etc.). Several other wind tunnels have been developed during this period of time, with different purposes.
A full professor at UPM, Prof. Meseguer taught aerodynamics and space technology, and his research activities have been reflected in more than 75 papers published in internationally recognized journals, 14 books, and about 200 experimental wind tunnel test reports. He has been supervisor of 13 PhD dissertations, and referee for a number of scientific journals.

In addition to his participation and leadership in the aforementioned projects, he contributed to research and academic management acting as General Manager of the Spanish National Program for Space Research (CICYT) and member of its advisory committees, as well as ESA's Physics, Fluids and Materials Working Group (PFMWG), and Central Technology Advisory Committee (CTAC); Space Advisory Group (SAG/EU) and Scientific Council for INTAS (International Association for the Promotion of Cooperation with Scientists from the Independent States of the Former Soviet Union) for the European Commission; for the Microgravity Processes and Science committee of the International Astronautical Federation; Editorial Council of the scientific journal “Microgravity Science and Technology” and other national and international committees (ANEP, CNEAI).

Among the prizes that he was awarded, he was eager to highlight the “Premio del Foro de Empresas Innovadoras” (FEI) issued on November 2014.
CHAPTER 1:

Rationale

1.1. Context

The I2_Tech proposal was presented by the Universidad Politécnica de Madrid (UPM) to support the development of the University Campus of Montegancedo within the government International Campus of Excellence program. After the international evaluation process was carried out by the Spanish Government, the I2_Tech proposal was awarded with the formal recognition of Montegancedo as an International Campus of Excellence (CEI)\(^2\) in 2010.

During the period up to September 2015, several intermediate reports have been prepared by the UPM and sent to the Ministry of Education, Culture and Sports (MECD) or to the Ministry of Economy and Competitiveness (MINECO)\(^3\) to fulfill the conditions set up in the open calls published by these ministerial departments (or former ministries) for feeding the monitoring and evaluation of the funded campuses and to maintain their formal recognition as a CEI. Intermediate evaluations were also highly positive (see 2013 report) backing the goals and instruments of change.

This document corresponds to the “final report” requested by the MECD\(^4\). This document will describe the main objectives, activities, infrastructures, results and milestones that occurred during the development of the CEI Montegancedo up to September 2015\(^5\); so it is not only a summary of actions but a common reflection of the role played by the Campus. The focus of this report is also to demonstrate the positive evolution of the Campus and the consolidation of its major components for the benefit of the whole UPM.

The final report will pay attention to the evolution of the UPM structure and associated innovative governance to adapt the University to sharing decision making with other entities and to be able to face the profound dynamic changes occurring in the university context since 2009.

\(^2\) This English version of the Final Report will keep the Spanish acronym (CEI, Campus de Excelencia Internacional).

\(^3\) Denominations of ministerial departments have changed over this period; we will refer in the text to the current names of ministerial departments which have inherited the responsibilities.

\(^4\) The MECD is the ministry responsible for the whole Spanish programme of excellence.

\(^5\) 2015 was also the final date chosen by the Spanish Government to lead the change in universities.
Looking at the future, the UPM is well aware that the implicit structural and behavioural reform process linked to the development of the Campus of Excellence of Montegancedo will not finish this year; the role of the CEI program was to pave the way towards better, stronger and internationalised universities.

Then, some ideas towards its foreseeable evolution until 2020, framed hereinafter as “Montegancedo 2020” UPM initiative, will be also included on the basis of the present capabilities and the strategic institutional positioning of the UPM in the near future.

Finally, the last chapter of the report analyses the evolution of key performance indicators of the CEI Montegancedo. This is not a simple exercise as some data are not easy to break down by campuses of the UPM. This chapter ends with an overall assessment of the effort made since 2010.

The final report includes some annexes with information on actions carried out by individual centres.

Finally, this final report is complemented by additional detailed information which is being loaded onto the Web page of the Campus of Montegancedo (see http://www.upm.es/Montegancedo)

1.2. Moving public universities forward in a globalised world

The motto used by the UPM for the project proposal submitted in 2010 was: “CEI oriented towards international technological innovation: I2_Tech”. The chosen title reflects the institutional will to give it specificity in the types of activities and their goals more than the selection of scientific and technological (S&T) thematic areas within the UPM.

Then, the I2_Tech proposal combined a geographical focus (located in Montegancedo\(^6\)) within a broad transversal theme (technology innovation). The roots of the motivation for this double selection will be explained later in this section.

In short, the CEI Montegancedo has combined the goal of excellence pursued by the ministerial program but smartly adapted to the features of a technical university like the UPM (focused on engineering and architecture) by placing the emphasis on (technology) innovation as the ultimate goal of any engineering mission.

The decision made by the UPM to focus the International Campus of Excellence of Montegancedo (CEI Montegancedo) on the support of technology innovation was empowered by adopting the open innovation paradigm as a guide. After that, the proposal took advantage of the role played by information and communications technologies (ICT) as an essential feature of world-wide competitiveness for all types of entities; especially for universities.

\(^6\) The Campus of Montegancedo is located in a UPM land property of 500,000 sqm in Pozuelo de Alarcón (Madrid).
In 2010 the UPM was convinced of the rightness of the choice made at that time. Today, where there is a broad consensus of the relevance of open innovation and ICT as powerful drivers for structural reforms in technical universities, the decision made was crucial.

Since 2010, the CEI Montegancedo has also become a key tool in catalysing the implementation of a multidisciplinary approach of the UPM’s activities in the three vertices of the so called “knowledge triangle” (powerful conceptual image where innovation, higher education and research intersect to offer an integrated vision of modern knowledge policies).

Today, even with the (short) historical perspective accumulated by the UPM during the last five years in implementing I2_Tech, the focus on open innovation taken as the main input of the submitted proposal has been widely recognised as a key element in ensuring institutional competitiveness in a globalised world. It is being applied to public and private entities, as well as persons, institutions, social groups, and governments have become progressively open to working with others to overcome challenges such as the lack of knowledge or to deal with unforeseen complexities.

Why focus on innovation at the UPM? Unfortunately, Spain is still a Member State of the European Union (EU) which exhibits low performance in a range of innovation indicators; the summary innovation index (IUS, 2015) grouping 25 individual indicators is drawn up annually by the European Commission as a benchmark of innovation performance both inside and outside the EU.

The last data available (2015) shows that Spain still performs below the EU average and the growth rate of this indicator since 2007 is also lower than the EU average value.

The solution to this weakness does not depend exclusively on the behaviour or commitment of isolated public administrations or public and private entities: it should be a collective task for the whole Spanish innovation system where main actors: governments, academia, enterprises and society (the so-called “quadruple helix”) should work together.

The UPM contribution to this global innovation challenge is being addressed by designing and implementing an innovative institutional toolbox taking advantage of the approval of its two campuses of excellence7. Both proposals were used as appropriate scenarios for university policy experimentation.

The intended evolution of the CEI Montegancedo was also anchored in the new role to be played by European public universities pursued by the European Union policies within the modernisation process of European higher education establishments initiated in 2010.

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7 The UPM was also awarded with the recognition of the CEI Moncloa which is coordinated by the Universidad Complutense de Madrid (UCM). Some actions were carried out during these years between both campuses.
As different policy-targeted projects such as ULAB (2013)\textsuperscript{8} or EUIMA (2015)\textsuperscript{9} have recently analysed, and other forecasting reports such as Horizon Scanning\textsuperscript{10} (2013) have also emphasised, European universities\textsuperscript{11} are facing a big challenge to keep their world-wide relevance and full usefulness for speeding up society's progress. Today, emergent economies are also making a consistent effort to improve their university systems and global competition for talent, and investment is growing very rapidly.

Even if \textbf{five years is a short period of time} to be able to observe how dramatic changes in the structure or governance of universities are consolidated, some trends can be clearly identified. Main inter-related trends for the evolution of universities are as follows:

- \textit{“Science-driven innovation”}. It reflects the view that technological breakthroughs are more feasible when they emerge from a close interaction between science and innovation; then, the role played by university ecosystems is to provide a wide-ranging exchange between research groups (and research centres) and external actors (from enterprises to user communities) in order to boost the deployment of disruptive innovative products and services to the market.

From this perspective, the UPM’s decision to locate new research centres in the Campus of Montegancedo to carry out research and innovation activities simultaneously, and to accelerate the pace of maturity to the market of the UPM’s intellectual property (e.g. through technology-based spin-off creation or by licensing know-how to other entities) was the right choice.

- \textit{“Open innovation”}. It is widely recognised that both public and private institutions cannot accumulate all the knowledge they need to generate the advanced products, processes and services they (or users) would like to have by themselves. They need to cooperate with other entities and to mutually share knowledge and research outcomes to generate very advanced items and be able to reach the global market jointly.

As a consequence, the creation of \textit{strategic partnerships} became a fundamental tool for all types of entities. The concept of “partnership”

\textsuperscript{8} ULAB University Laboratory (FP7 project coordinated by UPM in the period 2010-2012) focused on the definition of options for European technical universities. Oxford, TUM, POLITO and Paris Tech were partners with the UPM in the project.

\textsuperscript{9} EUIMA: University-Business Collaborative Research: Goals, Outcomes and New Assessment Tools: The EUIMA Collaborative research project European Union Association 2014.


\textsuperscript{11} These reports focused on “public” universities where public administrations (usually national or regional ones) assume a relevant role in their sustainability (at least, in terms of budget and regulation). Nevertheless, many of the identified trends are also key drivers for change in private universities all over the world.
reflects the view that to be sustainable in running innovation processes, the entities involved should move from *short-term agreements* (i.e. linked to individual consortia-based or subcontracted R&D projects as happened in the past) to *long-term agreements* to accommodate and influence the mutual alignment of research and innovation agendas.

Strategic partnerships could be very different depending on the resources committed (as a percentage of annual budget), the number of people involved (as a percentage of the total payroll), the relevance of the main theme chosen (in relation to the whole entity’s portfolio), and the period of time covered by the formal agreement. Universities should reflect and understand how to increase the **value of these partnerships** by selecting the right partners at the national and international levels and to focus on specific areas with the appropriate governance structures.

The concept of “**aggregation**” firmly embedded into the ministerial **Spanish CEI program** fulfils this view of strategic partnering; this document will reflect how this concept has been addressed in the case of the CEI Montegancedo by placing greater emphasis on aggregations (strategic partnerships) with the private sector.

- **“The powerful role of ICT as an enabling tool”**. The last five years have seen the dramatic acceleration of the emergence of innovative products and services in all areas of society (from personal to institutional levels) where information and communications technologies (ICT) have become a key driving factor for innovation-based competitiveness.

Today, along with the fast deployment of mobile and fixed broadband networks (achieving full coverage in all urban areas of Europe and progressively in the rest of the territory), a myriad of applications are available for users at one click through smart phones, tablets, PCs and progressively on all types of wearable devices. These applications have also penetrated corporate services (such as manufacturing, education, business intelligence or finance) hand-in-hand with the deployment of interoperable platforms, and at the individual level (e.g. for health or education purposes).

**Universities should act as drivers for accelerating change** if their (smart) campuses assume a leading role for testing the deployment of advanced services in a controlled way. The space opened up by the European Commission in some Horizon 2020 (H2020) calls for funding looking for “**experimentation spaces**” is a valuable trend.

The UPM Campus of Montegancedo constitutes an excellent experimentation platform where the UPM and its partners are deploying an innovative set of infrastructure and services (in cooperation with the CEI Moncloa and other private and public sources, where appropriate). The institutional intention was to test the applicability of immature technologies to support the accelerated development of innovative services or products working two years in advance on their possible introduction into the market (specific examples will be presented later in this report).


- **"Exploitation of research results".** All public universities (and public research centres) are under considerable pressure from public administrations to develop specific internal mechanisms in order to exploit the results of R&D projects funded by government programs. Tax payers (and governmental officers on their behalf) like to see returns from their money in terms of a better quality of life and increased visibility as the necessary social reward for the efforts made in science and technology.

Thus, universities were motivated to **protect their research results** (via patents or other IP tools) and to move protected items to the market as an institutional strategy to **"exploit" the research results.** Technical universities were even more pressed into acting in this direction as the relevance of applied research in their project portfolio made them more capable of reacting to that pressure.

The UPM reacted to this challenge with the creation of the Centre for Technology Innovation (CAIT)\(^ {12}\) in 2012 as a part of the activities funded by the CEI Montegancedo. CAIT became the main driver for supporting this change process by following other similar approaches developed in the EU.

Through its **entrepreneurship** (*actúaupm*) and **commercialisation** (*innovatech_UPM*) programs, open to the rest of the university\(^ {13}\), the UPM was able to build up and consolidate a solid reputation in Spain as the leading university in technology transfer outcomes.

- **"Contribution to the European Research Area (ERA)"**. The construction of ERA is a major milestone in the EU research and innovation strategy. All community-based R&D programs\(^ {14}\) were aligned with this objective which also affects the evolution of knowledge policies within Member States and their regions.

Since the beginning of this decade the EU has accelerated the role of innovation in its research and innovation policies. Three main milestones demonstrate this effort:

- The creation of the European Institute of Innovation and Technology (EIT) and their knowledge and innovation communities.
- The definition of H2020 as a research and innovation program for 2014-2020
- The Smart Specialisation Strategy for regional development.

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\(^{12}\) In Spanish CAIT stands for: "Centro de Apoyo a la Innovación Tecnológica (CAIT)"

\(^{13}\) From this perspective, CEI Montegancedo was not an isolated place and CAIT is working for the whole UPM community.

\(^{14}\) The period covered by the development of the CEI Montegancedo reported in this document corresponds to the EU FP7 and H2020 framework programs.
The “internationalisation” objective embedded in the Spanish program of Campus of Excellence is interpreted by the UPM in the context of the ERA goals (not only focused in the EU but also with third partner countries in the so-called “external dimension of ERA”)

The UPM has borrowed some policy elements from ERA progress which were deeply aligned with the I2_Tech objectives. Specifically, the alignment with the priorities of the external dimension of ERA and its roadmaps, the role of research infrastructures to attract talent (Masters/PhD students and researchers) and foreign investments, cooperation with Spanish industries abroad, and the lessons learned from variable geometry decision making structures. All of these issues will be addressed in the core part of this report.

Within and aside from the aforementioned general trends, the CEI Montegancedo has been instrumental in the progressive structural transformation of the UPM. From our point of view, the UPM is today much better prepared to face the coming challenges for the next decade than it was five years ago.

More specifically, the relevance of the CEI Montegancedo came from the application of an open approach for innovation and the institutional will to radiate alternative ways of addressing complex scientific and technological problems from it in order to increase both the efficiency and efficacy of available resources.

This is not an isolated case in the European university landscape; on the contrary, many other European universities face similar challenges, and they are looking for similar solutions. In the case of the UPM, the symbiotic relationships between the Schools of Engineering (the historical basis of the UPM’s organisation) and research centres (some of them jointly created with other entities) to combine postgraduate education, research and innovation required institutional attention to make it a driving force for accelerating progress. The CEI Montegancedo has pushed this model forward as a common institutional strategy.

Figure 1 schematically depicts the way that these trends influence and interact with the development of the CEI Montegancedo. Notice the intertwining of all the forces which avoids using a simple or fragmented policy approach.

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15 In a more subtle way, the support to an (implicit) internal change of mentality where open innovation, internationalisation and partnerships should be accepted by the UPM community as sources for future progress.
CEI Montegancedo and some of its funded proposals during this period have also been used as models for implementing other activities in the UPM and beyond. They were termed as “models” because there was a conscious goal of testing the applicability of new conceptual elements during their implementation and to extrapolate them to the rest of the university.

Some of the key conceptual elements pursued during these years are as follows:

- **Support to interdisciplinary work.** The benefits of interdisciplinary work are well understood as a basis and pre-requisite for acquiring efficient R&D activities in new S&T domains. The UPM had accepted the principle although discussions on the best way to address it were under way as it would require moving considerable change from conceptual discussions to implementation based on pragmatic cases.

The successes of the new “joint labs” created in the Centre for Biomedical Technology (CTB) with other universities (UCM and URJC), the new Centre for Computational Simulation, also created with research groups from URJC and UCM, hospitals (Ramón y Cajal) and research organizations (CSIC) or the participation in the Blue Brain project (BBP) where 65 researchers

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16 The number of institutional visits of delegations from private, public and governmental entities in recent years to learn from the experience has been very high. This fact was especially relevant for institutions abroad.

17 As an example of the governance consequences, the directors of these labs are researchers from other institutions.
from seven different disciplines work together have moved the interdisciplinary concept to practical implementation.

In the same way, the construction of the **UPM-Sat2** (mini-satellite for testing advanced technology on-board) by the *Instituto Universitario de Microgravedad “Ignacio Da Riva”* (IDR-CIDA) which requires multiple components to be integrated from energy to communications is also an excellent example of interdisciplinary work with the help of several firms.

- **The practical integration of education-research-innovation** with emphasis on the use of MOOCs\(^{18}\) or blended approaches (e-learning combined with face to face learning) to increase flexibility in teaching/learning experiences.

The successful participation of the UPM in the **European Institute of Innovation and Technology (EIT)** with co-location centres of the EIT Digital and EIT Health knowledge and innovation communities in Montegancedo, and similar approaches with some industrial partners (e.g. IBM, CITRIX, CISCO, INDRA, Telefónica or UCB-FARMA) paved the way to more ambitious goals by merging technical and entrepreneurship education with innovation. Shifting these experiences into undergraduate courses is well under way.

- **International vision** was pursued in the CEI Montegancedo with a three-fold objectives in mind: 1) to attract the best students, professors and researchers from other countries, teaching the academic offer in English, where necessary; 2) to increase the visibility of the UPM in other geographical areas through the creation of joint labs or double degrees with local partner entities; and 3) to participate in larger research projects or initiatives in the European context (e.g. ESA or H2020).

This effort was made by the UPM by using the funding of the CEI program as will be described later to support permanent bilateral agreements at the international level. The sustainability of this effort is a major concern which should be monitored in coming years.

- **Flexible agreements for aggregations, partnerships or strategic alliances** to recognise the specificity of each case and the need to accommodate relevant changes in the context and to ensure benefits for all parties involved in the agreements.

Note that these partnerships affect to universities, research centres or companies located in Spain, Europe or other counties with specific legislation, regulations, and administrative habits.

The UPM has avoided the use of homogeneous rules for cooperation. We were well aware of the need to adapt governance and goals to the interests of partners in a win-win approach.

\(^{18}\) MOOC: Massive Open On-line Course
Finally, the UPM has succeeded in promoting and implementing a **plethora of broad-range initiatives** where the directors or action leaders of the funded activities had enough freedom to act and to merge with the priorities of their respective units\(^\text{19}\); however, they were motivated to work together in joint activities whenever possible.

Notwithstanding the institutional initiative of the UPM around the CEI Montegancedo, it is going further than the constraints and borders of the funded actions. Other sources of funding and other internal changes have been promoted simultaneously to increase the transformational benefits of participation in the CEI program.

The UPM was (and still it is) well aware of the need to ensure a sustainable framework for the CEI Montegancedo to be able to continue the experiences and to exploit the results after 2015. In some cases, this sustainability objective only depends on the availability of economic resources, which is in turn very dependent on the European recovery process; but in other cases, a profound institutional involvement and commitment amongst the actors is also needed.

The next chapter will describe the general evolution of the CEI Montegancedo and the current situation of the so-called "**Montegancedo innovation ecosystem**". Other chapters of this Final Report will describe the activities carried out in detail.

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\(^{19}\) They were implemented as “sub-projects” where funding was coming from multiple sources.
CHAPTER 2:

General evolution of CEI Montegancedo

2.1. The CEI Montegancedo building process

The previous chapter has detailed a set of concepts and trends which have constrained and accelerated the evolution of the CEI Montegancedo from 2009 to today within the UPM’s race towards increasing its international relevance.

Based on these concepts, chapter 2 will present the evolution of the Campus during the last five years and, from the self-evaluation of its outcomes, be able to demonstrate how the relevance of the CEI Montegancedo in the context of the UPM was built and is still growing.

In this context chapter 2 will describe a high level view of the funded actions and milestones and their interaction starting from the situation of the Campus of Montegancedo in 2009 to today, in 2015. It is not necessary to detail all elements and implemented actions in this chapter because they will be explained in the following chapters of this final report; the main objective of chapter 2 is to obtain an overall view and understanding of the rationale, evolution and outcomes, and to discuss them as a basis for the near future of CEI Montegancedo.

As we mentioned before, European universities are being pressed to explore new integrated ways of fulfilling their university’s mission (in the context of the knowledge triangle) in a progressive internationalized and competitive environment. EU universities and the UPM in particular, have accepted this challenge as a part of the world-wide “battle for relevance” as mentioned in Chapter 1. The I2_Tech project for Montegancedo is part of the UPM’s armoury to face that challenge.

The institutional goal of the UPM behind I2_Tech is the creation of a “Montegancedo innovation-driven ecosystem” strongly supported by dynamic strategic alliances with public and private actors. The success of this goal will depend on the UPM’s capability of sustaining and enriching this ecosystem in the future by attracting talent, partners, firms and investments.

To understand the rationale for this ambitious goal we should accept that the development of the Campus of Montegancedo and its future sustainability goes beyond the funding support received from the CEI program. In fact, the CEI program could be considered as a key “structural change accelerator tool” in which the universities involved assume their integral modernisation as a relevant

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20 The total investment since 2006 is over €100 million and the CEI program has only provided €22 million of it (mainly based on loans to be reimbursed by the UPM in 12 years).
and desirable process, and not to see it as another funding program. An analysis of the attractiveness for getting additional funds from other sources will demonstrate its value in practice.

Furthermore, **Montegancedo is a geographically well-defined UPM Campus** (with nearly 500,000 m² mainly located in the town of Pozuelo de Alarcón, Madrid) which is owned and exclusively managed by the UPM. This situation has allowed the UPM to define its institutional strategy freely with simpler governance schemes.

Historically, the Campus has evolved very recently (in the last ten years) from a previous period where only the Faculty of Computer Sciences was in operation. In 2006, the UPM declared the Campus of Montegancedo as one of the sites of the Scientific and Technology Park of the UPM (**Parque UPM**).

The consequence of the location of one site of the **Parque UPM** was to access the open calls issued by the Spanish Government and to receive loans at very low interest rates (usually 0%) from the S&T Parks program. Note that this program had a limited impact on the multifaceted mission of universities because the objective was to support the location of high-tech companies in close cooperation with regional governments: explicit support to the educational perspective was not included.

Thus, the development of the Campus of Montegancedo benefited from two parallel and complementary sources of funding: the CEI program and the S&T Parks program. From these, other private investments were sought and catalysed.

In a few years the **construction of the Montegancedo ecosystem** was very visible to internal and external observers. Not only in terms of the creation of new research and support centres and facilities but also in terms of the number of signed agreements with public and private entities and the participation in large international research projects. Previous governmental evaluation recognised this fact with positive feedback.

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21 Since 2015 it has been known as “Escuela Técnica Superior de Ingenieros Informáticos” (ETSIIInf).
22 Other sites were located in Campus Sur (Madrid) and Tecno-Getafe (Getafe, Madrid).
23 This case can be found in the area lent by the Government of Madrid to the UPM on the Tecno-Getafe site.
24 Except when it is related to non-formalised entrepreneurship
The scheme represented in figure 3 classifies the different agreements signed in 2009 per type of entity (universities, research centres, enterprises and public entities) and the main goal of the agreement (research, education and innovation to follow the vertices of the knowledge triangle)\(^{25}\). Note that only a few agreements were signed before starting the I2_Tech project and they only represented a minor part of the UPM activity\(^{26}\).

Figure 3 also classifies these agreements as “national” or “international” depending on the company’s headquarters. This distinction is relevant because the CEI program is intended to increase and/or strengthen the international relevance of Spanish university campuses as a part of the CEI program.

\(^{25}\) In some cases, the agreements affect two or three axes. Figure 2 represents the dominant activity covered by the agreement.

\(^{26}\) The smaller agreements signed by the UPM with spin-offs or start-ups to locate them in the Montegancedo incubator are not represented in the figure.
These partnership agreements do not include those signed to develop specific research projects for a limited period of time. They reflect the will to continue the cooperation with the UPM for a long (or undefined) period.

In just a few years, the situation has changed dramatically (see figure 4). Today more than 36 long-term agreements have been signed with a large diversity of entities; many of them at the international level which is a consequence of the institutional goal to increase the internationalisation of the Campus.
This figure 4 sets out a static vision although the reality is very dynamic and new agreements will be signed in the near future while others could expire. In fact, agreements are signed and extended when both parties feel the benefits. Again, the adherence to a win-win approach is a key requirement to ensure sustainability over time. In other cases, even if the relationship with a company started in 2009, the relative strength of this interaction grew up in the period and even became international27.

This dramatic change in the evolution of CEI Montegancedo has been produced in a period of a very severe economic crisis in the EU and, especially, in Spain. Both the available resources from Spanish public administrations (i.e. from regional and national governments) and the level of cooperation between enterprises and universities have suffered from this situation. Initial estimates of the investments made in 2009 were too optimistic.

The construction of the Montegancedo innovation ecosystem should also be assessed as the role played by the Campus of Excellence from the territorial perspective. The contribution of selected universities to regional development is one of the axes of the CEI program.

In short, what is the contribution of the UPM, and specifically CEI Montegancedo, to the development of the region of Madrid? This is a controversial question because the UPM is not placing the emphasis of its activity on the territorial development as happens in other cases in the CEI program. Several reasons justify this relative “de-emphasis”.

First of all, Madrid is a small region in geographical terms without natural resources (except talent!!) and a weak historical identity. Many universities (6 public and 8 private), many research centres (both accountable to the central administration or the regional government)28, and a myriad of technology-based multinationals, SMEs or start-ups are located in the region29.

Nevertheless, the research and innovation agenda of these entities cannot be exclusively linked to relatively small local markets. They live and cooperate with others linked to global markets for their products and services. Even more, the partners of the intensive (global) research firms are selected from many places, and not just in the region of Madrid30. The evolution of the most important Spanish

27 This is, for instance, the case of IBM where from local contacts with IBM Spain the CAIT and the ETSI Inf have moved up to strong relations with IBM Research in the USA (in September 2015 a new SUR agreement (University Award) on cognitive technology intelligence was approved.

28 The central administration has the headquarters of CSIC, INIA, INTA, IEO, CIEMAT and IGME in the region of Madrid. The regional government also has several IMDEA research centres located in university campus (two of them in the UPM, and specifically the IMDEA software on the CEI Montegancedo)

29 The CEI programme has recognized the excellence of several campuses of public universities in the region. As a consequence, the regional government has a single reference point and has preferred not to support one specific campus; furthermore, regional R&D programmes reduced their budget during this period.

30 SMEs could be a different case when, even if the market became global, the partners are usually local.
technological companies reflects their wide-ranging internationalisation where revenues are increasingly obtained from outside Spain.

Madrid with 2% of the regional GDP related to R&D is well over the Spanish average (1.33%) and around the EU average; it is the same when technology innovation is taken into account (2.93% in Madrid compared to 1.38% for the rest of Spain). The consequence is that Madrid has become a dynamic hub of innovation.

In 2014 the regional government defined its **Smart Specialisation Strategy** as a part of the requirements to access structural funds promoted by the European Union. The strategic objectives are not far from the objectives of CEI Montegancedo although the main goal is to support innovative firms:

- To promote basic research in the key areas defined in the regional strategy
- To promote the effective transfer of knowledge and technology
- To promote the education of high quality researchers and attraction of talent
- To facilitate the creation of new enterprises in highly innovative sectors
- To support the industrial fabric in high value sectors.
- Development of industrial sectors though public-private cooperation instruments
- Development of infrastructures of industrial interest
- Development of the Information Society and ICT
- Adaptation of human resources to the needs of the productive sector
- Development of a technological environment

The UPM is a specialised university in which the schools of engineering and architecture cannot be constrained by the S&T demands of local (mainly SME) companies. The risk of becoming isolated from the mainstream of technology development is very high. In fact, participation in international research programs is, one of the strongest assets of the UPM, reflecting that its activity is clearly linked to high tech companies across the EU or outside Europe.

The UPM intends to become the strategic partner of these private companies. To do so, it is essential to adopt a global view in which the development of innovative science, technology, products and services is conditioned by the evolution of global markets.

This trend is particularly visible in the CEI Montegancedo. The analysis of figure 4 reflects that many of the partners are not linked to the interest of the "territorial development of the region of Madrid". It does not mean that the region of Madrid is not relevant; not at all!! Being here, it is possible to access high-tech firms or facilities not available in other places.

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31 “Estrategia Regional de Investigación e Innovación para una Especialización Inteligente de la Comunidad de Madrid” (17-9-2014). Nevertheless, the available resources in the period 2014-2020 are not very high.

32 As an example of this situation, the participation of the UPM in FP7 (with more than 200 funded projects) was mainly done in consortia-based projects where in more than 50% of them there were no Spanish companies. As a consequence, a large part of the UPM’s activity directly benefits companies abroad.
The interpretation that CEI Montegancedo has pursued in order to fulfil the CEI program commitment with the region of Madrid is based on the following three premises:

- CEI Montegancedo should contribute to the **attraction of foreign direct investments in science and technology** to the region of Madrid. It is done through participation in large research projects and the availability of technology-based platforms.

  The active participation of the UPM in the PPPs of "Future Internet" and “Big Data Value" promoted by the European Commission and a set of European companies is a good example of this attitude.

- CEI Montegancedo should help in the creation of an **innovative technology-based industrial fabric** which should attract risk capital and constitutes a source of high quality employment.

  The success of the actúaupm entrepreneurship program in the UPM (managed by the CAIT) with 18-20 new companies created annually (22 in 2014) was able to attract more than €45 M since 2007 from venture capital firms.

- CEI Montegancedo should help in the strengthening of Madrid as a **high-quality educational engineering hub** by attracting students from everywhere (both from Spain and abroad).

  The participation of the UPM in the EIT KICs (participation in EIT Digital and EIT Health is managed through centres located in Montegancedo)\(^{33}\) constitutes a very valuable approach because more than two, thirds of the students come from abroad.

In all these three cases, there is a clear benefit for territorial development in Madrid although it cannot be interpreted as simple support to local entities. The UPM is convinced of its role to serve as a catalyst for the progress of the region thinking globally.

### 2.2. Embracing the driving forces of structural change

The period 2009-2015 was strongly influenced by the recession crisis in Europe\(^{34}\). The evolution of the economic situation and its slow recovery has forced the UPM to readapt its initial plans and to limit the very ambitious economic goals initially

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\(^{33}\) The UPM is also participating in EIT Raw Materials although UPM activities will start in 2016.

\(^{34}\) Even if 2015 shows a clear recovery of Spain in GDP terms, the public budgets for research and education (nor the transfers to public universities) have not significantly increased. It has raised additional pressure to reimburse loans and made it impossible to access new ones.
set-up for the development of the CEI Montegancedo\textsuperscript{35}; fortunately, all major institutional goals related to the building of the UPM innovation ecosystem were well covered and the CEI Montegancedo is today a sound reality for the UPM.

The concept of a \textit{university-driven innovation ecosystem} which was formulated and schematically represented in the previous section (see figure 3) could not be pursued if the University (the Montegancedo Campus of the UPM in this specific case) were no able to convey the \textbf{critical mass of S&T facilities and people} (both students and researchers) to attract additional research, innovation and education activity from public and private sectors.

Thus, the definition and implementation of smart institutional policies to \textbf{ensure the level of critical mass in Montegancedo} has become a strategic challenge and concern of the UPM authorities during the last five years. The CEI program was used as the main tool for this purpose.

Figures 5 and 6 present the evolution of the CEI Montegancedo in two different time frames by using the conceptual image of the \textit{“knowledge triangle”}. In 2009 (see figure 5) the Campus of Montegancedo did not have any relevant activity in innovation (although the units performed many tech-transfer projects with the industrial sector). Only two research centres existed at that time (one of them in the process of moving), and the education dimension concentrated on the academic offer of the Faculty of Computer Sciences.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{CEI Montegancedo in 2009}
\end{figure}

As figure 5 shows, there has been a dramatic change since 2009. It is reflected not only by the creation of a number of additional research centres, the implementation of additional post-graduate education activities at the European level, or the considerable effort made to implement a number of advanced facilities to support innovation; in a non-visible way, transformations have also occurred in each of the centres in terms of equipment, researchers and internationalisation.

\textsuperscript{35} On-going conversations to install additional living labs and a research centre related to modular construction with a number of entities were postponed.
As a consequence of this evolution, the overall activity of the Campus in 2015 is much greater and diverse than it was in 2009; today, more than 1,000 faculty members and researchers work daily in the CEI Montegancedo.

To be able to ensure its long-term evolution, the UPM was also able to define the structure of the Campus with a long lasting goal in mind: to provide a close relationship between the new research and innovation centres and the pre-existing UPM engineering schools across the knowledge triangle.

The rationale behind this decision should be anchored in the historical setting of the university. In 1971 the UPM was created by bringing together 20 pre-existing (and quasi-independent) schools of engineering. This structure was complemented many years later through the creation of research centres with a multidisciplinary focus in mind. Many of these research centres located on Montegancedo (see figure 6) have strong links since their origins with specific schools of engineering of the UPM as some of the constituent research groups pre-existed in these schools.

Furthermore, technology demonstration facilities and experience labs located on the Campus were developed in close contact with other research centres and groups of the UPM located in other schools. In short, Montegancedo was not conceived as an isolated venture.

From this situation, cooperation in research activities arose in a natural way. Some of the funded actions involved researchers from several research centres, and the close contacts between researchers during these years also favoured a better understanding of capacities and opportunities.
The case of innovation was specifically promoted through the **creation of experimentation or technology demonstration platforms** derived from CEI Montegancedo activities. It was considered a natural extension of the research centres mission and was easily accepted; the movement towards **“user-driven open innovation”** was especially favoured through the use of these platforms.

Nevertheless, the educational dimension required a more detailed discussion and the implementation of specific policy measures as described in the next section.

### 2.3. New approaches for integrating the educational strategy

The integration of the educational activities with research and innovation in the CEI Montegancedo required several complementary strategies to be adopted. Globally speaking, the integration of the higher education perspective into the CEI Montegancedo reflects a structural change in the UPM. Within this process, two perspectives are relevant: personal and institutional.

At a **personal level**, UPM faculty members are free to join research centres (if they are accepted in accordance with the internal rules of each centre) but they remain members of one specific department located in one of the Schools of Engineering. Then, faculty members of the research centres located in the CEI Montegancedo keep their teaching responsibilities in one specific school.

At an **institutional level**, in 2009, it was not easy to see how research centres could contribute to the educational mission of the university with the exception of PhDs. Schools of Engineering (and their departments) were responsible for undergraduate and Masters’ degrees.

As a striking difference to the situation found in the majority of university campuses, undergraduate courses are limited in the CEI Montegancedo to one School (the ETSIInf\[^{36}\]). This situation has reduced the potential number of undergraduate students on the Campus (around 2,000 are studying in Montegancedo as compared to 30,000 undergraduate students for the whole UPM)\[^{37}\]. The potential risk is to isolate CEI Montegancedo from the mainstream of undergraduate students.

Thus, the main effort in the CEI Montegancedo was to provide a **rich environment to attract postgraduate students from Spain and abroad** by taking advantage of the location of many research centres with formal commitments in educational programs.

\[^{36}\]The former “Faculty of Informatics”.

\[^{37}\]The UPM has no strategy to increase the number of undergraduate students with new schools in the CEI Montegancedo; thus, the effort will be focused on post-graduate students.
To support this strategy, **changes in the UPM regulations** has allowed research centres to implement their own Masters’ Degrees\(^{38}\) and PhD programs (even with other institutions), and be involved in the latter years of undergraduate degrees by using their advanced infrastructure for specific labs or for facilitating the development of students’ final projects (an option which was also feasible for other Masters’ Degree students).

It is worth mentioning the **creation of new Masters’ Degree programs at an international level with other entities** (i.e. in clinical science with the University of Colorado, or through the participation in the EIT-Digital and EIT-Health knowledge and innovation communities of the European Institute of Technology and Innovation to mention just a couple of examples). Today, around 400 postgraduate students (in Masters’ Degree and PhD courses) study in the CEI Montegancedo (half of them from abroad).

Table 1 details these interactions of the research centres and their main strategic partners with Schools of Engineering. The far right column details how research centres participate in some educational activities at the institutional level.

<table>
<thead>
<tr>
<th>Research Centre</th>
<th>Main theme</th>
<th>Strategic Partners</th>
<th>UPM related School(s)</th>
<th>Joint educational activities</th>
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<tbody>
<tr>
<td>CBGP</td>
<td>Biotechnology and Plant genomics</td>
<td>INIA Campinas</td>
<td>ETSI Agrónomos, ETSI Forestal</td>
<td>Biotechnology degree Masters’ and PhD Degrees</td>
</tr>
<tr>
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<td>Biomedical technology</td>
<td>CSIC, UCM, URJC, HRyC, Elekta, Zeiss, EPFL</td>
<td>ETSI Telecom, ETSI Inf, ETSI Caminos, ETSI Industriales</td>
<td>Biomedical engineering degree Masters’ and PhD Degrees</td>
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<tr>
<td>IDR-CIDA</td>
<td>Satellite platforms</td>
<td>ESA</td>
<td>ETSI Aeronáutica y del Espacio</td>
<td>Aerospace engineering Degree</td>
</tr>
</tbody>
</table>

\(^{38}\) Except when they lead to “controlled” formal professions in Spain which should be implemented by the Schools of Engineering.
2.4. **New approaches for the exploitation of research results**

As we said in previous sections the *innovation dimension* constituted a key element in the development of the CEI Montegancedo. It complemented the research and education dimensions of the knowledge triangle and it was the main goal in the I2_Tech proposal.

Supporting it in innovative ways was behind the creation of CAIT. Figure 7 is a picture of the central building in Montegancedo where the CAIT (with its business incubator and experience labs) is located. It was funded by the regional government of Madrid (IMADE) and the CEI program.

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39 This centre will not be detailed in depth in this report because its activities are anchored in the CEI Moncloa although they have created an educational facility for GIS training in CEI Montegancedo.
The main effort towards **excellence in technological innovation** was conceived by the CEI Montegancedo under four inter-related and non-independent lines of activity (see figure 8).

As detailed in figure 8, research commercialisation, technology intelligence and experience support platforms mutually interact to increase the success rate in technological innovation. Even if **actúaupm** (the entrepreneurship program of the UPM) existed 10 years ago (but empowered in this period), the rest of the activities were promoted in the context of the I2_Tech project.
As this final report will detail in another chapter, CEI Montegancedo was the key program to obtain that “excellence” level in innovation.

### 2.5. Consolidation of strategic alliances

Throughout this report we have mentioned several times the **strategic value of alliances** between the UPM and other public and private entities as one of the main drivers of the construction of the Montegancedo innovation eco-system. Their consolidation constituted a major institutional objective for the UPM.

The strengthening of alliances with other universities and research centres is commonly found in other CEIs. Some of them were created from common proposals drawn up by several universities and research centres. This trend is firmly supported in Spain by the MECD as a policy tool to make the critical mass relevant. The UPM has adopted this view in the case of the CEI Moncloa (between the UPM and the UCM).

Another major goal (or at least a desirable goal) is to enforce a **greater interaction of public universities with the private sector**. This is the case in CEI Montegancedo.

If private entities played a strategic role in the knowledge triangle it would be necessary to change contract research agreements with individual enterprises (usually for short-term research projects as UPM did in the past) to **strategic partnerships**.

These agreements would be, where possible, linked to the three vertices of the knowledge triangle and not only in one of them. Figure 9 shows this change schematically where several instruments available at the European Union should be aligned to fulfil this goal.

Note that many instruments like the **PPPs** (public-private partnerships)\(^{40}\) are being promoted by the European Commission to align the interests of all relevant actors (also universities) and to commit resources from all parties over long periods of time.

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\(^{40}\) PPPs includes different type of instruments where commitments came from industrial sectors and administrations.
This strategy towards partnership does not mean that research projects are not needed anymore: not at all. They will continue to play a prominent role in the generation of scientific or technological knowledge; but it is not enough if the ultimate goal is to align research and innovation agendas for establishing stable and beneficial partnerships.

How to get these long-term partnerships and what should the UPM offer to do so is an open question. This was the initial question posed by the UPM itself on occasion of the drawing up of the I2_Tech proposal five years ago.

The accumulated experience showed that ensuring the involvement of private enterprises in long-term agreements with the university is not an easy task. They usually like to see immediate rewards from the cooperation. The UPM has explored the combination of several pre-existing instruments with new ones.

To use a palette of instruments allows companies to choose the most appropriate ones for their specific interests. Figure 10 positions a number of instruments used today according to the institutional commitment and the level of investment required to implement them. Note the fundamental role played by research infrastructures to consolidate these alliances.

The “cloud” intersecting all instruments refers to the need to extend the agreements to exploit research results, where necessary, with the participation of external partners.

We don’t like to convey the message that only the creation of joint entities with the private sector fulfils the ultimate goal; on the contrary, all the available instruments complement themselves and find usefulness in specific cases.
2.6. The challenge of human resources

Any university campus, and CEI Montegancedo is no exception, depends greatly on the quality of its human resources. Obviously, overall figures of the total staff working on the campus are also relevant and both aspects constitute a major challenge to ensure its international relevance and impact on education, research and innovation.

In recent years, Spanish public universities have suffered a huge problem derived from the government’s decision to freeze the number of positions to reduce the public deficit and the impossibility of filling vacancies. Combined with the natural retirement process of faculty members, all universities have reduced their payroll\(^\text{41}\). This situation has started to change in 2015 (universities are allowed to fill the 50% of the vacancies) and in 2016 will recover the situation before the crisis.

This situation has generated three types of consequences for universities:

- They have increased the average age of faculty members, making it very difficult to incorporate young professors and researchers.

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\(^{41}\) The instructions have affected both faculty members and administrative personnel.
The situation has stimulated many promising researchers to abandon the university because the current prospects for the development of professional careers are very low. Furthermore, universities have been unable to attract and retain talent from abroad (easily tempted to go to other places) with the consequence of reducing the degree of internationalisation of their staff.

As a consequence, the plans for nurturing the research centres and other units located in Montegancedo defined at the beginning of the launch of the I2_Tech project are on hold. We expect to reverse this undesirable situation from 2016.

Table 2 summarises the evolution of the human resources (faculty members and technical staff) of all units in CEI Montegancedo for the period 2010-2015. A different case is the School of Computer Engineering that suffered constraints to cover the empty positions for universities during the last years.

<table>
<thead>
<tr>
<th>Unit</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>School of Computer Engineering</td>
<td>235</td>
<td>262</td>
<td>255</td>
<td>231</td>
<td>218</td>
<td>188</td>
</tr>
<tr>
<td>CBGP</td>
<td>57</td>
<td>80</td>
<td>83</td>
<td>90</td>
<td>82</td>
<td>99</td>
</tr>
<tr>
<td>CTB</td>
<td>32</td>
<td>64</td>
<td>68</td>
<td>61</td>
<td>63</td>
<td>83</td>
</tr>
<tr>
<td>CEDINT</td>
<td>44</td>
<td>53</td>
<td>64</td>
<td></td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>CIDA</td>
<td>16</td>
<td>36</td>
<td>34</td>
<td>78</td>
<td>52</td>
<td>49</td>
</tr>
<tr>
<td>COM</td>
<td></td>
<td>24</td>
<td>54</td>
<td>62</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>CESVIMA/CCS</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>7/28</td>
<td>6/54</td>
</tr>
</tbody>
</table>

Table 2. Evolution of staff at the School of Computer Engineering and research centres on the CEI Montegancedo

2.7. Consolidating the future: Montegancedo 2020

The investment effort made by the UPM in the CEI Montegancedo (more than €100 million were invested in the last 10 years by using funding from the S&T parks and CEI program) will be very difficult to continue in the near future. The relevant question is not to discuss whether the investment was high or low, the relevant question should be posed in other terms: are we (UPM and CEI Montegancedo in particular) stronger in 2015 than in 2009? In this context, strength should be understood as a concept linked to international competitiveness; it is the only way to be able to address more ambitious S&T

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42 At least, while the public administrations orient their open calls for funding on loans and not on grants.
projects and attract more talent and investments. The definite answer to that question from the CEI Montegancedo perspective is **YES**.

The progressive consolidation of the research centres located on the Campus at the international level is both a pre-requisite and a consequence of the strength of competitiveness we have today. Nevertheless, other European universities will continue this improvement process; the **race for relevance has not finished**.

The next relevant question, and one much more difficult to answer for the UPM, is to know whether this better position we enjoy today can be upheld or improved in the years to come (e.g. until 2020). We are sure that competition will be harder and other universities (mainly from emergent economies) will enter in the battle.

During the next five years, in the advent of the year 2020, some ideas will frame its evolution. Figure 10 shows it as a **“wave” moving from the present situation towards four different corners of the CEI Montegancedo innovation ecosystem**.

Four main lines of action have been identified:

- **Energy efficiency.** There is a lot of work pending to optimize the use of energy on the Campus (both indoor and outdoor). There is also an opportunity to combine the efforts with the rest of the UPM and with CEI Moncloa by expanding the smart grids on energy generation and distribution available today. More advanced solutions for smart-lighting, green CPD (in CESVIMA) or support to electric vehicles are underway.

  In short, the CEI Montegancedo has a great opportunity to move the **“smart campus”** forward and to put it in the best location to conduct pan-European experiences.

- **Education-oriented services.** We are experiencing a great evolution in education powered by ICT. Probably the use of blended approaches (use of e-learning combined with face to face) and MOOCS in some cases will revolutionise the higher education landscape.

  The entire Montegancedo community (students, entrepreneurs, and faculty members) will massively use smart mobile devices and will access information everywhere to speed up learning experiences.

- **Research-oriented services.** The UPM does not currently need to build additional buildings in Montegancedo (unless for unforeseen needs) but to focus its efforts in purchasing and upgrading specialised S&T infrastructures where obsolescence will become a critical issue. This is a major requirement for maintaining our future competitiveness. Unfortunately, the CEI Montegancedo is located in a region with few

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43 As an example, the upgrade or substitution of the Magerit supercomputer in CESVIMA, the upgrade of the virtual reality cave, genomics platforms, cross beam microscopy, etc. Also, the purchase of new wind tunnels, medical image equipment etc.
resources from structural funds to invest in infrastructures. This fact will require innovative approaches with the involvement of enterprises.

The CEI Montegancedo could also innovate in the way that expensive material resources (scientific equipment or components) can be pooled and shared. Initial pilots initiated this year will be extended in 2016.

- **ICT platforms for innovation.** As mentioned in the first chapter of this report, ICT became the most relevant enabling technology and the CEI Montegancedo is exploiting it.

The UPM should continue the use of, and increase the living labs and experience labs located in Montegancedo. The effort should be placed towards its opening up to technology-based spin-offs and start-ups in order to accelerate the deployment of products and services. Furthermore, the full use of the accelerating facilities in the co-location centre of EIT Digital will complement it with powerful mechanisms to access pan-European venture capital.

The combination of these four areas of new ICT supported services will define the evolution of CEI Montegancedo in the near future as an expansive wave (see figure 11),

![Figure 11. An expansive wave towards 2020](image)

Finally, nothing has finished today and nothing will finish at the end of this year. The CEI Montegancedo project will continue into the future as a cornerstone of the modernisation process of the UPM.
This evolution under the name of Montegancedo 2020, following the lines of action described above will be described in the last chapter of this final report.

CHAPTER 3:

Development of the fundamental axes of the CEI Montegancedo in the period 2010-2015

3.1. Main axes in the development

This chapter 3 constitutes the main body of the CEI Montegancedo final report. The organisation of this chapter follows a thematic approach (sub-divided into the axes of the ministerial program on International Campuses of Excellence) instead of a more conventional structure focused on the individual description of the units located on the Campus (i.e. the School of Computer Engineering, the research centres, the support centres, etc.) as we did in previous intermediate reports.

The objective behind this decision is to make the idea of an “integrated international campus of excellence” visible in which all actions carried out in the period 2010-2015 mutually reinforce themselves and contribute to the ultimate goal of the I2_Tech project: to increase the international competitiveness of the UPM using CEI Montegancedo as an institutional catalyst.

The axes considered for this final report are as follows:

1. Educational dimension. It covers the regular and formal (e.g. participation in UPM degrees) and also non-regular (e.g. not related to official UPM degrees) education and training activities carried out by the units located on CEI Montegancedo for the benefit of the UPM community and beyond.

2. Research dimension. It covers the research capacities based on advanced scientific and technological equipment and participation in large international research projects. Emphasis will be placed on cooperation with public and private entities in long-term partnerships.

3. Innovation dimension. It is focused on the support of innovation activities (demonstrators or pilot projects), the exploitation of research results, and the support to entrepreneurship as the main drivers for the competitiveness of the UPM at international level.

44 For interested readers, the individual description of the units located in CEI Montegancedo has been included in the Web site of the Campus.
4. **Interaction with the environment**. CEI Montegancedo is not isolated. Relationships with the rest of the UPM, the territory (region of Madrid), scientific communities, etc. constitute the lifeblood of I2_Tech.

5. **Governance schemes**. This axis will specifically address the interaction of CEI Montegancedo within the UPM structures and the role played by the external aggregated entities.

Where appropriate, this chapter 3 will describe how these axes have jointly evolved in the period 2010 to 2015. As explained in chapter 2 the number of units and entities located on CEI Montegancedo has dramatically changed during this period and specific information on this evolution will be presented shortly.

Obviously, these axes are not totally independent and *interactions within the knowledge triangle* will be described where appropriate. Nevertheless, the intention is to show how all of them contribute to the objective of improving the attractiveness for students, researchers and entities in the creation process of the open innovation ecosystem of Montegancedo.

### 3.2. Development of the educational axis

#### 3.2.1. Main drivers

The educational mission of any university constitutes the basic ingredient of its social role. It is not different in the case of the UPM neither in the Campus of Montegancedo. As it was explained in chapter 2, there is an urgent need to set up focused programs to incorporate students (basically Masters’ and PhD Degrees students) in research and innovation activities carried out by the Campus units.

To support it, the following drivers were used for the development of CEI Montegancedo from this educational dimension in the period 2010-2015:

- **To increase the number of Masters’ Degree students**. The structure of the Campus with a number of research centres could take advantage of institutional policies focused on Masters’ Degrees.

- **To increase the number of PhD students**. Research centres constitute key elements for PhD students (today, the Spanish regulation states that there is no need to complete specific courses before starting PhD theses).

- **To increase the number of foreign students**. This is a pre-requrement for the internationalisation of the Campus. The participation in EIT and ERASMUS programs has been a relevant driver towards that goal.

- **To increase the use of blended approaches**. New approaches to combine face to face with e-learning schemes have been explored and implemented in official (embedded in academic degrees) and continuous education courses.
• **To increase internships with companies.** Specific periods have been planned within the Masters’ Degree thesis or PhD thesis.
• **To increase the number of courses in English.** The objective is to attract more students from abroad.
• **To increase the use of virtual desks.** It facilitates the continuous update of platforms and software packages in a number of courses.
• **To increase the participation in international double degrees** (both in Masters’ Degree or PhD).

### 3.2.2. Degrees offered by the School of Computer Engineering

The School of Computer Engineering (ETSIInf) is the only school of the UPM located on the CEI Montegancedo. Therefore, the majority of undergraduate students on the Campus are registered in the range of academic courses of the ETSIInf. In Masters’ or PhD degrees it is shared by the range from other research centres on the Campus. Table 3 summarises the evolution since the 2010-2011 academic year.

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Engineering</td>
<td>1402</td>
<td>1378</td>
<td>1462</td>
<td>1576</td>
<td>1576</td>
<td>1526</td>
</tr>
<tr>
<td>Master</td>
<td>202</td>
<td>162</td>
<td>147</td>
<td>137</td>
<td>133</td>
<td>No data available</td>
</tr>
<tr>
<td>Doctorate</td>
<td>222</td>
<td>236</td>
<td>218</td>
<td>197</td>
<td>183</td>
<td>No data available</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1826</td>
<td>1776</td>
<td>1827</td>
<td>1910</td>
<td>1892</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3.** Evolution of degrees and students in the School of Computer Engineering

Apart from the evolution on the degrees offered and in the number of students per academic year, the ETSIInf is also involved in other non-regular academic courses offered to external entities which will not be addressed in this document.
### 3.2.3. Participation of research centres in educational activities

The UPM regulation offers the possibility that research centres could participate in educational activities under three complementary schemes:

- Participation of members of those research centres as individual faculties
- Participation of the research centres in some subjects or labs of formal degrees under the responsibility of engineering schools.
- Participation of research centres in some Masters’ Degree programs designed and implemented by the research centres.

This section summarizes the situation in the period 2010-2015 for research centres in the last two cases. Table 4 presents a global view of the participation of the research centres of CEI Montegancedo in academic degrees.

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CBGP</td>
<td>Masters' Degree in agroforestry biotechnology</td>
<td>Masters' Degree in agroforestry biotechnology</td>
<td>Masters' Degree in agroforestry biotechnology</td>
<td>Masters' Degree in agroforestry biotechnology</td>
<td>Masters' Degree in agroforestry biotechnology</td>
<td>Masters' Degree in agroforestry biotechnology</td>
</tr>
<tr>
<td>CTB</td>
<td>Master and PhD of Biomedical Technology</td>
<td>Master and PhD of Biomedical Technology</td>
<td>Master and PhD of Biomedical Technology</td>
<td>Master and PhD of Biomedical Technology</td>
<td>Master and PhD of Biomedical Technology</td>
<td>Master and PhD of Biomedical Technology</td>
</tr>
<tr>
<td>CIDA-IDR</td>
<td>Masters' Degree in Space systems</td>
<td>Masters' Degree in Space systems</td>
<td>Masters' Degree in Space systems</td>
<td>Masters' Degree in Space systems</td>
<td>Masters' Degree in Space systems</td>
<td>Masters’ Degree in Space systems</td>
</tr>
<tr>
<td>CCS</td>
<td></td>
<td></td>
<td></td>
<td>Masters' Degree in Computer Engineering PhD program in SW and systems PhD program in systems and computation</td>
<td>Masters’ Degree in Computer Engineering PhD program in SW and systems PhD program in systems and computation</td>
<td>Masters’ Degree in Computer Engineering PhD program in SW and systems PhD program in systems and computation</td>
</tr>
</tbody>
</table>
Table 4. Participation of research and support centres in UPM degrees

A simple analysis of the table 4 shows a **steady growth in the involvement of research centres in post-graduate programs** and the added value from the use of some of their advanced infrastructures to support the development of master and doctoral thesis. This is also a good example of the beneficial intertwining of research and education promoted by the CEI program.

**Participation of CBGP in educational activities**

At the **undergraduate level**, CBGP has actively participated in the design of the curriculum of the new UPM **B. Sc. degree in Biotechnology**, currently ascribed to E.T.S.I. Agrónomos, and in its launching in the 2011-12 academic year. Since then this degree has the highest entry requirements for admittance in UPM, and has become one of the flagships of the educational renovation at UPM.

CBGP is actively involved in the teaching activities of this degree, so that students can take advantage of the facilities of this research centre. This is particularly so in matters more related to CBGP activity, or of a more practical scope, such as Plant Molecular Biology, Virology Bioreactors, Agricultural Biotechnology, Bioinformatics or Advanced Techniques in Biotechnology, which are taught totally or partially at CBGP. In addition, CBGP has been taking on Biotechnology undergraduates for external work practice, amounting to about 100 ECTs, and 11 out of 30 students from the first promotion have completed their Graduation Project at CBGP research groups. Finally, we want to mention the **Summer School**, also referred to in 3.1, a very innovative initiative launched in 2012-13, in which the most proficient students of the first and second year are given the opportunity to work for a 4 to 8 week period at a CBGP laboratory to become acquainted with research into Biotechnology. Since then, about 15 students have been following this program each summer.

Similarly, at the **graduate level**, CBGP has an active educational activity mostly centered on the **Masters’ Degree in Agroforestry Biotechnology**. Since the 2010-
11 academic year, courses amounting to 80 ECTs credits of this Masters’ Degree (65% in total) are taught at CBGP, so that, again, students can benefit from the centre's facilities and environment. Importantly, the seminar program at CBGP, which involves 30 scientific seminars annually, is a requirement for this Masters’ Degree, which gives students the opportunity to interact with first rate scientists from all over the world.

At the doctoral level, 23 PhD Theses have been completed at CBGP in the period 2010-2014.

Finally, it should be stressed that to further these educational activities, part of the funding allotted to CEI Montegancedo has been used to implement educational infrastructures. Specifically, these infrastructures (see figure 12 as example) include:

a) Building and furnishing two classrooms for about 40 people each
b) Furnishing a teaching laboratory with the suitable basic equipment for molecular biology
c) Acquiring audiovisual equipment for teaching and for enhancing the performance of the Seminar room at CBGP
d) Establishing state-of-the-art tele-conference facilities for remote audiovisual interaction

![Figure 12: Seminar Room and teaching lab (CBGP)](image)

**Participation of IDR-CIDA in educational activities**

IDR is the first Instituto Universitario (University Institute) that has proposed and Masters’ Degree in UPM and had it approved.

This Masters’ Degree in “Space systems” (MUSE, Master Universitario en Sistemas Espaciales) started in 2014, and has the support of the main Spanish space institutions, as well as ESA. The IDR facilities on the CIDA premises (Thermal Vacuum Chamber, CDF, UPMSat-2 integration room) are routinely used by the MUSE professors and students for teaching and research activities.

The idea of the MUSE Masters’ Degree studies is to take advantage of the experience of IDR members (and collaborators such as STRAST) in space
technology, for the same length of time as their participation in space projects, to offer a practical way of teaching engineering to the students.

**Participation of CTB in educational activities**

The CTB Education Programs, which has been named the Health Sciences Technologies (HST-CTB) Program, consists of a variety of postgraduate programs to provide the training needs in biomedical technology and related fields demanded by research centres, academia, industry, health centres, and health administrations. It takes advantage of an intense use of the CTB laboratories and researchers and the real immersion in the existing line of research. The HST-CTB range consists of the following programs and courses:

1. **MASTER’S DEGREE IN CLINICAL SCIENCE** Dual Masters’ Degree, UPM (CTB) - UCD (University of Colorado Denver)
   See figure 12 (from the Web page)

2. **DISCOVERY RESEARCH PROGRAM**

3. **Madrid+Vision programs (MIT)**

4. **UCB PHARMA– UPM(CTB) CHAIR Program**
The UPM participates in the Spanish node of the Knowledge and Innovation Community EIT Health of the European Institute of Innovation and Technology (EIT). Within this process, the UPM through the CTB and CAIT will start the E-Lab “EIT-Health Neuro Entrepreneurship and Innovation Lab (NEILab)” in January 2016. It corresponds to one of the Education Flagships of the EIT Digital.
The details will be summarized in the CAIT section.

EU Masters’ Degree (EIT label) in INNOVATION IN ENGINEERING FOR HEALTH

![Diagram of EIT Health master degree structure](image)

**Basic Master Structure: ECTS allocation**

**Figure 13. Structure of the EIT Health master degree.**

Summer courses in biomedical technologies are also envisaged to start in the summer of 2016 with the tentative title: “Aligning technology and health care models and vice versa”

**Discovery Research Program**

CTB open scholarship and training program to promote researcher vocations and specifically, within the biomedical technology.

As figure 14 depicts, main idea of the program is to enrol students in some labs of the CTB (mainly for preparing their final degree project) and then, to feed up the selection process for doctorate students in long term periods.
5. Madrid+Vision programs (MIT): Fellows Program and Innovation Program IDEAS2

The CTB is participating in the program signed by the government of Madrid with the MIT to support research and education activities in medical imaging. The main feature of the program is a deep involvement of hospitals of the region (see figure 15).

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**Figure 14.** Discovery program

**Figure 15.** Madrid+Vision
Education activities of the UCB PHARMA – UPM (CTB) Chair
The CTB is also pushing the interaction with big pharma companies in order to conduct advanced educational programs focused on health professionals. A university-industry chair was created with UCB Pharma and several seminars were organised with the UIMP (Universidad Internacional Menendez y Pelayo) in Santander (see figure 16)

![Figure 16. Educational activities with UCB Pharma](image)

### 3.2.4. Programs for training and education in the CAIT

One of the priorities of CAIT in 2015 is to consolidate its capacity for education and training in entrepreneurship and the commercialisation of research results as a complementary process to technical education carried out by specialised UPM departments across the schools of engineering.

Education activities carried out by CAIT are classified into three main groups:

- Participation in formal Masters’ Degree and PhD programs of the UPM,
- Participation in the specific training processes in actúaupm and Innovatech_UPM programs,
- Specialised seminars and events (e.g. summer schools, school for business angels, etc.). Figure 11 represents one of the events held in the School of Industrial Engineering.
These three approaches complement themselves but the responsibility of CAIT is also different.

The first type corresponds to the support given from CAIT staff to formal subjects in official UPM programs. More specifically, the participation in 2014-2015 has focused on some subjects in the engineering degrees and Masters' Degree in ICT (Schools Telecom and Computer Engineering) and biotechnology (School of Agriculture Engineering). The participation in EIT programs will be detailed later.

The CAIT was also very active in disseminating entrepreneurship programmes into students (see figure 17)

![Image](figure_17.png)

**Figure 17.** Business ideas presentation (*actúaupm* program) in the School of Industrial Engineering

As an example of new approaches related to the aforementioned second approach, the course on the “Commercialisation of technology” (60-hour course for UPM researchers) has reached its third edition45 (figure 18 corresponds to the leaflet of the 2014 course). Participants are selected from researchers with promising technologies and they should create a commercial sheet of their own technologies or solutions during the course.

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45 The 4th course is planned for November 2015. In 2016 this course will be offered to external participants from other universities or research centres.
Revised versions of the commercial sheets will be eventually incorporated into the technology portfolio of the UPM if they are mature enough for commercial purposes.

### 3.2.5. The activities of the CAIT in the EIT context

The *European Institute of Innovation and Technology* (EIT) was created in 2008 by the European Council after a proposal from the European Commission as a tool to work towards the effective implementation of the knowledge triangle strategy. The UPM has been successful in participating in three KICs (“knowledge and innovation community” of the EIT):

- EIT Digital ([https://www.eitdigital.eu/](https://www.eitdigital.eu/))

In all these cases, the activities focused on the strong interaction between research, innovation and higher education within the knowledge triangle. The EIT funds the innovation and entrepreneurship activities (research projects are considered as “carriers” provided by partners) and specifically, those programs oriented to offering Masters’ Degree and PhD students and entrepreneurs (an educational milieu to launch and nurture their business ideas).

Specifically, the educational process embedded in the EIT contextualises a *T-shape approach* where students should combine technical expertise in one KIC domain with horizontal skills in innovation and entrepreneurship which is the main focus of the CAIT.
**On EIT Digital**

Spain is represented in the *EIT Digital* through the existence of a **co-location centre** (CLC) in the IMDEA software premises located on CEI Montegancedo.

The EIT Digital has created a *Masters’ Degree School* and a *PhD Training Centre (DTC)* to promote the T-shape approach for new ICT professionals in Europe. Figure 19 sets out the conceptual structure of the *Masters’ Degrees*. Innovation and entrepreneurship activities count for 25% of the total effort (30 ECTS\textsuperscript{46}).

![Figure 19. T-shape educational model for EIT Digital](image)

The CAIT is participating in EIT digital with three types of funded activities:

1. **Coordination of the education and innovation learning processes in the Data Science Masters’ Degree.** The CAIT is providing the courses in innovation, entrepreneurship, commercialisation, technology intelligence and business development lab. In 2014-2015 the CAIT has designed this part of the curricula. EIT Digital has accepted 24 students (14 from abroad) to start the 2015-2016 academic year at the UPM.

2. **Coordination of the education and innovation education in the PhD Training Centre** located on the CEI Montegancedo. 6 new PhD students have been accepted to start in September 2015. The CAIT is in charge of providing them with the skills necessary to move the development of their PhD thesis to the market.

3. **Coordination of the FIWARE contest and training for SMEs.** The objective is to define a specific contest in which some selected SMEs should develop an application by using the services offered by the European supported platform for Future Internet (FIWARE). The CAIT is the responsible for business support while the School of Computer Engineering (with their help of Telefónica) to address the technical issues.

**On EIT Health**

Another relevant activity is the proposal of a “Flagship structure”\textsuperscript{47} (accepted to start in January 2016) to the EIT Health for the creation of a *Neuroscience*

\textsuperscript{46} ECTS stands for “European Credit Transfer System”

\textsuperscript{47} Flagships were defined in the EIT Health as specific structures to facilitate learning processes in innovation and entrepreneurship at the pan-European level within priority areas of health.
Innovation and Entrepreneurship Lab (NEILab). This proposal has been jointly prepared between the CAIT and the CTB (Centre for Biomedical Technology) in the context of CEI Montegancedo. Figure 20 describes the main elements of NEILab.

Figure 20. NEILab structural components

Furthermore, a proposal for a masters’ degree in "Innovation management of health systems" has been prepared and submitted by CAIT in cooperation with the CTB. The role of CAIT will be similar to that played in EIT Digital (it is also acting as coordinator in I&E).

We expect to generate synergies with the masters’ degree in EIT Digital and to be able to address the multidisciplinary masters’ degree thesis and creation of technology-based spin-offs.

On EIT Raw Materials

The CAIT with the OPE (Office for International Projects of the UPM) has generated a proposal to start in 2016 on the basis of pan-European contests for start-up creation in the field of raw materials (EuroRM). The proposal has been accepted and the final version was sent in mid-August as a part of the funded activities for 2016 and 2017.

During the first semester of 2016 an international contest with calls, selection processes, etc., should be defined. The contest will be held during the second semester of 2016 in several “nodes” (CLCs) of EIT Raw Materials.
Note that this activity is also linked to actúaupm and the experience gained in the FP7 ULab project on designing the technical university of tomorrow.

The consequence for CAIT during 2015 of its participation on all these educational activities is a dramatic shift in the effort with respect to pre-existing activities.

This is a major issue which also affects the necessary background and expertise of CAIT staff.

### 3.3. Development of the research axis

#### 3.3.1. General situation

The strengthening of research activities constitutes a key aspect of the development of the CEI Montegancedo. In this case, the relatively large number of research centres compared to one school of engineering located on the Campus, made research a key driver for the whole development of CEI Montegancedo.

From this perspective, research will be covered in this section under three main elements:

1. Evolution of publications
2. Participation in international projects
3. Availability of advanced state-of-the-art scientific equipment

Other aspects will be addressed in the specific description made by individual units.

Figure 21 represents the overall evolution of the UPM in the number of articles uploaded in the “Web of Science” (WoS) in the period 2004-2014. Note the strong growth obtained, where the initial number of publications at the beginning of the data series in 2004 has more than doubled in just a few years.
Figure 21. Evolution of the UPM documents uploaded in the WoS

Figure 22 represents the 2012 and 2014 distribution of these articles for each of the research centres and institutes of the UPM. Note that the first two positions are occupied by the CTB and CBGP respectively, both located on the ICE Montegancedo.

Note that the main research centres located in Montegancedo evolved positively even if the total number of papers from the UPM research centres were stable. CTB increased the number of papers from 66 in 2012 to 85 in 2015 and CBGP from 50 to 84. IDR had a moderate increase (from 10 to 16) while CEDINT decreased (from 30 to 16 although the figure in 2013 was 29).
Figure 22. Distribution of articles uploaded in the WoS (2014) for the research centers and institutes of the UPM.

Specifically, 45% of the total participation of the UPM is in the priority of Information and Communications Technologies (ICT) within the specific Cooperation program. These data confirm the suitability of the commitments.
made by the UPM by focusing the **I2Tech proposal** on the ICT domain during the preparation of the proposal in the call for the International Campus of Excellence. These incomes for R&D and innovation activities are also reflected in the scientific results generated.

**CTB**

The Centre for Biomedical Technology is a science and technology research centre of the Universidad Politecnica de Madrid that brings together researchers from different disciplines in biomedical technologies, in collaboration with other external institutions, in order to:

- Address major challenges in Biomedicine and Health whose success requires a stable and interdisciplinary collaboration, including both basic and translational research.
- Facilitate the development of biomedical technology to be handed over to industry.
- Create an environment conducive to the training of new researchers and professionals in this field.

The CTB has a consistent growth in the number of postdoc researchers and faculty members just spite of a decrease in the number of pre-doc students (see figure 23)

![Figure 23](image)

**Figure 23.** Evolution of CTB staff (2012-2014)

To cope with these objectives the Centre has been designed as a dynamic collaborative environment, where resources, researchers and infrastructure, together with scientific objectives have been organized as a highly interconnected matrix. On one dimension a set of well-dimensioned laboratories that cross-
fertilize their activities toward a few ambitious lines of research of the Centre, which configure the other dimension of the matrix.

As shown in figures 24 and 25, in the period covered by this report the participation in projects and the volume of grants received (outside the UPM) have consistently increased.

Figure 24: Evolution of research projects (2010-2014)

Figure 25: Evolution of external funding of the CTB (2010-2014)

This effort has generated a positive evolution in scientific publications (both in number and quality) as shown in figure 26.

Figure 26: Evolution of scientific publications (2011-2014)
a) Magnetoencephalography system

b) Microscopy (dual beam and confocal)

The CTB is organised in 12 labs (Some of these labs were created with the participation of other public and private entities). In many cases, equipment is used by all of them depending on the research activity.
The following subsections will describe main elements of these labs.

**Cognitive and Computational Neuroscience (UPM-UCM) Lab**

Neuropsychologists, physicists, engineers, and medical doctors from the UCM and UPM and other international visitors.

- **Study the relationships between cognitive functions and neurophysiological phenomena both in normal subjects and in patients with different neurological or psychiatric disorders:**
- **Functional Neuroimaging methods (MEG and EEG, MRI (DTI and Volumetry). Neuropsychological tests and genetic information.**
- **Data analysis Techniques (functional connectivity metrics, HERMES toolbox, time-frequency methods, complexity and entropy, source reconstruction).**
- **Behavioural Methods (evaluation of cognitive functions with neuropsychological tests and behavioural scales in different populations with cognitive impairments due to brain damage, dementia, and psychiatric disorders).**
- **Computational Analysis (data mining, simulation, graph theory approaches, etc.).**
- **Analysis of the oscillatory activity of the brain. Towards the understanding of brain functional networks. Biomarkers for the early detection of dementia.**

![HERMES software package](image)

**Figure 28. Hermes software package**

**Clinical Neuroscience**

The laboratory explores the cerebral basis of cognitive function in healthy people and in patients with neurological and psychiatric diseases. We are particularly interested in human memory function and emotional processing. Facilities are also
available in associated centres, including the possibility of acquiring EEG-fMRI and iEEG-MEG/EEG data simultaneously.

Based on the preoperative magnetic resonance (upper middle-left) and the postoperative computed tomography scan where the electrode artefacts can be seen (upper middle right) a fusion image of both may be created and the probability for each contact of being in a particular structural area can be computed (upper right). The figure 29 (bottom) represents the average of the activity specific for each emotional expression on the amygdala of several patients.

![Image Description](image_url)

**Figure 29**: Image Project. Collaboration with Fundación CIEN Proyecto Alzheimer Reina Sofía

**Cajal Cortical Circuits (UPM-CSIC): CCCL**

The main experimental line of research conducted at the CCCL focuses on the analysis of the microanatomy and neurochemical organization of the cerebral cortex.

**Cajal Blue Brain Project (Cajal BBP)**

The Cajal BBP is the Spanish representation within the International Blue Brain Project (BBP). The International BBP represents the first comprehensive attempt to reverse-engineer the mammalian brain, in order to understand its operation and dysfunctions through detailed simulations. The Cajal BBP is presented in three major lines of research: 1. Microanatomy of the cortical column, 2. Development and exploitation of software tools for experimental neuroscience, 3. Data analysis and visualization tools for brain simulation.
Figure 30. A: 3D reconstruction of the segmented synaptic junctions in a stack. B-D: The user can modify the position of any plane to visualize the 3D reconstructed objects.

The lab is also studying the micro-anatomical and neurochemical alterations of the cerebral cortex in Alzheimer's Disease (Cortical Alterations in AD). Figure 31 corresponds to the software developed by the Cajal Blue Brain project team to analyse the microscopic images of the brain at the ultrastructural level and to identify and determine the number of synaptic contacts in the brain automatically.

Figure 31. Espina software package.
Figure 32 shows some images showing synaptic contacts (green objects represent excitatory synapses; red, inhibitory synapses) after the reconstruction of the three-dimensionally portions of the cerebral cortex in an area without plaques (left) and in a region with plaques (middle; gray objects represent dystrophic neurites and yellow ones amyloid deposits).

![Figure 32](image)

**Figure 32.** Reconstruction of synaptic contacts

**Human Brain Project HBP**

A European Commission Future and Emerging Technologies Flagship that aims to achieve a multi-level, integrated understanding of brain structure and function through the development and use of ICT.

Through the HBP’s ICT platforms, scientists, clinicians, and engineers will be able to carry out diverse experiments and share knowledge, with a common goal of unlocking the most complex structure in the universe. With an unprecedented cross-disciplinary scope, the HBP seeks to integrate neuroscience, computing and medicine, and unify brain research, to the benefit the global scientific community. The development and use of ICT over the HBP's 10-year lifespan will pave the way for the project's ultimate goal, simulation of the entire human brain.

The HBP is developing six ICT Platforms to allow neuroscientists, clinical researchers and information technology developers to carry out diverse experiments and share knowledge, with a common goal of unlocking the most complex structure in the known universe. During its first two-and-a-half years (the Ramp-Up Phase), the HBP is collecting strategic data, develop theoretical frameworks and carry out the development work necessary to make the six ICT Platforms available for use by the scientific community.

**Nanomedicine Lab**

The Nanomedicine Lab. is made up of the Platform for Functional Characterization of Nanoparticles (a CIBER-BBN facility), and the Nanomedicine Unit (NU). The
Platform analyses the behaviour of nanoparticles that can be used as: hyperthermia agents, contrast agents for MRI and magnetic materials.

**Hyperthermia induction in living tissues (optical and electromagnetic).**

We are working on two different ways of applying optical hyperthermia, which uses gold nanoparticles as heat vectors, and on three different magnetic/radiofrequency designs, which use magnetic nanoparticles and microparticles to heat the samples.

![Figure 33](image)

*Figure 33.* Equipment for prototyping optical (left) hyperthermia systems and magnetic/RF hyperthermia (right)

Detection and identification of magnetic nanoparticles in biological tissues and the environment (intentional or contaminants).

**Biofunctionalized Nanostructures for MRI contrast** agents for in vivo early diagnosis of Alzheimer disease.

The major pathologic hallmarks of AD are extracellular deposits of amyloid peptides in the brain parenchyma that form amyloid plaques (AP) and intracellular accumulation of abnormally phosphorylated tau protein that forms neurofibrillary tangles (NFTs). Therefore, there is a great need to develop new techniques to detect these pathologic hallmarks in vivo.

![Figure 34](image)

*Figure 34.* MNPs-BTA-1 nanoconjugate in 5xFAD brain sections.
Labelling of human neural precursor cells (hNPCs) with magnetic nanoparticles for in vivo cell tracking in cell replacement therapies against neurodegenerative diseases (i.e. Parkinson’s disease). In collaboration with the “Severo Ochoa” Centre for Molecular Biology (CSIC-UAM), we have validated an efficient protocol to label hNSCs with MNPs.

**Figure 35.** Location of MNPs in 1321N1 cells using confocal laser scanning microscopy. Cells were stained with phalloidin (red), MNPs with an anti-dextran antibody (green) and the nuclei were counterstained with ToPro-3 (blue).

**Biophotonic Laboratory**

Micro-nano photonics and bio-photonics, Label-free Biosensing, Point-of-care devices, Lab-on-a-chip, Optical-readers, photonic transducers, advanced optical characterization

**Figure 35.** Optical Characterization Spectrometry optical fiber (1 nm resolution)
The "Dr. Alberto Salgado Alba" Laboratory of Technology for Healthy Ageing

The Laboratory aims to overcome the traditional disease-centred approach and focuses on one of the main health-related problems in the older people (disability) and its main risk factor (frailty). In the current context of health and care in Europe, the prevention and management of frailty and functional decline are considered critical factors for delivering excellence in care for the elderly.

The general objectives of this Lab are:

- "Understanding the fundamentals of ageing". Clinical and biological mechanisms of ageing, frailty, functional impairment, and related syndromes and pathologies.
- "Developing tools to care for older adults better". ICT-based systems and computational models for the integrated care of the elderly, including diagnosis and objective assessment via continuous, ubiquitous, and unobtrusive care.
- "Promoting autonomy". Including the prevention of decline and fostering self-management for both the elderly and caregivers.
- "Ageing and society". Economic, societal, legal, and other issues related to ageing. Studying the proper ecosystems for older people to develop an active and healthy ageing.
This lab has a joint program with the *Anschutz Health and Wellness Center (AHWC)* at Colorado University, with the participation of AHWC Commercial Ventures LLC, to develop technology and its integration into specific health programs.

**Computational Systems Biology (UPM-BBVA)**

The main research activities are devoted to a study of multistability and its control. One of the directions of research is a study of cognitive brain functions, in particular, the influence of brain noise on visual perception.

**Mechanisms behind memory and learning**

Noise-induced synchronization and multistability in neural networks are studies to reveal mechanisms for short-time memory and some neurodegenerative diseases, such as epilepsy, which may lie in the noise-induced synchronization of many neurons resulting in their synchronous collective firing.

**Biological Networks Lab**

To understand the structural and functional organization of biological systems using methods from statistical physics, nonlinear dynamics and network science, combining a comprehensive approach by mixing analytical treatment with large scale numerical modelling, and a corroboration of the entire body of predictions by means of real data analysis and experiments carried out at the laboratories of Nonlinear Dynamics & Networks and of Neuronal Cultures.

At the cellular level, we investigate self-organization phenomena in networks of in-vitro neuronal cultures during the course of development.
Figure 38. Self-organisational networks

At the macro-scale, our unique access to MEG recordings from both healthy subjects and patients suffering from different diseases, allows us to monitor the time-varying reorganization of functional networks. Together with the development of new theoretical and methodological tools aimed at describing and understanding how complex networks organize and function, with applications not only in biology but also in technological and social systems.

Figure 39. Construction, characterization and modelling of functional brain networks with tools coming from Network Science.

Bio-electromagnetism

Research into the effects on the brain of very low frequency/intensity pulsed magnetic fields, to study brain communication mechanisms and the neurophysiologic basis of pain. Development of Transcranial Low Field Magnetic
Stimulation Technology (TMS-LF), including research into stimulation protocols for specific pathologies and the design of new devices and magnetic actuators, fMRI/MEG compatible.

Development of new devices and magnetic actuators, fMRI compatible, for clinical applications and low electromagnetic fields: fibromyalgia, trigeminal neuralgia, migraine, depression, etc.

Figure 40. Spatiotemporal clusters of significant (p < 0.01, corrected) signal (suprathereshold-subthreshold) differences between patients and controls.
The application device has been authorized by the agency for medicine and health products (No. 2012 02 0783 CD) and it is now being used in clinical practice, showing results in the reduction in symptoms (pain, headache, sleep disorders, etc.) in over 80% of the cases.

**Pulsed Magnetic Field Stimulation to enhance Neurite Growth.**

The formation of new neuronal processes spatially directed by magnetic fields may be of great clinical interest in neuronal regeneration therapies, such as spinal cord sections and neurodegenerative diseases (Parkinson’s and Alzheimer’s disease).
Figure 42. Experimental design to condition axonal growth by pulsed electromagnetic fields.

Environmental EMF Dosimetry

Study of the effects of electromagnetic fields on the population: The low frequency of electric energy networks and HF (500 MH to 6 GHz) of radio communication networks.

Figure 43. Measurements made in the town of Leganes to measure the rate of environmental EMF Radiation and exhibition of the population, harvesting antenna system developed in the CTB.

Experimental Neurology Laboratory (UPM-HURyC)

Study the pathophysiological mechanisms and therapeutic opportunities for a variety of neurological diseases. We are currently developing new therapies for acute and chronic stroke conditions.

The identification of new potential targets in neuroprotective drug development as well as new strategies to induce brain repair after damage are a major challenge in neurobiology and clinical neurology and a main objective of our laboratory.
Investigate the neurogenic potential of BM mesenchyme stem cells in the treatment of strokes.

In collaboration with the Biomaterial and Tissue Engineering group at CTB, we are currently focusing on understanding how endogenous neurogenesis can be enhanced by the in vivo transplant of MSC embedded into bioactive silk fibroin (BSF) hydrogels. Our main aim is to help stroke victims recover brain function after a cerebrovascular episode.

Biomaterials and Regenerative Engineering

Design and development of new bio inspired fibres for biomedical applications, collagen-based materials applied to bio structural prostheses and cell mechanics, and scaffolds for tissue engineering.

Study the mechanical behaviour of tissues

In collaboration with research groups in different Spanish hospitals, we are studying the mechanical behaviour of tissues such as blood vessels, tendons and the pericardium.

New bioinspired fibres for biomedical applications

In collaboration with different groups we want to obtain proteins with optimized composition for the production of fibres by means of genetic engineering. Simultaneously, we are developing new ways of spinning fibres.

Cell mechanics

Study the mechanical properties of cells and the mechanics of cell adhesion to different substrates to be used in tissue engineering.
Figure 45. Lymphocyte observed by atomic forces microscopy (insert: scanning electron microscope).

The design and manufacture of biocompatible materials with controlled topologies

Single fibres, arrays and networks derived from both natural (silkworm silk fibroin) and synthetic materials (PLA-PGA copolymers) for tissue engineering applications.

Development of biofunctionalization techniques

The work in tissue engineering is complemented by the development of biofunctionalization techniques, based on the chemical vapour deposition method.

Figure 46. Device for wet spinning bioinspired fibroin fibres.
Neuromorphic Voice Processing lab

- Detection and monitoring the organic and neurologic pathology in speech
  The design of Modelling Tools for Speech Perception in Higher Auditory Pathways for Phonoetic Unit Representation Spaces and Phonemic Parsing

Based on these premises the NEUVOX Laboratory has developed several Voice Analysis Tools devoted to the Organic and Neurologic Disease Monitoring (BioMet®Phon) and Speech Discourse (BioMet®Neur) which are being currently used in the following fields:

- Organic and Neurologic Disease Monitoring from Voice Tests
- Biometrical Description of the Speaker with Forensic Capability
- Acoustic Quality Analysis of the Singing Voice
- Phonation and Speech Rehabilitation

Several applications have been developed to monitor Voice Quality in Medical, Forensic, Singing and Emotional Studies involving Phonation. The following picture shows the Graphical User Interface for Medical use.

Figure 47. Graphical User Interface for Advanced Voice Quality Analysis used in Organic and Neurologic Pathology Detection and Monitoring from Phonation.
Data Mining and Simulation Lab

The current main line of research is the analysis of Electronic Health Records. In this area both image processing and natural language processing is being applied before data analytics to capture the semantics behind the texts and to annotate images. The extracted patterns will be the basis for evidence-based medicine.

**Big Data pre-processing and analytics both with structured and non-structured datasets**

The main goal is the analysis of medical information to extract knowledge that can be the basis for evidence-based medicine.

EHR (electronic health records) analysis and understanding, which involves natural language processing, indexing and the discovery of knowledge.

MEG data analysis. Big data analytics is being applied to predict biomarkers for early stages of Alzheimer and Parkinson, as well as treatment progression identifiers for other pathologies (for instance those derived from TBI – traumatic brain injury).

Then post-processing of MEG records: With the idea of transforming MEG sensor data into an accurate estimation of deep inner sources. We apply soft computing techniques to hybrid optimization problems to fit candidate dipole distributions into the externally recorded sensor space.

**Medical image processing, analysis and understanding:**

Development of image processing algorithms and tools to assist in medical diagnosis and prognosis of diseases, as well as monitoring illnesses.

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**Figure 48.** High level architecture
3.3.2. CBGP

During the period 2010 to present, the research activity of CBGP has significantly increased in spite of the very unfavourable economic circumstances for research in Spain. This may be attributed first, to the merit and effort of the CBGP scientists who have been able to explore and successfully exploit new fields of research and new financial sources and, second, to the favourable environment provided by CEI Montegancedo. Data for the different indicators of research activity are as follows:

**Funding**

During the period 2010-2014 an average of 81 research grants and contracts have been active at CBGP. This has amounted to a yearly average of externally raised research funds of **€3.74M (€18.7M total for the period)**. Thus, and in spite of the severe budgetary reductions affecting research in Spain, CBGP researchers have been quite successful in obtaining external funds.

During this period, CBGP scientists have been able to explore and exploit new sources of funding, which is clearly shown by the fact that before 2010, 86.7% of funds raised came from Spanish Competitive Programs, while for the 2011-2014 period this figure dropped to 39.4%. Concomitantly, funding from International Competitive Programs or Research Contracts with Private Companies increased from 5.7 and 6.1% to 32.6 and 27.3%, respectively.

It is important to stress that during the evaluation period, three Starting Grants from the European Research Council have been active at CBGP, and that important research projects have been funded by the Bill and Melinda Gates Foundation or REPSOL, the leading Spanish oil company.

![Figure 49. Evolution of research funding at CBGP since its creation. (funding sources are indicated)](image-url)
Research structures
Since 2010 the CBGP research infrastructure has increased significantly with the acquisition of equipment in the following areas:

- **Metabolomics platform.** The metabolomics facility consists of a GC / MS system (BrukerScion TQ) with a triple quadrupole and robotized automatic injector; and an LC (UPLC, Ultimate 3000 and Easy nLCII) / MS /MS ESI-QTOF (microTOF-QII), all of them provided by Bruker. Instrument control, and data acquisition and processing are carried out by means of a control and data station with Bruker proprietary software.

![Figure 50. metabolomics platform](image)

- **Genomics platform.** Three real-time Q-PCR 480 instruments, for expression analyses, a High-Resolution Melting LightScanner 96 analyzer, high-throughput gene scanning analysis microarray hybridisation and processing devices for genome wide expression analyses, and robotic equipment for the automation of screening and replication of microbial colonies are available.

- **Microscopy.** A state-of-the-art, fully equipped Leica TCS SP8 confocal microscope has been acquired.
- **Image capturing and analysis equipment** including a NightOwl II LB 983 for fluorescence and luminescence applications, with an integrated CCD digital camera, a Molecular Imager PharosFX Plus, designed for imaging the most complex multifluorescence applications, detecting a wide range of fluorophores and quantifying different radioisotopes (32P, 33P, 35S, 14C and 3H), a high resolution Hamamatsu ImagEM C9100-14 camera, a Leica MZ10F Stereo Fluorescence Microscope, and an Infinite M200 Pro multimode reader, designed to cater for the needs of fluorescence, luminescence and absorbance applications.

- **Centrifugation and ultracentrifugation equipment**, including a 1,000K analytic ultra-centrifuge, with a 50.2 TI rotor and a J-26 centrifuge, with a JA-20 rotor.
- **Plant growth facilities.** Equipment for plant growth has been completed by the acquisition of growth chambers allowing vernalisation of plants, exposure to freezing temperatures, and exposure to high irradiation and high levels of CO₂.

![Plant growth chambers of the CBGP](image)

**Figure 53.** Plant growth chambers of the CBGP

- **Insect growth facilities.** An insectary has been built to allow experimentation with arthropod plant pests.
- **Biological confinement facilities.** A P2 level laboratory has been equipped and authorized, together with P2-level greenhouse space offering ample room for experiments with transgenic organisms. A P3 level laboratory has also been built and equipped, and is currently approved and fully functional.
- **A plot for field experimentation is being conditioned, which will extend to more realistic conditions in which to carry out our experiments.**

![Greenhouse facilities of the CBGP (view of one module)](image)

**Figure 54.** Greenhouse facilities of the CBGP (view of one module)

These infrastructures offer in-house and external research services, together with the metabolomics and microscopy laboratory which are part of the network of laboratories approved by the Madrid local government.
1) Human resources

131 scientists are currently carrying out research at CBGP. This includes 44 researchers with tenured or tenure-track positions and 6 junior scientists with five-year contracts from the Ramón y Cajal program, who, at the end of their contract, may access tenure-track positions. There are also 26 post-doctoral fellows, including four Marie Curie and three Juan de la Cierva fellows, and 57 graduate students, of which about 40% are supported by contracts from Spanish competitive public programs.

They are supported by 20 technicians, six of them institutionally supported, and the rest supported by grant funds. Activity at CBGP is supported by a 5-member technical staff for general services, and 6 general administration staff, including one computer expert, four administration staff, the Director’s secretary and a high-level administration officer who helps in organization, grant management and other general tasks.

Thus the CBGP human resources comprise a total of 162 people, of which 58% are women. The percentage of women at CBGP varies between 33% for tenured scientists to 68% for graduate students. Also, 18% of CBGP staff are non-Spanish citizens, including 7% of tenured scientists and 30% of graduate students. These figures underscore the internationalization effort at CBGP and its visibility and attractiveness for younger scientists from other countries.

The current human resources compare very favourably with those of 2010, that is, at the beginning of the evaluation period. At that time CBGP staff totalled 139 people of which 93 were scientists (39 permanent positions, 2 Ramón y Cajal fellows, 20 postdocs and 32 graduate students) supported by 32 technicians and the same number of people for general administration as today. In 2010, the percentage of women at CBGP was 60%, hence similar to today. However, the percentage of non-Spanish citizens was 12%, which indicates a clear progress towards internationalization.

2) Publications

During the period 2010-2014, CBGP scientists have generated a total of 337 publications in scientific journals, and a book. Most publications (279, that is 83%) were in JCR journals. Two relevant traits of CBGP scientific output must be highlighted. The first is the steady increase in yearly publications, from 44 in 2010 to 96 in 2014 (see table). The second is the high quality of the publication output, as 75% of JCR publications were in journals in the first quartile of their respective fields, and 38% in journals of the first decile.

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Table 4. Evolution of CBGP scientific output
3) **Doctoral theses**
During the evaluation period 23 PhD Theses have been competed at CBGP. Although numbers vary largely between the years, there is a clear increase in the number of graduate students completing the requirements for PhD studies, as it was 2.5/year in 2010-11 and 7.5/year in 2013-14.

4) **International congresses and events**
Two international congresses were organized by CBGP, and held at CBGP facilities, during the evaluation period.

The first, entitled "**New Frontiers in Plant Biology**" was partially funded by CEI Montegancedo, and took place on January 31 and February 1, in the context of the activities in 2013 aimed at disseminating the Montegancedo International Campus of Excellence. The event was attended by more than 150 scientists in areas of plant biology, including 15 invited speakers. The workshop focused on novel insights facilitated by the different "omic" approaches (genomics, epigenomics, proteomics, metabolomics) in the field of plant biology. The success of this meeting led us to decide to make it a series, and a second “Frontiers in Plant Biology workshop” is currently being organised to take place in June 2016.

The second was the **3rd European Workshop on Plant Chromatin**. The event took place on 29 and 30 August 2013. Ninety three scientists from fourteen different countries representing leading laboratories in plant chromatin research came together in this workshop to discuss the latest advances in this growing area of research. Thirty-two selected seminars and two conferences by invited speakers were included in the program. A report published in the journal *Epigenetics* highlights some of the new insights emerging in this growing area of research, presented at the 3rd EWPC.

![Figure 55. Posters of workshops in the CBGP](image-url)
5) Prizes

During the period 2010-2014, CBGP scientists have been awarded different prizes and awards, both national and international. Specifically:

- Elena Ramirez, was awarded with one of the five L’Oreal-UNESCO 2010 prizes “For Women in Science”.
- Fernando García-Arenal received the 2012 UPM Research Prize.
- Cristina Gómez-Casado won the first prize for the best contribution to the 2013 International Symposium on Molecular Allergology (ISMA organized by the European Academy of Allergy and Clinical Immunology (EAACI), which took place from 5-7 December in Vienna (Austria).
- Mark Wilkinson won the Prize for the Best peer-reviewed Article in the “International Academy, Research, and Industry Association’s Service Computation 2013 Conference”.
- Pilar Carbonero received a “Fundación Antama” award for Scientific Communication in Agricultural and Food Biotechnology in Spain, 2014.
- Professor Francisco García Olmedo, former CBGP scientist, was invested Doctor Honoris Causa by the “Miguel Hernández University” on January, 28th 2014.

8) International partnerships

Within the internationalization activities carried out by CEI Montegancedo, a Joint Research Centre has been created between UPM and the Universidad Estadual de Campinas (UNICAMP, Brazil), physically located in Campinas. This Joint Centre is sponsored by Repsol and by its Brazilian venture Repsol-Sinopec. After preliminary meetings and a Joint UPM-UNICAMP Workshop, held in October 2011, bilateral collaborations were established. Some of these developed into joint projects to be carried out within the Joint Centre. To date, all the joint projects are carried out by UPM researchers from CEI Montegancedo.

Among them, it is worth highlighting the “Saccharome” project. The Sugarcane Microbiome, A Key Element in Sustainability of An Energy Crop, funded by Repsol and Repsol-Sinopec, and carried out by groups from CBMEG (UNICAMP) and CBGP (CEI Montegancedo, UPM).

The Saccharome Project deals on the characterization of the sugarcane microbiome, as a key element for the sustainable growth of this crop. Brazil is the world’s main producer of sugarcane, of sugar, and of bioethanol, obtained through the fermentation of sugarcane syrup. Production is concentrated around the State of São Paulo, where the crops require limited fertilization, in such a way that, although approximately 150 Tm of biomass per hectare are taken out each season, the overall yield has not decreased for more than 50 years.

This reduced need for fertilizers is not general, as other producing countries (China, India, South Africa, Australia) need to fertilize extensively, especially as regards Nitrogen. For years it has been suspected that the microorganisms living in or with sugarcane (microbiome) are responsible for this sustainability. Despite repeated efforts, and the fact that new and interesting diazotrophic bacteria have been isolated from sugarcane, none of them can explain the high rates of nitrogen
fixation measured in the field. The recent development of methodologies for the overall study of the microbiome, through metagenomics, allows this problem to be tackled for the first time from a comprehensive standpoint, irrespective of the culturability of microorganisms.

The main goal is then to characterize the microbiome exhaustively in the different compartments of the plant, throughout the plant’s development, and including both prokaryotes and fungi. At the same time, a large (over 5,000) collection of sugarcane microorganisms has been created and is being characterized in order to study their ability to stimulate plant growth and sustainability under suboptimal conditions. The final objective is to design, optimize and produce a multi-microbial inoculant able to improve crop sustainability under limited fertilization.

This project has benefited from infrastructure provided by the UPM-UNICAMP Joint Centre, especially: confocal microscopy equipment that complements that available at CBGP; high performance growth chamber that allows growth of tropical plants such as sugarcane, and under conditions of modified atmospheres; and computer systems for metagenomics data storage and analysis. Within this computer equipment it is worth mentioning the RAID disc systems and an SGI UV200 tape backup system with 2 Tb RAM of overall shared memory, accessible by all of its 128 cores. This architecture is not common, but is required to handle the large data matrixes that Illumina-type NGS systems generate.

3.3.3. CEDINT

CeDInt (Centro de Domótica Integral – Research Centre for Smart Buildings and Energy Efficiency) is a multi-disciplinary R&D Centre. Founded in 2004 in order to strengthen a number of promising R&D areas at the time such as: energy efficiency and virtual reality with the home as the core common element, today it has evolved into wider areas of the use of ITC technologies mainly related to Energy Efficiency, Smart Environments, Internet of Things, Optical Engineering and Biometrics.

In order to develop these areas of technology it was necessary to bring together specialists from different areas of engineering: Communications, Computer Science, Software Engineering, Environmental Intelligence, Security and Biometrics, Renewable Energy, Advanced Optics and Architecture. It was this diversity of backgrounds that allowed CeDInt to begin carrying out R&D Projects from a holistic perspective. Like most research centres, technology transfer to the industry and Spin-off creation are also a priority.

Digital Manufacturing LAB: Digital manufacturing laboratory for quick prototyping and proof of concept testing.

The Digital manufacturing LAB was created with the double objective of using it as support for the projects that require it, and as a learning space to teach higher-education courses in digital manufacturing technologies. The Classroom-Workshop has been equipped with a full range of the latest generation of equipment as support to the practical learning of these courses. It has been also provided with
the elements necessary to produce content to be used for remote training and virtual courses wherever possible.

The constant use of digital manufacturing techniques by researchers as part of their day to day activity, on top of the increasing presence of these processes in industry, make the creation of specific courses and programs based on these technologies a necessary. 3D printing, laser cutting, CNC cutting milling or carving just to name a few are today integrated into the manufacturing processes not only in the early prototyping stages, but also in the production processes, thanks to economies of scale and low cost. Offering the means for high-end courses and training in these technologies is paramount to the education of the new professionals.

Starting from the existing infrastructures consisting of:

- The 1600x3200 mm, 3-axis Routing milling CNC machine.
- The Mod M2B/550 Lathe Maqelec.
- The ZCORP Spectrum 5103D colour resin dust printer.
- The MakerBot Replicator 2X3D ABS thermoplastic printer.
- The FORMTEC 450 Thermal Formation machine.

We have added the following equipment in order to extend the workshop to the new training uses:

- Workstation and accessories to operate the new 3D printers.
- Workstation I-Mac 27” with digital input accessories for 3D design, and multimedia postproduction for training media production.
- 3 visualization systems consisting of a micro-PC and a 47”screen to visualize the educational content.
- Webcams and optics to record classes and tutorials for remote training.
- Necessary memory upgrades for existing servers in order to accommodate the new services and functions for 3D training and manufacturing.
- Wide-band spectrum analyzer to ensure the correct interoperation of the elements in the classroom-workshop.
- Three autonomous cameras to be mounted in flying drones for the experimental 3D capture of terrain and buildings.
- The FormLabs Form 1+ 3D resin printer model (with resin and cleaning kits).
- The P3Steel3D ABS thermoplastic printer.
- HP network printer for use in the Classroom.
- The Secabo S120 IV Cutting Plotter.
- The TC-5 Thermal Press Secabo.
• Miscellaneous manual and electric tools for finishing projects (Makita Router, Lamelo biscuit Joiner, Makita circular saw, Adjustable frame, etc.).
• Air cleaning extraction system with particle filter system to guarantee safety.

Digital manufacturing has to be part of the training of professionals in applied sciences. To have all this equipment at hand is an unquestionable accelerator of the professional capabilities and currently a really necessary facility for the campus.

To be able to extend the reach of the courses by remote training, tele-education and multimedia tutorials make it available to more programs and audiences that may require the use of these facilities.

This classroom-workshop is another example of the innovative use of the digital technologies in industry. Is also a training tool in new manufacturing technologies and supports the research processes, thus facilitating the technology transfer to industry.

![Figure 56. Digital Manufacturing LAB](image)

**i-SPACE CAVE Environment:**

The i-SPACE infrastructure, a Cave Automated Virtual Environment consists of 5 rear projection screens arranged in CUBE (three walls, floor and ceiling) and which, in combination with the Stereo Active Infitec+ projection technology, provide an advanced fully immersive 3D visualization experience.

The CAVE infrastructure comprises the following components:

• 5 multichannel rear-projection screens: frontal + 2 lateral + ceiling + floor (4:3 format, 3.20 x 2.40 m.).
• 5 high resolution 3D projectors / video systems, 3D BARCO Galaxy 12 HB+ with DLPTM technology, native resolution SXGA+, 12000 ANSI lumens of brightness and contrast.
• 6 HPxw9400 workstation in cluster configuration with: 2 AMD Opteron 2220SE, 2.8MHz, 1MB of cache, 8GB ECC DDR2 667MHz RAM, 300GB HDD SAS 3Gb / s 10K rpm, Graphics Card nVidia Quadro FX5600 PCIe with 1.5GB of memory, DVD +/-RW 16x LightScribe, Intel PRO/1000 network card GT, 1Gibabit, Card SB X-Fi audio ExtremeAudio and Operating System Microsoft Windows XP Pro x64-bit.

• Infitec ® deLuxe tracking System and interaction devices: stereoscopic glasses, Flystick for first person navigation, ARTtracking optical tracking with 6 degrees of freedom (position and orientation), and four cameras equipped with CCD image sensors operating in the spectrum of near infrared light and two reference systems.
• Surrounding audio system based on technology 5.1.
• Virtual environment development platform.
• Very high speed network development connectivity.

Advanced Optics LAB:
The Advanced Optics LAB is equipped with all necessary precision optical equipment to allow: the analysis of the manufacturing quality of lenses and mirrors, complete characterization of light sources, characterization of optical properties of materials, defect detection, surface roughness, Far-field pattern, the measurement of luminance and spectral absorption.

The Advanced Optics Lab’s main equipment and systems are:
• 3D Scanner Laser for big pieces (LDI 3D Scanner System. Somatech ). It enables the profile of mirrors of diameter above 1 meter to be understood with a precision of less than 10 microns. One can also obtain the complete profile (3D) of lenses of any size.
• 3D Laser Scanner for parts of medium and small size (NextEngine Desktop 3D Scanner). 3D profile of lenses smaller than 20 cm in diameter is obtained with an accuracy of 1 micron.
• Profilometer (MICROMEASURE 2. 3D Measuring system. Light Tec. Stil) with a precision of up to 10 nm for measurements of flat surfaces. The device can also be used to define surface profiles.

• Microscope for the direct visualization of manufacturing defects on surfaces.

• Spectro-radiometer (GS 1252 Light Tec Spectroradiometer Gamma Scientific). With this equipment we can see the spectrum of the light source. The spectral band that can be measured is from 0.25 to 1.1μm, covering ultraviolet-visible-near infrared.

• Combined system Radiometer + Optics + Display (LUCA PHOTOMETRIC bench, Light Tec Opsira), the pattern can be obtained from any light source (headlamps, bulbs, LED's etc.). The equipment can also measure luminance, and the luminous intensity of the source.

• Light Meter/Radiometer is available (Radiometer/Photometer Light Tec DR 2000-1 Gamma Scientific) for the rapid measurement of illumination without using the above equipment.

• Xenon light source (96,000 150 W Solar Simulator, Newport) with the lenses necessary to achieve different angular distributions of light.

![Figure 58. A view of the Advanced Optics LAB.](image)

**Open IoT LAB:**

Since 2007, the IoT and Energy Efficiency Research Group has been working on networks of sensors and actuators for energy efficiency in different application scenarios (buildings, commerce, small industry buildings, laboratories and open areas). In 2012, a network based on open and standard protocols for IoT was developed. BATNet is currently the solution for Open IoT connectivity based on a network of nodes with a mesh topology that communicates through a Std.IEEE802.15.4 Physical Layer under a 6LowPAN over IPv6 to implement Link and Network Layers. The Transport Layer is UDP and the Application Layer is based on CoAP. Information encryption is carried out accordingly with AES-128.
The mesh topology has auto-configurable and auto-routing capabilities. Connection to the Internet is made through a border router that can group up to 200 nodes. The implementation has been carried out using Open Hardware, resulting in a modular and inexpensive design. The device’s firmware is Contiki OS.

**Figure 59.** BatNet topology

The strength of this solution relies on a robust communication network where the connectivity between nodes is guaranteed. Nodes are plug-and-play, so, the deployment of the network infrastructure is easy to do. Nodes are designed using a modular architecture in such a way that different sensors and actuators can be easily integrated into the nodes, obtaining different types of nodes IPv6 compatible. Some examples of nodes are:

- **BATSense** is a multisensor node that can measure Temperature, Humidity, Luminance, Background-noise and Presence detection.
- **BATMeter(singl-phase)** is a multi-sensor node able to measure electric power at 6 independent circuits.
- **BATMeter(three-phase)** is a multi-sensor node able to measure electric power at 18 independent circuits (6 circuits in each electrical phase).
- **BATWater** is a sensor node to measure volumetric flux and heat (in water pipes).
- **BATDimmer** in an actuator node that controls solid state lighting (SSL) emitted intensity from 0% to 100% (controlling dimmers both 0-10V and 1-10V).
- **BATLamp** is an actuator node to control the emitted wavelength of an RGB-SSL lamp.
- **BATPlug** is a combined node that integrates a sensor (to measure electric power consumption at the socket) and an actuator (to power up or down the socket).
- **BATStreetLighting** is a node specifically designed for urban smart lighting applications. It is a sensor and actuator combined device, including a luminance sensor, presence sensors, BATDimmer functionalities and electric consumption in each lamp.
- **BATHop** is an auxiliary node to increase the range of the network, acting as repeater.
This Open-IoT solution has been implemented in four pilots deployed in UPM Montegancedo SmartCampus: GreenLabs, SmartLighting, SmartBuilding, SmartHome. Working together with other legacy infrastructures they shape the **Open IoT LAB**. Each pilot has its function and objectives of its own, but the fact that they are interconnected and most of them geographically close, make them a unique infrastructure.

**GreenLabs Pilot:** The aim of this pilot is to monitor the electric power consumption at the greenhouses of the Research Centre for Plant Biotechnology and Genomics (CBGP-UPM). Open-IoT sensors and actuators have also been installed in one greenhouse module to check the improvement in energy efficiency due to the use of these IoT devices.

The GreenLabs pilot includes: 2 Gateways, 70 IoT-BATMeters single-phase to monitor power consumption in 420 independent circuits, 10 IoT-BATSense to measure Temperature, Humidity and Luminance in the greenhouse module and 25 actuators IoT-BATDimmers to control SSL lamps emitted power.

![Figure 60. GreenLabs Measurement Devices Installation](image-url)
SmartBuilding Pilot: The aim of this pilot is to carry out a profound study of the behaviour, from an energy efficiency point of view, of buildings. The CeDInt-UPM building has been equipped with:

- 40 IoT BATSense to monitor Temperature, Humidity, Luminance, Background-noise and Presence.
- 30 IoT-BATMeters (three-phase) in such a way that electric power consumption in 540 independent circuits is measured.
- 1 IoT-BATWater to measure volumetric flux and temperature of hot water supply.
- 1 IoT-BATLamp to control the emitted wavelength a RGB-SSL lamp.
- 1 Gateway.

This pilot is completed with 16 IoT-BATMeters (three-phase) and 17 Gateways installed in UPM buildings at Campus de Moncloa.
SmartHome Pilot: This pilot focuses on energy efficiency in homes. 20 houses with technician-inhabitants have been selected to test our solution for homes. Each home has been equipped with one Gateway, one IoT-BATMeter (single-phase) and three IoT-BATPlugs.

The SmartHome Pilot currently consists of: 20 IoT-BATMeters (single-phase), 60 IoT-BATPlugs, 20 Gateways.

![Figure 63. SmartHome Starter Kit.](image)

SmartLighting Pilot: The aim of this pilot is to demonstrate the savings made by intelligent IoT devices in urban SSL systems. It consists of 2 Gateways, 69 IoT-BATStreetLighting each of them installed in a lamp post, 2 IoT-BATPlug to control two architectural building lighting systems.

The SmartLighting system main functionalities are:

- Intelligent dimming based on presence and ambient lighting.
- Measurement of electrical energy consumption per lamp post.

After the deployment of the SmartLighting Pilot, the following saving in electrical energy consumption has been achieved at UPM Montegancedo Campus:

- 56% energy consumption savings through technology migration (HPS to SSL).
- Up to 68.8% extra savings due to the BATStreetLighting solution (depending on pedestrian transit).
- **85% of total electrical energy savings.**
High Efficiency PV Module: This infrastructure consists of two high-performance photovoltaic arrays with a tracking system and serves multiple purposes within the campus. Each array has a different type of PV cell technology implemented, sharing the Concentration lenses and the tracking mechanisms. This distribution allows the efficiency of the different technologies of each cell type and lifespan to be compared over large periods of time. Each Array has a theoretical production power of 12.5 Kw/h totalling 25Kw/h that will not only make the campus more sustainable by reducing consumption from the public power grid, but also will be integrated with BatMeter monitoring technology and other experimental micro generation systems in a heterogeneous campus micro grid extending the reach of application of the BatNet technology to the monitoring of the renewable energy sources.
CeDInt Showroom: This infrastructure aggregates multiple demonstrators related to finished projects and ongoing pilots of all the research areas of CeDInt: Energy Efficiency, Internet of Things, Optical Engineering and Biometrics.

In this facility visitors and researchers can see and work with live real time demos and working prototypes of the most relevant projects. The most relevant demonstrators are:

Energy Efficiency:
- DENISE Smart grid project prototype.
- e-medición Smart Metering early technology prototype.

Optical Engineering:
- Ultra-compact Projection System.
- Multiple LED lighting designs and applications.
- High Efficiency Concentration PV cell prototype.

Integrated with the open IoT LAB
- BatStreet Lighting control application demonstration.
- Green Labs Monitoring and Control Application Demonstration.
- BatHome Application Demonstration and Hardware Prototypes.
- IAm Ambient intelligence device demonstration.
- Bat DEVICES: Showroom of devices and prototypes developed under the BatNET Open technology umbrella for specific applications.
- Industry standard KNX, LongWorks, DALI, X10, and enOcean networks installed and interconnected to test legacy technologies with Open IoT.

Figure 66. CeDInT Show Room
Renewable Energy Experimental Micro grid: Installed in CeDInt building premises there is an experimental micro grid integrating 2.25 Kw/h Photovoltaic panels, 1.2Kw/h wind turbines, storage batteries and associated converters both for AC and DC.

![One of the installed Wind Turbines](image)

Figure 67. One of the installed Wind Turbines

**CeDInt Large international projects:**

**INSIGHT** (Innovative Policy Modelling and Governance Tools for Sustainable Post-Crisis Urban Development) is a research project funded under the ICT Theme of the European Union’s Seventh Framework Program. INSIGHT aims to investigate how ICT, with a particular focus on data science and complexity theory, can help European cities formulate and evaluate policies to stimulate a balanced economic recovery and a sustainable urban development.

For more information visit: [http://www.insight-fp7.eu/](http://www.insight-fp7.eu/)

**NGCPV** The Project, through a collaborative research between seven European and nine Japanese leading research centres in the field of concentration photovoltaics (CPV), pursues the improvement in current concentrator cells, module and system efficiency. A special effort will be devoted to the development of multi-junction solar cells (by researching metamorphic, lattice match, inverted and bifacial growth, use of silicon substrates and the incorporation of quantum nanostructures) with the objective of approaching the goal of 50% efficiency at the cell level and 35% at the module level (by incorporating advanced optics such as Fresnel-Kohler concentrators).

As a means of speeding up the progress, the Project will also expand the use of characterization techniques suitable for CPV materials, cells, trackers, modules and systems by developing new ones, incorporating advanced semiconductor techniques into the field of photovoltaics (such as three dimensional real-time reciprocal space mapping, 3D-RTSM, piezoelectric photo-thermal and optical time-resolved techniques) and by deploying a round robin scheme that allows the
qualification and standardization of the results derived from the measurements. To support all these studies from an overall perspective and, in particular, to ensure an accurate forecast of the energy produced at the system level, the Project plans to build a 50 kW concentrator plant.

For more information visit: http://www.ngcpv.org/cms/

**CPSE Labs** is a European Union-funded initiative with a mission to support small and medium-sized businesses which engineers or operates dependable cyber-physical systems (CPS) in Europe. We can provide funding and technical support for experiments which are designed and proposed by the businesses themselves. Experiments can focus on facilitating innovative and CS-enabled value chains in the European marketplace, demonstrate innovative CPS design technologies, or concentrate on the design of innovative new CPSs.

For more information visit: http://www.cpse-labs.eu/

**PCAS** (Personalized Centralized Authentication System) aims at providing an innovative, trustworthy, handheld device. The Secured Personal Device (SPD) will allow users to store their data securely, to share it with trusted applications, and to authenticate them easily and securely. The SPD will recognize its user using multiple biometric sensors, including a stress level sensor to detect coercion. Using the same biometric authentication, the SPD will be able to enforce secure communication with servers in the cloud, releasing the user from memorizing passwords.

For more information visit: https://www.pcas-project.eu/

**CeDint International Conferences:**

**JVRC 2012:** (Joint Virtual Reality Conference) is the meeting point for representatives of industry, integration and R&D for all VR-related environments including Augmented Reality, Mix Reality, 3D visualization, interfacing with the virtual environments, teleexistence, etc.

The 2012 edition continues the collaboration established at Lyon 2009 among:

- The 8th European Virtual and Augmented Reality Conference (euroVR)
- The 17 symposium Eurographics on Virtual Environments (EGVE)
- and The 19 International Conference of Artificial Reality and Teleexistence (ICAT)

The conference is built around four distinct participation tracks: Scientific Track, with presentations, papers and posters linked to the latest advances in R&D. Industrial Track, with presentations where industry leaders present the latest technologies embedded in their products to build state-of-the-art solutions. Demo Track, where both scientists and industry show live demonstrations of existing solutions. And finally Exhibition Track, where the latest products, services and solutions of the industry that are the building blocks of the RV, RA or tele-existence solutions can be seen.
Demonstrations and outstanding innovations this year were:

- Haptic systems capable of recording and playback of tactile sensations.
- Multiple degrees of freedom haptic systems.
- Next generation of 3D graphics engines.
- Disaster training simulation.
- General training augmented reality applications.
- Holography and stereoscopy.
- Advanced Image formation for 3D environments.
- New natural user interfaces and intuitive navigation.
- Sustainable architecture.
- Total subject immersion virtual environment games (on CAVE).

In this edition we had more than 120 participants from more than 18 countries as well as all relevant equipment manufacturers related to VR solutions, showing and demonstrating the latest technological advances and products available.

![Figure 68. The CeDInt JVRC 2012 organization team.](image)

**CeDInt awards:**

- Profesor J. C. Miñano: SPIE Conrady Award (2010)
- KNX Award (Young project) (2010)
- IV Treelogic Innovation Award (2010)
- Jose M. Infante: Kidger-Moore Optics Achievement Award (2011)
- ComputerWorld Honors Award to project CRANEO (2011)
3.3.4. CIDA

The CIDA centre located in Montegancedo is made up of two separate units: IDR-CIDA (facilities located in Montegancedo at the Ignacio da Riva Institute of Microgravity, IDR-CIDA) and the User Support and Operation Centre of the ISS (E-USOC CIDA).

3.3.4.1. IDR-CIDA

Figure 69 depicts the evolution of the IDR-CIDA staff. Note that the relative decrease in the number of faculty members (a consequence of the ministerial rules to cover vacancies) has been widely overcome with new research contracts and PhD students.

Figure 70: Evolution of IDR-CIDA staff (2010-2015)
IDR (CIDA) is participating in the main missions of the ESA Scientific Program

- Rosetta (http://rosetta.esa.int/)
- Solar Orbiter (http://sci.esa.int/solar-orbiter/)
- Exomars (http://exploration.esa.int/mars/)
- JEM-EUSO (http://jemeuso.riken.jp/en/)

in cooperation with some of the most relevant scientific institutes: for instance, the OSIRIS cameras for Rossetta mission were provided by a consortium of 9 institutes from 5 European countries and from ESA, under the leadership of the Max-Planck-Institute for Solar System Research (MPS) (Main Researcher: Holger Sierks). The participating institutes of the consortium are: LAM (Marseille, France), UPD (Padova, Italy), IAA (Granada, Spain), University of Uppsala (Sweden), ESTEC (ESA, Noordwijk, The Netherlands), UPM (Madrid, Spain), INTA (Madrid, Spain), IDA (Braunschweig, Germany).
Figure 72. Comet 67P/Churyumov-Gerasimenko by Rosetta’s OSIRIS narrow-angle camera on 3 August 2014. IDR was a member of the international consortium responsible for this camera.

Credits: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/The IDR-CIDA has participated in the period covered by this report as a member of international consortium in the following missions of ESA and NASA:

The IDR-CIDA participates closely in the test services offered to industry. Figure 73 depicts the evolution in a large period of time.

![Wind tunnel tests](image)

**Figure 73.** Wind tunnel tests

These activities have allowed IDR-CIDA to participate in multiple emblematic projects. Figures 74, 75 and 76 show some of the tests carried out.
Figure 74. Left: Zaragoza airport control tower (2010). Right: Tower in Ryad (2013)

Figure 75. Left: Dumbo heliostat (2012). Right: Stirling disc (2014)

Figure 76. Airfoils for wind turbine blades (2015)
Another relevant area of activity of IDR-CIDA is the development of mini-satellites. After the successful launching of the UPM Sat-1, another satellite (see figure 77) the UPM Sat-2 has been designed and built (waiting for launch in 2016).

![Figure 77. UPM SAT-2](image)

To facilitate the development of satellite platforms, a concurrent engineering facility was made operational in 2012 to support the requirements of the engineering phase, and an advanced “thermal vacuum chamber” is being used for testing payloads or components under space conditions.

![Figure 78. Concurrent Engineering facility](image)
Within the satellite program that IDR-CIDA is developing, the UNION/LIAN-HE - UPMSat 3 is being designed in collaboration with the University of Beihang.

Summarising, the main scientific and technical equipment installed in the last five years is:

- Thermal vacuum space-test laboratory (INNPLANTA project for scientific facilities Investment: €400,000, 2010-11)
- Concurrent engineering Facility (in agreement with the ESA. Investment: €200,000, 2012-13)
- Design laboratory and prototyping
- Vibration space-test laboratory (new shaker. Investment: €45,000. 2015)
- AB-6 wind tunnel for testing airfoils of wind turbines (in agreement with GAMESA)
- ACLA-16 Atmospheric Boundary Layer Wind Tunnel
- S4-A and S4-B. Two wind tunnels which satisfy the specific requirements imposed by the calibration of anemometers for several applications.

Finally, it is remarkable that Isabel Pérez Grande (Member of IDR) has played a significant role in high-level advisory structures of ESA:

- Chair of the Physical Sciences Working Group (PSWG)
- Member of the Human Spaceflight and Exploration Science Advisory Committee (HESAC).
3.3.4.2. E-USOC-CIDA

The E-USOC (Spanish Users Support and Operations Centre) is an aerospace R&D centre. The centre is delegated by the European Space Agency (ESA) to prepare and implement the operations of microgravity experiments in the International Space Station (ISS). The E-USOC was appointed in 1999 as a Facility Support Centre (FSC) for the Fluid Science Laboratory (FSL) on board the Columbus module in the ISS. Due to the Space Shuttle Columbia disaster in February 2003, the launch of the Columbus module and the development of the USOC network infrastructure was largely delayed, but in February 2008 the Columbus module was launched and integrated into the ISS, and operations started.

E-USOC was selected by ESA as the centre responsible for GeoFlow, which was the experiment selected by ESA as a demonstration of ESA's teleoperation capabilities in the ISS.

The E-USOC successfully carried out the experiment, but that was only the beginning of its activities. Today the E-USOC is also responsible for all ESA experiments carried out in the Material Science Glovebox (MSG), a multipurpose facility owned by NASA and currently installed in the US Lab, in the ISS.

In order to fulfil that task, E-USOC had to design, implement and validate a new operations infrastructure to allow direct communication with the ISS via NASA's Payload Operation and Integration Centre (POIC). The first experiment successfully performed in MSG was the SODI-IVIDIL experiment, in August 2009.

![Astronaut Bob Thirsk installing the IVIDIL experiment into the microgravity science glovebox (MSG) on board the International Space Station.](image)

E-USOC has carried out the following experiments in the ISS:

- GEOFLOW in 2008
- IVIDIL in 2009
- FOAM-S in 2009
- COLLOID in 2010
- COLLOID-2 in 2011
- EPO FOAM-Stability in 2012
- GEOFLOW-2 in 2012
- GEOFLOW-2B in 2013
- DCMIX-2 in 2014
- DCMIX-3 was sent to the ISS in 2014 on board Orbital 3, which unfortunately crashed

E-USOC is preparing the following experiments which will be sent to the ISS in the coming months:
- DCMIX-3
- TA-1 SEBA
- TA-1 SETA

E-USOC has wide-ranging theoretical and experimental experience in liquid bridges, but in recent years it has widened its research by developing new lines of researchs such as: stability of vibrated fluid interfaces under conditions of microgravity, thermal energy storage under conditions of microgravity and nanosatellite technology.

E-USOC has 17 researchers (4 of them faculty members of the UPM) and 6 PhD students in 2015. For comparison, in 2009 EUSOC had 11 researchers (with only 3 faculties).

**Infrastructure**

E-USOC has the infrastructure necessary to carry out the activities related to ISS operations, which include:

- A control room
  - A console for the ground control position
  - A console to operate experiments in ESA’s Columbus module
  - A console to operate experiments in NASA’s MSG
  - A security console
- A service room with the communications infrastructure necessary to receive real time telemetry, voice and video from the ISS, and send commands to the experiments on board.
- An ISO-8 clean room to host the engineering models of the experiments. The models are integrated with the E-USOC systems in order to prepare and validate the operational products
In order to develop its new lines of research, and since 2009 the E-USOC has implemented the following new laboratories:

- **Fluid physics laboratory:**
  - A specially constructed dual-axis experimental set-up capable of independently vibrating a container of fluid in the vertical and horizontal directions. Vertical driving is provided by a VTS-150 shaker while horizontal driving is provided by a VTS-100 shaker.
  - High speed camera
  - Infrared laser: 200W, 80 microsecond, 808nm
  - Optical Table: 2m x 1.25m x 0.21m
  - Fibre Optic Illuminator (two units)
  - Amplifiers (two units)
  - Digital to Analogue Converter
- Oscilloscope
- CNC Robotica milling machine.
- V110-RM contact transducer function generator.
- Assortment of small optical devices (lenses, mirrors etc.), mechanical equipment (construction railings, connectors, etc.), and electrical equipment (computers, converters, etc.) necessary to measure and record the experimental data.

- **Manufacturing laboratory:**
  - 4-axis CNC machine
  - Lathe
  - drill press
  - disk saw
  - grinder
  - assortment of small mechanical equipment

- **Electronics laboratory:**
  - digital power meter
  - oscilloscope
  - wave signal generator
  - digital probes
  - solder station
  - oven
  - PCB manufacturing equipment
  - source powers
  - assortment of small electrical equipment and components

- **Spacecraft laboratory:**
  - ISO-8 clean room with a 2m x 1.25m x 0.21m optical table (Thorlabs, PTR51508,PTP503
  - vacuum chamber
  - ground station with a tracking antenna for UHF and VHF bands
  - assortment of small thermal equipment

![Figure 83. Dual-axis experimental set-up capable of independently vibrating a container of fluid in the vertical and horizontal directions](image)
E-USOC main international projects:

**QB50:**

The QB50 project is funded by the 7 Frame Program. The QB50 mission will demonstrate the possibility of launching a network of 50 CubeSats built by University Teams from all over the world as a primary payload on a low-cost launch vehicle to carry out first-class science in the largely unexplored lower thermosphere. E-USOC is responsible for the design, manufacture and testing of one of the QB50 CubeSats.

The QBito satellite developed at E-USOC will carry the following payloads:

- Ion-Neutral Mass Spectrometer (INMS)
- Phase Change Material, in collaboration with Wallop, Belgium
- MIR Sensor (MIRS), VPD PbSe technology in collaboration with NIT, Spain
- Experimental Software for Altitude Control

And has the following subsystems fully developed in house:

- Electric Power System
- Antenna deployment mechanisms
- Structure
- Communication System
- Thermal Control System
- On board software
- Ground Station Communication System

The QBito satellite has already been manufactured and is currently in the validation testing stage. The tests are being carried out with the support of AIRBUS D&S and SENER who have established collaboration agreements with E-USOC.
The constellation will be launched in June 2016 from the ISS.

**Figure 85.** Integration of QBito’s solar panels before the shock test. QBito has an INMS payload, solar panels, deployed magnetometer, PCM external interfaces, altitude control system camera, IR detectors and GPS antenna.

**Fluid physics in microgravity**

Since 2011 E-USOC has actively participated in the ESA sponsored Topical Team on vibrated fluid interfaces. Collaborations have been developed with Team members including Michael Bestehorn (Cottbus, Germany) and Valentina Shevtsova (ULB, Belgium).

E-USOC is part of the scientific team preparing the Vibrational Phenomena in Liquids (VIPIL-FARADAY) project, which was approved in the ESA-ELIPS program (AO-2009-1061/103). The project, coordinated by V. Shevtsova and Farzam Zouestiaqgh (Lille, France), is currently in the pre-definition phase.

Other teams collaborating in the project are: the team led by Daniel Beysens (ESEME, France), the team led by Tatyana Lyubimova (PNRPU, Russia) and the team led by Satoshi Matsumoto (Jaxa, Japan).

Several parabolic flight experiments have been granted by ESA, by Belgium and by CNES.
E-USOC awards

- José Miguel Ezquerro Navarro, Zeldovich Medal for Young Researchers, from the COSPAR and the Russian Academy of Science, 2014
- Ana Laverón Simavilla, Jacobo Rodríguez Otero, José Miguel Ezquerro Navarro and José Javier Fernández Fraile: ESA ISS Awards 2013

Relevant positions or E-USOC staff:

- Ana Laverón Simavilla
  ▪ Member of the Council of the Ministry of Public Works and Transport
- Jeff Porter
  ▪ Member of ESA's Topical Team on Vibrated Fluid Interfaces in microgravity
- Jacobo Rodríguez Otero
  ▪ Active member of ESA's Payload and Operations Data File Working Group (PODFWG)
- José Miguel Ezquerro Navarro
  ▪ Active member of ESA's and NASA's Payload Operations Integration Working Group (POIWG)

Figure 86. Ana Laverón Simavilla and José Miguel Ezquerro Navarro receiving the ISS Award from ESA astronaut André Kuipers and ESA astronaut Thomas Reiter and current Director of ESA’s Directorate of Human Spaceflight and Operation
3.3.5. Centre for Open Middleware (COM)

The Centre for Open Middleware (COM) is a joint technology centre, created under the agreement signed with Banco Santander, ISBAN, PRODUBAN, UPM in October 2011 (approved by the Governing Council of the UPM on 26/1/2012. It has not got an independent research centre legal status, but performs under the regulations of UPM for joint technology initiatives, and implements research, innovation and transference activities led by UPM staff as well as from founding companies.

We devise an open, self-sustained, innovation-fostering, software ecosystem around middleware. COM is the incubator of this open ecosystem: it turns ideas into innovation and v agents to keep this innovation alive.

The COM staff comprises professionals from founding companies, as well as UPM professors and researchers. The UPM staff in COM currently comes from several UPM research groups:

- Computer Networks and Web Technologies Lab
- Distributed Systems Laboratory
- Group Internet New Generation
- Lab of Operating systems
- Ontology Engineering Group (OEG)
- Real time systems and Architecture of Telematics Services (STRAST)

Specifically the main technical goals for COM are:

- To develop an open source environment to be used by software developers in the banking domain and other industrial sectors and build up an ecosystem around it.
- To experiment new approaches for the design and implementation of component-based software architectures for distributed complex systems.
- To develop joint research initiatives around the key topics.

Main lines of research are:

- Methods and tools for the development of services and middleware.
- Open middleware architectures: services oriented architectures (SOA), complex event processing (CEP), unified communications.
- Autonomous systems, operation, infrastructure, cloud computing and IT governance.
- Content management and lifecycle: collaboration support, interoperability, big and social data management.

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48 In its most general meaning, middleware is any piece of software between the operating system and final applications, and takes care of software components, use of resources and network capabilities.
Thus, the line of research brings together software engineering, software technology and distributed software including Internet services. Topics were selected for their innovation potential, interest for the industrial partners and expertise of UPM research groups. In any event, COM carries out exploratory research which finishes once a Proof of Concept (PoC) is built; afterwards the creation of prototypes, industrial strength or products becomes out of the scope of the centre.

The line of research are developed by means of multi-year joint projects, so far:

- model driven software development: covering the application of model-based techniques for the definition of requirements, design and testing of banking applications. Most of the work has the eclipse technical ecosystem as a base.
- complex event-driven platforms: evaluation of platforms for managing customer events.
- social financial services: development of innovative financial services that rely on social networks for communication and interoperation.
- responsive web and mobile platforms: design of responsive platforms to be implemented on mobile devices offering rich interfaces for access to banking applications.
- big data infrastructures: identification, evaluation and selection of software infrastructure elements for storage and computation of big data under industrial restrictions.
- devops and Smart configuration and deployment: working on a banking platform, the project proposes the use of advances in analytics and feature engineering to reduce the burden of configuration and deployment of platforms and applications.
- predictive analytics for IT operation: research into algorithms for predictive analytics to be applied in the monitoring and management of large IT infrastructures.
- optimization of WAN networks: application of deduplication and similar techniques to reduce the wide area network traffic.
- application lifecycle management: the project provides a complete distributed toolset to manage the complete lifecycle of applications ranging from design workflows to the management of incidences, using semantic technologies.
- semantic technologies for natural language queries: development of natural language processor to query big databases.
- launching and growing an open middleware ecosystem: research into methods, techniques, organizational rules and processes used by large Open Source communities.
- quality improvement for PaaS software: the application of machine learning algorithms on code bases in order to detect levels of quality and predict their potential for failure.

The staff working at COM comprises:

- Researchers, under contract with UPM, some of whom are developing their
PhD theses on topics related to the projects.

- Student grants from ETSI Telecomunicación and ETSI Informática of UPM.
- UPM Professors, working part time at COM.
- Students following the Summer Camp – a packaged set of activities as an introduction to industrial research that has taken place in 2013, 2014 and 2015.
- Santander staff, some of whom collaborate in COM projects.

The evolution of the staff is detailed in the following figure.

![Figure 87. Evolution of staff of COM](image)

Without considering Summer Camp students, the distribution of staff is as follows:

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPM staff</td>
<td>29</td>
<td>50</td>
<td>58</td>
<td>45</td>
</tr>
<tr>
<td>Santander</td>
<td>15</td>
<td>15</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>TOTAL</td>
<td>44</td>
<td>65</td>
<td>76</td>
<td>67</td>
</tr>
</tbody>
</table>

Table 5.

COM operation and projects are completely funded by the companies that signed the agreement.
So far, incomes have been:

<table>
<thead>
<tr>
<th>Year</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget</td>
<td>754615</td>
<td>1661323</td>
<td>1907983</td>
<td>1632581</td>
</tr>
</tbody>
</table>

Figure 88. Evolution of funding 2015 (Q1-Q3)

Despite the short length of time since its creation, a lot of work has been carried out in an innovative way, which demonstrates the usefulness of this approach. We divide outcomes into three topics:

**Cooperative industrial research:**
- research-friendly environment: 1 large hall, 4 meeting rooms (1 video-conference), 2 classrooms, work rooms with 88 fully equipped desks, future banking living lab. Rack with servers, property of UPM, hosted on Produban.
- collaboration-research consulting through 14 technical projects.
- joint participation in 3 EU proposals.
- 19 OSS projects in github, 15 of them public releases.

**Outcomes in knowledge transfer:**
- two-weekly seminar sessions on innovative topics: 11 sessions 2013-14, 8 sessions 2014-15.
- actuacom contest: 3 prizes for innovative companies and research groups, after a 4-month training program and selection, given May 2014.
- 18 video sessions of seminar in UPM youtube canal –Seminarios COM
- support in the creation of Localidata and Nubadat university spin-offs,
- contacts with several companies interested in the COM topics: Indra, Bull,
VectorSF, quantobit, atSystems.

Academic outcomes:

- 8 grading Works (Grade, Master Thesis).
- 22 contributions to conferences, workshops and journal articles.
- AWARDS for Asunción Gómez (see ETSI Inf description)

### 3.3.6. CCS (Centre for Computational Simulation)

The Centre for Computational Simulation - CCS, was approved in January 2015. Its objective is to aggregate most of the research in Computational Sciences and Engineering at the UPM in order to create critical mass, attract talent and have the flexibility to tackle new projects, especially international and together with industry.

It was born as a UPM research centre, but it incorporates research groups from two other universities: UCM and URJC. It is expected that during 2016, after the formal approval process it will become a Centre in which the URJC participates fully. Long term plans call for the participation of other universities in order to become a centre of reference.

Right now, in its first iteration, it comprises 54 PhD members who are staff members from the three participating universities. Including the non-staff members (staff contracted by research projects at CCS) there are over 100 researchers in the Centre.

The Centre is structured along four main areas and another, complementary one: Big data analytics, Large-scale numerical simulations, Visualization and Data Interaction and New Computational Models and Algorithmic, complemented by an area of associated technologies that currently includes efficiency in ICT, especially in Data Centres.

The current area of large-scale numerical simulations also includes a section on industrial cooperation. This is so because the members of this area have a long standing career of collaboration with industry and many ongoing projects. The expectation is that this section will grow into a separate department in the short term.

A description of the current **research areas** of the Centre:

**Big Data Analytics:** This is a key area that is growing rapidly, representing the need to analyse and mine large Big Data repositories. Big Data evolves in the context of complex data management in which the 4 V’s identify existing challenges, namely: Volume (increasing amounts of data), Velocity (speed of data produced and consumed), Variety (different data types, and sources) and Veracity (data use to achieve informed decision-making strategies). The growth in Spain for 2012-2014 is more than 300%.

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Its impact on other technologies related to HPC is also very large, since Big Data applications often require significant simulation and visualization capabilities and, more recently, it is also used to extract knowledge out of large simulations. The term Big Data Analytics (or Big Analytics)\(^{50}\) refers to combined data analysis, mining and exploration techniques tightly coupled with Big Data technology and needs.

Big Data benefits greatly from the HPC infrastructure: close to 70% of supercomputing sites regularly run big data analysis, using around 1/3 of the cycles\(^{51}\). The need to carry out a large-scale data analysis is starting to be a golden ticket not only for large corporations but also in scenarios in which incipient SMEs can exploit large open-accessible repositories to create business opportunities.

The area of Big Data Analytics complements many of the Simulation-Based areas, providing the researchers with new tools for discovering knowledge hidden in the data they produce or analyzing incoming data to identify useful patterns to construct simulation models.

**Numerical Simulation (+Industry):** This is the traditional area of HPC application. Large numerical simulations are still one of the key supercomputing applications, from computational fluid dynamics to global warming, passing through mesoscale environmental simulations, combustion, etc. It is relevant to highlight that the UPM excels in several of these fields. The corresponding applications are also starting to be enriched with less traditional numerical techniques that are represented in other areas of the centre: Results and initial conditions for many numerical simulations are increasingly complex and are starting to require techniques or processes related to Big Data or advanced visualization.

The area also has a direct impact on industry. As the aforementioned digital manufacturing initiatives highlight, the advanced simulations enabled by HPC are seen as a fundamental skill to improve the competitiveness of a country. This area will also interact with SMEs through joint focused projects.

One of the objectives of the centre is to increase the effort devoted to SMEs, developing it into a full department in the short to mid-term. However, as a starting point, the industrial relations programs will belong to this area since it is the closest to direct industrial applications and has members with long-standing experience in working with companies. The future unit on industry will also cover specific programs on innovation that will be met in coordination with the innovation strategy of the Campus of International Excellence of Montegancedo.

**Visualization and Data Interaction:** Paradoxically, whereas computational simulations increase in complexity and take into account the ever increasing amount of data, its effectiveness does not grow at the same rate. Many times this is due to the difficulty in extracting knowledge from the huge amount of data that is being produced. This problem is expected to get worse, making visualization and analysis a fundamental part of science- and technology-driven simulation. This area includes the technologies to extract information from simulations, from the


\(^{51}\) [http://www.hpcwire.com/hpcwire/2013-06-17/idc_market_study_shows_strong_gains_for_coprocessors_and_big_data_at_hpc_sites.html](http://www.hpcwire.com/hpcwire/2013-06-17/idc_market_study_shows_strong_gains_for_coprocessors_and_big_data_at_hpc_sites.html)
new models of interaction and data representation to the interactive steering of large-scale simulations, turning effectively a supercomputer into an interactive scientific instrument.

This is one of the declared key results of big science projects such as the Human Brain Project, a project participated in by several groups in the CCS. Within the centre this area is conceived in a broad sense and will interact with the first area, Big Data Analytics. The overall direction is coincident with the view that these two areas together represent the fourth pillar of modern science, together with experiment, theory and simulation.

**New Computational Models and Algorithmic:** HPC is a technology that has undergone several important paradigm shifts: from sequential to vector and then to parallel and to massively parallel; from custom made "big iron" to commodity clusters and coprocessors; from purely HW centric, monolithic and self-contained data centres, to distributed infrastructures, to cloud and back again in a new form. In the future, there will be new computing models with the potential to solve problems intractable nowadays, and this centre must be aware of it and play an active role in these potentially disruptive technologies.

One of these models is **quantum computing**. This is a technology that, in its general form, was not expected in the near future. However, much research, especially in classic algorithms for quantum simulations, has turned out to be particularly relevant since this is an important application area: It is fundamental for nanotechnology, materials science, chemistry, biology, etc. Other quantum-derived algorithms, for quantum artificial intelligence or google-like search for example, have also a role-changing potential. Curiously enough, this also meets another important computing paradigm: **neuromorphic computing**. Both are explicitly addressed in the aforementioned H2020 LEIT. On the HW front, the prospect of building a quantum processor in the short term has recently experienced a renewed interest and two new centres dedicated to quantum computing have been created.

The unexpected appearance of a potentially commercial technology for quantum computers that apparently delivers, at least, part of the promises of quantum computing has ignited the interest, taking even the cover of major popular magazines\(^5\).\(^2\)


Other quantum technologies that are also relevant will be present in the area, such as quantum cryptography that, again in relation to quantum computing, has sparked new interest due to the recently uncovered program of the US National Security Agency to build one\(^5\), which is, in turn related to the problems of security and privacy in a highly-connected society with the computational means to mine data in a way that threatens fundamental rights; also a problem for other areas of the centre. The importance of quantum technologies is also underscored by the fact that some government agencies have approved large budgets for quantum
technologies\textsuperscript{54}. However, quantum computing is not alone and other computational models will be incorporated if excellent suitable researchers are found.

These areas, in which the members of the CCS research centre have active projects and enough people with international presence, are not the only ones of interest to the centre. CCS is a centre with an essentially open and dynamic character, and the ability to incorporate groups bringing relevant expertise and high-quality research into new areas is fundamental. There are areas that are obviously important application areas for Computational Simulation but they are present in other research centres of the UPM or other external institutions. An especially important one is bioinformatics.

The UPM already has groups in centres like the centre for Plant Biology and Genomics or the centre for Biomedical Technology that are working in the field in the same Campus. As a first step, the centre for Computational Simulation will seek to coordinate with these centres in order to bring HPC expertise and build up an organizational unit to tackle joint projects. MoUs are already in place and some projects started, although with limited resources.

The international presence will also be very important, as it is now in the founding groups. As a means of increasing the flexibility of the Centre and start incorporating researchers in new areas into the structure that might not have enough critical mass at the beginning to conform a centre’s main area by themselves, we include a multidisciplinary area that we call Associated Technologies. This area now includes ICT Energy Efficiency.

**Associated Technologies:**

As a starting point, it will include the two aforementioned technologies:

**Energy efficiency** is critical for the efficient use of the HPC resources of the UPM. CeSViMa has been implementing energy-efficient technologies in its own datacenter, from freecooling to queue control. CeSViMa uses now 1/3 of the power that it used just two years ago, although it has multiplied its capability by a factor of ten. A group of researchers specialized in energy-efficient technologies applied to ICT and to datacenters in particular will initially make up part of the Associated Technologies area. This group already has joint projects with CeSViMa and also includes industrial partners.

**Specialized Training and Higher Education Programs**

A further note about the character of the centre is its educational commitment. All their constituent members have played a significant role in the educational programs of their schools of origin, in particular as regards Masters’ Degree and PhD programs. Several of the members were active promoters of and participants Masters’ Degree and PhD program of Advanced Computing in Sciences and

\textsuperscript{54} UK HM Treasury, Autumn Statement 2013, pp.7, 42 and 56. 270 Million pounds to be invested in quantum technologies during the next five years.
Engineering (CACI: Computación Avanzada en Ciencias e Ingeniería\textsuperscript{55}), a program now finished that was awarded a seal of excellence by the Ministry of Education.

This educational character is taken as a mission of the centre - in line with the aims of the Campus of International Excellence - that will help in teaching subjects related to its areas of expertise, either in associated programs or as stand-alone courses and also providing advanced computational means whenever necessary. It is important to highlight that educational resources in HPC are considered as key enablers for future technologies in the EU\textsuperscript{56} and US\textsuperscript{57}. A short-term aim of the CCS is to prepare a set of courses in advanced computational techniques for science and engineering designed to be used as a six-month set part of a Masters' Degree in a computational intensive degree like civil or aeronautical engineering, bioinformatics, computer sciences, etc. The Centre currently participates in the EU IT Marie Curie Network: AIRUP. Airbus-UPM European Industrial Doctorate in mathematical methods applied to aircraft design. The extension to a new Master and PhD program will be started in 2016.

Some relevant projects in CCS

- HBP: Exascale visualization, structural data analysis, neuroscience visualization. (Flagship project)
- REPSOL: Multiphase simulations. (Industrial project)
- QUITEMAD+: Quantum Information Technologies Madrid. (Large coordinated project, Madrid Regional Government funding)
- AIRUP: Airbus-UPM European Industrial Doctorate in Mathematical Methods Applied to Aircraft Design. (Marie Curie action)
- Animetrics: Measurement-based Modelling of Complex Mechanical Phenomena (ERC starting Grant)

Collaboration with other Research Centres

The Centre is still too young to have established formal agreements (the first Centre Council, after the formal approval of the rules of association by the University in late May, took place during July of this year), but the different groups currently have many collaborations with other institutions - including those within the Montegancedo Campus - in their corresponding areas of research. There are several existing agreements that, because of their interest, will be promoted to a centre-level agreement. These will build a framework to develop research activities under the common umbrella of the collaboration between these partner institutions. We cite only a few of the institutions that have had continuous collaboration with researchers now at CCS and that will be among the first to be promoted to formal agreements in the short term:

\textsuperscript{55} http://caci.cesvima.upm.es


\textsuperscript{57} Earl C. Joseph, Steve Conway, Jie Wun. A Study Of The Talent And Skill Set Issues Impacting HPC Data Centers, Conducted On Behalf On The US Department Of Energy (2010);
- Collaboration agreement on visual analytics with the supercomputing centre in Jülich (JSC) and Aachen University based on the work with researchers now at CCS.
- Institute of Information Technology (IIT) belonging to the Canadian National Research Council. The original agreement was designed to support joint research in bioinformatics and medical domains. Nevertheless, the IIT is a large institute hosting other groups with research interests complementary to the research areas of the new centre. Based on the existing agreement, it is possible to extend it to cover other areas.
- University of Dalhousie (Halifax, Canada) institute in Big Data Analytics, led by Prof. Stan Matwin. There is an active collaboration between his group and researchers now in the CCS that hopefully will be translated into a collaboration agreement for the mobility of researchers between both institutions.
- IXXI, the Rhône-Alpes Complex Systems Institute, which is a multidisciplinary centre for education and research in the study of large-scale complex adaptive systems. In the last few years there have been several collaboration activities in the simulation of complex biological processes in-silico, in a joint collaboration in the field of artificial life with CCS researchers. This field is also of special interest to several areas of the new centre and this will be the opportunity to formalize the collaboration with IXXI at a more institutional level.
- PeacLab, Boston University, a group led by Prof. Ayse K. Coskun, into high-level power and thermal modelling and energy optimization of enterprise servers. This collaboration has already resulted in several joint publications and research stays in Boston, and could evolve towards a formal collaboration agreement for the mobility of researchers between both institutions.
- INTA: (National Institute of Aerospatial Technology) Collaboration in CFD and real time visualization of large data sets.
- CEDEX: (National Centre for Studies and Experimentation in Civil Engineering) Collaboration in numerical and mathematical modelization. Experimental geomechanics.
- AIT: Austrian Institute of Technology. There is a long-standing collaboration in the field of quantum communications that will be explored in order to sign a formal agreement.

Some other actions that will take place during 2016 to consolidate CCS:

- Expanding in the number of members and areas. We expect to grow in at least one more area of research and by about 10-20 staff members during the next year.
- Find new premises to allocate the bulk of the researchers beyond the now scarce and disperse labs.

58 https://bigdata.cs.dal.ca/
59 http://www.ixxi.fr/
• Create a yearly event to showcase the work of the Centre in cooperation with other research centres and associated industries.

• Establish a formal partnership with URJC in order to enjoy the full participation of another university in the Centre.
  o Start negotiations with other interested universities.

• Establish formal agreements with companies to kick-off the Industrial section in order to grow into a full, separate area. We will start with those that already have relationships with the CCS groups.
  o The objective is to have 4-6 companies located in the Centre by the end of 2016.

A brief summary of some of the contributions:

• High Impact Publications: Several publications in Nature, Science, Reviews in Modern Physics, Physical Review Letters (>40), NAS, Contributions to Industry Standards, etc.

• A current ERC Starting Grant.

• Members of several Royal Academies: Spanish Royal Academy of Sciences (President and one contributing member) and Royal Academy of Sciences of Seville.

• Relevant positions in international bodies: Member of the first Scientific Council of Erwin Schrödinger International Institute of Mathematical Physics, Vienna. Co-founder and first director of Grupo Interuniversitario de Física Teórica (GIFT). Vice-president and founding member of Quantum Industry Specification Group (European Telecommunications Standards Institute, ETSI), Member of the Intelligent Data Analysis (IDA) Council. President of ALERT Geo-materials, etc.

• Board of Editors of many (>12) relevant international journals in several areas.

3.3.7. IMDEA Software Institute

3.3.7.1. Mission and Research Areas

The IMDEA Software Institute (Madrid Institute for Advanced Studies in Software Development Technologies) is a non-profit, independent research institute promoted by the Madrid Regional Government (CM) to carry out research into excellence in methods, languages, and tools that allow the cost-effective development of software products with sophisticated functionality and high quality, i.e., which are safe, reliable, and efficient. Its legal form is a foundation governed by a Board of Trustees made up of internationally renowned scientists, representatives from industry, from Universities and research institutions based in Madrid and representatives from the CM.
Given the economic relevance of software and its pervasiveness, errors and failures in software can have a high social and economic cost. A recent study from Cambridge University found that the overall cost of debugging software has risen to $312 billion annually, while other studies estimated the cost to just the U.S. economy at $60 billion annually, or about 0.6 percent of GDP.

The areas of research of the Institute address technological and societal challenges which are related to or impede the more widespread adoption of ICT technologies for the benefit of society:

- “Greener” Software: Verifying and Controlling Energy Consumption.
- Formal Verification of Cyber-Physical Systems.
- Architecture-Driven Verification: Tackling the Complexity of Modern Software.
- Digital Privacy.
- Fighting Malware in Cybercrime & Targeted Attacks.
- Model-Driven Data Security and Privacy Management.
- Concurrent Software Reliability.
- Automated Software Testing and Failure Recovery.

### 3.3.7.2. Human Resources

Without any doubt, the main strength of the Institute is its people: its researchers and support staff.

The IMDEA Software Institute strives towards the level of excellence and competitiveness of the highest-ranked institutions worldwide. Success in this goal can only be achieved by recruiting highly-skilled staff internationally of the highest level for the scientific teams and support staff. The Institute considers this one of the key critical factors and measures of its success and has been thus since its creation as a major contributor to the internationalization of the Campus and an outstanding attractor of external staff.

IMDEA Software researchers have joined the Institute after working at or obtaining their PhD degrees from 32 different prestigious centres in 8 different countries, including Stanford U., Carnegie Mellon U., or Microsoft Research in the US, INRIA in France, U. of Cambridge in the UK, the Max Planck Software Institute in Germany, or ETH in Switzerland, to name just a few. In addition, more than 130 international researchers have visited and given talks at the Institute to date.

The scientific staff of the Institute currently comprises eight senior faculty (full or associate professors, one part-time), thirteen junior faculty (tenure-track or researchers), eight postdoctoral researchers, twenty two research assistants (PhD students), seven project staff, and ten staff members. Ten senior faculty visitors spent varying lengths of time (from one month to a year) at the Institute collaborating with faculty members under a contract with the Institute.
Figure 89 summarizes where these researchers obtained their PhD (by continents plus Spain), and figure 90 presents the nationalities of researchers at or above the postdoc level.

Figure 89. Country where PhD was obtained

Notice from the 89 and 90 figures the highly international staff of IMDEA which constitute one of its strongholds.

3.3.7.3. Research Infrastructures

Due to the nature of the research carried out in the Institute, the infrastructures needed are less specific than in other areas. However, the Institute has a small data and computing centre which houses several multiprocessors to host virtual machines which provide services to the researchers.

Additionally, the Institute manages the Madrid communications network (RediMadrid) and hosts part of its infrastructure at its computing centre (e.g., optical lines to close one of the loops of RediMadrid and the connection to the campus) including the 100Gb connection with REDIMadrid and RedIris.
3.3.7.4. Funding

An important source of funding and technology transfer opportunities for the Institute are cooperation projects, awarded through competitive calls for proposals by national and international funding agencies, and contracts with industry. Since the start of the campus of excellence action the IMDEA Software Institute has participated in many such projects. As an example of a snapshot in time, during 2014 the Institute participated in a total of 29 funded research projects and contracts, the majority of which (23, 79%) involve collaboration with industry. Of these 29 projects, 15 are from international agencies (14 funded by the European Union and 1 by the US ONR and Stanford University), 8 of them are direct industrial funding, and the rest are funded by national (4) and regional (2) agencies. In the same year, the Institute benefited from 15 fellowships.

The trend in external funding for the period 2008-2014 is shown in Figure together with forecast figures for 2015. The amount of external funding (and the percentage of external to total funding) has risen steadily since the Institute came about (and also since the Campus of Excellence was awarded) €1.95M in 2014 (42% of the total income of the Institute, including CM funds). Temporary factors made the 2014 funding higher than expected taking into account the trends in recent years. The dotted line represents the external funding without these factors, as well as a similar projection for 2015.

![Figure 91. IMDEA Software funding evolution and prediction for 2015](image)

3.3.7.5. Projects

Some of the most relevant recent projects are listed below:

**CADENCE: Cyber Attack Detector Engineering for Commercial Exploitation**

*Funding: European Institute of Innovation and Technology (Duration: 2014)*

The CADENCE project is a year-long action and a part of the EIT Digital activities in 2014 in its Action Line on Privacy, Security, and Trust. The project concentrates on
the development of a sensor capable of detecting advanced cyber-attacks in network traffic by applying innovative anomaly detection technology, with the goal of advancing cyber-defence expertise and creating more secure ICT environments in both governments and businesses. CADENCE aims at addressing the needs of a segment of a market whose size is estimated at €250 billion in Europe with specific innovative product and service prototypes. The project was developed together with TNO in Netherlands, and the Reply Spa group in Italy.

![Detecting Advanced Persistent Threats](image)

**Figure 92. CADENCE project**

**I3H: Incubating Internet Innovation Hubs**

*Funding: European Union – 7th Framework Program (2014–2016)*

The objective of the I3H project is to contribute to the sustainability of the FI PPP by creating a European network of Internet Innovation Hubs (IIH), regional or thematic clusters that bring together web entrepreneurs, mentors, investors, students, academia, industry, and public sector innovators to speed up the transformation of FI PPP results to services and applications addressing the needs of European citizens, companies, and society.

The starting point is the initial network of EIT Digital hubs in Budapest, Eindhoven, Helsinki, Madrid, Paris and Trento coinciding with the Nodes of EIT Digital. The seed network will grow organically with a robust life-cycle incubation stage gate process for identifying candidate hubs and guiding them through tangible milestones towards full-fledged IIH’s with hands-on coaching, resources and support, including knowledge and best practice transfer.
N-GREENS-CM: Next-Generation Energy-Efficient Secure Software


N-GREENS-CM is a consortium involving groups from Universidad Complutense de Madrid, Universidad Politécnica de Madrid, and the IMDEA Software Institute, which is the project coordinator.

The N-GREENS project addresses the ever-growing economic and strategic significance of the software industry, the presence and ubiquity of software and computer devices in everyday life, and the resulting need for revolutionary solutions to enable citizens to access myriads of such services in a secure and sustainable way. Along with an extensive research component carried out by a world-class expert consortium, the project has a strong technology-transfer component.

The N-GREENS Project aims at developing disruptive technologies in some of the key areas with a high social impact. Its technical areas include: green computing, cloud security, cyber-physical systems, parallelism for the masses, and the resulting software tools.

VerisTab: Formal Verification of Stability of Embedded Control Systems


The VerisTab project addresses the challenge of building high-confidence embedded control systems, by means of verifying their stability (resistance to perturbation in the initial state or inputs) using automated formal verification techniques that will be developed within the project. The objective is to facilitate the development of fully automated and scalable methods for stability verification, thereby addressing the shortcomings of the state-of-the-art deductive techniques.

An algorithmic approach to stability verification is a challenging task, since, even fundamental notions for abstraction and composition, which form the backbone of scalable algorithmic verification, have not been well explored. VerisTab proposes a three-phase plan from developing theoretical foundations to algorithm design and software tool development.

ADVENT: Architecture-Driven Verification of Systems Software


IMDEA Software is the main partner and coordinator of the ADVENT research project, funded by the very competitive EU 7th Framework Program, Future and Emerging Technologies (FET) Young Explorers Initiative, and has an overall budget of €1 million. In addition to IMDEA Software, the consortium includes Tel Aviv University (Israel), The Max Planck Institute (Germany), and Katholieke Universiteit Leuven (Belgium) as partners.
The ADVENT project (http://advent-project.eu) develops innovative methods and tools for the cost-effective verification of real-world systems software, making it possible to guarantee an unprecedented level of reliability. ADVENT will achieve this by exploiting a trend among programmers to use informally described patterns, idioms, abstractions, and other forms of structure contained in their software, which together are called its architecture.

Building on the emerging technology of separation logic, ADVENT will formalize these software engineering concepts used by systems programmers to reason about their software informally, and will use the results to drive the design of verification techniques. This is a radically novel approach to the problem of verifying complex software: it departs from the common practice of building generic verification tools which, not being able to take advantage of the programmers’ knowledge and intuition, do not scale to big and complicated systems.

The architecture-driven verification techniques resulting from the project have the potential to yield a dramatic leap in the cost-benefit ratio of verification technology. This will allow verification to scale itself to systems of real-world size and complexity that so far have been beyond the reach of quality assurance methods guaranteeing correctness.

**POLCA: Programming Large Scale Heterogeneous Infrastructures**

*Funding: European Union – 7th Framework Program (2013–2016)*

The POLCA project explicitly addresses the programmability concerns of both embedded and high performance computing. Both domains have generated strongly-focused approaches for solving their specific problems that are now confronted with the increasing need for parallelism even in Embedded Systems and the need to address non-functional criteria in High Performance Computing. Rather than improving both domains separately, POLCA takes a bold step forward by proposing a hybrid programming model that decisively increases programming efficiency in both areas and enables the implementation of multi-domain use cases.

**ENTRA: Whole-systems energy transparency**

*Funding: European Union - 7th Framework Program - FET proactive MINECC call (2012-2015)*

ENTRA is an FP7 project under the proactive objective “Minimizing Energy Consumption of Computing to the Limit”.
The ENTRA project proposes radical advances in energy-aware software design and management with the objective of providing significant key to the pervasive implementation of energy-aware computing.

Although huge advances have been made in power-efficient hardware, most of the potential energy savings are wasted by software that does not exploit the energy-saving features of hardware, and by poor dynamic management of tasks and resources. The budget of the project is approximately €2.7M.

The project is built around the central concept of energy transparency at every stage of the software lifecycle. The project develops novel program analysis and energy modelling techniques, making the use of energy transparent through the system layers. This will enable energy optimizations both during code development and at run-time, and promote energy efficiency to a first-class software design objective.

**AutoCrypt**

*Funding: US Office of Naval Research (ONR), through Stanford University (2012-2015)*

AutoCrypt is a joint project with Stanford University, University of Pennsylvania, and SRI, with an overall budget of €2M. AutoCrypt aims to use computer technology to provide mathematical guarantees that a cryptographic algorithm is secure, and that it is suitable for a given product, process, or service.

Within the project, the IMDEA Software team use their EasyCrypt tool ([http://www.easycrypt.info](http://www.easycrypt.info)) to develop a systematic classification of cryptographic algorithms and to create a cryptographic atlas that will be used by researchers and companies to choose the most suitable algorithm for their needs.
NESSoS: Network of Excellence on Engineering Secure Future Internet Software Services and Systems

*Funding: European Union, Cooperation Program (NoE) – 7th Framework Program (2011-2014)*

The Network of Excellence on Engineering Secure Future Internet Software Services and Systems (NESSoS) aims at constituting and integrating a long-lasting research community in engineering secure software-based services and systems. The NESSoS consortium involves 12 partners, including 2 companies (namely, Siemens and ATOS), from 7 countries. The budget for the project is approximately €3.5M.

The domain of Engineering Secure Software Services covers a collection of engineering activities that aims at the creation of software services that are both behaviourally correct as well as secure. The approach of engineering secure software services is based on the principle of addressing security issues from the very beginning in system design and analysis, thus contributing to reducing system and service vulnerabilities, improving the necessary level of assurance, thereby considering risk and cost issues during development in order to prioritize investments.

VARIES: Variability in safety critical embedded systems

*Funding: ARTEMIS- European Union - 7th Framework Program (2012-2015)*

VARIES is an ARTEMIS Joint Undertaking project granted under FP7. The 26-partner strong international consortium includes the participation of national partners Hi-Iberia, Integrasys, and Tecnalia. The main goal of the VARIES project is to help Embedded Systems (ES) developers to maximize the full potential of variability in safety-critical ES.

The objectives of this project is therefore (i) to enable companies to make informed decisions on variability use in safety-critical ES; (ii) to provide effective variability architectures and approaches for safety-critical ES; and (iii) to offer consistent, integrated, and continuous variability management over the entire product life cycle.

The VARIES project develops the VARIES Platform: a complete, cross-domain, multi-concern, state-of-the-art reference platform for managing variability in safety-critical ES. Special attention is paid to aspects specific to safety-critical ES, in particular the impact of reuse and composition in certification.

DESAFIOS-10: High-Quality, Reliable, Distributed, and Secure Software Development

*Funding: Spanish Ministry of Science and Innovation (2011-2014)*

The overall goal of the DESAFIOS-10 project is to contribute both foundations and technologies for the development of software systems with certified quality and
reliability, based on formal methods and declarative programming. The consortium involves groups from three different Institutions (Universidad Complutense de Madrid, Universidad Politécnica de Madrid, and IMDEA Software) and a number of industrial users.

This project arises as a natural evolution of the previous coordinated project DESAFIOS, which involved only the research groups from Universidad Complutense de Madrid and Universidad Politécnica de Madrid. In contrast, DESAFIOS-10 emphasizes the security and reliability aspects of this research, which is precisely the work package led by IMDEA Software.

**PROMETIDOS-CM: Methods for Rigorous Software Development**

*Funding: Regional Government of Madrid (2011-2014)*

PROMETIDOS-CM is a consortium involving groups from Universidad Complutense de Madrid, Universidad Politécnica de Madrid, and the IMDEA Software Institute, which is the project coordinator.

The PROMETIDOS-CM research program focuses on four main areas: specification and validation, to provide a solid foundation for the description and analysis of services; reliability and security, to guarantee robust solutions from start to finish; declarative programming, to develop the next generation of languages for services; and efficiency, to optimize quality of service as regards performance. A common goal for all these lines of research is the development of tools that will rigorously support their scientific results and that can be eventually transferred to industry.

**StrongSoft: Sound Technologies for Reliable, Open, New Generation Software**

*Funding: Spanish Ministry of Economy and Competitiveness (2013–2015)*

The goal of the StrongSoft project is to define, implement, evaluate, and disseminate disruptive technologies that are able to keep pace with the rapid evolution of software systems and address the challenges it implies. The project provides solutions for supporting the cost-effective development of a new generation of software systems that are reliable, efficient, and secure while connected to an open, untrustworthy world, across different application domains.

The workplan is organized in a number of coordinated lines that cover security and cryptography, verification, debugging and testing, language technology, and tools. To achieve its objectives the StrongSoft consortium coordinates some of Spain’s leading research groups in reliable software technologies together with a number of key foreign researchers and highly interested industrial end users.

**ARVI: Runtime Verification Beyond Monitoring**

*Funding: European Union, COST Action (2014–2018)*

Runtime verification (RV) is a computing analysis paradigm based on observing a system at runtime to check its expected behaviour. RV has emerged in recent years
as a practical application of formal verification, and a less ad-hoc approach to conventional testing by building monitors from formal specifications.

There is a great potential applicability of RV beyond software reliability, if one allows monitors to interact back with the observed system, and generalizes to new domains beyond computer programs (such as hardware, devices, cloud computing, and even human-centric systems). Given the European leadership in computer-based industries, novel applications of RV to these areas can have an enormous impact in terms of the new class of designs enabled and their reliability and cost effectiveness.

**CryptoAction: Cryptography for Secure Digital Interaction**

*Funding: European Union, COST Action (2014–2018)*

As increasing amounts of sensitive data are exchanged and processed every day on the Internet, the need for security is paramount. Cryptography is the fundamental tool for securing digital interactions, and it allows much more than secure communication: recent breakthroughs in cryptography enable the protection – at least from a theoretical point of view – of any interactive data-processing task, including electronic voting, outsourcing of storage and computation, e-payments, electronic auctions, etc. However, as cryptography advances and becomes more complex, single research groups become specialized and lose contact with “the big picture”. Fragmentation in this field can be dangerous, as a chain is only as strong as its weakest link. To ensure that the ideas hatched in Europe’s many excellent research groups will have a practical impact, coordination between national efforts and different skills are needed.

The aim of this COST Action is to stimulate interaction between the different national efforts in order to develop new cryptographic solutions and to evaluate the security of deployed algorithms with applications to the secure digital interactions between citizens, companies and governments. The Action will foster a network of European research centres thus promoting the movement of ideas and people between partners.

**AMAROUT and AMAROUT II Europe**

*Funding: European Union, Marie Curie Action (PEOPLE-COFUND) - 7th Framework Program (2012-2016)*

AMAROUT (now finished) and AMAROUT-II Europe are two PEOPLE-COFUND Marie Curie Actions AMAROUT II continues the AMAROUT action and shares the objectives of fostering and consolidating the European Research Area with it by attracting top research talent to Europe and, in particular, to the region of Madrid. Researchers from any country can apply for AMAROUT II fellowships at any of the seven IMDEA Institutes participating in the program. The program is seeking to attract, over 4 years, more than 150 experienced researchers to carry out research projects within the IMDEA network of research Institutes.
As in AMAROUT, the AMAROUT-II Program is a joint initiative from the seven IMDEA research institutes. The IMDEA Software Institute was in charge of writing and submitting the proposal and is the beneficiary, acting as the administrator of the program for the other institutes.

EIT Digital CLC

The headquarters of the IMDEA Software Institute hosts the Madrid Co-Location Centre (CLC) of EIT Digital. The CLC is the central place for organizing and implementing EIT Digital activities in Spain, and the main meeting point for the Spanish Associate Partner Group (APG), led by IMDEA Software, which includes some of the most prominent actors in the ICT innovation arena, such as Telefónica, Indra, Atos, Universidad Politécnica de Madrid (UPM) and the Barcelona Supercomputing Centre (BSC).

![EIT Digital headquarters in IMDEA Software](image)

*Figure 94. EIT Digital headquarters in IMDEA Software*

EIT Digital FI-PPP Liaison: Liaison with the Future Internet Public-Private Partnership

In 2014, IMDEA Software coordinated the activities of selecting and training startups and SMEs from the EIT Digital eco-system in Spain that use FI-WARE (FI-PPP) technologies and generic enablers for developing and bringing to market innovative products and services. The public competition attracted around 40 companies, 10 of which were selected and given training in FI-WARE technologies in cooperation with Telefónica I+D. Finally, three finalist companies received prizes for the most innovative market solutions.
EIT Digital Business Development Accelerator

During 2014, the local activities of the EIT Digital Business Development Accelerator (BDA), part of the EIT Digital BDA network, started in the Madrid node. Across Europe, a group of 50 specialists started by helping to bring ideas to market and providing services such as coaching, access to finance, or soft landing, at a pan-European level. This has also included participation in and organization of events related to innovation and entrepreneurship such as, e.g., Spain Startup.

Microsoft Research

The strong cooperation between scientists in IMDEA Software and Microsoft Research was further boosted in 2014 through the opening of the Microsoft Research - IMDEA Software Joint Research Center (http://www.msr-imdeasw.org/). This included the organization of the first Microsoft Research - IMDEA Software Cooperation Workshop (MICW 2014) which was followed by a similar workshop in 2015 (MICW 2015). Within the Microsoft Research - IMDEA Software Joint Research Center, scientists from both sides work together on a number of research topics, such as cryptography and privacy, concurrency and memory models, and programming languages and verification. The MICW has been established as an annual forum for presenting the results of the joint work.

Telefónica I+D

As mentioned before, in 2013, Telefonica Digital and the Institute also established a Joint Research Unit (JRU) within their more global strategic partnership. Since 2012, IMDEA Software has been cooperating with Telefónica I+D in research and development in components for the automatic management of cloud scalability towards their integration into Claudia, a product developed within the European FI-WARE initiative. Claudia facilitates the definition and automatic deployment and management of virtual machines, storage, and connectivity resources that comprise the virtual infrastructure on which cloud applications are run.
Boeing Research & Technology Europe

The IMDEA Software Institute has also been contracted since 2012 by Boeing Research & Technology Europe (which is located in Spain) to work jointly in research and development in the fields of Big Data and Social Network Analytics. In particular, the Institute and Boeing are jointly designing and implementing a framework for data mining in social media.

The framework includes a declarative embedded language designed by IMDEA Software. This language supports the description of workflows that integrate map-reduce jobs and native applications. The implementation avoids costly recomputations, thus increasing the efficiency of social media processing, with applications in rich Web interfaces that rely on the live collection of social network information from Twitter streams and other sources.

LogicBlox

In 2013, the IMDEA Software Institute started cooperation with LogicBlox, located in Georgia, USA, applying IMDEA’s expertise in logic engines within the LogicBlox commercial deductive database system.

The smart database and its high-level declarative query language (LogiQL) enable users used to build applications that combine transactional, analytical, graph, probabilistic, and mathematical programming. This makes it possible to build new classes of hybrid applications that are hard or impossible to build on traditional technology stacks that involve a cocktail of multiple programming languages and databases. This system includes sophisticated logic for optimizing database query execution, and is able to take advantage of multi-core and cloud programming, while abstracting away much of their intrinsic complexity.
Publications

A large part of the dissemination of results of the Institute is carried through publications in prestigious conferences and journals. Since the starting of the Campus of Excellence in 2010, to date, Institute researchers have co-authored 80 journal articles and 239 papers in refereed conferences. Figure 96 shows the evolution of papers published per year since 2008 until 2014 (last year where the total numbers are known).

![Figure 96. Evolution of publications of the IMDEA Software Institute](image)

Awards and Research Achievements

Besides paper publication, the Institute has received recognition in the form of awards given to its researchers. Among these are the following:

1. In 2012, two Institute researchers received two of the ten Microsoft Software Engineering Innovation Awards, which Microsoft uses to give yearly in a competition drawing contestants from all over the world.
2. In 2015 Michael Emmi, a researcher at the Institute, won four medals in the International Software Verification Competition (2015). Each competition entry is a computer program called a “verifier”, and each “problem” is a computer program whose correctness must be verified by the verifier. The verifiers classify problems either as “correct”, “incorrect”, or “unknown”, within a time limit of 900 seconds per problem. In each problem category, the three highest-scoring verifiers are awarded medals: gold, silver, and bronze.
3. In collaboration with the University of Utah and Microsoft Research, the IMDEA Software Institute’s competition entry, named SMACK+Corral, was awarded medals in four categories -two gold, one silver, and one bronze- placing it among the top-performing verifiers.
4. ETH Zurich Gold Medal: Benedikt Schmidt, a postdoctoral researcher at the IMDEA Software Institute received a medal for an outstanding PhD dissertation by ETH Zurich, on the topic of formal analysis of key exchange protocols and physical protocols.

5. Two Institute researchers were awarded (in different years), the prestigious EAPLS Best Thesis Awards, given every year by the European Association for Programming Languages and Systems.

6. In the last two years, 10 papers from the Institute received the best paper awards in top-level conferences.

7. The Institute was awarded the Comunidad de Madrid (Madrid regional government) Public-Private Cooperation Honourable Mention of the MadrI+D Foundation, for its cooperation with the Italian industrial group Reply and Dutch TNO on cyber attack detector engineering and its commercial exploitation.

8. The Institute has so far made five SW registrations and produced and maintains more than 5 major SW systems.

9. Institute researcher Pierre-Yves Strub was one of the discoverers of the TLS encryption FREAK vulnerability, which impacts encryption mechanisms widely used on the Internet to access web pages securely. The flaw can be exploited to trick web browsers into interacting with malicious websites. The problem affects a large number of web servers and clients and has thus received major media impact.

3.3.7.7. Events

The Institute has also organized a number of industrial, research, and entrepreneurship events, some of which we list below:

- Industrial training day on ActionGUI technology: As part of the activities of the NESSoS Project, the IMDEA Software Institute organized a one-day training course on the ActionGUI technology, with the participation of representatives from ATOS Research & Innovation.

- The IMDEA Software Institute hosts Itinerant Cryptography Seminars. The first edition of the Itinerant Cryptography Seminars, a multi-institutional series aimed at promoting cryptography research, was hosted by the IMDEA Software Institute and organized by Dario Fiore.

- FI–PPP Liaison Demo Day. The Madrid CLC of EIT Digital at the IMDEA Software Institute hosted the FI–PPP-Liaison Demo Day, with presentations from the three SMEs that have won prizes from the FI–PPP Liaison project for using FI–WARE technologies to bring innovative products and services to the market:
  - SmartTaxi, with a smart app that helps taxi drivers reduce waiting time and to increase their customer pick up rate.
  - WeCollect (Wellness Telecom), who developed the eGarbage system to improve waste collection management.
  - B-SEED (Pyro Fire Extinction), with a platform to incorporate smart-city technologies into the natural environment, in order to improve the prevention and management of forest fires.
The Joint EasyCrypt-F*-CryptoVerif School, which took place in Paris in November 2014, attracted over 80 participants from Europe, North America and Japan. EasyCrypt is developed by researchers at the IMDEA Software Institute led by faculty Gilles Barthe.

The IMDEA Software Institute has organized joint workshops with Microsoft Research.

The IMDEA Software Institute has also organized and hosted the Second Prometidos Winter School, which had 12 talks from researchers from the IMDEA Software Institute, UPM, and UCM.

The Institute has also organized the CDTI - IMDEA Software H2020 Info-Day on Entrepreneurship.

3.3.7.8. **Industrial Partnerships**

The Institute has also established strategic partnerships with the main stakeholders in the sector which facilitate longer-term collaboration across projects. In particular, the Institute has established close ties with Telefonica, Indra, Atos, and BBVA which have led to a number of strategic cooperation initiatives.

An important instance is the joint establishment of the European Institute of Technology (EIT) Digital Spanish Associate Partner Group (also with participation of UPM and BSC), coordinated by the Institute, which includes the hosting and operation of the EIT Digital Madrid Co-Location Centre and many other joint activities in innovation and entrepreneurship, such as the aforementioned Telefónica-IMDEA Software Joint Research Unit and the Microsoft Research–IMDEA Software Joint Research Center.

Participation in Spanish and EU Technology Platforms is another strategically important line of cooperation with industry. These platforms include the Technology Clusters of the Madrid Region, and the Internet of the Future Es.Internet Spanish platform. All of these activities contribute towards aligning research agendas and promoting joint participation in projects.

Another important form of technology transfer is the commercialization of technology developed at the Institute. Given the controversy around software patents (and the difficulties in filing software patents in Europe) the Institute is combining the protection of its intellectual property with other innovative exploitation models, such as those based on open-source or free software licenses, together with the licensing of this technology, and the creation of technology-based start-ups. For example, five software registrations have been completed to date, including ActionGUI (jointly developed by IMDEA Software and ETH Zurich); GGA; and EasyCrypt, ZooCrypt, and Masking (the latter three developed jointly by IMDEA Software and INRIA).

Other forms of collaboration with industry include the industrial funding of PhD and Masters’ Degree students working at the Institute on industry-relevant topics (e.g., Microsoft funds research assistants working on software verification and security), transfer of research staff trained at the Institute to companies (IMDEA Software and INRIA).
Software-trained staff has already been transferred to companies such as Atos, Microsoft, Google, or Logicblox, funding by industry of research stays of Institute researchers at company premises (e.g., Institute researchers have made industrially-funded extended stays at Deimos Space, Microsoft Redmond in the US, or Microsoft Cambridge in the UK, and a framework agreement has been signed with Microsoft for this purpose), access to the Institute’s technology and scientific results (e.g., researchers of the Institute have met with representatives from BBVA, Telefónica I+D, Ericsson, GMV, INDRA, IBM, Canal de Isabel II, Interligare, or Lingway, among many others, to present their main research results), access to the Institute’s researchers as consultants, participation of company staff in Institute activities, etc.

3.3.7.9. Cooperation with Research Institutions

As an international research organization, the Institute collaborates with many universities and other research centres worldwide. As in the industrial case, and besides partnerships in research projects, the Institute has established longer-term, strategic partnerships with a number of research institutions in order to allow more strategic collaborations and reach objectives that go beyond those of individual projects. At present the Institute has active long-term agreements with the following universities and research centres:

- Universidad Politécnica de Madrid (since November 2007).
- Universidad Complutense de Madrid (since November 2007).
- Universidad Rey Juan Carlos (since January 2008).
- Roskilde University, Denmark (since June 2008).
- Consejo Superior de Investigaciones Científicas (since November 2008).
- Swiss Federal Institute of Technology (ETH) Zurich (since November 2012).
- Microsoft Research (since December 2012, with a Joint Research Center established in 2014).

These agreements establish a framework for the development of collaborations that include the joint participation in and the development of graduate programs; the joint use of resources, equipment, and infrastructure; exchange of staff; joint participation in research projects; the association of researchers and research groups with the Institute; or the joint commercialization of technology.

As an example, under the agreement with the Consejo Superior de Investigaciones Científicas (The Higher Committee for Scientific Research), two of its researchers —César Sánchez and Pedro López— are full-time faculty at the Institute; under the agreement with Roskilde University, one of its full professors —John Gallagher— is also part-time senior researcher at the Institute; the agreement with ETH Zurich includes the joint development and commercialization of the ActionGUI technology.

The Institute also has a strong presence in national and international bodies. It is a member of Informatics Master Europe, the organization of all deans, chairs, and
directors of the leading Departments and Institutes of Computer Science in Europe. In addition, the Institute is a member of ERCIM, the European Research Consortium for Informatics and Mathematics through SpaRCIM, the Spanish representative in ERCIM. Manuel Hermenegildo, Director of the IMDEA Software Institute, is the President of the SpaRCIM Executive Board and a member of the Informatics Europe steering committee.

### 3.3.7.10. EIT Digital

In June 2013, IMDEA Software officially became an Associate Partner of EIT Digital, as the first Spanish organization to enter this Pan-European institution, with seven full national nodes (in Helsinki, Stockholm, Berlin, London, Eindhoven, Paris, and Trento) and two associate nodes (Budapest and Madrid, the latter located at IMDEA Software within the Montegancedo Campus of Excellence). The Madrid node hosts the Associate Partner Group (APG), whose members are the Universidad Politécnica de Madrid (UPM), Telefónica, Indra, Atos, and the Barcelona Supercomputing Center (BSC).

![EIT Digital co-location centers in Europe](image)

**Figure 97.** EIT Digital co-location centers in Europe

EIT Digital is a Knowledge and Innovation Community (KIC) of the European Institute of Innovation and Technology (EIT), which includes some of the leading educational, research and industrial actors in the ICT innovation ecosystem in Europe.

Its mission is to combine the educational, research and industrial tools and activities to drive and foster ICT innovation on the European scale in the following strategic areas: Smart Energy Systems, Future Networking Solutions, Future Cloud, Health and Wellbeing, Privacy, Security and Trust, Future Urban Life and Mobility, Smart Spaces, and Cyber-Physical Systems. These areas are complemented by an integrated and innovation-driven Masters’ Degree and PhD School and a Business Development Accelerator.
One of the key goals of IMDEA Software as the Spanish Associate Member is to promote, encourage, and organize the presence of EIT Digital in Spain, and to foster the evolution of the Spanish Associate Partner Group (APG) towards a fully operational EIT Digital node. Together with UPM and the other strategic partners, the Institute is working on developing innovation-oriented projects within the framework of EIT Digital, increasing EIT Digital presence in Spain through interaction with regional and national governments, and boosting and creating synergy between the entrepreneurship initiatives and mechanisms led by the members of the APG and beyond.

IMDEA Software has participated in the EIT Digital Business Plans in the years 2013 to 2015 in the following activities:

- Three research and innovation activities in the fields of Privacy, Security, and Trust (project CADENCE), Cyber-Physical Systems (project cPAS), and the FI-PPP Liaison.
- Development of the Madrid Co-Location Centre (CLC), hosted in the Campus of Excellence within the premises of IMDEA Software, which is the home for the EIT Digital activities and the meetings of the Spanish APG. The CLC is equipped with videoconferencing equipment that allows online collaboration, ample office space and meeting facilities, office space for start-ups, and work and collaboration areas for the students in the EIT Digital Masters’ Degree and PhD programs.
- Development of the Madrid Business Development Accelerator (BDA) segment which is a part of the EIT Digital BDA network, a group of 50 specialists helping to bring ideas to market and providing services such as coaching, access to finance, or soft landing, at a pan-European level. This has also included participation in and organization of events related to innovation and entrepreneurship such as, e.g., Spain Startup.
- Launch of the EIT Digital PhD Training Centre and the Masters’ Degree Program in Data Analytics in 2015, in cooperation with UPM, which is a part of the EIT Digital educational initiative that allows PhD and Masters’ Degree
students to obtain not only a recognized technical education, but also entrepreneurial skills and the opportunity to work with European top research facilities and leading business partners.

3.3.7.11. Microsoft Research – IMDEA Software Joint Research Center

The Microsoft Research - IMDEA Software Institute Joint Research Center (http://www.msr-imdeasw.org/) started operations in late 2013 with the objective of framing and fostering significant research collaborations between Microsoft Research and the IMDEA Software Institute in Software Science and Technology. The Joint Research Centre was presented officially on April 3, 2014, on the occasion of the first Microsoft Research and IMDEA Software Institute Workshop (MICW 2014), which took place on April 2–4, 2014, at the IMDEA Software building in Madrid and was repeated in 2015. These workshops bring researchers and students together to discuss work on hot topics in software and, where possible, to bring those advances to market. The collaborations between IMDEA Software and Microsoft involve around 30 researchers from both sides and have resulted in more than 25 publications in top-level venues to date, including, for example, four joint papers at the top-ranked ACM Symposium on Principles of Programming Languages (POPL), in 2014.

Figure 99. Presentation of the IMDEA - Microsoft joint research center

3.3.7.12. Telefónica – IMDEA Software Joint Research Unit

Through the Joint Research Unit, and since 2012, IMDEA Software and Telefónica I+D cooperate on developing software architectures and high-level components within the framework of the FI-WARE initiative. The Joint Research Unit works on different topics, such as brokerage in the context of the Internet of Things (IoT), and facilitating the definition and automatic deployment of cloud application components. In 2014, the Joint Research Unit was expanded with an expert in IoT component controllers and brokers, and is active...
within the ongoing Phase 3 of the FI-PPP Program. The Joint Research Unit also organizes educational activities in the area of FI-WARE technology.

3.3.7.13. RediMadrid

The IMDEA Software Institute manages the academic and research Internet backbone of the Madrid Region, REDIMadrid, funded by the Madrid Regional Government, which currently provides high-speed connections at up to 10 Gbps to the universities and research institutes located in the Madrid region (including IMDEA Software and the other IMDEA institutes).

The IMDEA Software Institute also hosts and operates the new EIT Digital node of the Madrid and Spanish networks, located at the EIT Digital Madrid Co-location Centre and provided jointly by the Spanish High-speed Research Network Backbone, RedIRIS-NOVA, and REDIMadrid. This link is available as an experimentation infrastructure and can support speeds of up to 100Gb. This recent expansion of RedIRIS-NOVA and REDIMadrid has been funded jointly by the Spanish and Madrid Governments in direct support of the EIT Digital associate partner group in Spain.

![Figure 100. RediMadrid](image-url)
3.3.8. School of Computer Engineering

Human resources

The School of Computer Engineering has an academic staff of 167 and an administrative and support staff of 78. The size of the academic staff has not changed over the last five years, although there has been a sizeable reduction in the number of administrative and support staff.

Research staff and structures

Of the 167 academic staff, 109 are members of research groups, whereas other academic staff members conduct research individually.

There are currently 20 UPM-approved research groups based at the School of Computer Engineering:

1. Biomedical Informatics Group (GIB)
2. Theory and Applications of Constructive Approximation
3. BABEL: Development of Reliable and High-Quality Software based on Declarative Technology
4. Validation and Business Applications Group
5. Hydroinformatics and Water Management
6. Human-Computer Interaction and Advanced Interactive Systems
7. Computer-Assisted Signal and Image Processing
8. Ontology Engineering Group
9. Artificial Intelligence Group (LIA)
10. Quantum Information and Computing Research Group (GIICC)
11. Orthogonal Polynomials and Fractal Geometry
12. Data Mining and Simulation (MIDAS)
13. Computer Technology and Communications Research Group: CETTICO
14. Distributed Systems Laboratory (LSD)
15. Decision Analysis and Statistics Group
16. Computational Intelligence Group
17. Natural Computing Group
18. Software Engineering
19. Computational Logic, Languages, Implementation and Parallelism (CLIP)
20. Decoroso Crespo

Three new research groups have been set up over the last five years, whereas another two have closed down.

As per the School of Computer Engineering’s rules of procedure, all research groups employing more than two people a year over the last four years are entitled to a research space. Accordingly, research space is allocated proportionally to the size of the research groups based at the School of Computer Engineering. A total of 1,700m² are set aside for research laboratories.
Other human resources for research

The School of Computer Engineering is one of the most active research centres within the UPM. Apart from the 109 members of the academic staff working within the 20 UPM-approved research groups, many research grants and contracts are entered into every year.

The table 6 below lists the grants and contracts entered into at the School of Computer Engineering over the last five years.

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<td>2010</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>59</td>
<td>33</td>
</tr>
<tr>
<td>2011</td>
<td>253</td>
<td></td>
</tr>
<tr>
<td></td>
<td>183</td>
<td>70</td>
</tr>
<tr>
<td>2012</td>
<td>252</td>
<td></td>
</tr>
<tr>
<td></td>
<td>175</td>
<td>77</td>
</tr>
<tr>
<td>2013</td>
<td>232</td>
<td></td>
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<tr>
<td></td>
<td>161</td>
<td>77</td>
</tr>
<tr>
<td>2014</td>
<td>228</td>
<td></td>
</tr>
<tr>
<td></td>
<td>158</td>
<td>70</td>
</tr>
</tbody>
</table>

Table 6. Evolution of research projects

Additionally, the number of PhD students supporting tenured and non-tenured research staff in their research work at the School of Computer Engineering are listed below.

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>PhD Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010-11</td>
<td>222</td>
</tr>
<tr>
<td>2011-12</td>
<td>236</td>
</tr>
<tr>
<td>2012-13</td>
<td>218</td>
</tr>
<tr>
<td>2013-14</td>
<td>197</td>
</tr>
<tr>
<td>2014-15</td>
<td>183</td>
</tr>
</tbody>
</table>

Key research infrastructures

Robert Wayne Newcomb Speech Communication Laboratory

The Robert Wayne Newcomb Speech Communication Laboratory carries out projects on digital signal processing and applications for robust automatic speech recognition, noise cancellation, computer-assisted language learning, automatic detection of vocal tract diseases, neural networks, etc. For the pursuit of these
activities, the laboratory has a soundproof room fitted with a range of audio recording, logging, analysis and calibration equipment and other devices for supporting ongoing research and development projects.

Montegancedo Astronomical Observatory

The observatory is located on the roof of Building 6 at the School of Computer Engineering. It is the world's first open access observatory, being accessible via a Web 2.0 where internet users have the power to make decisions and generate content.

Figure 101. Astronomical observatory

It is also equipped with a weather station whose data are published free of charge. The robotic observatory is fitted with the following equipment:

- 3.5-metre diameter observer dome
- Meade LX200GPS 10" telescope
- SBIG Model ST-237A CCD camera + CFW-5C filter wheel
- ToUcam Pro I and II webcams, of which two have been modified for long-exposure photography
- Vantage Pro 2 Plus weather station with fan-aspirated radiation shield.

Note that this observatory has been used as a base for several European projects.

Awards received

2015 Ada Byron Award for Women in Technology

Asunción Gómez-Pérez received the 2015 Ada Byron Award for Women in Technology awarded by the School of Engineering at Deusto University.
The award aims to draw attention to women working in technology who are quietly making more and more important breakthroughs in numerous fields.

The award is named after Ada Byron (Ada Lovelace), one of the most outstanding women in the history of engineering who is considered to be the first computer programmer.

**Spanish National Computer Science Awards — 2013 Aritmel Award**

Pedro Larrañaga Múgica was awarded the 2013 Aritmel Award for his outstanding scientific contributions to the field of computer engineering. He has made very significant methodological breakthroughs in Bayesian networks and evolutionary computing, as well as bioinformatics and neuroscience applications.

**Award for the Best European R&D Project for Cooperation**

The Best European R&D Project for Cooperation Award is awarded by the Madri+d Knowledge Foundation in recognition of excellence in the pursuit of international cooperative research and development activities. The 10th award went to the
LeanBigData project, a system capable of bringing together the capabilities of two types of databases (operational and analytical). The project is coordinated by Ricardo Jiménez Peris (technical coordinator) and Marta Patiño Martínez (financial and administrative coordinator), both of whom are members of the School of Computer Engineering.

**Award for the Best Practical Paper at the IEEE Security and Privacy Symposium**

Together with International Computer Science Institute at Berkeley CA and other researchers from Google Inc., Antonio Nappa, a PhD student in Software and Systems, received the award for the best practical paper at the IEEE Security and Privacy Symposium for his paper titled “Ad Injection at Scale: Assessing Deceptive Advertisement Modifications”.

**Fujitsu Laboratories of Europe Innovation Award**

Alejandro Fernández, Daniel Vila and Óscar Corcho, members of the Ontology Engineering Group at the School of Computer Engineering, received the Laboratories of Europe Innovation Award at the 2015 Fujitsu Linked Open Data challenge for the Citizen Science and Gaming for the Purpose of Improving Open and Linked Data Initiative.

**Research Results**

**Publications**

The table 7 below lists the number of publications by the School of Computer Engineering researchers.

<table>
<thead>
<tr>
<th>Publications</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI</td>
<td>109</td>
<td>120</td>
<td>188</td>
<td>130</td>
</tr>
<tr>
<td>Book and book chapters</td>
<td>53</td>
<td>45</td>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>

*Table 7. Evolution of publications*

**Major agreements**

**Samsung Tech Institute**

The UPM and Samsung have entered into an agreement to set up training courses in mobile applications and operating systems for young people aged from 18 to 25. Additionally, this agreement opens up possibilities for research cooperation between the School of Computer Engineering and Samsung. The first contacts in this respect are now underway.
UPM-CERN FRAMEWORK COLLABORATION AGREEMENT

This agreement entitles the UPM to send academic staff and graduates to CERN in the capacity of project associates. As a result, 10 to 15 members of the UPM will get the chance to participate in ITC-related CERN projects, forging links between UPM and CERN research groups.

3.4. Development of the innovation axis

3.4.1. Evolution of the Centre for Technology Innovation

The Centre for Technology Innovation (CAIT)\textsuperscript{60} was conceived, designed, approved and implemented within the development of the I2\_Tech project for the CEI Montegancedo.

Its main function for the benefit of the UPM community is to push forward the institutional strategy of the UPM towards improving the exploitation of research results and support to entrepreneurship. It also serves as an institutional driver to foster education and training in open innovation, technology transfer and entrepreneurship as a cross-cutting feature of UPM engineers and architects.

Behind the operational mission for the exploitation of results, the authorities at the UPM were firmly convinced that the CAIT should play a prominent role in leading a cultural change in the mentality of UPM researchers, while accepting that the commercialization of R&D results should be an institutional aim which benefits all parties involved. As we will present later in this chapter, preliminary results obtained after only two years of CAIT operation show a clear progress in that direction.

The creation of the CAIT was planned during 2012 and it was finally approved by the Governing Council of the UPM in the October of that year to enter into operation in January 2013. Some of its activities and programs previously existed within the Vice-Rector for Research's Office while others were redefined and re-launched at that time; others were new and have been progressively implemented.

The CAIT is located in a new building in the Campus of Montegancedo funded by the I2\_Tech project\textsuperscript{61}. In fact, CAIT has been acting as coordinator and cornerstone of the I2\_Tech project to implement the main goal of the CEI Montegancedo: to

\textsuperscript{60} Its formal denomination in Spanish is “Centro de Apoyo a la Innovación Tecnológica”. Formally, it was not approved by the UPM as another research centre but as a catalyst of the institutional change towards an entrepreneurial university by delivering advanced innovation and entrepreneurial services to the whole UPM community.

\textsuperscript{61} The new CAIT building was occupied in March 2013. It is attached to the Montegancedo Business Incubator centre which was funded by IMADE (Development entity of the Regional Government of Madrid) in 2007. Today, both buildings have merged into a single one which constitutes the CAIT premises.
support technology innovation with a set of aggregated entities (see chapters 1 and 2 of this final report).

The main function of the CAIT is schematically represented in figure 2. It is perceived as a "bridge" between the activities carried out by the research groups or research centres of the UPM and access to high-technology market structures (from pre-existing companies to start-ups). Special attention is paid in figure 2 to the links with venture capital entities (mainly those interested in seed capital or early stage investments) and the CEI Montegancedo aggregated entities which have been incorporated into the open innovation ecosystem built up around CEI Montegancedo as presented in chapter 2.

Figure 104. The CAIT in the global context

Figure 104 also suggests that CAIT does not operate as an isolated entity. Its mission is accomplished in close cooperation with actors from the external world and the rest of the UPM community. Furthermore, there is an interaction with the UPM governing structure (as happens with the other research centres), and public administrations at the regional, national or European level in order to take advantage of specific research and innovation policies even in cooperation with other entities if necessary.

Even if the CAIT premises are located in a new building in the CEI Montegancedo its activities and programs are spread out over the whole university as a horizontal service unit of the UPM. Then, the CEI Montegancedo community has
no priority with respect to students or research groups from other UPM schools in order to get access to CAIT services.

Figure 105 gives a complementary view of the CAIT role “as a bridge” between the technology providers (mainly the research groups and research centres of the UPM) and the access to the international technology market.

![Diagram showing the role of CAIT in the UPM innovation ecosystem.](image)

**Figure 105.** The role of CAIT into the UPM innovation ecosystem.

Internally, several CAIT programs have also been created or enhanced to support that mission. They will be detailed in the following sections. These programs are, again, not independent of other activities and programs carried out by the UPM (but they are the responsibility of other UPM units). Here we can highlight following which are extensively used and contacted by CAIT staff in order to accomplish its mission:

- The unit for the administration of research projects (OTT) belonging to the Vice-Rector for Economic Affairs’ Office,
- The unit for patent filing and outreach (OTRI) and the Office for International Projects (OPE), both of them belonging to the Vice-Rector for Research’s Office,

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62 OTRI stands in Spanish for “Oficina de Transferencia de Resultados de Investigación”. In the case of the UPM this is a misleading term because with the exception of patent filing (not the exploitation) the rest of functions were assumed by CAIT.
• The support for e-learning platforms (GATE\textsuperscript{63}) belonging to the Vice-Rector for Graduate and PhD Studies’ Office.

The CAIT can implement the defined \textbf{institutional strategy for the exploitation of research results} when the UPM is the owner of the results\textsuperscript{64}; however, in many research and innovation projects directly funded by industry (typically known as \textit{contract research projects}) it is not possible to use this approach because the exploitation rights are usually transferred to industry as a part of the deal\textsuperscript{65}.

Figure 105 might suggest that the CAIT is working on the research results exclusively generated by research groups and research centres or in consortia-based structures with other European or non-European partners in international research projects. Nevertheless, although it is not explicitly detailed in figure 105, CAIT staff also supports business ideas or exploitable results coming from individual faculties, PhD students or researchers when they can be developed as stand-alone initiatives and the UPM is the owner of the associated intellectual property (IP).

The \textbf{external technology market} is addressed by using a series of complementary approaches depending on the type of results and the best strategy to obtain market rewards. Figure 3 sets out three complementary options:

• \textbf{To enforce the creation of specific (technology-based) spin-offs} to continue the development of technology, products and services. This approach means that the licensing from the UPM (the owner) is passed on to the new spin-off the intellectual property (IP) required to develop and nurture the company.

The institutional decision of the UPM is not to become a shareholder of those innovative companies but to negotiate specific agreements to generate revenues from royalties and to facilitate the use of advanced equipment or other facilities and the participation in educational programs through specific agreements with UPM units. Then, it is in the interest of the UPM to be able to increase the relationship with spin-offs and start-ups but leaving room for their own decision-making and strategy\textsuperscript{66}.

This function is also embedded into the more generic \textit{actúaupm} program on entrepreneurship (created 11 years ago and now integrated into the CAIT) which constitutes the basis for start-up and spin-off creation from the

\textsuperscript{63} GATE stands in Spanish for \textit{“Gabinete de Tele-educación”}. This unit provides services for on-line multimedia material creation and use, live recording and exploration and testing of e-learning platforms and tools.

\textsuperscript{64} In some cases, there is a co-ownership of results and the CAIT activity in these cases implies to reach at an agreement with the other institutions to exploit the results on behalf them.

\textsuperscript{65} The UPM signs between 600 and 800 projects with industry annually. In some cases, property could be shared between the UPM and industry but, even in these cases, the exploitation rights are in hand of industry.

\textsuperscript{66} Apart from the administrative difficulties inherent in participating in a relatively large number of boards of trustees or to select them, there is also a deep conviction in the position of risk capital firms that prefer to invest in start-ups in which public administrations were not on board in order to ensure hands-free evolution and full adherence to private behaviour.
UPM community. The main features and results of the program will be presented later in this chapter.

Only a fraction of the annually supported new technology-based companies created by the actúaupm program can be classified as pure “spin-offs” (where the IP of the UPM is formally transferred to those new firms through a licensing contract to provide the basis for the company’s operation); in other cases, they are “start-ups” promoted by members of the UPM community (i.e. students or faculty members) without the explicit licencing of protected knowledge but based on the experience gained from their studies or positions at the UPM. In these cases, there is no need to sign up any licensing contract although other agreements are possible.

- To proceed towards the **direct commercialisation of technology, products and services** to pre-existing companies interested in them in the national or international market (or even to promote the creation of specific ones to support their commercialisation abroad).

This activity is framed within the **Innovatech_UPM** program which was launched in 2013 as a part of the implementation process of the CAIT. The main results of the program will be presented later in this chapter.

The **Innovatech_UPM** program will provide the basis for the identification of promising technology, the generation of a portfolio of commercially exploitable results, the support to technology, product and service maturity, and the searching for potential partners at the national and international level. A specific **network of brokers** at the national and international level has been created to support the commercialisation of UPM assets.

- To **integrate UPM technology or technology-based solutions with selected products or services from other companies or institutions** to hit the international market with better or more complex product or services by joining forces in an open innovation approach.

This activity is also embedded into the **Innovatech_UPM** program as a part of the “product and service development” process. It usually derives from the identification of the suitable public and private partners and to agree on the type of product or service to be developed. Note that the CEI Montegancedo ecosystem presented in chapter 2 in this report constitutes a valid source for speeding up this type of agreement.

From an operational perspective, this approach for product and service development means that the signature of specific agreements in which the involvement of the research centre or research group becomes essential in the development of the product or service in parallel with the support of CAIT staff, if necessary, for market identification, partner selection and the technology marketing strategy.
The added value of the CAIT within this area is related to the provision of specific “accelerator facilities” (e.g. living labs or pilots or demonstrators of technologies) to support product or service integration and experimentation with end-users to get early feedback. The CEI Montegancedo has been a key element in achieving this goal.

3.4.1.1. Internal structure of the CAIT

In order to accomplish its multi-faceted institutional mission, the CAIT is organised as the elements or units below (see figure 106):

Six main “functional areas” have been developed since 2013 to 2015:

- Area of the strategic management of innovation
- Area of entrepreneurship
- Area of the commercialisation of technology
- Area of product and process development
- Area of technology integration and demonstration
- Area of business incubation

Obviously, these are not isolated components in the CAIT operation. Interactions are emphasised by cross-cutting initiatives and the dynamic allocation of staff to specific task forces.

Figure 106. Main internal units of CAIT
In 2014, the CAIT also incorporated the previous business incubator of Montegancedo, which was created in 2008. Today, this is another CAIT unit in which 15 spin-off and start-up companies are located in specific business modules through renting contracts. See annex 1 to see the type of companies located and the network of interactions we are building up with them through specific agreements.

Note that the incubator is open to companies not necessarily generated from actúaupm. Nevertheless, the institutional intention is to increase the interaction of located companies with other research centres of the UPM and specifically, with those located in the CEI Montegancedo in order to increase synergies in the three vertices of the knowledge triangle.67

The following sections will summarize the activities carried out in all of these programs and the main results obtained in the period covered by this report (2010-2015).

**For entrepreneurship support**

The UPM has as one of its distinctive features and institutional objectives for the near future to keep its prominent role as the most relevant university in Spain in relation to spin-off and start-up creation with the participation of faculty members and students.

Its key figures (see the following sections) in this field are also very good in comparison to other European universities. The intensity of applied research activities and the practical educational bias of UPM engineering and architecture faculties and students probably explains this fact and the relatively low barriers found in a change of mentality.

The actúaupm program is an institutional program created 11 years ago to facilitate the transition of the UPM towards an entrepreneurial university in the sense proposed by the European Union within its program of modernisation of European universities launched in 2010.

The program has been renewed in 2007 on the basis of the accumulated experience and today we can proudly say that more than 180 new technology-based companies have been created. Figure 5 details this evolution over time. With 22 companies created, 2014 was the record year68 in parallel with the full operation of CAIT.

Within the scientific and technological domains, 60% of the companies created are related to the “information and communications technologies” domain. Furthermore, many others are IT-intensive to be able to deliver their products and services as is currently the norm in all industrial sectors.

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67 Apart from the business incubator of the CAIT, the CEI Montegancedo also has a specialized business incubator related to the CLC of the EIT Digital Node in Madrid. In this case, it is also intended to locate high-tech spin-offs participating in the EIT Digital entrepreneurship activities.

68 10 new companies were created in the first semester of 2015. Then, it is estimated that the final figure in 2015 will be very similar to last year’s figure.
It is also very relevant to mention that the survival rate of these companies after three years (to discard initial peaks) is very high (75%) compared to other university ecosystems. It is probably a consequence of the high rate of business ideas coming up every year. Furthermore, these companies were able to attract more than €40 million from venture capital entities in the period 2007-2015.

The actúaupm program organises its annual activities around a “start-up creation contest” where business ideas proposed by UPM teams are received, filtered out, trained and matured towards the definition of sound business plans.

Figure 108 depicts the evolution of the business ideas received in the last years. In 2015 this figure was 446 involving more than 1,200 people. During the 12 issues of the program, the UPM has managed more than 3,000 business ideas with more than 500 business plans evaluated.

Obviously, many business ideas received at the beginning of the annual contest cannot progress to the last phase (by completing a sound business plan) for a number of reasons: an impractical idea from the business perspective, too far from a mature product/service to enter into the market, difficulties within the business team for personal reasons or due to inappropriate background or skills, lack of investment to develop the idea to a proof of concept, etc.

More precisely, the analysis of individual situations and the mentoring/coaching of selected teams to give them early feedback constitute the most important added value of the program.

69 These “business teams” are made up of students, faculties or both and complemented, if necessary, with other types of people (e.g. students from business schools).
This very large number of business ideas presented to the competition have variable degrees of maturity. The *actúaupm* program needs the focus the effort in the most promising and mature ones.

As figure 109 shows, with data from 2014, 170 business ideas were retained for further training and mentoring after the initial selection process. From them, 50 business plans were finally presented, and 22 companies were created.\(^7^0\)

The strengthening of the relationship of the UPM with the 180 new companies created until now has become an institutional goal in order to consolidate the UPM innovation ecosystem. Informally, it is being addressed as a specific “CAIT innovation sub-ecosystem” where added value from/to start-ups is relevant to retain and to attract new ones and to promote mutual interaction.

A specific program to support UPM spin-offs and start-ups is being launched in 2015 for supporting this start-up based ecosystem (see the final section of this chapter) where the most part of them are not physically located in CEI Montegancedo. In short, they will help the UPM as a part of the mentoring network for the *actúaupm* and they can also participate in educational activities.

Preliminary analyses made in 2013 and 2014 on the evolution and status of these companies offered a mixed set of results. Even if their “survival rate” is very high (above 75%) compared to other ecosystems, the average number of employees’ remains relatively low (around 11 employees), and the “exit operations” are still

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\(^7^0\) Data from 2015 show an increase in the number of ideas received (446) and in the ideas retained for training and maturity (200 approx.), but it is still too early to know the final number of business plans which will be presented in the contest.
exceptional. These data reflect some of the difficulties found in the UPM to promote high-growth companies in the market and push them into the international arena is seen as a crucial step to be addressed in the near future.

Figure 109. Evolution of the flow of actúaupm

In order to know better the rationale, behaviour, strategy and barriers to create a new technology-based company in the ICT domain and its evolution and growth over time, a joint team between the CAIT and the School of Telecom Engineering within the UPM-EVERIS (Spanish IT company of the NTT Data Corporation chair has generated a specific report71.

Furthermore, the CAIT has also explored the benefits of launching specific entrepreneurship contests on focused technical challenges for start-up creation defined and funded by the private sector. In 2014 a pilot program was implemented with the Santander Group (actúaCOM) in cooperation with the Centre for Open Middleware (COM) where 30 business ideas in mobile banking services and platforms were received. In September 2015 another contest signed with Frontiers (A Swiss company of the Nature Publishing Group) (actúaLOOP) is being launched into the technical challenges related to on-line publishing technology.

The intention of CAIT, in the near future, is to increase this type of “challenge-based entrepreneurship program” in cooperation with other private entities as a mechanism to promote closer interaction with aggregated entities and to increase the CAIT revenues by exploiting the experience gained in holding this type of entrepreneurship contest.

71 The open part of the report can be found in www.upm.es
3.4.1.2. Programs for the commercialisation of technology

The **commercialisation of technology** is one of the major drivers for the CAIT design and evolution. It became the main goal of the UPM to ensure its social role within the innovation dimension of the knowledge triangle. Behind this process, the **protection of technology and know-how** is reinterpreted to maximise its added value for the positioning of the UPM.

Figure 110 summarises the conceptual framework of the commercialisation process as seen from the CAIT’s perspective. Note that after the analysis of the potential commercialisation of research results from selected R&D projects, two possible (although not totally independent) ways are envisaged. One of them emphasises the so called "**academic valorisation**" (out of the responsibility of CAIT), and the other called "**commercial valorisation**" is the main objective of the **Innovatech_UPM** program.

**Figure 110. Identification of potential exploitable results**

There are many pre-conditions to facilitate the commercialisation of research results. Figure 110 suggests that **patent filing** is one of them (a key element in some industrial sectors) but it is not the only feasible possibility\(^\text{72}\). In fact, the use of **industrial secrets** is being actively promoted by CAIT as a very useful approach when patenting is not the most appropriate approach (e.g. in software services or in some industrial processes where the UPM wants to maintain its leadership) in order to protect pre-existing know-how\(^\text{73}\). Afterwards, patent filing is also a pre-

\(^{72}\) The administrative processes of patent filing are a responsibility of the OTRI.
\(^{73}\) Differences in relation to open publications and the potential interaction with the academic way also influence decision making.
requisite to be able to continue the academic valuation (by publishing scientific papers) without compromising further commercial valuation strategies.

The UPM performs very well in the number of patents in comparison to other Spanish entities. Figure 111 represents the evolution in the number of patents presented in the OEPM\textsuperscript{74} in the period 2010-2014 and the excellent position (3rd) occupied by the UPM in 2014 in Spain. Today, more than 100 patents have been internationalised\textsuperscript{75}.

![Figure 111. Evolution of UPM patents (2010-2014)](image)

The key strategic factor from the CAIT perspective is not to maintain or to increase the rate of patents filed (in spite of the crisis, this number has not decreased) but to increase the number of licenses based on them to increase economic revenues but also to stimulate further agreements with licensees.

Today, the UPM has a total number of 400 active patents although only 15\% of them are under commercial exploitation\textsuperscript{76}. Even if this number is not far from figures presented by other world leading universities, there is still a margin for improvement if licensing efforts become a priority for the UPM.

The CAIT’s vision of this issue is to embed the objective of receiving royalties into the knowledge triangle to be able to combine them with contract-research and

\textsuperscript{74} OEPM stands in Spanish for: “Oficina Española de Patentes y Marcas” (Spanish Office for patents and Trademarks). The different number of patents declared by the UPM (66) from the OEPM figure (58) comes from the decision made in that Office to link patents only to the first entity in the filing process. The UPM has some more co-patented with other institutions.

\textsuperscript{75} Economic and efficiency reasons have constrained the full use of internationalization processes where clear perspectives of licensing in short periods of time were not evident.

\textsuperscript{76} Both exclusive and non-exclusive licenses,
advanced training as side benefits. In the end, all of these issues and trade-offs should be balanced in the negotiation process\textsuperscript{77}.

If the protection of knowledge and technology constitutes a pre-requisite in the commercialisation process, the success is also conditioned by the **level of maturity** of the research results obtained in previous projects. In short, the level of maturity is usually measured as TRL\textsuperscript{3} (or even lower); however, licensed companies have to work on TRL\textsuperscript{5} (or higher) to be able to hit the market within the time window of opportunity for that specific product or service.

One of the existing bottlenecks in technology commercialisation policies in the public sector is to find the way to cover that gap when, on the contrary to the private sector, fewer internal structures and less institutional experience (and also funds available for public universities) are available. Figure 10 summarises the activities necessary to close the gap, which have been addressed by the UPM.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure112.png}
\caption{Technology maturity}
\end{figure}

As seen in figure 112 the maturity process of a promising technology not only implies the involvement of the UPM research group (assuming they have the technical knowledge to do so) but also CAIT staff in order to carry out a series of complementary activities to facilitate the pre-commercialisation through market analysis and specific agreements with interested entities who provide the

\textsuperscript{77} In many cases, the license agreement is also complemented by R&D contracts or even advanced training; then, the commitments from licensees and the benefits for the UPM should be evaluated from a broader approach where benefits can be understood throughout the whole life-cycle of the patent.

\textsuperscript{78} TRL stands for "Technology Readiness Level" and it is used as a standard metric for technology maturity. From the historical experience with NASA, the European Commission has defined 9 TRL levels which are being used to assess the closeness to the market exhibited by any product, service or process in European research and innovation programmes (as happens today in H2020).
necessary funds and complementary expertise. Then, mutual trust in their respective expertise is a key factor for success.

In the end, the promising technology reaches at the desired level of technology readiness to be licensed or to support the successful creation of a technology-based spin-off.

The CAIT, as a part of the Innovatech_UPM program has consolidated the identification process of promising technologies through a number of meetings and discussions with research groups to be able to extract those results which could potentially merit the interest of the market. As figure 113 sets out schematically, the selected results constitute the basis for generating the UPM technology portfolio. From the 200 research groups formally recognised by the UPM, 110 research groups cooperate with the CAIT in identification and commercialisation activities. To speed up this process, specific training in commercialisation issues has been provided by CAIT to selected researchers (on behalf of their research groups) involved in the commercialisation of their technologies.

![Figure 113. Cooperative creation of commercial sheets](image)

This activity has evolved very rapidly over the past two years. Today, more than 100 commercial sheets have been prepared by CAIT in cooperation with research groups; figure 114 shows the cover of the two last printed catalogues (in English) published in October 2014 and July 2015 respectively (two annual versions are being published although the CAIT web site will be regularly updated with additional Spanish and English versions). The use of these catalogues as a commercial tool to sell the UPM capacities is crucial for international positioning.
Note that commercial sheets follow a unified format where the emphasis is placed on market demands and how the “UPM technology-based solution” can address it but not on detailed technical aspects. If necessary, during the negotiation process, an NDA (non-disclosure agreement) should be signed between the UPM and interested entities to deliver the technical details.

![Portfolio of technologies](image)

**Figure 114.** Covers from the autumn 2014 and summer 2015 portfolio of UPM commercial technologies issues by the UPM.

Finally, the number of UPM technology licences is also growing. Figure 115 details the evolution in the number of UPM licences generated since 2009 until 2014. As figure 115 shows, even in a period of economic crisis where other inputs from national or regional administrations declined, licences performed better. In 2014 11 new licenses were signed (4 of them with UPM spin-offs) and during the first semester of 2015, 9 more licenses were signed (5 with UPM spin-offs). The total number of license agreements under negotiation in July 2015 is 11 and we expect to see them signed by the end of the year.

We are well aware that the volume of royalties is not relevant compared to the annual budget of the UPM (more than €300 million). Nevertheless, its qualitative relevance is higher because it is an indicator of the institutional interest as an entrepreneurial university and as a basis for increasing the number of sustainable spin-offs.

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79 One relevant issue is the growing number of problems in receiving the agreed royalties due to the critical situation of many of the licensed SMEs. This situation has forced the CAIT to increase the number of legal actions from the UPM legal department.
Figure 115. Evolution of licences and royalties (data from 2015 until July)

Institutional policies promoted by CAIT in the last two years were focused on the following goals:

1. To renegotiate the **structure of licensing agreements** on the basis of fixed and variable royalties. Note that the impact of new license agreements will come to fruition in forthcoming years.

2. To facilitate the negotiation with other entities in the case of the co-ownership of results by increasing the **flexibility in assuming responsibilities** for maintenance or co-development of patents between interested entities.

3. To discuss licensing agreements within **broader frameworks** related to maturity projects, internationalisation or training of human resources. In other words, licenses constitute a tool in strengthening partnering agreements.

In the case of UPM, the licensing process was also used as a tool to help in the institutional goal of spin-off creation. We were facilitating the process in which spin-offs could make use of the required licences to develop faster even if the negotiations on royalties included gratia periods where royalties are not paid (or small amounts for fixed royalties during longer periods of time)\(^8^0\). This strategy is related to the creation of a specific innovation ecosystem with spin-offs and start-ups to be presented later in this report.

To help in the licensing process of IP not linked to spin-offs, the CAIT has explored the use of complementary approaches to increase commercialisation at the international level. On the one hand, the use of "brokers" as companies which can

\(^8^0\) In the period 2010 to 1st semester 2015, 21 licenses contracts with UPM spin-offs were signed.
support UPM licensing at the international level with some intermediation percentage of the deal. On the other hand, the creation of an “international advisory board” to learn from the experience of other countries and to increase the network of contacts. As a result, licences with foreign universities and firms were signed.

### 3.4.1.4. Programs for experimentation on products and services

Speeding up the development of products and services and the need to adjust them to user requirements constitute basic ingredients for commercialisation success. Within this framework, the CAIT has created a set of experimentation structures where innovative products and services could be tested with actual users in order to provide early feedback to designers.

These experimentation structures are usually known in the EU as “living labs”. Figure 116 sets out the role of living labs for research groups but also for spin-offs embedded into the creation process of technology-based enterprises.

![Figure 116. The role of experience labs](image)

Furthermore, it is intended to use them as “interactive learning tools” within the innovation and entrepreneurship programs where CAIT is participating (see education section on this report).

Discussions are currently underway to evaluate the benefits of opening these innovation-support infrastructures up to other established companies for attracting additional investments.
**Living lab of internet of things**

As a part of the I2_Tech project a configurable space able to re-create near-to-reality space contexts (hotel, houses, restaurant, etc.) with ambient intelligence to test a series of advanced ICT services with real users was implemented on the CAIT premises.

The idea is to be able to integrate a set of digital services (see figure 117) which have been designed by the research group of radar and signal processing in the School of Telecom Engineering located in the CEI Moncloa.

![Figure 117. Smart spaces living lab located in CAIT premises](image)

A detailed presentation of this living lab and its services is included in annex 2 of this final report.

**Living lab of TV 3D**

The main target of the three-dimensional television (3DTV) demonstrator is to test and develop new and innovative technologies in the 3D video area. That is why its main goal was to have an infrastructure that gives support to research, development and testing of three-dimensional television equipment considering the whole chain of signal manipulation, comprising:

- **Capturing**: camera systems to capture visual information in multiple views.
- **Representation**: set of procedures and standards for characterizing signals uniquely and jointly, allowing their exchange, storage and transmission.
- **Coding**: set of procedures and standards for reducing the volume of data required to represent the signals, to achieve both a more efficient storage and transmission.
- **Post-production**: 2D and 3D post-production system to resolve problems in capturing three-dimensional video sequences both in stereoscopic compact cameras as in cameras configured on rig.
• **Distribution**: 3D real time transmission system over IP networks allowing a communication that provides the feeling of real presence.

• **Display**: display systems for the visualization of signals, both stereoscopic and multiview, that show different views depending on the position of the observers, allowing them to perceive that the visual information provides depth and perspective.

Figure 118 shows some of the facilities of the 3D TV living lab.

![Figure 118. TV 3D living lab located in CAIT premises](image)

The living lab of TV 3D was also created to support the research activities of the group on digital image processing of the School of Telecom Engineering located on the CEI Moncloa.

A detailed presentation of the living lab is included in annex 3 of this report.

**Living lab of future banking**

From a comprehensive agreement with the Santander Group a living lab for future banking (see figure 119) was created. Technology from four different research groups of the UPM (biometry, mobile services, software platforms and TV 3D) was integrated and tested (see figure 119). Some of these technologies were initially tested in the living labs of smart spaces and TV 3D.

The space has been modularised to support a range of experiences, to identify customers, to track their internal walking and to record the experiences for future analysis. The facility is not yet fully operational as we are waiting for specific equipment from the Santander Group.
In the near future, the CAIT is analysing with its industrial partners the evolution and transformation of the living lab of banking towards a broader “living lab of retail” in which payment services and others will be combined in “smart shopping experiences”.

The final objective is to offer a set of integrated services throughout the whole lifecycle of users’ experiences in blended digital/physical shopping.

3.4.1.5. Programs for consultancy in innovation and entrepreneurship

The growing interest in innovation issues around the world is also a key element to consolidate the external positioning of the CAIT. This type of activity has also been instrumental in increasing the revenues and to move forward the long-term sustainability of CAIT.

The innovative CAIT model implemented in the CEI Montegancedo has sparked the interest of multiple public and private entities both within and outside Spain. In some cases, it has given rise to the preparation of specific consulting activities.

Apart from the activities funded by the EIT and presented above, the CAIT is also conducting several smaller projects at the national level (EOI, OPINNO, INDRA, Telefónica, EVERIS and IBM) as well as at the international level:

1. Colombia (2014 and 2015) with SILO
3. Chile (2013 and 2015) with CONICYT

Figure 119. Living lab of retail
Finally, all these activities have led to the formal creation of a new CAIT unit in 2015: the **Technology Intelligence Unit** (see figure 120). Under that unit, the CAIT intends to serve a twofold purpose:

- To become a reference point on technology intelligence in the Spanish public system. This focus of specialisation will also provide the possibility to enter into a number of additional innovation projects in this field.
- To offer specialised training and support to the UPM community. Figure 120 details the interaction with the CAIT programs.

![Figure 120. Technology intelligence unit of the CAIT](image)

This CAIT unit is the basis for a new generation of technology intelligence services to be offered to SMEs in order to facilitate their positioning in key technologies. Figure 121 shows a number of recently prepared technology watch reports in cooperation with UPM research groups to support market analysis. Furthermore, during 2015 an e-learning seminar on Technology Intelligence (1 ECTS) was also prepared.
At the moment, the Intelligence Unit is involved in two research projects:

- An agreement with the "Instituto de Salud Carlos III" (The Carlos the Third Institute for Health) will be the basis for the development of a series of technology watch reports on key technologies relevant to health systems (initially the agreement, pending of administrative procedures, will be developed during 2015 and 2016 but the goal is to have a long-term partnership between both institutions in this area).

- An agreement with IBM Research for the development of a cognitive-based service for SMEs (in cooperation with the Ontology Group of the School of Computer Engineering) by using the Watson system. The project will run until the end of 2017.

### 3.4.1.6. Programs focused on business incubation

As stated above, the CAIT is operating a business incubator for technology-based start-ups. The resources generated via this activity are main elements in ensuring the sustainability of CAIT\(^81\).

A recent agreement with the European Space Agency (ESA) through the Madri+d Foundation (public foundation attached to the regional Government of Madrid)\(^82\) will provide a number of added value services for up to 3 start-ups to develop products or services from the space sector to other industrial sectors. These companies will be selected in October 2015 and we expect that they will occupy their spaces at the end of the year.

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\(^81\) To give a single figure of reference, the renting of space to start-ups generates approx. €400,000 annually which is enough to reimburse the loans received from the Spanish Government to build the CAIT premises within the I2_Tech project. In this way, in only two years, the CAIT reached break-even and has firmly set the basis for its sustainability.

\(^82\) Three public universities, the UPM, the UCIII and the URJC and the Scientific Park of Madrid participate in the initiative.
In the last two years, the number of companies located in the business incubator grew from 3 to 15 (to 18 with the ESA agreement). These companies will also be supported through specific agreements to provide them with training or access to a number of horizontal facilities in the CEI Montegancedo (from supercomputing to sports facilities).

Recently, a pre-incubation space was also prepared to support advanced training for highly qualified business teams (see figure 122). Some of the business teams can use the space as an accelerator.

The pre-incubation space was also used in July 2014 and 2015 for the CAIT Summer School on Entrepreneurship. The 2015 edition brought 50 students from a number of UPM schools together to increase their awareness of entrepreneurship. Also, in July 2015 the space was the basis for “creativity courses” oriented to secondary school students (from 15 to 17 years old) in order to stimulate their interest in engineering and architecture studies.

Figure 122. Pre-incubator facilities

3.4.1.7. Tuning the CAIT ecosystem for spin-offs

Chapter 2 presented the concept of the CEI Montegancedo innovation ecosystem as a driving force for increasing the impact of the CEI in society and the transformation of the UPM into an entrepreneurial university. In that chapter, no explicit mention of the spin-offs and start-ups created by the UPM during the last years was made (more than 100 have been created since 2010); however, from the CAIT’s vision, they will become key elements for its future development.

Figure 24 explicitly describes the type of ecosystem (a subset of the general one from CEI Montegancedo) which is being built. Even if the UPM has created 180 firms (spin-offs and start-ups) only some of them are formally related to the CAIT at the moment. Five types of complementary relationships are envisaged:

- Companies located on CEI Montegancedo (see Annex 1)

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83 In July 2015, only three modules in the CAIT premises are not occupied or booked.
• Companies participating in joint R&D projects with the UPM
• Companies with educational agreements
• Companies involved in licensing
• Companies acting as brokers

As we can see in figure 123 (see the coloured “bubbles”), some companies have signed a range of agreements (or multi-purpose agreements) with the UPM which is seen as the intensity of the relationship.

From the CAIT perspective, this open ecosystem under construction could be a valuable tool for attracting additional investments in close cooperation with the UPM research groups.

This specific ecosystem with the UPM spin-offs and start-ups is currently going through an incipient phase. The idea is to strengthen it at the institutional level in the same way as other institutions do at the individual level (e.g. with ex-alumni). For this purpose, a set of initiatives are on the way to being fully developed in 2016.

3.4.1.8. An overall assessment of the CAIT development

Previous sections have presented specific data and results from individual types of activities framed in the so called “CAIT areas”. Even if this analytical approach
seems appropriate to understand the CAIT evolution during these two and a half years, it also crucial to assessing its benefits for the whole UPM from an overall and integrated perspective in the long-term goal of mentality change as stated above.

Figure 124 summarises the effort made by the CAIT-UPM since its creation. We are well aware that three years is a very short period of time to consolidate any initiative, but the context of CEI Montegancedo has been an excellent catalyst for this objective.

![Figure 124. Evolution of CAIT (2010-2015) with accumulated data](image)

The key question to be addressed is to know whether the effort made with the creation of CAIT is worthy for the entire UPM. To answer that question three elements need to be taken into account:

- The evolution of selected indicators to be able to present data which should be better than in the past (or even by opening up new avenues of innovative working).
- The vision of the service offered to the UPM community where both students and faculties increase their interaction with CAIT staff.
- The visibility gained from the external world where CAIT is playing a role to “sell” UPM capacities, results and future opportunities.

As regards the first point (evolution of indicators) some figures related to business ideas (and the people involved), the number of start-ups and spin-offs created, the licenses signed, training courses on innovation and entrepreneurship, etc. have been presented in previous sections. It is evident that the creation of CAIT has been a catalyst in improving the social role of the UPM in the exploitation of results
and in the creation of an entrepreneurial mentality. Consistent rankings in these issues clearly reflect this position.

As regards the second point (internal visibility) these two and a half years have been very intense in meeting with research groups and organising events in different schools related to actuaupm or Innovatech_UPM programs.

As regards the third point (external visibility) the whole CEI Montegancedo and CAIT in particular has received a lot of attention from external entities. Institutional visits from the central administration and also from abroad are common every month. Explanations on the CAIT model have been presented in international congresses and to a number of companies or venture capital entities. Periodical newsletters are widely distributed and blogs are getting more than 5,000 visits a month. Figure 125 shows some of the activities and documents generated with respect to points 2 and 3.

![Figure 125. Dissemination activities of CAIT (web and social networks)](image)

This effort is not enough. We are well aware that the development of CAIT needs to be continued. New challenges are on the horizon and we need to react very soon. The evolution of CAIT in the framework of the CEI Montegancedo until 2020 is covered in the last chapter of this final report.

To finalise, the International Campus of Excellence of Montegancedo was designed to facilitate technology innovation in close partnership with other public and private entities around ICT-based services. That goal has led to a coherent
effort to create and consolidate a set of advanced research centres and technology innovation support through pilots and demonstrators

The UPM strategy for the exploitation and commercialisation of research results is an institutional vision of the UPM role in the knowledge triangle context (education + research + innovation)

The Support Centre for Technology Innovation (CAIT) and its main Innovatech_UPM and actúaupm programs, are the instruments created for that purpose.
ANNEX 1: Spin-offs and start-ups located in the CEI Montegancedo

<table>
<thead>
<tr>
<th>Company</th>
<th>Creation date</th>
<th>Origin</th>
<th>Location</th>
<th>Main activity</th>
<th>Interaction with the UPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gennion</td>
<td>2014</td>
<td>ETSIInf</td>
<td>CAIT</td>
<td>- Digital service platforms</td>
<td>R&amp;D</td>
</tr>
<tr>
<td>Plant Response Biotech</td>
<td>2007</td>
<td>CBGP</td>
<td>CAIT</td>
<td>- Plant immunology</td>
<td>-Broker</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-IP licenses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Use of facilities in the CBGP</td>
</tr>
<tr>
<td>Air Drone Tech Services</td>
<td>2015</td>
<td>External</td>
<td>CAIT</td>
<td>- Pilot for drones</td>
<td>Joint projects</td>
</tr>
<tr>
<td>Air Electronics</td>
<td>2012</td>
<td>External</td>
<td>CAIT</td>
<td>- Electronic pilot controllers for UAVs</td>
<td>Joint projects</td>
</tr>
<tr>
<td>Algenex</td>
<td>2010</td>
<td>INIA-CBGP</td>
<td>CAIT</td>
<td>- Alternative gene expression</td>
<td>Joint projects</td>
</tr>
<tr>
<td>Frontiers software</td>
<td>2010</td>
<td>EPFL</td>
<td>CAIT</td>
<td>- Platform for on-line publishing</td>
<td>Actúa-LOOP</td>
</tr>
<tr>
<td>Bio-optical detection</td>
<td>2013</td>
<td>CTB-UPM</td>
<td>CAIT</td>
<td>- Biochips for detection of illnesses</td>
<td>Use of facilities in the CTB</td>
</tr>
<tr>
<td>Fastack Advanced technologies</td>
<td>2015</td>
<td>External</td>
<td>CAIT</td>
<td>- Internet satellite</td>
<td></td>
</tr>
<tr>
<td>Masdediagram m</td>
<td>2011</td>
<td>External</td>
<td>CAIT</td>
<td>- Technical engineering services, technical services for architecture and urbanism and scientific and technical research.</td>
<td>Joint projects</td>
</tr>
<tr>
<td>Advanced Intelligence developments</td>
<td>2008</td>
<td>ETSIN</td>
<td>CAIT</td>
<td>- Advice and consultancy on business intelligence</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Year</td>
<td>Client 1</td>
<td>Client 2</td>
<td>Project Description</td>
<td>Outcome</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------</td>
<td>------------</td>
<td>------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Softtelecom desarrollos I+D</td>
<td>2005</td>
<td>External</td>
<td>CAIT</td>
<td>Development and marketing of hardware and software and related services</td>
<td>Joint projects</td>
</tr>
<tr>
<td>Dail Software</td>
<td>2013</td>
<td>ETSIInf</td>
<td>CAIT</td>
<td>Design, development and marketing of linguistic engineering applications.</td>
<td>Joint projects</td>
</tr>
<tr>
<td>LeanXcale</td>
<td>2015</td>
<td>ETSIInf</td>
<td>CLC EIT</td>
<td>Large scalable databases</td>
<td>IP licenses</td>
</tr>
<tr>
<td>Mimetrics</td>
<td>2014</td>
<td>CEDINT</td>
<td>CEDINT</td>
<td>3D Design</td>
<td>Use of facilities in the CEDINT</td>
</tr>
<tr>
<td>LPI</td>
<td>2010</td>
<td>IES</td>
<td>CEDINT</td>
<td>Advanced Optics</td>
<td>-R&amp;D</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-Use of facilities in the CEDINT</td>
</tr>
</tbody>
</table>
ANNEX II. Experience labs located in the CAIT

The Experience Lab of the Spaces of the Future

The Experience Lab of the Spaces of the Future is a working space comprising a number of reconfigurable semi-open rooms, specifically conceived to test advanced concepts and evaluate user experiences in services based on state-of-the-art ICTs.

The Lab is focused on technologies and concepts for Smart Spaces, specially those which enable the personalization of space, on the one hand, and an improvement in any aspect of the standard of living and comfort, and on the other: work, relaxation, health care, social life, etc. The Lab is conceived with facilities for creating different user spaces to simulate different circumstances and scenarios, including private and social environments. The key technology concepts that set up the framework of the space are those that might be included in the general “ubiquitous computing” paradigm, i.e. personal smart devices, smart objects, natural interaction, and ubiquitous visualization and sensing. However, the primary objects of interest of the Lab are not the technologies themselves, but rather “the experiences” (constructed from services offered from the technologies), understood as the personal perceptions and some objective measurable results on new ways of making things in a given context.

The primary motivation to conceive and deploy such a Lab was the conviction that the successful advancement of *a priori* valuable ubiquitous computing-based services and concepts require a phase of user-based evaluation and feedback under realistic conditions. But the key idea behind the Lab is not merely to carry out experiments in order to assess the acceptability or usability of given specific services to propose incremental changes to a given app or gadget. On the contrary, the main vocation of the Lab is to grow as a creation environment to imagine new ways of using a combination of technologies and services for the living spaces of the future. In a sense, the Lab is intended to be an incubator for concepts for the spaces of the future.

Deployed technologies and individual services include: proximity-based event detection, environmental monitoring, augmented reality, RFID-based services, domotics, location-sensing multimedia contents, device-centric displaying, gesture based interaction, mobile-based interaction, physical objects programming tools, camera-based scene analysis, precise user positioning, reasoning for personalization, etc.

In short, the objectives of this Lab are:

- To become a **space for the demonstration, evaluation and user validation** of technologies and service concepts in various niches, spaces and in the city itself.
• To provide a set of facilities specifically deployed to **analyze different functional areas of a complex smart space**, such as, interaction, communication, energy issues, smart objects or organization and productivity from a multi-disciplinary integration perspective.

• To serve as a **space to promote creativity** for the development of concepts and services, combining open methodologies for the generation of solutions by complementary groups of agents, with the end user playing the central role. Specifically, the laboratory will also serve as a forum for generating new ideas for R&D (though it is not itself a space for implementing technological R&D).

• To be a live space to maintain a continuous relationship with various concerned **business sectors** in order to conceive emerging services and to evolve immature technologies, through interaction and (open) cooperation with researchers and users.

**Facilities and Service Portfolio**

As outcomes of the research and innovation activities, different software platforms and infrastructures have been designed and crafted into pre-commercial products. Some of them are:

• MOBILOC: The MOBILE Bidirectional notification service based on LOCation. MOBILOC is a positioning system that offers location as-a-service, using Bluetooth Low Energy/WiFi technologies. It provides robust proximity and zone-based identification in multiuser environments and includes a management interface to control the sensor network and deliver location-aware notifications configured to provide bidirectional real-time user feedback.

• HOOPOE: A Hybrid approach for 6-dof Object pOse (Position + Orientation). In order to make indoor AR services possible, it is necessary to have centimetre-accurate positioning systems. HOOPOE solves this issue by using low-cost resources, such as paper tags and webcams.

• SAM: Smart spAce Manager. In a new smart space, SAM enables the deployment and integration of hybrid sensor and actuator networks (Arduino devices, REST-based devices, etc.), together with visualization devices. Under a simple JSON syntax, it integrates a smart space controller, a DLNA controller, a multiuser controller and a space monitoring interface that enables the information from the different sensors deployed in the environment (lights, automation devices, proximity/movement sensors, etc.) to be customised, configuring scenes and delivering content to the different visualization interfaces.

• WoTOP: Web of Things Open Platform. WoTOP is a platform based on the Web-of-Things paradigm, which uses web technology to facilitate the integration and management of heterogeneous sensor networks.

A number of applied products have been built on these underlying technologies. Nine of them are briefly described below:

• MAGAZIN: Mobile-mediated Augmentation of GAdgets with personaliZedd multimedia coNtents. This tool facilitates the augmentation of an object (e.g. a magazine) with cheap mobile-readable tags and related virtual content. The
user’s smartphone provides profile information that serves to adapt the content to the user’s particularities and visualize it in an external device (e.g. TV, screen-like), thanks to its integration with SAM.

- **MECCANO**: Mobile-Enabled Configuration framework to Coordinate and Augment Networks of smart Objects. Smartphones have a great potential as mediators and interaction tools with the environment. MECCANO delivers a very simple object discovery protocol and configuration interface that makes it possible for the user to build scenes and share them with other MECCANO users.

- **PERSEO**: Personalization of the Environment Response through Smartphones and Objects. On object touch or proximity, PERSEO facilitates the easy transfer of phone actions to the different interfaces available in the environment. SAM executes the control actions defined by PERSEO reasoner, which consider device occupancy and service characteristics to decide the best action to take.

- **VIEW**: A system to deploy Virtual windows to the Real World. Architecture for future spaces will increasingly integrate technological resources. Built on COTS, VIEW virtual windows enable the viewer to take a look anywhere in the world in a realistic way, using recorded videos or real time streaming.

- **GENIE**: A Gesture-Enabled Interaction method designed for smart Environments. How to exploit gestures for interaction within the smart space is a challenge. GENIE provides the technology to train and identify gestures through smartphones, smartwatches or depth sensors (Kinect, Leap Motion-like). Moreover, GENIE provides a configurable compiler that facilitates the creation of interaction grammars through the concatenation of gestures. Integrated with MOBILOC, it makes it possible to interpret the grammars depending on the user location.

- **Point2Act**: Point2Act delivers the infrastructure to make a room sensitive to pointing movements by using COTS sensors. Integrated with SAM, Point2Act delivers digital object control by deictic pointing.

- **ARTHE**: experiencing Augmented Reality with THings of the Everyday. ARTHE facilitates the exploitation of AR indoor concepts, by augmenting real objects with virtual controls, accessible through the mobile device. Integrated with HOOPOE it delivers a complete system for low-cost indoor AR service deployment.

- **FollowMe**: The next generation of smart home services will not limit its functionalities to basic commands of lighting, heating or security control, but contents, preferences, activities will be seamlessly transported between living spaces as the user moves around. By relying on the MOBILOC and SAM infrastructure, FollowMe makes it feasible to transport multimedia activities automatically.

- **DECIDA**: Direct and Enhanced Contactless IDentification and Authentication. DECIDA is a set of simple, low cost, reliable identification technologies for non-critical services that facilitate the identification or authentication of a user by the way s/he performs the gestures or by the shape of the hand.

Within the Lab facilities, a number of user studies to validate services and interaction concepts have been carried out. In particular, services such as PERSEO,
GENIE, Point2Act, ARTHE or DECIDA have been tested in user groups in specific validation sessions.

Figure 126. Some views of a number available services in the Experience Lab of Future Spaces. From left to right, up to bottom: GENIE, ARTHE, VIEW, GENIE for Mobile, PERSEO.

**Infrastructure. Investments.**

A significant investment in infrastructure facilities, equipment and material has been made to build and run the Lab. Some examples are:

- Computers and processing equipment (servers, hubs, etc.) from various companies: BENOTAC, SMO, Misco, Taysa, etc.
• State-of-the-art sensors (for movement detection, interaction, smart home sensing, etc.) and advanced devices to implement services (smartphones, tablets, etc.), bought to various providers: Microsoft, Estimote, Arduino, Alava, Google, Apple, etc.
• Miscellaneous furniture enabling to create and decorate the physical space and to host and install the ICT equipment, from several companies: ORGANYTEC STUDY, Ofibroker, LM, Mipuf, etc.
• Recording equipment (cameras), projection devices (3D) and multimedia presentation devices from various brands and companies: SATEC, SMO, Mediamarkt, etc.
• Wooden structures and other auxiliary structures to build the internal architecture of the Experience Lab.
• Accessories and other tools to build the spaces.

Projects

The Experience Lab of Future Spaces infrastructure has been used or it is being used in different research projects, such as:
• THOFU, Technologies for the Hotel of the Future (2010-2014), funded by Spanish Ministry for Science and Innovation-CDTI and private (CENIT program). Different services designed and develop in the project context have been adapted, matured and installed for user evaluation in the ExpLab.
• Experience Lab on Future Banking (2014), funded by Banco Santander. The ExpLab of Future Spaces has developed and installed specific hybrid location infrastructure to deploy personalized services in the Bank Office of the Future.
• RETAILS, REsearch on pervasive Technologies for Advanced Interaction in smart public Living Spaces (2015-2017), competitive project funded within the National Program of R&D&i oriented to Societal Challenges, 2014 call, Spanish Ministry of Economy and Competitiveness.

Additionally, the infrastructure is a relevant facility within several European proposals that have been presented to different calls of the Horizon2020 Program.

Educational activities

In the last two years, 13 M.Sc. thesis and 6 Ph.D. thesis have been completed, and some are still being developed in the Experience Lab, contributing to and using its infrastructure and facilities for user testing.

Living Lab and Demonstrator of 3D TV (Dem-3DTV)

The main target of the three-dimensional television (3DTV) demonstrator is experimenting and developing of new and innovative technologies in the area of 3D video. That is why its main goal was to have an infrastructure that gives support to research, development and testing of three-dimensional television equipment considering the whole chain of signal manipulation, comprising:

• Capturing: camera systems to capture visual information in multiple views.
• **Representation**: set of procedures and standards for characterizing signals uniquely and jointly, allowing their exchange, storage and transmission.

• **Coding**: set of procedures and standards for reducing the volume of data required to represent the signals, to achieve both a more efficient storage and transmission.

• **Post-production**: 2D and 3D post-production system to resolve problems in capturing three-dimensional video sequences both in stereoscopic compact cameras as in cameras configured on rig.

• **Distribution**: 3D real time transmission system over IP networks allowing a communication that provides the feeling of real presence.

• **Display**: display systems for the visualization of signals, both stereoscopic and multiview, that show different views depending on the position of the observers, allowing them to perceive that the visual information provides depth and perspective.

![Figure 127. Facilities for 3DTV](image)

Since its beginnings, the Dem-3DTV has been created as an innovation, experimentation and co-creation environment, where researchers, companies, standardization bodies and public institutions work together, in the search for new solutions, products or services, involving real users in the entire research process, promoting the cooperation.

**Equipment**

As the main goal of the Dem-3DTV is to have an infrastructure that gives support to working with three-dimensional television systems, considering the whole chain of signal manipulation, its equipment is focused to this target:

1. **Capturing systems**: The Dem-3DTV is equipped with a set of 3D compact cameras (semi-professional and consumer) and 2D cameras configured in a rig, allowing the acquisition of visual content from multiple
viewpoints. Thus, the Dem-3DTV can generate its own digital content that is used, among other objectives, for the publication of research results.

2. **Lighting and audio systems:** It is equipped with a lighting system that is suitable for shooting in chroma-key environments. It is also equipped with an audio system that is compatible with every camera available in the Dem-3DTV, as well as a surrounding audio system that enables immersive experiences.

3. **Postproduction system:** Several systems for the processing of stereoscopic signals have been acquired: both educational and professional. These systems include DI systems, edition, composing, effects and colour correction for 2D and 3D productions, in any resolution from SD to 2K. They handle the real-time processing of time-lines using high-end equipment and provide creative capacities and techniques that are superior to the standard tools offered by other finishing and colour correction systems.

4. **Display systems:** The Dem-3DTV is equipped with a wide range of 3D display systems: several stereoscopic (two views) displays and TVs, with sizes up to 55”, for shutter and passive glasses, a stereoscopic projector with passive glasses and a 28-view auto-stereoscopic display that offers different viewpoints depending on the position of the observer, allowing visual information to be perceived with depth and perspective. These systems can be used in the demonstration of new technologies and research results, both our own and those from external companies.

5. **Playing systems:** To facilitate the display of 3D content in the Dem-3DTV, several playing systems were acquired for the generation of 3D signals that are compatible with existing display systems without loss of resolution.

6. **Information processing systems:** The Dem-3DTV has multiple signal processing systems for the digitalization, analysis, coding and representation of stereoscopic 3D video signals.

**Results**

**3D Video Subjective Quality Testing**

One of the purposes of the Dem-3DTV, due to synergies similar to those considered in the Living Labs, is the collaboration with companies from the audiovisual sector in every step of the innovation activity to generate cross-fertilization.

One of the main activities of the Dem-3DTV as a Living Lab has been the design and implementation of Quality of Experience (QoE) tests, such as the subjective video quality testing of 2D and 3D video for standardization bodies, such as MPEG, and consortia within European projects.
Subjective video quality testing for the new 3DVC standard (3D Video Coding)

Many aspects of 3D video technology are still the focus of significant research work that aims to provide the viewers with high-quality content that will significantly improve their visual experience compared to traditional video. MPEG led the development of 3D video coding standards under the name of 3D Video Coding (3DVC). The Dem-3DTV was one of 13 ITLs (Independent Testing Laboratory) that MPEG selected worldwide for carrying out subjective quality tests of the proposed 3D video formats and associated compression technology.

The Dem-3DTV was especially equipped in accordance with international standards, for the evaluation of encoding algorithms in the displays selected by MPEG (stereoscopic and auto-stereoscopic). The group of test subjects had to assess aspects such as the feeling of discomfort that 3D video content sometimes produces as well as the quality of the sequences.

Project JEDI: “Just Explore Dimensions: End to End High Definition 3DTV for the Consumer”

The main objective of the JEDI project was the study and development of an end-to-end 3D television (3DTV) system. In particular, an end-to-end processing chain for high-quality stereoscopic video was developed using multiview video coding, satellite broadcasting networks and IP networks. Within the JEDI Project, the Dem-3DTV team carried out a series of subjective 3D video quality tests, in which the overall 3DTV user experience was analyzed. In this case, it was decided to avoid the traditional testing laboratories, defined by the ITU, which seek to minimize the elements that distract the observer: surrounding objects, display position, distance to the screen, brightness setting, etc., as they are very different from the home environment in which 3DTV is intended. For this reason, a domestic living room was recreated in the space dedicated to the tests.

Subjective quality assessment of an adaptive streaming model

With the recent increased popularity and extensive use of HTTP Adaptive Streaming (HAS) techniques, various studies have been carried out in this area which have generally focused on the technical enhancement of the HAS technology and applications. However, the lack of a common HAS standard led to
multiple proprietary approaches which have been developed by major Internet companies. In the emerging MPEG-DASH standard the packaging of the video content and HTTP syntax has been standardized; but all the details of the adaptation behaviour are left to client implementation.

Nevertheless, to design an adaptation algorithm which optimizes the viewing experience of the end user, the multimedia service providers need to know about the Quality of Experience (QoE) of different adaptation schemes. Taking this into account, the objective of the Dem-3DTV was to study the QoE of an HAS-based video broadcast model.

The experiment has been carried out through a subjective study of the end user response to various possible client behaviours for changing the video quality by taking different QoE-influence factors into account. The experimental conclusions have given us a good insight into the QoE of different adaptation schemes which can be exploited by HAS clients for designing the adaptation algorithms. These tests have given the Dem-3DTV the international recognition they deserve thanks to the publications of our researchers and their participation in standardisation bodies (e.g. MPEG).

**Design, development and optimization of algorithms**

The advances in stereoscopic technology in representation formats and efficient coding systems, along with the transmission channels that send information at very high speeds, are also allowing the spectacular nature of 3D to be applied in live transmissions, giving way to surprising possibilities. Since live 3D content transmissions over IP networks are still in an experimental phase, the Dem-3DTV is researching and developing new methods and algorithms for high-speed 3D video transmission using efficient 3D video coding systems over existing IP networks. Within the Dem-3DTV, a platform of stereoscopic 3DTV transmission over IP has been developed, that can prove the viability of such transmissions with existing equipment on the market.

Finally, a real-time coding and decoding software was implemented, based on the Multiview Video Coding standard, and multiple auxiliary programs for the composition of sequences of stereoscopic 3D video for different 3D representation formats.

**Training in 3DTV**

The Dem-3DTV is using its equipment to train UPM students. Undergraduate students did the practical work on the generation and manipulation of 3D digital content within the “3DTV” and “Digital Television Laboratory” courses of the Telecommunications Engineering studies, and courses in the new subjects of the specific Sound and Image itinerary in the undergraduate degree in Telecommunications Technologies and Services Engineering.
Furthermore, both undergraduate and Master's Degree students use the infrastructure for carrying out research work that leads to the completion of, respectively, Bachelor and Master's Degree Theses.

Finally, PhD students are also making use of the infrastructure for their research work that leads to the completion of their PhD Theses.

**Impact**

**Project “Experience lab on Future Banking”**

In 2012, UPM and Grupo Santander (Santander, Isban and Produban) decided to create the "The Banking Office of the Future" Living Lab in the "Centro de Apoyo a la Innovación Tecnológica" (CAIT) on the Campus of Excellence at Montegancedo. Within the project, the Dem-3DTV seeks to develop:

A visual communications system with depth perception to provide an immersive and proximity experience. The development of this telepresence system, contributes to bringing employees and customers together, providing the sensation of a face-to-face meeting, without the need for a physical presence. These new capabilities of communication systems open the door to new and better customer-worker relationships.
A system for the location and tracking of multiple persons in a bank office using visual information captured and processed by the system itself. With this system, it will be possible to obtain interesting data for the evaluation of bank offices, such as, the average customer waiting time or their typical behaviour.

Figure 131. Camera recording

VIDEOCELLS “Application of Femtocell Technology to the video distribution for the 3G/LTE/4G terminal”

The main purpose of this project is the development of a platform that provides video and television distribution services through IP (IPTV) for 3G/LTE/4G terminals using femtocell-based technology. These services are based on the HTTP Adaptive Streaming (HAS) technology and consist of a series of modules that are responsible for the selection, request, receipt, buffering and playback segments in which the multimedia content is divided into depending on the characteristics of the scenario in which transmission occurs.

A DASH server has been installed (http://dem3dtv.gti.ssr.upm.es/index.php/proyectos) in Dem-3DTV’s facilities.
Specialization course
The Spanish Ministry of Industry, Energy and Tourism (MINETUR), through the public corporate entity Red.es, and UPM, have created the Production and Experimentation Centre in the Dem-3DTV. The Centre has a Mistika 2K post-production system with a stereoscopic module. With this system, the Dem-3DTV gave a specialization course to media professionals who were interested in the study of the problems of video signal generation and the later post-production stage.

![Figure 132. 3D Facilities.](image)

Support to companies and organizations in the audiovisual sector
The Dem-3DTV has organized and provided support for the demonstration of 3D video technology and the drawing up of small reports for audiovisual sector companies, allowing them to use the Dem-3DTV facilities for evaluation purposes.

In this sense, due to its recent creation, it currently collaborates with academic centres and companies in the Greater Madrid area, with the aim of collaborating with major Spanish companies that lead the field of audiovisual technology.
Partnerships with the private sector are of great importance for the CBGP and significant efforts are being made in this area in order to build strategic partnerships within the sector, with considerable success as shown by the share that funding from contracts with private companies has in the total research budget.

Significant efforts are also being made for the Industrial protection of our research, so that the number of filed patents, although modest, has more than doubled since before 2010. Currently about 25% of the patents are licensed.

3.5. **Interaction with the external socioeconomic ecosystem and contribution to territorial development**

3.5.1. **Context**

A university campus cannot live in isolation from society. Strong links and continuous adaptation to the external context are necessary to ensure its social role, to serve as a loudspeaker for the needs of society, and to contribute to territorial socioeconomic development. The recognition of this situation becomes crucial for public universities which are (partly) funded by public budgets.

Nevertheless, the way to address this need differs widely from one university to another depending on historical and cultural ties with other social agents, the academic and research possibilities available and capabilities, and the specific institutional strategy put in place for that purpose.

CEI Montegancedo is a relatively new campus which is not located in the middle of any city or large village as mentioned at the beginning of this report; however, the UPM commitment to contribute to the socioeconomic development of the region and Spain was firmly anchored from the very beginning of the I2_Tech proposal taking into account its specificities as a campus of a public technical university.
Apart from the obvious interaction with society through the yearly enrolment processes of students in their academic degrees (and the related offer-demand trade-offs which are necessary to adjust them to Spanish needs\(^{84}\) and to ensure its long-term economic sustainability) the CEI Montegancedo has taken advantage of the CEI program to launch the organisation of a large number of activities to disseminate its capabilities and/or to enforce closer relationships with social actors in the region in which the campus is located\(^{85}\).

This section provides a summary of the initiatives carried out in the period 2010-2015 by the CEI Montegancedo to develop and strengthen its interaction with other public and private actors and to push forward its contribution to the territorial socioeconomic development in the region of Madrid (indirectly in other parts of Spain or the EU when these initiatives are carried out in an international context).

Furthermore, progressive improvements in its physical infrastructure to become more useful to the CEI Montegancedo community have also been pursued since 2010 within the economic constraints suffered by public universities during recent years. The main activities will be also summarised in this section.

The activities carried out by CEI Montegancedo within this context have been classified into three main different types:

- **Infrastructural issues.** These refer to aspects related to living, transport or leisure facilities available for the CEI Montegancedo community. Three activities were funded:
  - Energy efficiency
  - Electronic communications
  - Transport and communications

- **Interaction with external actors.** These refer to activities for specific groups of people inside or outside the UPM.
  - Informal educational activities open to society
  - Institutional gender policy
  - Support office for students and researchers

- **Advanced services.** These refer to technical services offered to the UPM community (they are not restricted to the CEI Montegancedo).
  - CeSViMa
  - 3D manufacturing and rapid prototyping

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\(^{84}\) The concept of “needs” is something blurry. It has been historically assumed that a technical university should prepare highly-qualified professionals for the national industry and public administrations. Even if this approach is still valid, a broader scope is emerging where universities should also attend to supra-national needs (e.g. in the framework of the EU or in the international agenda).

\(^{85}\) This section will not address the international scientific events which are mentioned in other parts of the report.
The following subsections will develop them. Additional information on all of these issues can be found on the web page of the CEI Montegancedo.

3.5.2. Infrastructural issues

The allocated budgets for deploying common physical infrastructures allocated to the Campus during recent years were not very large; the UPM has preferred to allocate the resources available from the I2_Tech project to improving the R&D and innovation facilities86. Nevertheless, a number of improvements have been made in some key aspects: energy efficiency, high-speed communications, and transport facilities.

Where possible, solutions in all these areas were based on the use of advanced technology (even with non-totally mature alternatives to emphasise the implementation of pilot but operational projects).

**Improvement of energy efficiency**

The cost of energy consumption currently constitutes a large part of the fixed costs in the operation of the Campus. As happens in other areas of society, the monitoring, control, and economic savings in this area have clear long-term benefits even if it requires initial investments to adapt pre-existing infrastructures.

Three actions were initially addressed using innovative solutions:

1. To improve the external lighting system through the implementation of a smart sensor-based LED system.
2. To reduce the electricity consumption of Magerit (CESVIMA) by improving the cooling system of the supercomputer (and computing centre).
3. To monitor the energy consumption of some labs (green-labs initiative) in the greenhouses.

**External lighting system:**

Within the actions funded in 2013 and 2014, the CEI Montegancedo devoted a substantial effort to improving the external lighting system on the Campus in order to improve consumption, security and convenience. This initiative tried to address two complementary goals: to provide a better and efficient lighting system to cover the whole campus, and to deploy and test the UPM technology developed in the area (sensors, detectors and protocols).

The project was carried out between CEDINT with Philips to deploy an LED-based smart lighting system using a distributed network of sensors designed by CEDINT and coupled in the pre-existing conventional street lamp system.

86 As previously reported the initial idea of building the “agora” to serve as a central meeting point for the UPM community was abandoned due to the lack of resources (mainly loans) which were necessary to fund it.
Figure 134a details the sensors used on the Campus on street lamps and in figure 134b the effect on the facades of some buildings of the Campus (where lighting is combined with promotion of the Campus).

a) Low consumption lighting system in the Campus

b) Night view of some buildings in the Campus

**Figure 134.** Smart lighting technology demonstrator

The technology demonstrator deployed has also allowed information associated to the movement of people and vehicles within the Campus to be generated through additional sensors (see figure 135) and to create specific tools for remote and mobile control.

**Figure 135.** Low consumption systems in the Campus
Both sensors and software protocols were designed by the UPM and it is also the basis for current and future proposals in the area of “smart cities” where the campus could host innovative applications (see chapter 4 of this final report).

![Figure 136. CEDINT sensors used in the Smart lighting system](image)

**Energy consumption of supercomputing**

The cost of electricity for a computing centre is one of the main budgetary areas for its operation. The CeSViMa computing centre was a typical case in which large mainframes (or supercomputers in this case) are involved in the reduction of costs.

Solutions came from the combination of two complementary approaches: 1) change in technologies used in which new generations of processors clearly reduce the watts per FLOPs; 2) the use of smarter cooling systems.

Both approaches were implemented in the CEI Montegancedo with the help of IBM during 2013 and 2014. The consequence was a sharp reduction in the electricity consumption of Magerit (less than the 50% of the pre-existing bill even if the total CPU power is higher.

**High-speed communications.**

CEI Montegancedo is firmly committed to providing high-speed communications with a two-fold purpose: the serve to the campus community where a large percentage of activities are IT-enabled and to attract the interest of relevant stakeholders on the basis of the services offered.

Within the 2010-2015 period, the I2_Tech project has worked in two complementary areas:

- The deployment of a high bandwidth communication network in the campus with a dramatic improvement in the external connections to

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87 The relevance of this issue explains why large IT companies are moving their “servers’ farms” to places where the cost of electricity is cheaper.
RedIris. It has been based on a new router and links of up to 100 Gbs (the central node of "Redimadrid", the regional academic research network, is located in the IMDEA software building). In 2015 a second phase to cover with a double-fibre optics link is being deployed.

- The implementation of an external Wi-fi infrastructure in some parts of the campus to complete the wireless networks deployed in the buildings; however, the final objective of covering the whole campus still requires additional investment.

**Transport infrastructure**

The UPM staff, companies and students working daily on the Campus has grown dramatically during the development of the CEI Montegancedo. Unfortunately, the public transportation system available to get to the CEI Montegancedo is only based on two bus-lines connecting the Campus to Madrid (to Moncloa and Aluche respectively). So, the private car is used by a large majority of the population on the Campus. It has generated the need to expand the initial external parking lots available\(^8^8\).

Two additional parking areas were built in 2014 and 2015 in relation to the full operation of CAIT:

- Parking CAIT in front of CTB (2014): 45 places
- Parking 2 CAIT in front of CAIT (in contract phase): 60 places

Furthermore, internal roads were also improved to cover damage suffered after the construction phase.

We are well aware that the plans to increase postgraduate studies on the campus will require both additional space and better public communications in the near future. This need should be addressed in the next period of the CEI development in agreement with the transportation authorities in the region.

**3.5.3. Interaction with society**

Universities usually pay attention to their students or to the companies or entities they cooperate with in education, research or innovation activities. Unfortunately, interaction with society-at-large is still poor and it does not contribute to increasing the relevance or impact of universities in our society. UPM is not an exception in this general situation.

We are well aware that the CEI Montegancedo should work on these lines, even if the organisation of extension courses or events for general citizens are difficult to do on a Campus not located in the centre of the city and with a poor public transportation system. As a consequence, only well-targeted events are possible.

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\(^8^8\) Even if the CAIT and IMDEA Software buildings had an internal parking area, the remaining buildings would still depend on external space.
During the period 2010-2015 the CEI Montegancedo has implemented a number of initiatives to address this issue as follows.

**Informal educational activities open to society**

CBGP researchers actively participate in events to introduce and explain science. These activities include imparting seminars and conferences specifically aimed at improving the social perception of biotechnology and introducing science to primary school and high school students. CBGP also offers outstanding students the opportunity to carry out stays at a CBGP laboratory.

- **Undergraduate Summer Fellowship Program (2011).**
  - CBGP offered outstanding students from Spanish and non-Spanish Universities an opportunity to spend an eight-week research training program at CBGP where they were exposed to world-class research including seminars, talks and social events in a convivial and motivating environment.

- **Summer schools.**
  - They are periodically organised for interested UPM students by some of the centres of the CEI Montegancedo to increase the interest of the students in these areas. These students are not registered in any course on the Campus. Two examples were:
    - CAIT Summer course on “entrepreneurship” (2014 and 2015)
    - COM Summer Camp on “open software platforms” (2013, 2014 and 2015)
  - A summer course for secondary school students in order to promote their interest in engineering and architecture studies was organised at the CAIT (July 2015).
  - Summer School for Biotechnology undergraduates organised by CBGP (2013, 2014, 2015). UPM students in their first and second year were given the opportunity to carry out a 4-week stay at a CBGP laboratory. Up to 24 students have been following this program each summer distributed between 15 CBGP laboratories.

- **Activities in the Science Week.**
  - Annually, with the cooperation of the OTRI (outreach section) some departments or research groups participate in open experiments at several centres at Montegancedo open to the general public. The variety of centres and equipment makes these activities very attractive.
  - Regular participation of CeDInt: in “Semana de la Ciencia de la Comunidad de Madrid” (Madrid Regional Government Week of Science) with an average participation of 350 visitors per edition.
We also have visits from companies and institutions adding another 400 more visitors per year.

- The CBGP (2010, 2011, 2012, 2013, 2014, 2015) organizes hands-on practical i-workshops, guided tours with demonstrations of the facilities, and lectures every year. Attendees are mainly high school students who are organized into 25 student groups and rotate through the various activities.

- **Fascination of Plants Day** (2012, 2013, 2015). This activity is part of an international program aimed at making society aware of the services provided by plants to humans. This includes sustainable food production through agriculture as well as non-food products such as timber or materials used to produce paper, timber, chemicals, energy, and pharmaceuticals, from both agriculture and forestry, or the environmental benefits provided by plants. Many plant science institutions, universities, schools, botanical gardens, and museums, together with farmers and companies, have opened their doors at the Fascination of Plants Day with a variety of plant-based events. CBGP has organised talks and discussions about plant biotechnology and guided tours of the Centre.

- **Biotech Week** (2014). The European Biotech Week comprises a weeklong series of events celebrating biotechnology. More than 100 events and manifold activities took place across Europe to highlight the benefits and applications of biotech. CBGP held conferences on plant biotechnology and an event discussing advances in biotechnology to improve agricultural activity with direct applications on improving the environment and human health.

- **Visits of secondary schools to the Campus.**
  - Students from the secondary schools in “Pozuelo de Alarcón” will visit the School of Computer Engineering after an agreement with the town's Major.
  - The CBGP receives more than 200 students annually on average (200 students in 2014). Students come from 25 secondary schools (from the Region of Madrid but also from Castilla La Mancha and Castilla and León). As regards the local environment, visits have been arranged with schools from Boadilla, Alcorcón, Las Rozas and Majadahonda.

- **Improvement of the “Museum of History of Computing” located in the School of Computer Engineering.**
  - This is a major effort (partly funded by the CEI program) to extend the previous museum of the Faculty of Computer Sciences. Today it has eight areas with equipment and didactic panels to understand the evolution of computers and peripherals (from their origins to the present day). Figure 4 shows one of the rooms of the museum.
Social events around wind tunnels

In June 2014 the wind tunnel of CIDA-IDR in the Campus was used for one special event: the presentation of the final designs of the Fashion School. To our knowledge it was the first time that a wind tunnel used for aerodynamic...
tests has hosted a fashion collection in front of a very different audience. This example also shows how imagination has a place.

- **Recruitment of students for the new degrees implemented on the Campus.**

As mentioned above, the School of Computer Engineering is the only one located in Montegancedo and the capture of students has become a key issue. Figure 138 corresponds to a study (2014) of the best specialised Masters’ Degrees in Computer Sciences in Spain. Note that the UPM (in CEI Montegancedo) occupies the first position.

![Figure 138. External ranking of degrees offered by the ETSI Inf in Spain](image)

In conclusion, the CEI Montegancedo has implemented (mainly in the last three years) a number of “social events” with the intention of disseminating its activities and to spark the interest of society. The combination of these events with scientific conferences, workshops or seminars contributes to the global visibility of the CEI Montegancedo.

### 3.5.4. Institutional gender policy

There is no specific gender policy on the Campus of Montegancedo; however, it has implemented the generic policies approved by the UPM.
Figure 139 gives a snapshot of gender distribution in the UPM (data from 2013). Surprisingly, the proportion is similar in the case of students as faculty members\(^89\). Obviously, the percentage of men is higher in the highest ranks of faculty members as a consequence of the well-known problem of the “glass-ceiling” suffered by women in an academic context and the historical low interest of women in traditional engineering studies.

\(89\) Historically, Spanish engineering schools have kept a very biased gender balance in favour of men. Even though this situation has slowly improved in recent times, the situation is still today unbalanced and it is reflected in the graduates.
From the research perspective, the UPM situation is changing very rapidly. Figure 141 summarises the gender's distribution of the “main researcher” in the official research groups of the UPM. Practically, all UPM engineering schools have research groups led by women. In the case of ETSI Informatics located on the CEI Montegancedo the percentage is more than 25% which is also above the average percentage at the UPM.

**Figure 141.** Gender's distribution of the main researcher in the official research groups of the UPM

Another relevant indicator refers to the “inventors” with registered IP at the UPM (patents for licensed software). Figure 141 shows that percentages are slightly up but much effort is still needed. Probably, as a consequence, the number of spin-offs led by women is also very small.

**Figure 142.** Women/men balance in UPM inventors
In 2013 the participation of women in the actúaappm program was, in percentage terms (27% from a total of 1,072 participants), lower than the number of women as UPM students. This fact is even worse in terms of the composition of business teams; the number of teams only made up of women was a mere 10% compared to the 55% of teams only made up of men.

In order to find out the roots of the situation and to promote the entrepreneurial mentality amongst women, during 2014 the CAIT has conducted an initiative funded by the “Instituto de la mujer” (Institute for Women) at the Ministry Health, Social Services and Gender Balance. The initiative addressed three main tasks:

1. Course on the Introduction to business creation
2. Round table with the experiences and perspectives of entrepreneurial women and the investment of technology-based projects.
3. Coaching sessions to analyse the feasibility of business ideas.

It is still too early to know the impact of this specific attention paid to entrepreneurs but the CAIT will monitor them in the years ahead. Nevertheless, two additional project proposals have been submitted in 2015 to the “Instituto de la mujer” to continue those activities.

3.5.5. Support’s office for researchers

As mentioned above, the need to increase the number of foreign students was one of the key performance indicators of the internationalisation process on the CEI Montegancedo. As a side effect, the growing number of foreign students and researchers (many of them from outside the EU) has advised the creation of one specific support office to deal with the specific needs of these students.

The office has two sites (in the ETSI Informatics for undergraduate students and in the CAIT for graduates or researchers). Within the activities carried out in 2013 and 2015, we mention the visa and accommodation help (more than 50 expected in 2015)

Figure 143. Office in the CAIT
3.5.6. Electronic communications

CEI Montegancedo requires interaction mechanisms to be set up with the scientific community to take advantage of the possibilities of high-speed communications both fibre optic and wireless.

During 2014 and 2015 apart from this infrastructure, two other elements were set up:

- **Montegancedo Web page:**
  - [http://www.upm.es/Montegancedo/Montegancedo](http://www.upm.es/Montegancedo/Montegancedo)
    - English and Spanish versions
    - News

- **Social networks**
    - Followers of actúaupm
    - Blogs

![Figure 144. Winners of the last actúaupm competition (2015)](image)

3.5.7. Supercomputing services

**CeSViMa** (Centro de Supercomputación y Visualización de Madrid (The Madrid Centre for Supercomputing and Visualisation)) was created to support research and the use of large supercomputers for the UPM Community and the Spanish supercomputing community. Today, it is part of the Spanish network of Supercomputing promoted by the Ministry and signed in April 2015. Since its creation, CeSViMa has focused its efforts on supercomputing, visualisation and storage services; however, since 2014 the centre has diversified the catalogue of
available services in order to increase the added value offered to the UPM community. Today, CeSViMa offers three families of services.

- Cloud storage
- High performance computing
- Private virtual servers

These families of services are summarised as follows:

**Cloud storage (cloud UPM)**

The service provides the access to the “disk in the cloud” from any device connected to the Internet (tablet, smartphone, laptop, etc.) by providing added value and reducing costs for users. The service currently offers 75GB free to the UPM staff.

Figure 145 summarises the use of the services by the different units of the UPM. In some schools the use of the services is very large while in others it still requires additional effort in the promotion.

![Figure 145. Use of Cloud services](image)

**High performance computing**

This is the oldest and most basic service offered by CeSViMa. On the basis of state-of-the-art hardware and software architecture (Intel Xeon and Power7 with co NVIDIA K20X and Intel Xeon Phi-processors) the services offered a number of modalities and costs depending on the activity and use (i.e. PhD theses, research
groups, national RTD projects, etc.). Figure 146 details one of the periodical reports on CPU use. It implies more than 4.5 million hours of computing.

![Figure 146: Use of supercomputing services](image)

It is also relevant to mention that more than 25% of the available computing time is allocated to external users from the Spanish Supercomputing Network as the Madrid node of the network. Computing time is allocated through an external committee on the basis of scientific proposals received.

**Private virtual servers**

This approach allows the move from conventional department servers to a more efficient centralised system accessible through a high-speed network. This service is open to the UPM research groups who freely use a virtual web to host their web pages or applications. Figure 147 represents the distribution of virtual servers between the UPM units (Q1 2015).

![Figure 147: Use of virtual servers](image)
3.5.8. Virtualisation services for students

'Virtualise the IT' infrastructure is one of the main drivers for reducing the costs of the deployment of information technology and, simultaneously, for increasing the efficacy, use and flexibility of available systems. This approach is being used in small and large companies, and more recently on university campuses.

This approach as also used to implement new flexible labs (see figure 148) where students could find any required software configuration to cover the tasks in any subject of the School of Computer Engineering.

Figure 148. Virtualised room for "Project based learning in the School of Computer Engineering"

In the School of Computer Engineering (ETSIInf) this approach has been implemented (see figure 148) using state-of-the-art technology (CISCO systems, NetApp and XenDesktop) with the CEI Montegancedo as a pioneer in the use of these approaches at the UPM. Furthermore, this approach has had the following advantages for the School and its students:

- **Mobility.** Access to the virtual desk can be made from any terminal with access to the Internet. In this way, students could use their own portable PCs for accessing their work assignments (BYOD. Bring-Your-Own-Device) or access the lab environments at home.
- **Availability.** It increases the productivity of their work equipment.
- **Security and control.** The information is stored and protected in the Computing Centre of the Engineering Schools and data does not travel to/from student devices;
- **Flexibility.** Data will be available wherever and whenever the students want to access them.
- **Virtual PC service.** Students registered at the centre can have a virtual PC allocated which follows him/her throughout their studies at the UPM.
3.5.9. 3D manufacturing services

The evolution of rapid prototyping techniques and the widespread use in a large number of areas has given rise to the creation of services under a spin-off company from the UPM. Figure 149 shows some of the machines and the type of prototypes generated in several areas.

![Figure 149. 3D lab in CEDINT](image)

The very fast evolution of 3D printers (not only in terms of speed or performance but also in their capability to use a broad range of materials) makes it necessary to make additional investments to keep the competitiveness of the current facilities. These investments should be addressed in the near future as a part of the Montegancedo 2020 proposal.

3.5.10. Contribution to territorial development revisited

A key issue at this stage is to answer to the question on the contribution of CEI Montegancedo to territorial development. In other words, to what extent, the UPM with the development of the CEI Montegancedo, has contributed to the socioeconomic development of the region of Madrid,

This issue has increased its relevance after the change of knowledge policies promoted by the European Union after 2010. As a sample of opinions, the

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90 The concept of "territorial development" is very broad and vague. In the context of this report it is understood as the improvement in socioeconomic indicators in the region.
following sentences reflect the role to be played by universities from the European Commission’s perspective:

“They (Universities) can contribute to a region’s assessment of its knowledge assets, capabilities and competencies, including those embedded in the institution’s own departments as well as local businesses, with a view to identifying the most promising areas of specialisation for the region, but also the weaknesses that hamper innovation” Source: ‘An agenda for modernisation of Europe’s higher education system’ European Commission COM (2011) (567).

Universities (plural) must “act as strategic institutions pulling together all their know-how to create bigger economic and social impacts. Smart specialisation calls on universities to do more”. Source: Commissioner Geoghegan-Quinn

“The key to universities (plural) becoming strategic institutions is to take a holistic view of their activities, rather than treating them in isolation. By integrating research, teaching and external engagement, the knowledge created can have a much greater impact”. “University management as well as academic staff need to become pro-active and move beyond mono-disciplinary and mono functional actions. However, EU and national incentive structures also need to change because they are overly biased towards research output and can hinder universities in playing this strategic role” Source: Robert Jan Smits, Director General for Research and Innovation

An overall assessment of the previous sentences reflect the conviction of the EC as to the relevant role to be played by European universities in the regional policy of the European Union. The implementation of “smart specialisation strategies” for European regions in the period 2014-2020 is both a challenge and an opportunity to reaffirm the role of public universities.

As explained in chapters 1 and 2 the UPM’s strategy is not focused on the region of Madrid; the specialisation of the UPM (in education and research) makes it difficult to focus on specific needs. Nevertheless, after reviewing the activities carried out in recent years, some conclusions as to the contribution to territorial development can be answered.

To address the question, the generic answer is broken down into the following:

1. Is the UPM attracting additional investments to the region?
2. Is the UPM attracting international talent to the region?
3. Is the UPM improving the positioning of the region at international level?
4. Is the UPM facilitating the adoption of open innovation schemes and strategic partnerships?

Obviously, the answers of the above questions do not depend exclusively on the performance of the units located on CEI Montegancedo; there is a cross-influence from the other UPM units and the adequacy of the strategies followed by national and regional authorities in implementing their knowledge policies. A crystal clear separation of factors is not possible as has been demonstrated in a number of
Furthermore, a quantitative analysis of the UPM’s impact (e.g. on the regional GDP) is not possible and even less so if the focus is only on one of the campuses; the volume of funds is so small that influences in indicators would be negligible. Then, only a qualitative analysis is possible.

In spite of these limitations there are some clues that can explain the role played by the I2_Tech projects and related UPM programs in this overall objective from the perspective of Madrid.

- Madrid is a multi-university landscape without raw materials on which to base its development. Its growth strategy should be linked to “knowledge policies” where universities play a prominent role. Within this framework, technology and technology change are among the main motors for changing territorial patterns of economic development.

The UPM is a technical university which acts as a key factor in moving forward technology-based knowledge policies with the private sector. Specifically, the CEI Montegancedo has developed I2_Tech as a driver for long-term partnerships with the private sector as part of the open innovation ecosystem.

As a result of the activities carried out at Montegancedo Open IoT Lab, the UPM has started a cooperation program in Smart Cities with the Pozuelo de Alarcón local administration. The aim of this activity is to collaborate with technicians and councillors from the local administration to foster the use of IoT technologies developed at CEI Montegancedo to offer new services to citizens (mainly related to energy efficiency and mobility).

From the education point of view there is another initiative with the Pozuelo de Alarcón local administration, focused on promoting cooperation between CEI Montegancedo researchers and secondary school teachers to encourage the interest of students through science and engineering studies.

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• Madrid is moving from a traditional manufacturing industry to a more sophisticated services industry where IT plays a catalysing effect for improving overall competitiveness.

The units located on the CEI Montegancedo are all IT-enabled research and development cases. Even the Centre for Biotechnology and Plan Genomics (closer to the primary agro-food sector) has moved its lines of research to areas like bioinformatics and data mining.

• Madrid is an area open to new companies where barriers or restrictions to accommodate new businesses are very low and thus, industrial regeneration has become a driver for growth.

The UPM has exploited this fact to promote new businesses as spin-offs and start-ups from the university. The figures for the actúaupm program or the participation in the KICs of the EIT presented above in this report shows the success of this approach.

Additionally, the huge impact of entrepreneurship in the region of Madrid (a myriad of business incubators, events, entrepreneurship programs, etc. have been created in recent years) could make the region a hub for technology-based entrepreneurship. More recently, these ventures are looking for deal flow in universities making by the complementarities easier with programs launched by public universities.

• Madrid has the intention of becoming an international hub for attracting talent from many other parts of the world.

The number of qualified immigrants (a concept linked to the average educational level and not only the number of people from abroad) interested in studying or to doing research at the UPM is a good proxy for measuring the degree of internationalisation.

Coming back to the questions posed at the beginning of this section, some answers can be found:

1. Is the UPM attracting additional investments to the region? Yes, CEI Montegancedo is supporting a series of high-tech initiatives through the signing of specific agreements.

2. Is the UPM attracting international talent to the region? Yes, figures for students and researchers from abroad are growing.

3. Is the UPM improving the positioning of the region at the international level? Yes, not only through the implementation of some specific activities but also with its spin-offs and start-ups.
4. Is the UPM facilitating the adoption of open innovation schemes and strategic partnerships? It is clearly one of the main positive results obtained from the CEI Montegancedo effort as presented in this report.

After this analysis we conclude that the CEI Montegancedo is having a positive qualitative effect on the territorial development of Madrid.

3.6. The model of governance of the CEI Montegancedo

The model of governance of the CEI Montegancedo has been developed based on the following premises:

1. Maintaining strategic decision making relative to the development of the Campus in the Governing Council of the UPM
2. Activity from the 1st January 2013 to the present time of the Vice-Rector for Strategic Programs as “Delegate for the CEI Montegancedo”.
3. Creation of a management structure of the Campus in accordance with the regulations approved by the Governing Council of the UPM on university campuses and adapt to the characteristics of university campuses, adapted to the characteristics of this Campus.
4. Inclusion of the activities of the Montegancedo Central Office of the Science and Technology Park of the UPM (UPM Park) in the strategic plan of the CIE Montegancedo.
5. The establishment of a specific relationship with the Rector’s Council of the CIE Moncloa with the objective of promoting and facilitating the synergy between both Campuses of International Excellence in which the UPM is involved.
6. Creation of an Advisory Board of the Aggregated Entities of the CEI Montegancedo.

These aspects as well as their evolution from the achievement of the recognition of the Campus de Montegancedo as a Campus of Excellence are detailed below. Figure 150 details schematically the interaction between the aforementioned different bodies and each individual position.
Figure 150. Conceptual model of the Governance of the CEI Montegancedo

**Rector's Delegation for the CIE Montegancedo**

The function of the "Rector's Delegate for the CIE Montegancedo" was assumed directly by the Vice-Rector for Research from the beginning to the 2nd January 2013. From this moment, coinciding with the reorganisation of the Rector’s team, the figure of Deputy Rector for Strategic Programs who assumes the responsibilities of Delegate of the CEI Montegancedo.

Given that the CIE Montegancedo is directly tied to technological innovation, there is a direct interaction with different units that are organisationally accountable to the Vice-Rector for Research:

- **The UPM Park**, the **Office for the Transfer of the Results of Research** (OTRI), the **Office for European Projects** (OPE), the **Research Service**.

Likewise, interaction with other units of the UPM is carried out through the intermediation of the Vice-Rector for Financial Affairs, Manager, Vice-Rectorate for PhD and Postgraduate Studies, Vice-Rectorate for Students, Vice-Rectorate for International Relations, Vice-Rectorate for Computer Services and Communications, Vice-Rectorate for Organizational Structure and Quality.
The Governing Committee of the CEI Montegancedo

The Governing Committee of the Montegancedo CIE is the basic body for the coordination of the activities carried out on the Campus. Specifically, in 2013 it was constituted by the representatives of the following entities located on the Campus:

1. Representative of the Vice-Rectorate for Research (President)
2. Representative of the Vice-Rectorate for Organizational Structure and Quality
3. Representative of the Faculty of Computer Sciences
4. Representative of the CBGP
5. Representative of the CEDINT
6. Representative of the CESVIMA
7. Representative of the CTB
8. Representative of the USOC-E
9. Representative of the IDR
10. Representative of the COM
11. Representative of IMDEA Software
12. Representative of the Business Centre / CAIT

The specific functions assumed by the Governing Committee are as follows:

1. The drawing up of proposals or modifications to them that are presented to public calls in a coordinated way (not those carried out directly by the research groups of each of them).
2. Financial monitoring of the actions financed through the interaction with the research service of the UPM and the services of the Vice-Rectorate for Financial Affairs.
3. Discussion of the proposals for activities to improve the campus and interaction with the governing bodies of the UPM as necessary.
4. Knowledge of the agreements on the location of new entities or centres
5. Knowledge of the institutional agreements that affect the activity of the CIE
6. Discussion and proposals on PhD and Masters’ Degree programs or undergraduate programs as regards schools and faculties
7. Organization institutional events (conferences, seminars, institutional visits)
8. General information and maintenance of the Web page.

Relationships between CEI Montegancedo and CEI Moncloa

As expressed in chapter 1, the UPM was awarded the recognition of two proposals in the ministerial program of Campus of Excellence. This situation has also been an opportunity to implement several joint actions between both campuses. It was not necessary to create any specific governance structure for that mission because the delegates from the UPM perspective in both cases were nominated by the Rector.
Explicitly, the joint actions carried out in the period 2010-2015 were as follows:

a. Implementation of some CIESPC facilities (computer room for courses) in the CAIT building.

b. Intelligent network of distributed energy generation coordinated by the CEDINT and CEI (Centre for Industrial Electronics located in the School of Industrial Engineering).

c. Activities in relation to the “Ciudad del Futuro” (City of the Future) initiative to foster smart campus pilot projects.

d. Activities in relation of the Bio-Tech initiative to develop several activities (mainly in CTB and CBGP) from the research, education and innovation perspectives.

**Services and Maintenance Committee of the Montegancedo CIE**

For a better and simpler administration of the aspects related to the services of the Campus a Services and Maintenance Committee of the Montegancedo CIE is constituted.

The Commission will be chaired by the **Vice-Rector for Financial Affairs** and will be made up of the representatives from the different centres housed on the Campus and contemplated in the Governing Committee. It is likewise aimed to have the following representatives of collectives of the university community:

1. A **Representative of the Students** (initially, the Student Delegation of the **Faculty of Computer Sciences** as it is the only undergraduate teaching centre,

2. A **Representative of the Teaching and Research Staff** (PDI) of the UPM based in some of the units on the Campus.

3. A **Representative of entities external** to the UPM based on the Campus

4. and a **Representative of the Administrative and Service Staff** (PAS) based on the Campus

The **Functions** of the Services and Maintenance Committee of the CIE Montegancedo are as follows (the list is not exclusive):

1. Look after the maintenance of the general facilities of the Campus at the service of the university community (sports areas, garden areas, common facilities, etc.).

2. Agree the activities necessary to guarantee the security and perimeter and buildings vigilance.

3. Establish and agree the needs for the contracting of services: cleaning, electricity, gas, water, telecommunications, etc.

4. Establish the plans for the collection and treatment of waste products

5. Support and negotiate the transport services with the Transport Consortia

6. Undertake the actions for the necessary accessibility and signposting
7. Put into effect specific activities in these areas that have been proposed and agreed by the Governance Committee.

**Advisory Board of the CEI Montegancedo**

The importance that a close relationship with both the business sector and the different public and private entities linked to the different degrees of implication in the development of the CIE has for the development of the CIE Montegancedo makes it very advisable to establish an **Advisory Council** with the following functions:

1. To know and have an opinion on the activities of the development of the CIE Montegancedo. It is expected that with this there is sufficient information to allow possible interests to be identified.
2. To know the activities carried out in the different research centres and units located on the Campus with the objective of establishing possible scientific and technical cooperation agreements.
3. Propose and state new possible activities in the forthcoming years given that the Campus still possesses great expansion possibilities.
4. Consolidate mechanisms for joint activities for the R&D activity or the commercialization of the results.

The **partner entities** in September 2013 are as follows:

AMETIC, the Pozuelo de Alarcón local council, BICG, Clarke-Modet & Co, CSIC, FDI, ISBAN, Elekta, IBM, IMDEA software, INDRA, INIA, LPI, Plant Response, PRODUBAN, Repsol, Santander, Telefónica, T-Systems, UCM, Zeiss, Accenture, GMV, Hospital Ramón y Cajal.

In September de 2012 a **joint meeting with the Advisory Council and the Governing Council** was held to present the ideas on the future evolution of the CIE and the possible expansion of the joint activities carried out to date.

**Two plenary meetings** were held in 2013 for the setting up of two work groups of the Committee: The Commercialization Group and The Internationalization Group which have held two meetings and with both drawing up documents which will were debated in the plenary held in December 2013.
Economic commitments

An example of the institutional commitment accepted by the UPM can be described by analysing the resources (mainly loans) obtained in the calls of the International Campus of Excellence in several open calls published by the Ministry of Education, Culture and Sports, and others from the Ministry of Economy and Competitiveness (and their former denominations). Figure 150 shows the evolution over time of the commitments from loans with the "Administración General del Estado (AGE)" in the two cases of International Campus of Excellence with the participation of the UPM: ICE Moncloa and CEI Montegancedo.

The economic volume and calendar for the repayment of the loans changes over the years (see figure 150). In the case of ICE Montegancedo the UPM has received a total of €9,800,000; the annual repayment fluctuates between €333,333.33 in 2013, to €876,939.90 between 2014 and 2024 (inclusive) and €543,606.57 in 2025.

Figure 151. Loans obtained and repayment commitments of the CEI Montegancedo and CEI Moncloa (Source: Vice-Rectorate for Research, UPM)

Figure 151 also shows the political consequences in the year 2014 where there was a dramatic increase in the volume of the amount to be repaid from the resources obtained from the calls of the Program of International Campus of Excellence. The UPM should be ready to make a collective effort to increase the income from those research centres which received the loans in order to fulfill one of the most important goals: to ensure the role of the investments made as a catalyst to obtain higher and better research activity and to increase the obtaining of external resources.
CHAPTER 4: Evolution of CEI Montegancedo: Montegancedo 2020

4.1. Policy options and alternatives

The I2_Tech proposal for the CEI Montegancedo was conceived by the UPM as a sustainable institutional initiative where the initial set of activities proposed in 2009 and others defined later should continue and evolve after finishing the CEI program in 2015\(^\text{92}\). As mentioned in Chapter 1 behind the development of CEI Montegancedo was the institutional will to push forward a sound structural reform at the UPM to be more competitive at the international level... and it will take time to consolidate.

This long-term approach also implies that other sources of funding (from the UPM budget or from other external sources) will be necessary to keep the momentum achieved within the Spanish CEI Program even if, obviously, some specific objectives envisaged in 2009 should be necessarily adapted to varying circumstances.

The objective of this chapter is to describe future (medium-term) scenarios for the evolution of the CEI Montegancedo. These scenarios will be framed within the strategic initiative “Montegancedo 2020” which will be presented later in this Chapter as the next phase of the I2_Tech project.

We have limited the description of the desirable evolution of the Campus of Montegancedo within a relatively short time window (five years from now) to be able to envisage a set of feasible activities in some detail while assuming a known and stable external context during this period of time.

Specifically, the contextual framework for "Montegancedo 2020" is based on the following assumptions:

- **Spain** will recover from 2016 onwards from the hard economic crisis it has gone through since 2009. The consequence of this assumption will be the progressive improvement in the Spanish macroeconomic figures\(^{93}\) and the foreseeable increase in State and regional annual budgets.

- **State R&D and innovation plans** will be more ambitious aiming at reducing the gap with respect to the estimations made in 2011 on the

\(^{92}\) This date is the final year for the ministerial programme launched in 2009 although other ministerial programmes could take over with similar objectives. This case will not be explicitly considered in this chapter.

\(^{93}\) The latest estimations provided by the Spanish Government (July 2015) consider that GDP will grow 3.3% in 2015 and 3% in 2016 unless world-wide crisis affects it. These figures are higher than the EU average.
occasion of the last R&D plan through a moderate but steady annual increase in State budgets.

- The Spanish private sector will restart its effort to improve competitiveness through higher investments in innovation and organisational changes and better participation in research and innovation programs.

- The Spanish private sector will continue its internationalisation process by extending the agreements with other entities (such as universities, research centres or firms) both in Spain (with international Spanish firms) or abroad with full adherence to open innovation principles.

- The budget of public universities will recover its former levels of 2008 (at the beginning of the CEI program). Nevertheless, still in this improved situation, Spanish public Universities should make continuous efforts to attract external resources.

- The contribution of the regional government of Madrid (block funding) for the UPM will be between 55% and 60% of the total annual budget.

- Public universities will be allowed to fill all their empty teaching and researchers positions by reversing the constraints suffered in the last four years in which the replacement rate of their staff was kept very low.

- National and regional legislation will allow universities to incorporate young professors and researchers more easily than today. It will facilitate a reduction in the average age of staff and then, faculty members will be prone to innovation with better career prospects).

- Open public calls for institutional support from ministerial departments will become common, with more and better balanced resources (i.e. at least, “grants” will overtake “loans”) in order to increase the involvement of universities in structural reform programs with monitored accountability of progress based on a set of key performance indicators.

We firmly believe that this Spanish macro scenario will become a reality in the next five years. Dramatic changes derived from societal (i.e. world-wide economic crisis or natural disasters) will not be addressed in this chapter.

Nevertheless, even within the stable external context presented above, all entities in the Spanish innovation system should define their own strategy and develop

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94 Even, if the very optimistic values for R&D expenses with respect to GDP (2%) will be extremely difficult to get, we think that Spain could reach the 1.5%-1.6% range by 2020 but not more.
internal policy options to face challenges. They correspond to different institutional visions for the near future\textsuperscript{95}.

Taking this macro scenario into account (out of the control of individual public universities) the UPM should envisage the definition of its future institutional policies, the evolution of its campuses and, in particular, the next phases of the CEI Montegancedo as a powerful tool to build up its future international competitiveness in education, research and innovation around it.

More specifically, in the case of the UPM, the possible evolution of the CEI Montegancedo will be framed within three different internal UPM policy scenarios which belong to a number of institutional alternatives where the pressure towards addressing institutional reforms differ greatly. For each of them some relevant consequences for the evolution of CEI Montegancedo will be discussed.

In short, the identified policy scenarios are as follows:

- \textit{Scenario 1}: “Business as usual”
- \textit{Scenario 2}: “Empowerment of campuses”
- \textit{Scenario 3}: “Dilution of campus identity”

The rest of the chapter will address these issues as follows: first, a high level SWOT of the CEI Montegancedo will be presented to frame the situation found today (2015) and to identify the main challenges.

The description of the three policy scenarios would allow us to know how the proposed \textit{Montegancedo 2020} strategy could be implemented in all these cases. On this basis, a short description of the feasible evolution of each of the engineering schools, research and service centres located in Montegancedo can be presented.

The evolution of key performance indicators (KPI) should maintain the monitoring and assessment of progress towards 2020; finally, some conclusions on the overall governance of the CEI Montegancedo will be posed.

### 4.2. Simplified SWOT for Montegancedo 2020

The time horizon of \textit{Montegancedo 2020} is not too far from today (2015); then, we will assume that profound transformations of the Spanish innovation system will not occur in this period. As a consequence, structural changes in public universities due to external factors will not be very abrupt although they should reflect a consolidation of previous trends.

To be able to discuss future options and actions for the CEI Montegancedo, a high level (not too detailed) SWOT of the situation found today could serve as a starting point for developing the rest of the chapter.

\textsuperscript{95} Note that the UPM will have elections in the first quarter of 2016 and it is not possible to define today what the priorities of the next Rector will be.
By 2015 the CEI Montegancedo SWOT\textsuperscript{96} could be described as follows:

- **Weaknesses**
  
  - There is not a relevant UPM annual budget allocated to the Campus of Montegancedo for the improvement or expansion of infrastructures or to co-fund resources provided by public administrations\textsuperscript{97}.
  
  - The UPM has noticed a sharp reduction in the volume of research contracts with the Spanish private sector during the last four years. This fact has been partially compensated by its very good participation in European programs (e.g. FP7, H2020, and ESA) but the recovery of former figures (in 2009 or 2010) is still pending and it is becoming urgent to re-launch frozen initiatives.
  
  - The number of students on the Campus of Montegancedo is not very high and although the total number has increased in the last three years, critical mass is not guaranteed to maintain all the post-graduate activities related to research centres. Then, the connection with other sources of students (on other UPM campuses and from other places) becomes a key issue.
  
  - The lack of dormitories for students and residences for researchers or visiting professors makes the organisation of periodical extra academic activities in the Campus difficult creating problems in making it a cultural reference. It is a big challenge to address in the near future.
  
  - The slow creation and implementation of the UPM PhD School (still in its initial steps) has prevented its use as a catalyst for attracting PhD candidates from abroad and fostering industrial PhDs with aggregated entities of CEI Montegancedo.
  
  - There is still a low level of commitment from aggregated entities in participation in cooperative R&D and innovation activities. Today’s commitments are linked to cooperation in specific projects but not in dealing with global partnerships firmly anchored in joint governance schemes. Then, the innovation ecosystem of Montegancedo would require the intensity of the links between actors to be increased to fulfil its final objectives.
  
  - The institutional links between the Campus of Montegancedo and the UPM engineering schools or other research centres in the

\textsuperscript{96} As we expressed in previous chapter, the Campus of Montegancedo is not isolated (and it cannot be) from the rest of the UPM. Even if the implementation of some of its activities has a territorial root, they will depend on the evolution of general research, innovation and education policies at the UPM. The recent decision of the Spanish Court to force the regional government of Madrid to pay the UPM €86 million in infrastructures could facilitate the launching of new programmes.

\textsuperscript{97} This constraint is not only related to CEI Montegancedo and similar problems could be found in other campuses of the UPM in recent years. Nevertheless, Montegancedo was a campus in expansion and the need to reach its critical mass is an essential condition to take advantage of the efforts made during recent in a post CEI programme period.
implementation of education and research could be strengthened. They exist on the basis of individual commitments derived from the double adscription of faculty members to one research centre (for research and innovation activities) and to one Department located in one School (for teaching activities).

- There is a poor interaction with territorial development goals. Note that the largest part of the Campus property pertains to the town of “Pozuelo de Alarcón” (in the region of Madrid) but several kilometres from the centre of the city (and without a fast and direct transportation system). Then, the dependence and interaction with the activities carried out in Pozuelo de Alarcón is still very weak.

**Threats**

- The continuation of the economic crisis (at least, a stagnation situation of EU growth) or very low recovery process will prevent (or delay) extra budgets to be made available for infrastructures or human resources to public universities. The negative consequence could to accelerate the obsolescence of advanced equipment or to delay the recruitment of researchers. Both aspects will become a problem in ensuring the long-term competitiveness of the UPM research units.

- The lack of long-term commitment from the industrial sector to create joint units or long-term partnerships because the relatively complex decision making process of multinationals located in Spain, and the short-term mentality focused on contract-research exhibited by the majority of Spanish companies, will constrain the consolidation of the innovation ecosystem of Montegancedo.

- The future ministerial R&D programs will continue to be focused on the evaluation of individual smaller projects (presented by research groups) without critical mass to provide structural impact within universities.

- The trust in S&T prioritisation in university institutions is still weak and no additional open calls for institutional support will be issued by ministries. The possible consequence is the progressive loss of the concept of CEI.

- The stagnation in the number of undergraduate students in Montegancedo is accelerated by institutional policies to group them in a reduced number of campuses in central Madrid in order to attract more students.98

- Relative distance and insufficient public transportation systems to/from the centre of Madrid generates some difficulties for attracting students living in the region. It is also a problem to

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98 The conceptually possible movement of the ETSINF-UPM to another UPM campus is not considered in the SWOT because it will not be addressed in the next five years.
compete for foreign students with other universities (or with other campuses of the UPM) located in or near the centre of Madrid.

Institutional visibility remains linked to the performance of individual research centres but there is no overall visibility of CEI Montegancedo in the UPM and beyond.

- **Strengths**
  - There is a progressive consolidation of the international competitiveness of the research centres located in Montegancedo in terms of staff, equipment, R&D projects and the exploitation of research results. In many cases, they have some relevance at the international level in their specific fields of S&T.
  - The Montegancedo community shares the will to address multidisciplinary research projects with the cooperation of two or more centres. This situation facilitates the preparation of ambitious research and innovation proposals between several research centres to address complex challenges.
  - The existence of world-class research facilities with very well equipped labs which has been instrumental in the participation in international projects and for opening the activity up to other promising areas of research.
  - The attractiveness from postgraduate (Masters’ Degree and PhD) students by allowing them access to sophisticated equipment and/or very ambitious projects is a must for the whole campus.
  - The concentration of some facilities for innovation support (e.g. experience labs) makes the Campus of Montegancedo an attractive location for accelerating product/service development by running technology demonstrators.
  - The participation in large international research projects constitutes a very relevant asset (e.g. Bill & Melisa Gates, HBP or Blue Brain) for attracting additional investments from external sources.
  - International relevance of IDR - CIDA through participation in ESA-NASA missions such as Rosseta, Solar Orbiter, Exomars and JEM-EUSO, and the USOC - CIDA with the support to the International Space Station (ISS).
  - The CEI Montegancedo has diversified its sources of funding at the national and international levels as a side effect of the economic crisis.
  - The participation in EIT Digital and EIT Health will lead to in a great increase in high-level and international students, and a stimulus to get finding at the European level.
**Opportunities**

- There is an excellent opportunity to consolidate the so-called *Montegancedo innovation ecosystem* initiated in 2010 by attracting additional actors and by strengthening the agreements with the current ones.

- It is possible to increase the number, commitment and scope of the agreements signed with “aggregated entities” from a win-win approach. This is a key opportunity to consolidate long-term partnerships at least with a subset of the aggregated entities.

- Montegancedo could become a “*smart campus*” by deploying an advanced set of (digital) services in all domains of the knowledge triangle (i.e. education, research and innovation) open to the campus community and beyond.

- The UPM can facilitate the implementation of additional double diploma degrees with other partner entities at the international level and, if possible, with industry-university mobility schemes.

- The fast evolution of MOOCs and e-learning platforms will also offer the possibility of reducing face-to-face periods for students abroad and to increase its presence in other countries.

- The extension of the “T-shape educational approach” (combination of technical and managerial subjects in a blended approach with e-learning and face-to-face) to all masters and doctorate degrees should be a distinctive feature of the UPM and, specifically, the CEI Montegancedo.

- The attractiveness of technology-based high-growth start-ups related to the Montegancedo centres’ activity and to enforce strong relationships with them and between them is a pre-requisite to facilitate their high-growth.

Figure 152 details schematically how the elements defined in the SWOT interact and the identification of some issues where the institutional effort should be placed in the near future. Note that some aspects have been identified as *cross-cutting issues* between the strengths, weaknesses, opportunities and threats boxes. Many of the variables could change very rapidly and the UPM should periodically monitor the situation to make the suitable decisions in time.
A quick analysis of the very high-level SWOT presented above indicates that the UPM lives today at an **inflexion point**. The end of the CEI Program in 2015 is a challenge to reflect on the advances made to date and the missing points to be addressed in the near future.

To get to a positive or in a negative evolution and consolidation of CEI **Montegancedo** from the current situation will depend on the capability of the University to modernise using some of the schools, research units or Campuses as **“competitiveness accelerator tools”** to open the way to non-conventional avenues or, on the other hand, to come back to conventional approaches to preserve well-known structures and “safer” activities.

We assume that the analysis and debate on the consequences of the identified strengths, weaknesses, opportunities and threats in the case of the CEI Montegancedo constitutes the basic ingredient to enforce its **positive evolution in the near future**. This is the will and expectation with the definition and implementation of the institutional program termed as **“Montegancedo 2020”**.

Before that, it is relevant to consider a number of institutional policy options in the UPM which acts as **“internal scenarios for the future”**.

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**Figure 152. SWOT CEI Montegancedo**
4.3. Three CEI Montegancedo policy scenarios

4.3.1. Rationale

As mentioned above in this report, even if the external macro-scenario outlined remains stable until 2020, internal policy decisions made at the UPM will condition the evolution of the CEI Montegancedo.

Possible evolution paths will be framed in this section around three potential policy scenarios which clearly identify policy options for the organisational design to be adopted by the university99.

The three simplified future “scenarios”: Scenario 1: Business as usual, Scenario 2: Empowerment of campuses, and Scenario 3: Dilution of campus identity will be analysed and compared in this section. Figure 153 shows schematically the evolution over time from the present situation.

![Figure 153. Evolution 20125-2020](image)

We do not claim the advantages or disadvantages of each of the scenarios for the whole University; it does not correspond to the objectives of this final report. The objective is to analyse how these policy scenarios can affect the evolution and consolidation of the CEI Montegancedo in particular, and what will be the drivers in each case.

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99 Scenario-building is a well-known foresight technique to facilitate decision making or, at least, to anticipate problems or opportunities. As scenarios represent “pure” possible evolutions, hybrid situations become more common; however, the analysis of the future is simpler if attention is paid to well-identified scenarios.
The selection of the three policy scenarios has been done from a very pragmatic point of view: from our point of view, all of them could become a reality if university policy decisions were adopted in the appropriate direction. Other conceptually possible policy scenarios (e.g. the “merging of the UPM with another university” located in Madrid to get critical mass, complementarity and better efficiency, or the UPM transformation into a quasi “postgraduate technical university” prioritising masters and doctorate programs linked to research and innovation activities) were not considered. From our point of view, the probabilities to realise them in a very short period of time are very low and, even if these approaches were strongly supported by regional and national administrations, and some decisions in that direction were taken by the UPM, the full implementation will occur after the time horizon (2020) adopted as reference in this chapter.

4.3.2. Business as usual

This policy scenario reflects the maintenance of the current structural situation at the UPM. In this scenario the UPM will maintain the current structure of the pre-existing Engineering and Architecture Schools as the basic UPM components; however, some of them focused on similar issues could merge by following the same trends initiated years ago with other engineering schools. Under this assumption, the research and innovation centres will continue their activities firmly anchored in specific schools linked to the educational responsibilities of the faculty members of the research centre. Even under that assumption, multidisciplinary activities within research groups from different schools or research centres will still be promoted although their development will depend more on personal interests or funding opportunities than as a consequence of a sound institutional strategy and impulse. We do not envisage any acceleration of the creation of additional research centres of the UPM in this scenario.

The campuses of the University in 2020 will be considered as loci of common services but they will not be supported through institutional policies specifically adapted to each of them. From this perspective, there is a homogeneous view of the activity across the UPM which is understood by UPM governance bodies as easier to manage and less conflictive.

100 Where the number of postgraduate students clearly exceed the undergraduate ones.
101 We do not assess the appropriateness of these cases; they were left out of the discussion because there do not imply consequences for the CEI Montegancedo before 2020.
102 That process was motivated from the existence until several years ago of “university schools” and “engineering schools” linked respectively to 3- and 5-year curricula. The implementation of the Bologna process of curricula reform made that distinction obsolete. Internal decisions have accelerated or delayed the merging processes in specific cases.
In the **specific case of CEI Montegancedo** we envisage the following aspects and consequences until 2020 under this scenario 1:

1. **The Ministry of Education will keep the label of CEI** for well evaluated campuses in 2015 and Montegancedo will keep it; nevertheless, no specific funding for the awarded campuses will be provided.\(^{103}\)
2. **The Campus will not have any independence of action with respect to other policy areas of the UPM. Resources will be distributed at the UPM using pre-existing conventional indicators** (in terms of students, buildings, research groups, etc.) but without paying attention to the qualification of the Campus as a CEI.
3. **The School of Computer Engineering will continue to be the only school of engineering located on the Campus.** Both the size of its faculty members and students will remain stable although the balance between undergraduate and postgraduate students could change with a higher percentage of postgraduate students.
4. **All research centres located on the CEI Montegancedo will continue their activities with no relevant changes.** Obviously, there will be a continuous adaptation of the activity to the international research agenda and grants received from open calls issued by public administrations. Internal funding programs for research centres will consider them regardless of the Campus where they were located.
5. **Small joint units** (university-industry chairs, joint labs, management of common infrastructures, etc.) will be created with enterprises or other not-for-profit entities within pre-existing centres.
6. **Business incubator** (located in the CAIT) will be full with the location of some start-ups and spin-offs which will collaborate more with other research groups of the UPM.

The main systemic risk derived from policy scenario 1 is to dilute the concept of "International Campus of Excellence" as an internal UPM policy driver. This situation could change if the Spanish Government decides to continue and strengthen the CEI program after 2015 with additional open calls and substantial funds (grants). In other cases, the UPM by itself will not have enough resources to push it individually and there are no internal reasons or excuses to focus the (scarce) resources on them. In fact, the pressure to adopt internal compensation policies will become stronger.

### 4.3.3. Empowerment of campuses

This second policy scenario reflects the transformation process of the University structure towards a more flexible context where the UPM “units” (schools of engineering, research centres or innovation facilities) located in

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\(^{103}\) Probably, some minor advantages in calls for human resources or networking could appear but they cannot constitute the basis for co-funding institutional programmes.
individual campuses cooperate in all types of activities (education, research and innovation) by stimulating policy experimentation at the Campus level in order to take advantage of multidisciplinary work and the possibility of deploying advanced innovative services in a controlled area.

In this scenario, the concept of open innovation is institutionally pursued both within the university units and with external entities who assume the role of strategic partners of the UPM in specific campuses (they could also appear as partners in more than one campus).

In this scenario, even if each campus has its own specificities, good practices can be moved from one campus to another and inter-campus cooperation in specific activities will become common using the appropriate ad hoc coordination structures at the UPM level.

Behind this scenario there is the belief that the external attractiveness of any institution (like the UPM) at the global level is linked to a relatively few number of excellent units which serve as the basis and hook for attracting the interest in the rest of the university.\textsuperscript{104}

In the specific case of CEI Montegancedo we envisage the following aspects and consequences of scenario 2 by 2020:

1. Montegancedo will become the reference point for open innovation with the private sector in Spanish universities which is also recognised by public administrations.
2. A relatively large number of the present aggregations with public or private entities will be consolidated through the creation of “joint units” at several levels to carry out critical mass activities in education, research and/or innovation.
3. The Campus will be internationally known in some areas of S&T (e.g. in neurotechnologies, bioenergy, energy efficiency, supercomputing, smart cities, ICT services, plant genomics, cognitive computing, satellite platforms, blended education, and experience labs).
4. Agreements with manufacturing companies will increase the possibility of purchasing, receiving as deposit, or accessing additional advanced equipment and reducing or avoiding obsolescence in order to keep the state-of-the-art scientific equipment.
5. All research centres will participate intensively in Masters’ degree and PhD programs in connection to other schools of engineering or architecture or as a part of their own overall strategy. The use of blended approaches and close links with research, innovation and entrepreneurship activities will constitute an excellent added value.
6. The campus will be used as a “smart campus” test-bed in which to carry out large-scale pilot experiences, advanced technology demonstrations or

\textsuperscript{104} In some sense, this approach was considered in the past when the UPM decided to incorporate the sentence “Campus of International Excellence” into its institutional logo without mentioning any specific campus (Moncloa or Montegancedo could be used) and making the rest of the UPM part of it.
the controlled evaluation of services with real users both at the national and international level.

7. Coordination is ensured through the **implementation of ad hoc governance structures** with the participation of all relevant stakeholders in the Campus as an evolution of the structures created in the I2_Tech project.

### 4.3.4. Dilution of campuses

The last policy scenario reflects another different but feasible trend: the option taken by the University towards the progressive **loss of the relative importance of individual campuses** in an institutional effort to increase the homogeneity of the UPM and to apply the same kind of policies everywhere\(^{105}\).

In some sense, this scenario tries to avoid the existence of big differences between campuses as a consequence of ministerial political pressure to choose between S&T areas, schools or research centres as was the case when the CEI program was launched\(^{106}\). Then, a sense that the UPM needs to pay more attention to **“horizontal institutional policies”** is widely accepted in this scenario.

Behind this approach lies the consideration that the national and international **attractiveness of the UPM will come from global figures of excellence** (e.g. publications, patents, awards, etc.) or **well-known historical units** (like some well-appreciated schools of engineering in Spanish society) and not relatively new isolated cases or campuses.

By 2020 we envisage the following aspects and consequences of policy scenario 3 for the specific case of CEI Montegancedo:

1. **CEI Montegancedo is not specifically promoted by the UPM** and other alternatives to sell its excellence in terms of S&T areas or well positioned research centres or schools will be used instead.
2. Campuses are understood in this scenario as the basis for providing a minimum **series of basic services managed at the technical level** (e-learning, broadband (mobile) networks, security, energy efficiency, etc.) without influencing institutional policies in the range of education or research programs.
3. Future **institutional proposals** to administrations will empower UPM capabilities in specific areas (depending on the call or program) with a global view.
4. **Institutional strategies in selected topics** crossing the UPM campuses will take the lead in promoting excellence and opportunities for the whole

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\(^{105}\) In the specific case of the UPM, the university was born in 1971 as a “federation” of pre-existing schools of engineering and architecture; then, there was (and still is) a consistent effort to give them a sense of belonging to a single entity by keeping their own specificities alive.

\(^{106}\) As mentioned above, we assume that no additional funds (grants) for CEIs will be made available in the next period. Then, the UPM will not be specifically interested in discussing them internally when the benefits are not evident.
UPM. This is the case of “BioTech”, “City of the future” or other future initiatives with the same objective.

5. **Links between research centres and schools** will be based on technical areas to be able to use labs and researchers for supporting the implementation of educational purposes.

6. **The initial concept of aggregation with the private sector within the CEI program is lost** but it is still bilaterally promoted at the unit level. Then, aggregations will disappear from any campus governance structure.

7. **Central services** for research and innovation are defined, implemented and managed by the headquarters of the university.

### 4.3.5. Comparison between policy scenarios

As we have mentioned in a previous section of this report, the **three scenarios chosen represent a series of institutional policy options of the UPM** which impact the evolution of the CEI Montegancedo in different ways. The relevant question at this point of the discussion is to know what **would be the best scenario for the entire UPM** and not only for one specific campus (even if they were termed as “campus of excellence” as happens today).

In other words, the objective is to improve the general **key performance indicators (KPIs) defined by the UPM as overall indicators to measure its competitiveness**, and not only the specific ones defined for one Campus as has been the case during the past CEI program in the monitoring process carried out on the actions funded by the Ministry of Education. The answer of that relevant question cannot be addressed here but the UPM should take into account the analysis made to take the best possible option for the future.

The impact on CEI Montegancedo should condition the strategy that the units located today on the Campus should continue in the near future. In terms of visibility, figure 154 intuitively shows the “**volume of visibility**” of the CEI Montegancedo in each scenario.

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107 The term “visibility” is understood here as the relevance of the activities carried out in the Campus from external observers at the international level. Maximising visibility in this context becomes an institutional goal.
A quick internal review of the three policy scenarios concludes that **CEI Montegancedo should continue its development in any of the three scenarios** although the role played by the Campus for the entire UPM is different and the external perception will be also different.

Implicitly, the discussion calls back to a very relevant issue from the very beginning of the definition of the CEI program in 2009: **is the excellence label a recognition for all universities or only part of them?**

Initially, when the CEI program was launched, it called for institutional proposals referring to specific *geographical areas* (this is the concept of "university campus" found everywhere) and looking for *strong prioritisation* (both thematically and geographically)\(^\text{108}\). Nevertheless, the interpretation of the concept of "campus" shifted in individual proposals presented by Spanish universities from areas to whole universities, and both cases were recognised and awarded by the Ministry of Education in the evaluation of the open calls for proposals.

At the end of the Spanish CEI program in 2015, there is **no single approach for the concept of Campus within the awarded universities**; then, a broad margin of interpretation has been accepted in order to accommodate very different governance decisions within universities. Even in those cases where the concept was clear at the very beginning, the lack of funds shifted in pragmatic evolutions of the concept.

The future framework proposal called "**Montegancedo 2020**" which will be presented later in this chapter was conceived as the continuation framework of the I2_Tech proposal finishing in 2015. This proposal assumes that **regardless of the**
scenario chosen by the UPM, there are a number of activities which could be implemented to the benefit of the Campus and the whole university.

4.4. Montegancedo 2020

4.4.1. Context

I2_Tech was the main instrument used by the UPM to access the funds of the CEI Program for the Campus of Montegancedo during the last six years (2009-2015). The results have been presented in previous chapters of this report (see Chapter 3) and we do not insist on them here.

Montegancedo 2020 has been proposed as the institutional answer of the UPM to frame the evolution of the Campus of Montegancedo in the next period 2016-2020. It has been conceived as a set of principles and main directions which could be implemented in any of the aforementioned UPM policy scenarios but it does not imply specific economic commitments.

From our point of view, even if the UPM progresses towards one of the aforementioned policy scenarios with potential consequences on the institutional support to the Campus of Montegancedo, the “CEI Montegancedo community” could assume a pro-active role by looking for other sources of funding (e.g. at the international level) or by signing agreements with aggregated entities through a new generation of education, research and innovation agreements regardless the policy scenario chosen by the UPM.

Within this context, “Montegancedo 2020” should be interpreted as a conceptual proposal and not as a totally defined “project” with a fixed list of activities, resources and milestones. In this sense, it is not possible to compare it with I2_Tech which was a project in itself and funded by the Ministry for implementing specific activities.

Furthermore, the uncertainty for the next period both externally and also in terms of the internal UPM policy scenarios which will eventually be adopted will avoid the planning of a detailed program of activities.

The individual activities of the school and centres of Montegancedo for the next few years summarised in a later section reflects a series of actions which will continue the consolidation process of each of them from a pragmatic point of view. Nevertheless, the accumulated experience with I2_Tech advises us to take advantage of an overall view of the future of the CEI Montegancedo to be shared by all units involved. That is the vision of Montegancedo 2020.

Figure 155 details a high level view of the context of Montegancedo 2020 with the main internal and external drivers which will condition its implementation. Note that the external drivers correspond to key elements used in the past for the development of the Campus while internal drivers correspond to the identified policy scenarios.
The specific goals of Montegancedo 2020 are fourfold:

- To serve as a **guideline** for the development of the CEI Montegancedo beyond the specific activities envisaged by individual centres.
- To create a **shared view** in the negotiation with external entities in order to attract additional investments or talent.
- To define **interdisciplinary project proposals** with the participation of several centres and the engineering school located in the Campus in close interaction and alignment with UPM headquarters.
- To mobilise the UPM as a whole in the development of an entrepreneurial university firmly anchored in strong partnerships with the private sector.

The following sections will detail each of these elements.

### 4.4.2. Guidelines for Montegancedo 2020

Guidelines act in this context as basic principles to guide the definition and implementation of overall activities in the Campus of Montegancedo across all perspectives of CEIs (education, research, innovation, aggregation, and internationalisation). The identified guidelines are as follows:

1. To empower the development of **multidisciplinary projects** (involving several units located on the Campus) as a key strategy for increasing the impact of the CEI Montegancedo in a broad range of thematic S&T areas. The experience gained in I2_Tech is a good starting point to achieve it.
2. To extend the principle of **open innovation** as a distinctive feature of the Campus by opening up the activities to a larger number of external entities in all types of activities (from education to innovation).

3. To increase the **internationalisation** of the centres located on the Campus in terms of projects, students, researchers and positioning in other countries (through partnerships in selected areas where the UPM can offer an added value).

4. To promote the **creation of additional joint units** (from joint labs to joint centres) from education, research, services or sharing infrastructures supported by private or public entities.

5. To push an **integrated view of education, research and innovation** within the paradigm of the “knowledge triangle” looking to maximise the potential synergy.

6. To empower the **deployment of generic and advanced common services** in the Campus to improve quality of life for the Montegancedo community (e.g. in terms of transportation, accommodation, sports, or cultural activities).

There are no contradictions between these guidelines and the UPM policy scenarios. Any University direction will accept them as a driving force to improve the competitiveness of the entire University (applied overall or to specific areas, geography or mission). In some sense, we consider the identified guidelines as **invariants regardless the chosen UPM policy scenario**.

Obviously, the potential difficulties which could be found in implementing all of these principles will depend on the scenario finally chosen by the University; however, all of them can be moved forward based on the **freedom and will of UPM faculty members and the directions of schools and research centres** within their own competences and responsibilities.

### 4.4.3. Shared views for Montegancedo 2020

The full potential of the guidelines stated for Montegancedo 2020 requires the adherence to some **shared views amongst all involved stakeholders in the Campus**. These are as follows:

- **The internal competence for UPM resources will not be based on CEI labels.** The shared view is that future extra resources should be found everywhere outside the UPM (in national/international calls or in agreements with the private sector) by adopting a very proactive mentality. The recognition of this situation should push the combination of capacities and resources to increase the attractiveness of proposals.
• **Human talent is a key factor for success.** Then, in order to increase the impact of CEI Montegancedo is necessary to attract, maintain and recover excellent graduate researchers. CEI Montegancedo should explore innovative ways in cooperation with some of its aggregated entities.

• The **alignment of meta-agendas** between school and research centres produces objective benefits for units involved but is it very difficult to implement in larger multi-functional entities; the bottom-up interest of researchers (research groups) is still the basis for agenda setting until 2020.

• **Education-driven activities** are a must for improving research and innovation activities and, if possible, it should be embedded into specific actions mainly embedded into postgraduate initiatives at the international level.

• The implementation of **flexible soft governance structures with the involvement of aggregated entities** is a useful mechanism to exploit opportunities arising in the next few years but by keeping lean structures.

• **High-level impact** of the Campus is directly linked to the availability of critical mass in one specific activity; then, thematic prioritisation to focus the institutional resources on a limited number of areas of S&T is a key governance issue.

These shared views are compatible and probably shared with other campuses of the UPM. Nevertheless, even if we do not intend to combine them with others outside the CEI Montegancedo in this report, the links with CEI Moncloa could be very effective in the case of a re-launching of the CEI program by the Spanish government.

The combined use of principles and shared views will generate an excellent starting point to fight for **high-level impact projects**. As an example, the commitment to increase the internationalisation of the Campus requires the alignment of meta-agendas.

### 4.4.4. Interdisciplinary project proposals

Today, it is widely accepted that the rapid advancement of scientific and technology disciplines is strongly conditioned by the possibility to using successful results or approaches previously found in the field. Even more, the transfer of research results found in one domain to another constitutes an excellent source of disruptive advances. This is the basis of the policy support to **interdisciplinary research**.

The same approach is being used successfully in **areas of education** in which blending approaches require using sophisticated ICT tools, cognitive theory and the deployment of innovative services or products. Again, the participation of experts from a number of disciplines is a necessary condition for success.

One of the **constraints for running multidisciplinary projects** is the lack of appropriate policy instruments to assess their benefits with respect to other more conventional approaches. Knowing that, the European Commission has pushed
forward the support of **relevant large-scale pilots** in order to accelerate the marketing of innovative products and services in the context of H2020.

By 2020 the Campus of Montegancedo should **host a number of large-scale pilots** for testing and accelerating the deployment of advanced services in different sectors and fields.

These activities are growing in relevance and resources within H2020 through the implementation of public-private partnerships (PPPs), namely Internet of the Future (FI-WARE) or Big Data Value (BDVA) and the EIT KICs where the Campus is well prepared to carry them out\(^{109}\).

The following (non-exhaustive) list (see table 8) identifies **four examples of multidisciplinary projects** to support pilots and demonstrator activities with indication of the goals, technologies, potential participating centres and required infrastructure (where ICT plays a prominent role):

<table>
<thead>
<tr>
<th>Pilot name</th>
<th>Main goal</th>
<th>Technologies involved</th>
<th>Research centres involved</th>
<th>Infrastructure required</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Smart energy campus</strong></td>
<td>To provide smart control of energy generation and consumption in all units located in the Campus.</td>
<td>Distributed network of sensors and actuators. Distributed generation of renewable energy (wind, solar, etc.). Internet of things. Big data 3D visualisation platforms.</td>
<td>CEDINT, CESVIMA, CSC, ETSIInf, IDR-CIDA And other units as users.</td>
<td>Extension of the smart grids for energy distribution. Modular housing. Deployment of a campus-wide network of sensors for energy issues.</td>
</tr>
<tr>
<td><strong>Mobile higher education</strong></td>
<td>To test new learning approaches with smart phones and tablets.</td>
<td>MOOCs, Big data e-learning, cognitive computing Smart devices Immersive videoconferencing Virtual labs</td>
<td>ETSIINF-UPM, spin-offs, COM And other units as users</td>
<td>Smart phones, broadband WIFI, on-line repository of modules e-learning platforms</td>
</tr>
<tr>
<td><strong>Healthy campus</strong></td>
<td>To monitor and help the campus community in big data.</td>
<td>Wearable devices. Big data.</td>
<td>CTB, CEDINT, CBGP, UPM spin-offs</td>
<td>Involvement of users with wearable devices</td>
</tr>
</tbody>
</table>

\(^{109}\) The only constraint is the case of digital services when they need to be tested by a large number of users. For instance, smart cities or big data applications would require to capture information to be captured from thousands of users with different types of profiles not possible to find in CEI Montegancedo in the next five years.
| Environmental control | To obtain real-time information on the environmental situation of Montegancedo. | Distributed network of sensors and actuators, Big data visualisation and analytics, Internet of things | CEDINT, CBGP, CTB, IDR-CIDA, Deployment of a campus-wide network of sensors for environmental control. |

**Table 8. Potential pilot projects**

It is also possible and useful to identify and promote the definition of other possible pilot projects for specific areas of S&T although they have a limited impact on the entire life of the campus. In any event, they could be instrumental in increasing the visibility for specific areas.

The development of these projects could require the participation of other research groups or research centres of the UPM located in other schools or campuses and also spin-offs, start-ups.

### 4.4.5. Mobilisation towards an entrepreneurial university

Montegancedo 2020 should be also a very relevant tool to support the **transformation of the whole UPM into an entrepreneurial university**. Here, the goal is not only to develop a series of activities concerning the CEI Montegancedo but also to **extend the experience to other UPM campuses**.

More, specifically, this mobilisation process will be based on the following type of activity:

1. Involvement of other UPM research centres, schools and faculties in **targeted spin-off creation programs** (for well-defined technological areas) in close interaction with the **actúaupm** program.
2. Generation of **inter-campus pilots and demonstrator projects** in which different physical contexts introduce an added value.
3. Extension of **small pre-incubator processes** and space of technology-based companies (before their formal creation) linked to some schools.
4. Analysis of **opportunities for long-term partnerships** with private entities for the commercialisation of research results with the participation of schools of engineering.
4.1. Discussion

Montegancedo 2020 will be built on the “shoulders of the I2_Tech results”. Figure 156 details schematically the new actions that, hopefully, could appear in 2020

From the perspective of the knowledge triangle used in chapter 1, the main changes are as follows:

- **Education** will move in two complementary directions: full use of MOOCs and the generation of double Masters’ Degrees with other entities.
- **Research** will emphasize the involvement of the private sector in industrial PhDs and the expansion of joint research units with aggregated entities.
- **Innovation** will continue to be a driving force of the campus with the implementation of additional living labs, platforms for large-scale projects and platforms for product or services development.

![Diagram](image)

**Figure 156. Additional elements for CEI Montegancedo in 2020**

Table 9 summarises the evolution of the key performance indicators at the beginning of the program, in 2015, and at the end of the envisaged period in 2020.

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110 Figure 5 does not include the rest of the centres and activities presented in previous chapters nor specific activities for individual research centres (see the following section).
<table>
<thead>
<tr>
<th>Indicator</th>
<th>2009</th>
<th>2015</th>
<th>2020</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. of students</td>
<td>40565</td>
<td>40986</td>
<td>42000</td>
<td>Mainly on Master Degrees</td>
</tr>
<tr>
<td>% postgraduate students from abroad</td>
<td>8%</td>
<td>11%</td>
<td>13%</td>
<td>Includes Masters’ Degree and PhD students</td>
</tr>
<tr>
<td>No. of researchers</td>
<td>3235</td>
<td>3202*</td>
<td>3500</td>
<td>*in 2014</td>
</tr>
<tr>
<td>% researchers from abroad¹¹¹</td>
<td>1.3</td>
<td>1.0*</td>
<td>1.3</td>
<td>*in 2014</td>
</tr>
<tr>
<td>Volume of built facilities</td>
<td>6,000</td>
<td>12,000</td>
<td>13,000</td>
<td>No need to build another building is envisaged. Small additions in pre-existing ones.</td>
</tr>
<tr>
<td>No. of research and services centres</td>
<td>2</td>
<td>9</td>
<td>10</td>
<td>We assume the creation of one service centre in 3D printing technology.</td>
</tr>
<tr>
<td>No. of papers¹¹²</td>
<td>400</td>
<td>600</td>
<td>1,000</td>
<td>The UPM will enter the international rankings</td>
</tr>
<tr>
<td>% of papers in Montegancedo¹¹³</td>
<td>29.6%</td>
<td>32.5%</td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td>No. of patents¹¹⁴</td>
<td>50</td>
<td>64</td>
<td>80</td>
<td>The emphasis is to license them</td>
</tr>
<tr>
<td>% of patents in Montegancedo¹¹⁵</td>
<td>8%</td>
<td>5%*</td>
<td>6%**</td>
<td>*in 2014. **Activity is mainly focused on sw where patents are not essential.</td>
</tr>
<tr>
<td>Aggregations</td>
<td>6</td>
<td>32</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Joint units</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Spin-offs created annually</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Created from the whole UPM community (in many cases, they cannot be linked to one specific centre)</td>
</tr>
<tr>
<td>Licences</td>
<td>8</td>
<td>12</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Royalties (K€)¹¹⁶</td>
<td>150</td>
<td>300</td>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>

Table 9. Estimated evolution of KPIs

A quick analysis of table 9 reflects the expansion of the Campus in many of the indicators.

¹¹¹ Doctoral students with a fellowship are recognised as researchers according to the Spanish Law.
¹¹² First author located in one of the units of Montegancedo.
¹¹³ Referred to the total number at the UPM
¹¹⁴ Referred to the total number at the UPM
¹¹⁵ Referred to the total number of the UPM
¹¹⁶ For the whole UPM.
4.2. Conclusions

This chapter has analysed how the CEI Montegancedo could evolve from the present situation until 2020. The initial assumption was based on a positive macroeconomic framework for Spain in the near future. Within it, a high level SWOT of the present situation (2015) serves as initial starting point.

The future evolution of CEI Montegancedo is framed in three potential policy scenarios of the UPM evolution in which the role of campuses could differ dramatically; they are used as backbones for the discussion on the impact on the CEI Montegancedo until 2020.

A conceptual proposal namely Montegancedo 2020 has been presented to frame the discussion and to build on on the specific activities which are envisaged for each unit (see Annex). We are aware that some of them will become a reality, others will be abandoned, and others will appear.

The final conclusion is summarised as follows: **CEI Montegancedo will continue to be a driving force for the structural reform and modernisation of the UPM in the next five years by consolidating the effort made in the recent past.**
CHAPTER 5: Evolution and assessment of key performance indicators of CEI Montegancedo

5.1. The relevance of performance indicators

When preparing the I2_Tech proposal, the UPM identified some performance indicators to the CEI Montegancedo and allocated estimated figures to all of them. Since 2010, some additional indicators were added and values for those indicators were regularly reported to the Spanish Government on the occasion of the evaluation of the CEI Montegancedo.

This final chapter will provide an overall view of those key performance indicators, their evolution over time and a self-assessment of the satisfaction of objectives. The chapter is written as a conclusion of the final report and it does not try to repeat or extend into descriptions or rationales presented in previous chapters.

After justifying the indicators used, the evolution of these figures in 2010, 2013 and 2015 will be presented and discussed individually. Finally, an overall assessment of CEI Montegancedo performance will conclude Chapter 5 and the whole report.

5.2. Selected indicators

In a project like I2_Tech where many perspectives have been addressed simultaneously in the last five years, the number and diversity of possible performance indicators could be very large. Individually, they could be useful to monitor the evolution of one aspect while it also allows attention to be paid to the need for corrective measures.

Nevertheless, from an overall governance perspective, this number should kept under control to be able to relate them to specific institutional policies and to monitor the overall evolution and not too detailed aspects of the Campus where the comparison or stability of sources is not guaranteed.

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117 In the European Union, the innovation performance of the 28 Member States of the EU is assessed by the use of 25 individual indicators in the so-called “Innovation Trend-chart”. The annual publication of the results serves as a basis for comparison amongst the EU Member States and also with other countries outside the EU. Discussions about the type of indicators and their respective weight to generate the value of a synthetic innovation indicator lasted several years until common agreement on sources, interpretation, etc. This situation is not far from the case of CEI Montegancedo.
For our purposes, the taxonomy of selected indicators is represented in figure 1. Note the existence of 6 main types as follows:

1. **Indicators related to education dimension**
   1.1. Total number of students
   1.2. % of foreign students
   1.3. Engineering Degrees offered
   1.4. Masters’ Degrees offered
   1.5. Gender balance

2. **Indicators related to research dimension**
   2.1. Number of researchers and faculties
   2.2. % of foreign researchers
   2.3. PhD programs offered
   2.4. Theses read
   2.5. Research centres
   2.6. Participation in international projects
   2.7. Total funding from research projects
   2.8. JCR papers

3. **Indicators related to the innovation dimension**
   3.1. Identified technologies
   3.2. Spin-offs and start-ups created
   3.3. Business ideas received
   3.4. Licenses of technology
   3.5. Patents granted
   3.6. International patent application

4. **Indicators related to investments**
   4.1. Total investments on the Campus
   4.2. Resources obtained from government calls
   4.3. Resources obtained from international open calls

5. **Indicators related to services**
   5.1. Supercomputing users
   5.2. Virtual cloud users
   5.3. Use of green-houses
   5.4. Visa support to foreign students

6. **Indicators related to governance**
   6.1. Number of aggregated entities
   6.2. Agreements with international entities
   6.3. Joint education/research/innovation units
   6.4. Joint activities with other CEIs

The evolution of these 24 indicators has been monitored in 2009, 2011 2013 and 2015 to be able to assess the progress.

Many other possible indicators could be identified. They could be useful for the entire UPM purposes but not necessarily for one specific campus\textsuperscript{118}. Then, CEI

\textsuperscript{118} Remember that some Spanish CEIs were conceived for the whole university and not for one specific campus as it is the case of the UPM.
Montegancedo has reduced the scope to ensure the provision of data for the monitoring process.

Regularly, the CEI Montegancedo provides data on request from the central administration of the university.

### 5.3. Evolution of specific indicators of the CEI Montegancedo

#### 5.3.1. Indicators related to education dimension

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2015</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of students</td>
<td>40565</td>
<td>42255</td>
<td>41394</td>
<td>40986</td>
<td>Stability in spite of high increase in tuition fees</td>
</tr>
<tr>
<td>Percentage of foreign students</td>
<td>8%</td>
<td>10%</td>
<td>11%</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Offer of engineering degrees</td>
<td>39</td>
<td>39</td>
<td>41</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Offer of Masters’ Degrees</td>
<td>42</td>
<td>55</td>
<td>61</td>
<td>78</td>
<td>Emphasis in postgraduate studies</td>
</tr>
<tr>
<td>Gender balance</td>
<td>32%</td>
<td>32%</td>
<td>32%</td>
<td>32%</td>
<td></td>
</tr>
</tbody>
</table>

Table 10.

Table 10 reflects the redesign of the academic offer. Main goal was to offer students a renewed set of master degrees by taking advantage of the availability of equipment and staff from research centres.
5.3.2. **Indicators related to research dimension**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2014</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of researchers and faculties</td>
<td>3235</td>
<td>3263</td>
<td>3157</td>
<td>3202</td>
<td></td>
</tr>
<tr>
<td>Percentage of foreign researchers</td>
<td>209</td>
<td>1,3</td>
<td>1,2</td>
<td>1,0</td>
<td>Difficulties to create additional positions during the crisis.</td>
</tr>
<tr>
<td>Offer of PhD programs</td>
<td>31</td>
<td>43</td>
<td>47</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Theses read</td>
<td>176</td>
<td>224</td>
<td>294</td>
<td>283</td>
<td>Good progress</td>
</tr>
<tr>
<td>Research centres</td>
<td>16</td>
<td>18</td>
<td>19</td>
<td>18</td>
<td>Creation of CSS in 2015 (19)</td>
</tr>
<tr>
<td>Participation in international projects</td>
<td>65</td>
<td>79</td>
<td>85</td>
<td>44*</td>
<td>* 7FP finished and H2020 started</td>
</tr>
<tr>
<td>Total funding from projects</td>
<td>9.96</td>
<td>19.5</td>
<td>19.8</td>
<td>8.38*</td>
<td>* 7FP finished and H2020 started</td>
</tr>
<tr>
<td>JCR papers</td>
<td>1348</td>
<td>1564</td>
<td>1871</td>
<td>1860</td>
<td>Good progress</td>
</tr>
</tbody>
</table>

**Table 11.**

Table 11 reflects the relative strenght of the UPM although effort should continue in the near future. It is a pity that the UPM (and Spain in general) could not find instruments to attract and retain foreign researchers in permanent positions. This is a key bottleneck to be addressed in the future.
5.3.3. Indicators related to the innovation dimension

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2014</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identified UPM technologies</td>
<td></td>
<td></td>
<td></td>
<td>53</td>
<td>These numbers will decrease because the dealflow is limited.</td>
</tr>
<tr>
<td>Spin-offs and start-ups created</td>
<td>15</td>
<td>17</td>
<td>18</td>
<td>22</td>
<td>Good rate. Effort should be placed on growth of companies created.</td>
</tr>
<tr>
<td>Business ideas received</td>
<td>266</td>
<td>415</td>
<td>405</td>
<td>350</td>
<td>450 in 2015</td>
</tr>
<tr>
<td>Licenses of technology or know-how</td>
<td>12</td>
<td>13</td>
<td>11</td>
<td>11</td>
<td>These numbers should increase in the future.</td>
</tr>
<tr>
<td>Patents granted</td>
<td>25</td>
<td>47</td>
<td>43</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>International patent application</td>
<td>34</td>
<td>75</td>
<td>23</td>
<td>38</td>
<td></td>
</tr>
</tbody>
</table>

Table 12.

Globally, figures of table 12 correspond to an entrepreneurship university where emphasis should be reoriented towards quality and not only volume.

5.3.4. Indicators related to investments in CEI Montegancedo

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total investments</td>
<td>11.216.430</td>
<td>8.965.612</td>
<td>11.714.321</td>
<td></td>
</tr>
<tr>
<td>Resources obtained from national open calls</td>
<td>7.354.817</td>
<td>6.297.22</td>
<td>5.659.723</td>
<td></td>
</tr>
<tr>
<td>Resources obtained from international open calls</td>
<td>3.861.613</td>
<td>2.668.38</td>
<td>6.054.598</td>
<td></td>
</tr>
</tbody>
</table>

Table 13.

Compared to the rest of the UPM the CEI Montegancedo has performed much better as a consequence of the maturity of research centres. The expected economic recovery of the EU and, specially, Spain, will provide the basis for continuous improvement of data.
5.3.5. **Indicators related to services**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2014</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supercomputing users</td>
<td>143</td>
<td>90</td>
<td>152</td>
<td>87*</td>
<td>* Until September 2015</td>
</tr>
<tr>
<td>Virtual cloud services</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>*</td>
<td>This service started in 2015: 750 users</td>
</tr>
<tr>
<td>Use of green houses</td>
<td>-</td>
<td>-</td>
<td>42.4</td>
<td>77.8</td>
<td></td>
</tr>
<tr>
<td>Services provided in containment chambers</td>
<td>-</td>
<td>-</td>
<td>55%</td>
<td>61%</td>
<td></td>
</tr>
<tr>
<td>Visa support to foreign students</td>
<td>25</td>
<td>25</td>
<td>13</td>
<td><em>8+33</em></td>
<td>Data in 2015 + CAIT</td>
</tr>
</tbody>
</table>

Table 14.

This level of progress is adequate although the shared use of research facilities would constitute a driver for better figures. Services offered to external entities will also depend on the UPM capability to fight against the obsolescence of equipment in a region where structural funds cannot be the basis for funding.

5.3.6. **Indicators related to governance**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
<th>2015</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of aggregated entities</td>
<td>6</td>
<td>-</td>
<td>37</td>
<td>37</td>
<td>Steady effort to convince other entities to join the CEI</td>
</tr>
<tr>
<td>Agreements signed with international entities</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td></td>
<td>Headquarters outside Spain</td>
</tr>
<tr>
<td>Joint units created</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>8</td>
<td>Centres, labs or joint research units</td>
</tr>
<tr>
<td>Joint activities with CEIS</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>CEI Moncloa</td>
</tr>
</tbody>
</table>

Table 15.

Main figure in table 15 is the high level of aggregated entities. This number will grow up in the future but even more important should be the intensity of the interactions; both the UPM with them but also other links between aggregated entities stimulated by their participation in CEI Montegancedo.
5.4. **An overall assessment of CEI Montegancedo**

Individual indicators offer a patchy view of the evolution of the CEI Montegancedo from several dimensions. Nevertheless, these are not independent dimensions as mentioned above; then, an overall assessment is needed.

The assessment could be done by identifying the way that the open innovation ecosystem of Montegancedo has fulfilled its main objectives. Figure 156 expresses this view.

![Figure 157. Overall assessment of CEI Montegancedo](image)

Figure 157 represents the six dimensions used in the report to show their main contributions to the creation of the open innovation ecosystem and some drawbacks which still persist today.
ANNEX 1

Aggregated entities

The annex classifies the aggregated entities taking into account their legal status. For each of them a short description of their field of S&T and type of agreement is included. The development of specific R&D projects is not considered.

We do not consider as aggregates entities those entities that have rented space in the business incubator unless another type of agreement is signed.

Large companies

1. IBM (activities mainly with CESVIMA and ETSIInf)
   - Cognitive computing (Watson system)
   - Supercomputing (Magerit)
2. Santander (activities mainly with COM and CAIT)
   - Joint centre on Open middleware
   - Living lab on banking
3. Telefónica (activities mainly with CAIT, ETSIInf and IMDEA SW)
   - Joint Research Unit on FI-WARE
4. T-systems (activities mainly with CEDINT)
   - Virtual reality (5-wall cave)
5. ISBAN (activities mainly with COM)
   - Joint centre on Open middleware
6. PRODUBAN (activities mainly with COM)
   - Joint centre on Open middleware
7. Accenture (activities mainly with CAIT)
   - Entrepreneurship (sponsor of actúaupm)
8. Zeiss (activities mainly with CTB)
   - Dual beam microscopy
9. CISCO (activities mainly with CESVIMA and ETSIInf)
   - Virtualisation of services
10. UCB (activities mainly with CTB)
    - Education on medical innovation
11. Repsol (activities mainly with CBGP and CCS)
    - Bioenergy
12. CITRIX (activities mainly with CESVIMA)
    - Virtualisation of services
13. INDRA (activities mainly with IMDEA SW)
    - Education
Small and medium enterprises

14. LPI (activities mainly with CEDINT)
   - Advanced optics system
15. BCCG (activities mainly with CAIT)
   - Consulting
16. Plant response (activities mainly with CBGP and CAIT)
   - Plant genomics
   - Brokerage
17. Frontiers (activities mainly with CAIT)
   - Business ideas competition
18. Elekta (activities mainly with CTB)
   - MEG education
19. ADTS (activities mainly with CAIT)
   - Drone operation
20. Sharing matters (activities mainly with CAIT)
   - Platforms for use of equipment
21. Mimétrica (activities mainly with CeDiNT)
   - Research and innovation

Universities and research centres

22. UCM (activities mainly with CTB and CCS)
   - Magnetoencephalography
   - Magerit
23. HRyC (activities mainly with CTB)
   - Medical imaging
24. IMDEA Software (activities mainly with CAIT and ETSIIInf)
   - Foundation with the UPM and other entities
25. UNICAMP (activities mainly with CBGP)
   - Joint centre in Campinas (Brazil)
26. University Toulouse (activities mainly with ETSIIInf)
   - Joint lab on software
27. UC Colorado (activities mainly with CTB)
   - Education: joint Masters’ Degree
28. INIA (activities mainly with CBGP)
   - Joint research centre (CBGP)
29. CSIC (activities mainly with CTB)
   - Neuroscience
30. URJC (activities mainly with CTB and CCS)
   - Medical image
31. BSC (activities mainly with CESVIMA and CCS)
   - Supercomputing
32. EPFL (activities mainly with CTB)
   - Neuroimaging processing
33. ISCIII (activities mainly with CAIT)
   - Technology watch
Institutions

34. ESA (activities mainly with CIDA and CAIT)
   - Business incubator
   - Fluid-dynamic experiments for the ISS
35. IMADE
   - Business incubation
36. Madri+D (activities mainly with CAIT and CTB)
   - Business incubation
   - Medical imaging
37. EIT Digital (activities mainly with IMDEA SW, ETSIIInf and CAIT)
   - Co-location centre
   - Masters’ Degree in DS
   - Doctorate
38. EIT Health (activities mainly with CTB and CAIT)
   - Neuroscience Innovation and Entrepreneurship Lab
ANNEX 2:

List of acronyms

BBP: Blue Brain Project
BIC: Business Incubator Centre
BSC: Barcelona Supercomputing Centre
CAIT: Centro de Apoyo a la Innovación Tecnológica
CBGP: Centro de Biotecnología y Genómica de Plantas
CEDEX: Centro de Experiencias
CEDINT: Research Centre for Smart Buildings and Energy Efficiency
CEI: Campus de Excelencia Internacional
CESVIMA: Centro de Supercomputación y Visualización de Madrid
CIDA: Centro de Investigación y Desarrollo Aeroespacial
COM: Centre for Open Middleware
CPD: Centro de Proceso de Datos
CSC: Centre for Computer Simulation
CSIC: Consejo Superior de Investigaciones Científicas
CTB: Centro de Tecnología Biomédica
DTC: Doctoral Training Centre
EIT: European Institute of Technology and Innovation
EC: European Commission
ECTS: European Credit Transfer System
EOI: Escuela de Organización Industrial
ERA: European Research Area
ESA: European Space Agency
ETSIInf: Escuela Técnica Superior de Ingenieros Informáticos
EU: European Union
EUIMA
FIWARE: Future internet-ware
FP7: Framework program 7
SWOT: Strenghts, Weaknesses, Opportunities and Threads

S&T: Science and Technology

TUM: Technical University of Munich

UAV: Unmanned Air Vehicle

UCM: Universidad Complutense de Madrid

UCIII: Universidad Carlos III

UE: Unión Europea

ULAB: University Laboratory

UPM: Universidad Politécnica de Madrid

URJC: Universidad Rey Juan Carlos

USOC: User support and operation centre

WoS: Web of Science