MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD
Apoyo a Centros de Excelencia Severo Ochoa

Referencia: SSOC1500X000493XV0

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1. Entidad Solicitante

Entidad: BARCELONA SUPERCOMPUTING CENTER CENTRO NACIONAL DE SUPERCOMPUTACION

Adscripción del Centro dentro de la institución: BARCELONA SUPERCOMPUTING CENTER - CENTRO. NACIONAL DE SUPERCOMPUTACION

¿Coincide el Centro con la denominación anterior? Si

Centro (Centre):

Dirección postal entidad: JORDI GIRONA
Barcelona
BARCELONA - 08034

Representante Legal

Nombre: MATEO Apellidos: VALERO CORTÉS

Correo electrónico : MATEO.VALERO@BSC.ES Teléfono : 934137716

2. Centro

Centro (Centre):

Dirección postal del Centro

Comunidad autónoma : CATALUÑA Provincia : BARCELONA

Localidad : Barcelona

Dirección postal : CALLE JORDI GIRONA 31 Código postal : 08034

3. Datos personales del Director Científico

Lugar de Nacimiento (país): ESPAÑA

País de residencia: ESPAÑA

Tipo Documento : NIF Documento : 17684150W

Nombre : MATEO Apellidos : VALERO CORTÉS

Domicilio : JORDI GIRONA 29 1 Localidad : Barcelona

Provincia : BARCELONA Nacionalidad : ESPAÑA Código postal : 08034

Teléfono : 934134053 Correo electrónico : MATEO.VALERO@BSC.ES

4. Datos académicos del Director Científico

Grado: Doctor Titulación: Doctor Ingeniero de Telecomunicacion

Año de obtención del título de Doctor o equivalente: 1980 Universidad española: Si

Entidad : UNIVERSIDAD POLITECNICA DE MADRID

Categoría Profesional : Catedrático de Universidad Vinculación con el centro : Funcionario

Impacto Normalizado de su producción científica para el periodo 2011-2015 : 1,948

Base de datos científica : Scopus

Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías

Campo científico (1er nivel) : Computer Science

Campo científico (2º nivel) : Computer Networks and Communications

5. Investigadores garantes

Apellidos: Doblas Reyes Nombre: Francisco

NIF 29029481P Sexo: ☒ V ☐ M Año de nacimiento: 07/06/1968

Titulación académica: Doctor en Fisica Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto

Categoría profesional: Contratado CCAA (Tipo ICREA)

Vinculación con el Centro: Contratado

Contrato indefinido : Si

Impacto Normalizado de su producción científica para el periodo 2011-2015: 4.183

Base de datos científica : Scopus

Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías

Campo científico (1er nivel) : Earth and Planetary Sciences

Campo científico (2º nivel) : Atmospheric Science

Apellidos: Torrents Arenales Nombre: David

NIF 43424952D Sexo: ☒ V ☐ M Año de nacimiento: 17/12/1967

Titulación académica: Doctor en Bioquimica Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto

Categoría profesional: Contratado CCAA (Tipo ICREA)

Vinculación con el Centro: Estatutario

Impacto Normalizado de su producción científica para el periodo 2011-2015: 9.999

Base de datos científica : Scopus

Campo científico : Ciencias de la Vida

Campo científico (1er nivel) : Biochemistry, Genetics and Molecular Biology

Campo científico (2º nivel) : Molecular Biology

Apellidos: Jorba Casellas Nombre: Oriol

NIF 46235919P Sexo: ☒ V ☐ M Año de nacimiento: 09/07/1975

Titulación académica: Doctor en Ingenieria Ambiental Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto

Categoría profesional: Investigador Contratado

Vinculación con el Centro: Contratado

Contrato indefinido : Si

Impacto Normalizado de su producción científica para el periodo 2011-2015: 2.384

Base de datos científica : Scopus

Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías

Campo científico (1er nivel) : Earth and Planetary Sciences

Campo científico (2º nivel) : Atmospheric Science

5. Investigadores garantes

Apellidos: Labarta Mancho — Nombre: Jesus
NIF 17146867E — Sexo: ☒ V ☐ M — Año de nacimiento: 10/11/1958
Titulación académica: Doctor en Ingeniería — Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto
Categoría profesional: Catedrático de Universidad
Vinculación con el Centro: Contratado
Contrato indefinido : Si
Impacto Normalizado de su producción científica para el periodo 2011-2015: 2.952
Base de datos científica : Scopus
Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías
Campo científico (1er nivel) : Computer Science
Campo científico (2º nivel) : Hardware and Architecture

Apellidos: Carrera Perez — Nombre: David
NIF 38109007P — Sexo: ☒ V ☐ M — Año de nacimiento: 15/05/1979
Titulación académica: Doctor por la Universitat Politecnica de Catalunya — Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto
Categoría profesional: Profesor Contratado Doctor
Vinculación con el Centro: Contratado
Contrato indefinido : Si
Impacto Normalizado de su producción científica para el periodo 2011-2015: 3.48
Base de datos científica : Scopus
Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías
Campo científico (1er nivel) : Computer Science
Campo científico (2º nivel) : Hardware and Architecture

Apellidos: Torres Viñal — Nombre: Jordi
NIF 38794157B — Sexo: ☒ V ☐ M — Año de nacimiento: 27/05/1964
Titulación académica: Doctor en Informatica — Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto
Categoría profesional: Catedrático de Universidad
Vinculación con el Centro: Funcionario
Impacto Normalizado de su producción científica para el periodo 2011-2015: 2.339
Base de datos científica : Scopus
Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías
Campo científico (1er nivel) : Computer Science
Campo científico (2º nivel) : Hardware and Architecture

5. Investigadores garantes

Apellidos: Ayguade Parra Nombre: Eduard

NIF 38428764L Sexo: ☒ V ☐ M Año de nacimiento: 15/05/1962

Titulación académica: Doctor en Informatica Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto

Categoría profesional: Catedrático de Universidad

Vinculación con el Centro: Funcionario

Impacto Normalizado de su producción científica para el periodo 2011-2015: 1.954

Base de datos científica : Scopus

Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías

Campo científico (1er nivel) : Computer Science

Campo científico (2º nivel) : Computer Networks and Communications

Apellidos: Cela Espin Nombre: Jose Maria

NIF 72529003K Sexo: ☒ V ☐ M Año de nacimiento: 15/05/1965

Titulación académica: Doctor en Ingenieria de Telecomunicaciones Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto

Categoría profesional: Profesor Titular Universidad

Vinculación con el Centro: Funcionario

Impacto Normalizado de su producción científica para el periodo 2011-2015: 1.675

Base de datos científica : Scopus

Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías

Campo científico (1er nivel) : Computer Science

Campo científico (2º nivel) : Computer Graphics and Computer-Aided Design

Apellidos: Folch Nombre: Arnau

NIF 46233863E Sexo: ☒ V ☐ M Año de nacimiento: 29/04/1970

Titulación académica: Doctor en Matematicas Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto

Categoría profesional: Investigador Contratado

Vinculación con el Centro: Contratado

Contrato indefinido : Si

Impacto Normalizado de su producción científica para el periodo 2011-2015: 2.042

Base de datos científica : Scopus

Campo científico : Matemáticas, Ciencias Experimentales e Ingenierías

Campo científico (1er nivel) : Earth and Planetary Sciences

Campo científico (2º nivel) : Atmospheric Science

5. Investigadores garantes

Apellidos: Guallar Tasies Nombre: Victor

NIF 43714250J Sexo: ☒ V ☐ M Año de nacimiento: 26/06/1971

Titulación académica: Doctor en Quimica Teorica Grado: ☒ Doctor ☐ Licenciado / Ingeniero / Arquitecto

Categoría profesional: Contratado CCAA (Tipo ICREA)

Vinculación con el Centro: Estatutario

Impacto Normalizado de su producción científica para el periodo 2011-2015: 1.658

Base de datos científica : Scopus

Campo científico : Ciencias de la Vida

Campo científico (1er nivel) : Biochemistry, Genetics and Molecular Biology

Campo científico (2º nivel) : Biophysics

6. Áreas científicas

Campo científico:	Matemáticas, Ciencias Experimentales e Ingenierías
Campo científico (1er nivel):	Computer Science
Campo científico (2º nivel) :	Computer Networks and Communications Computer Science Applications Hardware and Architecture
Áreas ANEP:	Ciencias de la Computación y Tecnología Informática

7. Scientific Report

7.0. Overview of the Centre

Please give a brief presentation of the center including the main strengths and achievements concerning research activities and scientific leadership of the center as compared to its international partners. Refer to the center's most relevant characteristics and data showing its critical mass for conducting research and any other information relevant to demonstrate research excellence and international leadership.

BSC is a unique fusion of a classic national scientific support structure and a cutting-edge research institute, endowing it with a synergism that empowers it to develop and design the next generation of supercomputing technologies and apply multidisciplinary research teams to effectively bridge the gap between the ever-increasing complexities of HPC hardware and the user-friendly applications required by scientists and industry in order to address key social challenges.

BSC can justifiable claim to be among the very best supercomputing centres in the world. This leadership has been recognized both locally and internationally: BSC was one of the original 8 Spanish research centres awarded Severo Ochoa in 2011; BSC is a founding member and key driver of PRACE (the pan-European Research Infrastructure for HPC) with BSC's Operations Director serving as the Chairman of its Board of Directors and BSC hosting one of the 6 European Tier-0 supercomputers servicing scientists globally; BSC was invited to be a founding member of JLESC (Joint Laboratory for Extreme Scale Computing), a select club of the very best international supercomputing centres, the others being NCSA (USA), Argonne (USA), INRIA (France), Julich (Germany) and Riken (Japan); in the recent European calls which established eight European Centres of Excellence in HPC, BSC achieved outstanding results, being the Supercomputing center in Europe with the highest success. BSC leads one application-transversal domain consortium (for performance optimization) and participates in five other successful consortia (on energy, bimolecular simulation, weather and climate, materials discovery and materials design).

Other indicators include BSC's excellent publishing record, with 375 top quartile and 207 top decile journal publications and 114 confreence proceedings in A and A* CORE rank in 2011-14. BSC has achieved an outstanding success rate in the EU competitive funding program H2020, with 34 out of 92 proposals being funded which is a success rate of 37%. This compares to an overall European success rate of around 14%. This follows BSC's success in the previous European funding program, FP7, where BSC was ranked 12th of all Spanish entities in total awarded funding, the second public research centre, and the first in the Research Infrastructure priority of the programme. Two ERC Advanced grants (RoMoL and PELE), one Starting grant (Hi-EST), and one Proof-of-Concept grant (eDRUG) have been awarded. In 2014 alone, BSC received over 6 million euros in European competitive funding.

BSC's areas of research include both HPC hardware and software, with research lines covering the full spectrum from chip design through operating systems, programming models and performance tools, as well as multidisciplinary teams developing cutting edge applications in Life and Earth sciences and Engineering. Research excellence is closely scrutinized by an independent Scientific Advisory Board (SAB) comprised of truly world-class scientists, whose guidance has helped shape development of BSC over the last 4 years.

This combination of depth in computer sciences combined with broad coverage of key fields that make use of HPC, enables BSC to play a pivotal role in many national and international collaborative initiatives. At the international level, BSC is a very active participant in the global workshop BDEC (Big Data and Extreme-scale Computing) whose 3rd edition was hosted in Barcelona in January 2015; BSC is developing new codes and big data solutions for ICGC (the International Cancer Genome Consortium); BSC collaborated with the World Meteorological Organization (WMO) and the Spanish Meteorological Agency (AEMET) to create the Regional Centre for Sand and Dust Storm Warning System covering Europe, northern Africa and the Middle-East, and also the Barcelona Dust Forecast Centre (BDFC) specialized in atmospheric sand and dust forecast. The development of inter-continental projects has allowed BSC to act as a bridge between Europe and Latin America as a consolidating action for the RISC (Red Iberoamericana de SuperComputación).

At the national level, BSC has longstanding scientific collaborations with numerous other Severo Ochoa centres covering a wide range of scientific disciplines, including a joint research program with IRB (Institute for Research in Biomedicine) and CRG (Centre for Genomic Regulation), and joint projects with CNIO (National Centre for Oncology), CNIC (National Centre for Cardiology), ICN2 (Catalan Institute of Nanoscience and Nanotechnology), IAC (Instituto Astrofísico de Canarias), and research centers in hospitals (Sant Pau, Vall d'Hebron, Can Ruti).

Beyond research, BSC aims to influence the way future supercomputers are designed, built and used. It does this by establishing long-term joint research activities with the world's leading computing companies: IBM, Intel, Microsoft, Samsung and NVIDIA. Key multinationals in other fields have similarly invested in long-term application-oriented research projects, including Repsol (Petrochemicals) and Iberdrola (Renewable energies), and even the European Space Agency (ESA). These companies consistently fund research at BSC totaling more than 3 million euro annually.

This level of activity and leadership would not be possible without strong teams of very talented people, and an effective organizational and management structure. These have been strongly developed over the last four years, mainly thanks to initiatives driven by the Severo Ochoa program. BSC currently totals some 380 staff from around 40 different countries, hosts around 50-70 visitors, and trains in the order of 15-20 new PhDs every year. Talent attraction and retention are core activities, with numerous programs having been put in place in recent years, including the European Human Resource Excellence in Research Award (achieved in 2015), formalized Career Development planning, strong mentorship of young researchers, summer schools (some well established such as the PUMPS summer school in the framework of the BSC GPU Center of Excellence), training workshops (mainly as PRACE Advanced Training Center), relocation support for foreign researchers and their families, a gender action program, an alumni association and a social welfare program. It is important to realize that, despite the deep economic crisis of recent years and the relatively low salaries offered under Spanish research salary bands, the proposed talent attraction measures, combined with the excellent scientific reputation of BSC's senior staff and the strong international profile of BSC, have ensured a steady growth in both absolute numbers and quality of personnel.

As highlighted earlier, BSC is not only a research institute, it is also the National Supercomputing Centre and a PRACE node, offering Spanish, European and international users access to one of the six most powerful supercomputers in Europe. BSC also coordinates the Spanish Supercomputing Network (RES) comprising 15 nodes all around Spain, managing user access as well as planning and training of technical staff for upgrades and services. BSC runs workshops throughout the country to promote and facilitate access to first-time users from the entire spectrum of scientific disciplines.

BSC also works hard to stimulate public interest and awareness of HPC and its current and future impact on society. BSC's main supercomputer, MareNostrum III, is beautifully located in a converted chapel and is the focal point of BSC's outreach activities. Over 8000 people visit MareNostrum annually, including schools, companies, and international dignitaries. Online activity has also been strongly increased in recent years, leading to over 1 million visits each year to the BSC website and significant activity on Facebook, Twitter and Youtube.

To conclude this section, we provide a summary of the scientific achievements and frontier inter-disciplinary research activities carried out by the center over 2011-2015 heavily supported by BSC's Severo Ochoa program. The program was designed around four sub-projects to be developed with the support of inter-departmental collaborations: the proposal and development of novel models in three application domains which rotate around novel energy-efficiency based components in the hardware and software stacks to achieve the Exascale and Big Data challenges proposed.

1. Personalised medicine: the combination of genomics, proteomics and transcriptomics analysis with computer simulation has been explored to create models capable of predicting certain diseases or the effects of drugs on patients before a pathology starts.

7.0. Overview of the Centre

2. Multi-scale air quality climate modelling: a high-resolution modelling system for short and long-term applications has been developed, as well as new methodologies to run complex high-resolution models on Exascale machines and to handle big amounts of generated data.
3. Computational biomechanics: the Alya Red infrastructure has been developed, with special emphasis on a new cardiac computational model, through the implementation and validation of various advanced physiological models.
4. Novel components in the hardware and software stacks in the Exascale/BigData convergence, to facilitate the implementation of the applications developed by the scientific departments and to improve the utilization of resources in an energy-efficient way.

Additional details related to BSC's Severo Ochoa 2011-15 program are included in:
* Annex a) Scientific Report", providing a summary of the achievements and research activities carried out by BSC over 2011-2015 linked to the Severo Ochoa award
* Annex b) tables and figures, containing the main planning and monitoring Indicators
* Annex c) garantes reports, including the individual reports of each garante, valorizing the impact of the award in their career and their contribution to institutional strengthening.

7.1. Organization, Management and research capabilites

Please summarize the strategic plan for the center during 2011-2015, or, if this is missing, the center's research lines and activities developed in the period and that show the existence of common shared scientific goals. Refer to the main research areas or lines of the center and the synergies and grade of integration or complementarity existing between the research areas or lines and the developed activities during the period. Describe the governance and management of the center with a focus on decision making, setting research priorities, and allocating resources across different research activities.

BSC has had formal Strategic Plans in place since 2009 (the current plan runs till 2016), all of them externally evaluated as excellent by the Spanish Ministry of Economy and Competitivity (MINECO). The plans provide continuity of Vision and core objectives whilst updating specific areas of focus and activity to reflect the changing environment.

BSC's vision, as Spains National Laboratory for Supercomputing, is to be of service to the rapidly changing needs of its users and to assist the countrys scientific and industrial communities to transition to and participate in the convergence of computation platforms and the emergence of new paradigms such as Cloud Computing and Big Data. To do this it synergistically combines its capacities as a European Tier 0 HPC infrastructure and a world-class HPC research centre, positioning itself as a key international leader in developing and providing the next generation HPC technologies and pro-actively assisting Spanish and European science and industry to integrate these technologies into their activities, boosting competitiveness and productivity in a broad spectrum of fields.

This Vision is reflected in BSC's three core strategic objectives:
1. Backbone of e-Science in Europe and Spain
BSC has established itself, and aims to continue to be, an internationally leading HPC installation providing access to scientists locally and globally across all scientific disciplines. BSC not only provides time on its machines, but also value added services assisting scientists port their code and optimise their experiments.

2. Research Excellence
By establishing cutting-edge, multidisciplinary research teams with critical mass in key areas of HPC hardware, software and application areas (Computer Sciences, Life Sciences, Earth Sciences, Engineering), and giving them privileged access to BSC's HPC infrastructures, BSC aims to be a global leader in these key fields and establish a synergistic feedback loop with the first objective the infrastructure supports the researchers, which in turn contribute to and influence the next generation of infrastructure upgrades.

3. Social Impact
BSC represents an immense investment of public funds by both the Spanish Government and the European Community. This investment is done for the public good, which should give rise over the long-term to new technologies that will benefit society and improve the competitiveness of Spanish and European industry. This does not happen automatically BSC implements specific actions to collaborate with industry and public agencies in order to realise the vast potential of the knowledge it generates.

The above broad objectives have remained constant during the past 6 years and will be maintained for the coming period through to at least 2019. Their detailed sub-objectives and associated actions are discussed in more detail in sections 8.0 and 8.1.

The BSCs strategic plan defines four main research areas:
a) Computer Science aims to influence the way computing machines are built, programmed and used. This is done through ideas, cooperation with manufacturers via technology transfer activities and product-quality open source developments that are usable by the scientific community. The Department includes researchers with a holistic and vertical background and vision and combines both stable and exploratory research paths, always with a co-design approach in mind, which covers from computer architecture, to resource management, performance tools, programming environments and algorithms, targeting not only supercomputer architectures but also BigData, realtime, embedded and mobile platforms. Performance, programming productivity, power/energy and reliability are the factors that drive the Departments co-design approach.

The Computer Science is structured in 11 research groups. Although each group has its own specialised topics of research, the teams often come together to collaborate on projects that require vertical integration, such as the Exascale EU projects Mont-Blanc/Mont-Blanc2 and DEEP/DEEP-ER, the ERC RoMoL award, the Human Brain Project (HPB) flagship and the Severo Ochoa program itself. This vertical interaction is considered critical to the quality and success of the research, as feedback between the different groups enables application programmers to influence the direction of future systems architecture while better knowledge of architectures improves the design and implementation of novel programming models, execution environments and applications.

b) Life Sciences seeks to understand the molecular biology and evolution of living organisms using theoretical models and simulation algorithms. Life Sciences benefits greatly from its unique situation in a major supercomputer centre, co-existing with a large and active environment of research in experimental biology. Its research line is tightly integrated in a collaborative effort with the Institute for Research in Biomedicine (IRB) under the Joint IRB-BSC Research Program on Computational Biology, with an extension signed in December 2013 to also include research groups from the Centre for Genomic Regulation (CRG). The Department also has strong collaborations with the National Institute of Bioinformatics (INB).

The structure of the Department and the technology platforms enables coverage of the entire field of computational biology, from atomistic detail to holistic views of the entire ecosystem. The Department is composed of 4 research groups and 2 research platforms: BSC-CNS research groups Electronic and Atomic Protein Modelling (EAPM), Protein Interactions and Docking (PID) and Computational Genomics (CG), the Molecular Modelling and Bioinformatics (MMB) and the Experimental Bionformatics Laboratory (EBL), jointly run by BSC-CNS and IRB, and the Computational Node (CN) of the National Institute of Bioinformatics, jointly run by BSC-CNS and INB.

c) Earth Sciences has the aim of modelling and understanding the behaviour of the Earth System, focusing its research activities on atmospheric processes and climate change modelling. It applies the latest advances of HPC and Big Data on Earth system modelling, putting the department at the forefront of the emerging problem of environmental forecasting. This very broad and ambitious objective is divided into four specific goals: First, to develop a modelling capability of atmospheric processes, from urban to global scales, along with their impacts on weather, air quality, climate, health and ecosystems. Second, to implement the most efficient climate prediction system to cover time scales ranging from a month to a few decades at global and regional spatial scales. Third to research the impact of weather, atmospheric chemistry, and climate on socio-economic sectors through the development of user-oriented services that ensure the transfer of developed technologies, and facilitate societal adaptation to a rapidly changing environment, especially for highly vulnerable communities. And finally, to use cutting-edge HPC and big data technologies to increase the efficiency, portability, and user-friendliness of the Earth system models, including pre-processing and post-processing of weather, atmospheric chemistry and climate data.

Currently, the Group maintains daily high-resolution operational air quality forecasts for Europe and Spain under the umbrella of the CALIOPE project; and also mineral dust forecasts for the Euro-Mediterranean region and East Asia. The Department, in collaboration with the World Meteorological Organization (WMO) and the Spanish Meteorological Agency (AEMET), created the Regional Centre for Sand and Dust Storm Warning System (SDS-WAS) covering Europe, northern Africa and the Middle-East and the first WMO regional meteorological centre specialized in atmospheric sand and dust forecast, the Barcelona Dust Forecast Centre (BDFC).

d) Computer Applications in Science and Engineering (CASE) aims to identify, engage and support user communities in science and engineering that are potential users of HPC, boosted by its own research lines in High Performance Computational Mechanics. CASE serves as a bridge between e-Science and advanced computer science technologies, developing new computational strategies to simulate complex problems specifically adapted to run efficiently on modern supercomputers. The research areas covered are truly multidisciplinary, requiring a deep level of expertise in many fields and collaborations with experts in other areas, both from Spanish and foreign institutions. This is complemented with strong links with industrial partners in need of advanced simulations of complex technology problems, such as REPSOL or Iberdrola.

Major research areas are Computational Fluid Dynamics and Solid Mechanics, Ab-initio DFT and TD-DFT molecular dynamics, Seismic Imaging and Parallel Programming. Major application areas are Aerospace, High Energy Physics (plasma core and edge transport, plasma wall interaction), Biomechanics (Cardiovascular and Respiratory systems), Geophysics and Atmospheric flows, and large scale social simulations. The research is complemented with the development of five main high performance codes, which are used in national/international projects and are the core of the collaborations and contracts with companies: Alya (high performance computational mechanics), FAll3D (volcanos ash transport), BSIT (Barcelona Seismic Imaging Tools), SIESTA (ab-initio molecular dynamics) and Pandora (agent-based modelling framework for social simulation).

During the 2011-2015 period, stimulated by the BSC's Severo Ochoa program, BSC's four main research areas all experienced strong growth and consolidation. But more importantly, the program has fostered a deep spirit of interaction and cooperation between all four departments. Knowing about the difficulties of generalized cooperation at medium or large scale in research environments, the Severo Ochoa program has been able to break those barriers successfully increasing the degree of cooperation between research teams in different Departments. Topics of collaboration include: 1) the use of Computer Sciences performance tools to understand performance bottlenecks and inefficiencies to drive the optimization process of some of the production codes, for example NMMB and EC-EARTH from the Earth Sciences Department; 2) the use of Computer Sciences programming models (OmpSs and COMPSs) to program parallel applications and workflows following a dataflow model, for example GWAS and HERMES workflows in Life and Earth Sciences departments, respectively, just to name two; 3) the co-design of a new coarse-grain programming environment for Python workflows making use of key-value and persistent data storages to ease and make more efficient the access to big amounts of data, driven by the requirement of applications from the scientific departments; 4) the development of a Domain Specific Language and execution infrastructure to ease the programming of applications based on partial differential equations, raising the attention of REPSOL who decided to invest in the development of this joint project; or 5) the joint efforts in developing the dispersion models for the dust model at the Earth Sciences department and the volcano hash model at CASE.

Annex 1 Supporting 2011-2015_BSC includes the following additional information related to the contents in this section:
* BSC-CNSs organizational chart and a description of the governance, organizational structure and management model of the centre
* Benchmarking of the center with respect to its international centres of reference
* Conclusions and recommendations from BSC-CNSs Scientific Advisory Board together with its appointment (date and period of evaluation) and its composition.

7.2. Research Outputs 2011-2015

7.2.1. Outstanding scientific contributions

Please describe the scientific contributions of the center over 2011-2015. Special reference should be given to the 10 outstanding scientific contributions and/or publications of the center for the period and that show the capacity of the center to generate highest international impact at the frontiers of knowledge.

In this section we present the 10 most outstanding contributions of the Centre for the 2011-15 period. But before going into them, we would like to comment that the contributions and results of the research activities carried out at the BSC-CNS in the Life and Earth Sciences and CASE Departments are usually published in prestigious high impact journals in each scientific area. Similarly, the research in Computer Sciences is usually published in the proceedings of high quality conferences in the area, using journals to publish more consolidated research results. The consistent and extensive scientific production of the Centre is summarised the table contained in Annex 1 SO Supporting 2011-2015 attached document, with an explanation of the additional metrics used to rank top conferences in the computing systems area. For BSC, another metric measuring the impact of the research results is the participation in joint projects through competitive calls and research initiatives among prestigious international institutions as well as production use of codes and models by companies. So in the description of the 10 selected outstanding contributions, we make references to publications, projects, collaborations and industrial use to back up their relevance.

The next bullets describe the 10 selected outstanding contributions, by Departments (Computer, Life and Earth Sciences and CASE):

1. Montblanc (European scalable and power efficient HPC platform based on low-power embedded technology) EU projects coordinated by BSC with the objective of demonstrating that energy-efficient and specially cost-effective High Performance Computers can be built using technologies from the mobile industry. The projects are Mont -Blanc (FP7-288777) and Mont-Blanc 2 (FP7- 610402), and included three technology providers Bull, ARM and Allinea 6 supercomputing centres Juelich, LRZ, GENCI, CNRS, CINECA and BSC and 5 additional research institutions University of Bristol, CEA, INRIA, HLRS and Universidad de Cantabria. These projects have revolutionized the way companies from all sectors (supercomputing, mobile, embedded) and research centres look at high performance computing and drew the attention even of non-technical media. The paper by Nikola Rajovic et al. "Supercomputing with commodity CPUs: are mobile SoCs ready for HPC?" was accepted for presentation and publication at the Proceedings of the International Conference on High Performance Computing, Networking, Storage and Analysis (SC13) and got the Best Student Paper award. With the industrial leadership of Bull, a new H2020 project Mont-Blanc 3 has been accepted, with the aim of designing a balanced node architecture (SoC and memory system) based on the technologies already explored in MB1 and MB2.

2. The RoMoL project, built around the ERC grant obtained by the Director of BSC, Prof. Mateo Valero, is leading research in the area of co-design between algorithms, programming model runtime and processor and system architecture in 10 years from now. A team of young researchers has been set up under the direction of two outstanding postdocs. Four publications in 2015 in highly ranked conferences endorse the quality of the research results that are being produced: 1) L. Jaulmes et al, "Exploiting asynchrony from exact forward recovery for DUE in iterative solvers", accepted for publication at the International Conference on High Performance Computing, Networking, Storage and Analysis (SC15) and selected as Best Paper Award finalist; 2) Lluc Alvarez et al., Coherence protocol for transparent management of scratchpad memories in shared memory manycore architectures, published at the 42nd Annual International Symposium on Computer Architecture (ISCA 2015), the top forum for computer architecture and has been so since 1975, taking only 30-35 papers a year (there are no short papers, no posters) with and acceptance rate of 15-20%, after a double-blind review process with 5-6 reviewers; 3) Timothy Hayes et al. VSR sort: A novel vectorised sorting algorithm and architecture extensions for future microprocessors, published at the 21st IEEE Symposium on High Performance Computer Architecture (HPCA 2015), with the same scope as ISCA, selection process and acceptance rates; and 4) Kallia Chronaki et al. Criticality-aware dynamic task scheduling for heterogeneous architectures, published at the 29th ACM International Conference on Supercomputing (ICS 2015), the most important academic conference on supercomputing technologies with acceptance rates in the order of 25% in the last 15 years.

3. Evolution of the OpenMP programming standard. The vision, research outcomes and prototype implementations of the OmpSs programming model and BSC performance tools have had a huge impact in the evolution of the specification of the latest versions of the dominant threading standard OpenMP, with worldwide recognition of the contributions of the centre. Features such as the tasking model, task dependencies, reductions and priorities have been included in the specification following BSC proposals; others are under discussion but already resulted in contributions to draft versions, such as the OpenMP tools application programming interface for performance analysis in which a prototype implementation in the Extrae and Paraver has been used to validate the proposal. Both OmpSs and Extrae/Paraver are distributed open source and have become the parallel programming and performance analysis backbone in a number of EU Exascale projects, including Mont-Blanc MB1 and MB2, DEEP and DEEPer, and the new EXAnode and the recently awarded Performance Optimization and Productivity (POP) Centre of Excellence, coordinated by BSC with the aim of diagnosing problems with codes using the tools of the group (including new performance analytics modules) and point to improvements to be made using OmpSs.

4. Tools for genome analysis in personalized medicine. The most relevant contributions are enumerated next: 1) development of Smuffin, a tool for the fast and comprehensive determination of genomic alterations in cancer, resulting in (including David Torrents and other BSC members) Comprehensive characterization of complex structural variations in cancer by directly comparing genome sequence reads, in Nature Biotechnology, 32, 1106-1112, 2014 publication; 2) the development of tools for Genome-Wide Association Study (GWAS) analysis of complex human pathologies, being (including D. Torrents) A genome-wide association study identifies CDHR3 as a susceptibility locus for early childhood asthma with severe exacerbations in Nature Genetics 46, 51-55, 2014 a publication example; 3) collaboration in one of the biggest metagenome projects on the human microbiota (Metahit consortium) that has resulted in the following publication (including D.Torrents and other BSC members) Enterotypes of the human gut microbiome, Nature 473, 174-180, 2011, which has already collected more than two thousand citations; and finally 2) development of a methodology for the analysis of cancer-related changes in the genome, with special emphasis in Leukaemia, in the framework of the ICGC-Leukaemia Project.

5. Tools for the study and engineering of proteins. Several contributions have been done in this direction, including the generation of bioinformatic pipelines for the generation of new and improved protein tags, resulting in Georgieva et al (including J.L.Gelpí and other BSC members) Inntags: small self-structured epitopes aimed at innocuous protein tagging. Nature Methods, In Press 2015; or Structural bases for the interaction and stabilization of the human amino acid transporter LAT2 with its ancillary protein 4F2hc. Proc. Natl. Acad. Sci. USA, 111, 2966-71, 2014, which illustrate the development of new generation protein-docking algorithms and their use to predict novel protein-protein complex structures of importance in cancer development. Medicahead is the industry-oriented project that has emerged from this scientific contributions aiming to provide state-of-the-art solutions for target and drug discovery.

6. Creation of the Barcelona Dust Forecast Center, first specialized centre of mineral dust prediction of the World Meteorological Organization. On June 2014, the first WMO Regional Meteorological Center Specialized on Atmospheric Sand and Dust Forecast, the Barcelona Dust Forecast Centre (BDFC; http://dust.aemet.es/), was publicly presented to cover the demands of many national meteorological services on mineral dust forecast. The centre is managed by a consortium composed by BSC and AEMET (Spanish meteorological agency). The centre operationally generates and distributes predictions for the North Africa Middle East and Europe region. The dust forecasts are based on the NMMB/BSC-Dust model developed at the Barcelona Supercomputing Centre (BSC-CNS), and improved within the context of the Severo-Ochoa activities.

7. Development, performance improvement and deployment of chemical weather prediction system (NMMB/BSC-CTM) in state-of-the-art HPC environments

7.2.1. Outstanding scientific contributions

and involvement of BSC in the International Cooperative for Aerosol Prediction community, (Including J.M. Baldasano, S. Basart and O. Jorba as contributing authors) describe the steps towards a global operational aerosol consensus, where BSC contributes together with the more important meteorological operational centres (ECMWF, NOAA/NCEP, NRL, NASA, JMA, UK Met Office) to a global ensemble on aerosol predictions. Publication (including J.M. Baldasano) "Soil Dust Aerosols and Wind as Predictors of Seasonal Meningitis Incidence in Niger" Environmental Health Perspectives, 2014.

8. Alya Red research initiative in the field of Biomechanics for Computational Cardiac and Vascular Modelling. The Alya Red system is the backbone of various multidisciplinary, multi-centre, translational research projects: 1) functional and imaging-based 3D modelling of ventricular substrate for accurate characterization of in-vivo scar-related monomorphic ventricular tachycardia; 2) Biological and computational characterization of mechanisms underlying atrial fibrillation. Both projects are being performed under a formal research agreement between institutions, BSC and CNIC (Centro Nacional de Investigaciones Cardiovasculares); 3) coupling to the Anatomically-Detailed Arterial Network (ADAN, from the Laboratório Nacional de Computaçao Científica LNCC) under the EU-Brazil Cloud Connect project (FP7-614048/CNPq 490115/2013-6), resulting in the greatest attempt up to date to model the cardiovascular system; and 4) fluid-structure interaction of the atherosclerotic plaque in carotid arteries, in conjunction with Mount Sinai School of Medicine, New York, USA, through the Cardio-Image (CNIC-MSSM) Program.

9. Sedar wind farm modelling system, used by Iberdrola to design wind farms with higher accuracy than existing commercial codes (according to internal validation by Iberdrola more than 8% reduction in the error). The model is based on the HPC in-house code Alya that is one of the two CFD codes in the PRACE benchmark suite. Alya has been adapted to solve Atmospheric Boundary Layer flows to fit the requirements of the wind energy community and complemented with pre and post process tools that make it friendly to industrial end-users. Its contribution to the field has been recognized by invitations to participate in important international projects, three of which have already been granted (EoCoE - Energy Oriented Centre of Excellence for Computer Applications, NEWA - Developing a New European Wind Atlas, HPC4E - High Performance Computing for Energy). The results from this research have been published in high impact journals (Procedia Computer Science, Geophysical Research Abstracts and Atmospheric Research).

10. The Repsol-BSC Research Centre focuses on producing state-of-the-art knowledge in HPC Geophysics. The project has led to relevant contributions to the field in terms of both algorithmic and numerical methods, while pushing the limits of optimization for modern HPC hardware architectures. Among the most relevant contributions are the ten-fold improvement on the accuracy and efficiency using Mimetic seismic wave modeling including topography on deformed staggered grids, by de la Puente et.al. 2014 (Geophysics) and developing Finite-Difference Staggered Grids in GPUs for Anisotropic Elastic Wave Propagation Simulation, Rubio et.al. 2014 (Computers and Geosciences). This research has been a key contribution to the competitiveness of Repsol SA in geophysical exploration (BSIT, www.bsc.es/bsit). Moreover, international funding for R&D has been obtained by means of the research projects GEAGAM (H2020-MSCA-RISE-2014-644202) or the recently funded H2020 HPC4E, involving partners such as INRIA (France), KAUST (Saudi Arabia), University of Texas (USA) and COPPE-UFRJ (Brazil).

7.2.2. Other Research Outputs

Please provide information on other relevant research outputs over the 2011-2015 period, such as patents, other IPR outputs, and research and collaborations with the private sector. Refer only to those results with highest scientific, societal and economic potential impact. Make special reference to activities of knowledge transfer and their applications, as well as science communication and outreach and any other output not included in section 7.2.1.

In BSC's 2011-15 Severo Ochoa program, a concerted effort was made to further consolidate BSC's collaborative partnerships with leading industrial players, and to stimulate and enable other forms of technology transfer and entrepreneurial activity in the Centre. Actions included the establishment of a formal IP protection policy, procedures for establishing start-ups, the formation and staffing of a Technology Transfer Office, support for development of open source codes and standards, technical seminars and staff exchanges with private industry R&D laboratories, among others.

These efforts resulted in a significant increase over the period across the whole range of mechanisms for translating research results based on hardware, software, middleware tools and platforms to produce societal and economic impacts, as detailed below:

1. Patents
BSC protects IP by patenting when it is possible, although it should be noted that in software, copyright and trade secrets are more commonly used than patents. During 2011-2015, BSC increased its patent portfolio with 17 new patents: 6 European, 3 American, 1 Spanish, 1 German, 1 French, 1 Finnish, 1 English, 1 Swedish, 1 Japanese, and 1 Chinese. 15 of these 17 patents derive from the Computer Sciences Department, and are related with new algorithms and methods that help improve high performance computing in terms of better storage solutions and better mechanisms for executing parallelization projects. The other 2 patents derive from the Life Sciences Department, and are related with the biotech sector, both of them focused in genomic analysis tools to fight against important diseases, and therefore of high potential societal impact.

In 2014, BSC started work on transferring some of its patented technologies into a spin-off company in order to facilitate commercialisation. The process of transferring technology to a spin-off is proving rather difficult in BSC due to its particular legal status as a public government-owned consortium. Although time consuming and legally complex, progress is being made and first results are expected soon.

2. Software Portfolio
During 2011-15, BSC continued to develop its software portfolio. Most of the software developments which are of utility to the wider research community are disseminated as open source codes, managed under the GNU Lesser General Public License (LGPL), which is designed to guarantee the freedom to share and change software, with both original and improved derivations of the software free for all its users. Some software developments with commercial applicability, however, are commercialised through the companies with which BSC conducts joint research programs, or in a few cases, via third parties.

BSC currently holds a software portfolio with 60 distinct tools/platforms, 21 of them derived from the Computer Science Department, 25 derived from the Life Sciences Department, 7 derived from the CASE Department, 5 derived from the Earth Sciences Department and 1 from the Management Department. Once developed and launched, in most cases BSC continues to refine and update the codes, based on feedback from the user communities. The most important ones are detailed below:

The set of most widely used tools, offered under the LGPL license by the Computer Science department to boost parallel computing are:
* PARAVER - a performance analysis tool for massively parallel applications based on traces with great flexibility to explore collected data.
* DIMEMAS a simulator to predict an application's behavior under different scenarios. Performance analytics modules extract insight from the raw performance data. Provided with such tools, the analyst can generate and validate hypotheses to investigate the trails provided by the execution trace.
* EXTRAE a software package devoted to generate Paraver trace-files for post-mortem analysis. Extrae is a tool that uses different interposition mechanisms to inject probes into the target application so as to gather information regarding the applications performance.
* OmpSs programming model a data-flow task programming model which has had a clear influence in the evolution of the OpenMP standard. (OpenMP is one of the oldest multiprocessor programming languages in use, with implementations by many major vendors on three General Purpose Programming Languages). BSC's OmpSs Mercurium compiler and Nanos runtime system, together with benchmarks, have been used to demonstrate and prototype extensions that have enabled OpenMP to target a much wide spectrum of parallel applications for shared-memory architectures, including recursive divide-and-conquer and exploratory algorithms.
* TAREADOR - to help develop OmpSs applications. Tareador provides a very intuitive approach to visualize different parallelization strategies and understand their implications. The programmer needs to use simple code annotations to identify tasks and Tareador dynamically builds the computation task graph, identifying all data-dependencies among the annotated tasks.
* COMP Superscalar (COMPSs) a programming model which aims to ease the development of applications for distributed infrastructures, such as Clusters, Grids and Clouds. COMPSs also features a runtime system that exploits the inherent parallelism of applications at execution time. During Severo Ochoa, a new API for Python (PyCOMPSs) has been developed interfacing key-value and persistent data storages to influence BigData programming.

The Life Sciences Department produces computational biology tools to work with target and drug discovery, genomics, system biology, BioSupercomputing and biophysics. Some of them are under LGPL license and some of them under commercial license:
* PELE Based on technological advances in protein structure prediction, BSC developed PELE (Protein Energy Landscape Exploration), a novel method to perform protein energy landscape explorations by combining a Monte Carlo stochastic approach with protein structure prediction algorithms. PELE is capable of accurately reproducing long time scale processes in only few hours of computing. The BSC website hosts a free service to scientists wishing to analyse their proteins using the tool (pele.bsc.es)
* SMuFin - Somatic MUtation FINder, is a reference-free method designed to identify somatic variation on tumor genomes from the direct comparison with the corresponding normal genome of the same patient. Through a single execution SMuFin is able to identifying somatic single nucleotide variants (SNVs) and structural variants (SVs) of any size. The tool is available for download on the BSC website (cg.bsc.es/smufin/)

The Earth Sciences Department develops models for the study of air quality, climate change, atmospheric behaviour, and mineral dust. The most advanced of these are placed into production, meaning they are hosted on publicly available websites and fed real data from monitoring sites around the world to produce real-time forecasts and analyses. The key systems in production are:
* CALIOPE - Daily high-resolution operational air quality forecasts for Europe and Spain (www.bsc.es/caliope)
BSC-DREAM - Mineral dust forecasts for the Euro-Mediterranean region and East Asia (www.bsc.es/projects/earthscience/BSC-DREAM/)
* SDS-WAS - The Regional Centre for Sand and Dust Storm Warning System covering Europe, northern Africa and the Middle-East (sds-was.aemet.es), created in collaboration with the World Meteorological Organization (WMO) and the Spanish Meteorological Agency (AEMET).
* BDFC - Barcelona Dust Forecast Centre (dust.aemet.es), the first WMO regional meteorological centre specialised in atmospheric sand and dust forecast.

Finally, the CASE Department has developed advanced simulation tools as a result of its collaborations with other scientific groups across diverse fields of science and technology, and also its strong links with industrial partners who are in need of advanced simulations of complex technological and engineering problems. CASE has 5 major HPC simulation tools, 4 of them under the LGPL license and 1 of them owned by Repsol as a result of their joint research unit.
* ALYA - BSCs simulation code for multi-physics problems, specifically designed to run efficiently in supercomputers. It solves fluid mechanics, solid mechanics, electric propagation, combustion, etc.
* FAll3D - Volcanic ash transport simulator. Currently used in production in the South American Volcanic Ash Advisory Centres (VAAC).

7.2.2. Other Research Outputs

* SIESTA - Ab-initio molecular dynamics simulation platform. CASE is a co-developer of this code which is widely used by thousands of scientists and companies worldwide for simulating materials at the atomic scale.
* PANDORA - An HPC agent-based Modelling framework to develop social simulations.
* BSIT (Barcelona Seismic Imaging Tools) - Acoustic/elastic waves, forward modelling, RTM and FWI. Licensed by Repsol.

3. Research with companies
BSC has a long history of collaboration with private industry and income from projects with companies makes up 30% of BSCs competitive income for research. The 2011-2015 period saw both the renewal of BSCs strategic long-term collaborations with IBM, Microsoft and Repsol in the form of joint centres, as well as new multi-annual agreements with Intel and NVIDIA also as joint research centres. Multi-year research projects were also signed with Samsung. In addition, an important scholarship program with La Caixa was initiated, as were various other smaller projects with companies. The next paragraphs summarize the most important projects.

The collaboration with IBM was established in the framework of a 3-year initiative starting in 2013, structured through a series of Joint Study Agreements (JSA) with IBM research laboratories. Specifically, with the Watson Research Laboratory BSC has worked on High-performance in-memory databases; Software-defined environments for HPC workloads; Adaptive resource management for IBM Power architectures; Use of the OmpSs programming model for the new P8/Nvidia systems; Resilience compiler support; Performance API for OpenMP; and Smart cities, this one also in collaboration with IBM Madrid and Barcelona Ecologia Urbana. The collaborations with the Zurich Research Laboratory pivoted around the use of the OmpSs programming model for asynchronous applications; and applicable research to interconnection networks, this one also in collaboration with the University of Cantabria. More than 20 researchers from BSC have been involved in these JSAs, including senior, junior and doctoral researchers.

The BSC-Microsoft Research Centre started in 2006 focused on using software requirements to drive computer hardware design. One of the main topics tackled in the new center was Transactional Memory, the software/hardware technology that makes programming multi-core chips easier by abstracting away the complexities of lock-based scheduling. The team created one of the top research teams in Transactional Memory (TM) worldwide in a couple of years. The research work on TM by the group has led to more than 100 publications in peer-reviewed conferences and journals; and 4 best paper awards. Partially thanks to the work done in the center, recent chips from Intel (Haswell) and IBM (BlueGeneQ, Power8, SystemZ) have been shipping with hardware support for transactional memory which will empower a new generation of programmers. In 2013, topics related to improving the cost-efficiency of Big Data deployments became the main focus of the Centre. The research team developed the Aloja platform (hadoop.bsc.es), which is a solid open source framework to collect, analyze, and predict performance properties across Big Data deployments.

The Intel-BSC Exascale Lab started its activities in October 2011 on topics around programming models and performance tools. The work has evolved from pure HPC-oriented activities to other areas such as Big Data. In this field, BSC is developing PyCOMPSs, a programming model where annotated regular Python code ends up being executed in parallel by the runtime on either a multicore, a hybrid host-MIC node, a cluster or even the cloud. BSC is also adapting the BSCs performance tools to analyse the behavior of other Big Data infrastructures such as Hadoop. All of these topics are of great relevance to the progress and success of the OmpSs programming models proposal and performance tools developments. The interest of the studies is reflected by BSC researchers being periodically asked to present results to different groups at Intel. Some of the proposals (e.g. reductions, priorities) have already been accepted in the OpenMP standard that is now being implemented by all major manufacturers and compiler developers and will be used by all parallel programmers at node level in the future. BSC tools are being recognised worldwide as an extremely powerful framework, able to deliver real insight on the behavior of large production codes

The main objective of BSC collaboration with Samsung Co., Ltd., which began in September 2013, is to understand memory requirements of HPC applications, and to design and evaluate next-generation memory systems for HPC. BSCs analysis has determined which memory technology and packaging provide the best performance and performance-cost ratio in HPC domain, information that is essential for designing next-generation HPC memory systems. Also, BSC detected and analysed DRAM errors of production HPC workloads running on BSC's MareNostrum supercomputer. BSCs analysis provided a better understanding of in-field DRAM errors, leading to re-optimisation of DRAM design and test processes, and higher stability of large-scale HPC systems.

BSC, in association with Universitat Politècnica de Catalunya (UPC) was recognised as a GPU Center of Excellence by NVIDIA in 2011. The program recognises, rewards and fosters collaboration with leading institutions at the forefront of parallel computing research. BSC joined a network of 22 elite institutions worldwide that have demonstrated a unique vision for improving the technology and application of parallel computing, and are empowering academics and scientists to conduct world-changing research. This collaboration is fostering multi-GPU and cluster-aware programming environments for GPUs, promoting unified resource management. BSC has also built an Education Program on Massively Parallel Programming, and has organised the well-known Programming and Tuning Massively Parallel Systems (PUMPS) summer school since 2010. The Centre is also promoting OmpSs, by means of integrating this model with CUDA.

During 2011-2015, activities with the wind power company Iberdrola Renovables included various publicly and privately funded projects on high-resolution wind energy simulation. The most significant scientific outcome has been the development of microscale atmospheric boundary layer models in the context of HPC, which allow a much higher resolution (less uncertainty) in the wind resource assessment for on- and off-shore wind farms. This knowledge transfer has allowed industry to use, for the first time, HPC resources for wind farm design and optimisation.

The Repsol-BSC Research Center has been key in Repsol's strategy for improving their geophysical imaging capabilities. This research collaboration has generated significant mathematics and physics developments. For example, BSC found ways to simulate subsurface (seismic) waves much more accurately than with traditional numerical methods while, for the electromagnetic problem, waves can now be modelled in very large, heterogeneous and complex media thanks to new algorithms developed in-house. Both findings are advancing current imaging capabilities to new and challenging regions. The results of the research, which includes more than 50 contributions to international journals and conferences in the last 5 years, allows for faster and more efficient subsurface imaging capabilities, which implies a dramatic risk reduction in exploration efforts (less uncertainty, less drilling, less risk) and reduced negative environmental impacts. Furthermore, this success encouraged Repsol to expand its research activities to virtualised chemical laboratories and simplified scientist-computer interfaces. BSC's expertise on numerical methods and parallel programming techniques has led to the development of several software products aimed at solving a wide range of engineering problems that can be modeled with Partial Differential Equations (PDEs). Repsolver Fase I, a joint project between Repsol and BSC, was executed to explore potential solutions to this challenging problem. The outcome of the project was the specification of a Domain Specific Language to model and solve PDEs.

4. Outreach
During 2014, more than 450 IT and senior executives from over 400 companies of different types and sizes visited BSC facilities, and were given presentations with examples of usage of HPC in their respective sectors. A total of 24 sectorial visits were organised. Some of the industrial sectors covered were: aeronautics, automotive, telecommunications, robotics, pharma, logistics, textile, and governmental IT related organisations.

Since BSCs foundation, the Centre has dedicated a part-time person to explain BSCs activities to the general public by organising visits to the supercomputer. On average, BSC receives some 6000 visitors yearly including schools, individuals, companies, private associations, universities, etc. Since 2008, BSC has also organised annual Open Day on a Saturday that has been a great success, especially for families. During Open Days the aim is to explain what is a supercomputer, its scientific applications, and its long-term impact on society, as well as to promote scientific careers in general. In recent times, BSC has involved researchers in guiding the visits. The presence of researchers makes visits more interesting as the general public value closer contact to

7.2.2. Other Research Outputs

academics.

Further activities addressed to the general public have been done such as: videos for the Science Museum in Barcelona (Cosmocaixa); promotion of scientific careers by mobility programs such as PRACE Summer of HPC; participation in IT exhibitions in a shopping center in Barcelona (lllla) with a MareNostrum blade; a booth at the Sonar Music Festival in Barcelona; videos in the Science Festival in Barcelona (Festa de la Ciència); talks in Saló de lEnsenyament and Aula in Madrid promoted by the Spanish Agency for Science Communication (FECYT) in order to promote scientific careers; participation in a childrens book about science promoted by the Catalan government; participation in a video game development; participation in a city promotional spot as well as participation in a TV program (Tadeo Jones, chap. 6) aimed at children.

7.3. Human Resources and Research Facilities

7.3.1. Human Resources

This section is aimed at providing evidence on the existence of a solid scientific base and critical mass along its departments, units and research groups. Please refer to the research career, international recognition, scientific awards and leadership skills during the 2011-2015 period of the Scientific Director and the 10 researchers garantes of the application.

Since its creation in 2005, BSC has grown strongly year on year, totaling 388 staff members in 2015, of which 129 (33%) are of foreign nationality.

Research is structured around four Departments (Computer Sciences, Earth Sciences, Life Sciences and Computer Applications in Science and Engineering), each of which further comprises a number of Research Groups (31 in total). The Departments are all led by highly distinguished researchers who are international leaders in their fields. Groups typically consist of a Group Leader (Principal Investigator) plus 1 or 2 permanent people, and a few PhD students and post-doctoral researchers. Many groups also host visiting researchers and young students undertaking summer or end-of-degree studentships. This structure has been fairly stable since the early years of the Centre, with gradual evolution of groups and the occasional creation of new groups as new research lines are developed.

BSC Group Leaders are all researchers with excellent CVs, either directly recruited by BSC itself or associated to BSC through the Universitat Politècnica de Catalunya (UPC) or the Spanish national research council (CSIC) or the Catalan Institute for Research and Advanced Studies (ICREA) that selects the best researchers of their fields worldwide and awards them tenure-style position in a Catalan research institution. In addition to Group Leaders, a number of senior researchers within the groups are funded via highly selective fellowship programs, such as the Spanish Ramon y Cajal, a 5-year fellowship leading to tenure-track, and the European Marie Curie Individual Fellows, a highly competitive European post-doctoral fellowship. During 2011-2015, BSC was assigned 2 new ICREA, 2 Ramon y Cajal and 7 Marie Curie fellows.

In 2015 a new director of Earth Sciences joined BSC from the Institute of Climatic Change (Barcelona), and his group of about 20 people will join BSC by the end of the year, resulting in significant growth of this Department.

BSC's strong growth has been a direct result of the excellence of BSC's researchers and their proactive leadership and involvement in project consortia at an international level. BSC ranked 12th in terms of financial return among all organisations in Spain for participation in the 7th Framework Program of the EU. Results in the new H2020 program which launched in 2014 have been even more impressive, with 36 approved out of 104 proposals evaluated (34% success rate). Scientific output in terms of journal and conference publications, as well as societal impacts, is also excellent as detailed in sections 7.2.1 and 7.2.2, and international benchmarking in Annex 1.

Tables in Annex 1 Supporting 2011-2015_BSC provide quantitative information about BSCs research staff evolution for the 2011-2015 period by status, sex and nationality split by departments.

In the rest of this section we present the achievements of the Director and 10 Garantors. We wish note that 2 of BSC's best researchers are women, but as result of new administrative rules imposed by this call, they cannot be included as Garantors (one is associated to the Centre and the other had career break for family reasons during the 2011-2013, and thus does not comply with the publication requirement for the calculation of Normalised Impact Factor).

1. MATEO VALERO - BSC Director
Prof. Valero was appointed founding Director of the Barcelona Supercomputing Center in 2004. He is a world-recognised computer architect, the only living European researcher endowed with the Eckert-Mauchly Award, the most prestigious world-wide award in computer architecture, awarded by both IEEE and ACM (http://www.sigarch.org/awards/acm-eckert-mauchly-award-past-winners/). He made seminal contributions to the design of vector, superscalar and VLIN architectures. Many of the proposed ideas were adopted by market leading companies.

He has been one of the main drivers for re-establishing computer architecture research as a priority in the EU research agenda. Among his noteworthy contributions, he was founding coordinator of HiPEAC, the EU Network of Excellence with more than 1000 researchers from industry and academia that incubated of a number of key European projects.

In 2013, he was awarded an ERC Advanced Grant, ROMOL (Riding on Moores Law), focused on designing future HPC systems. This project is developing new hardware components to support activities of runtime systems and accelerate the execution of parallel applications. In the context of this project, Prof. Valero is leading a team of 15, including two senior researchers, a research support engineer and ten PhD students. To date, they have produced over 20 publications in top tier international conferences and journals, including ISCA, HPCA, PACT, IPDPS and SC. Finally, RoMoL researchers are collaborating with internationally recognized research centers such as IBM T. J. Watson and the Lawrence Livermore National Laboratory and companies like Intel and ARM.

Since 2011, Prof. Valero has published more than 80 papers in Conferences (3 ISCA, 2 MICRO, 2 HPCA) and more than 25 in Journals, and is co-author of The international exascale software project roadmap which describes the work of the community to prepare for the challenges of Exascale computing. During the last five years he has given over 111 talks, 20 of them Keynotes at International Conferences like Supercomputing, ISC, HIPEAC, PaCT, ACSA, EUSIPCO, etc. He is also member of the Steering Committee of JLESC (Joint Laboratory for Extreme Scale Computing).

Since 2011, Prof. Valero has obtained the following awards:
* Honorary Doctor by the Universities of Zaragoza, Complutense of Madrid and Cantabria
* Elected Correspondant Academic by the Academy of Science of Mexico (2012)
* ACM Distinguish Service Award (2012).
* Elected Member of the ACM Europe Council
* Euro-Par Achivement Award. Citation: For special contributions to Parallel Processing (2015)
* Honour Award from ACET, Asociación Catalana de Ingenieros de Telecomunicación and COEINF, Colegio Oficial de la Ingeniería Informática (2014)
* First National Award from the Catalan government for cooperation between research centres and companies. Awarded to BSC and IBM for their long and fruitful collaboration in research (2012)

2. FRANCISCO DOBLAS REYES - Director of Earth Sciences Department
ICREA Prof. Reyes joined BSC in 2014 following a competitive open selection among international candidates. Previously he was leader of a research group at the Catalan Institute for Climate Sciences (IC3), which he grew from 6 to 20 people during 2011-2014, most of whom will be joining BSC during 2015. Most of the group are financed through competitive projects, having obtained more the 3 million of funding through 10 EU projects, including coordinating the largest FP7 project on climate prediction.

3. ORIOL JORBA - Group Leader of Atmospheric Composition Group
Dr. Jorba's group comprises 5 post-doctoral researchers, 1 associate researcher and 6 PhD students. His research activities and interests have included high resolution mesoscale meteorology and air quality and development of online meteorology-chemistry models. He coordinates the development of the

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multiscale chemical weather forecasting system NMMB/BSC-CTM at BSC. He held a research position at the University of California Irvine (USA) in 2011, and at the NASA Goddard Institute for Space Studies (USA) in 2013. He has co-authored more than 55 papers in international scientific journals, 30 from 2011-2015, and over 100 communications to international conferences. He has a citation average during the last 5 years of 42,17 citation/year and an H-index of 13. He has supervised 5 PhD students. He participated in several Spanish and European projects of the FP5 and FP7 Framework Programme (e.g., EARLINET, ACCENT, IS-ENES, FIELD-AC, IS-ENES2), and was principal investigator of two Spanish research projects CGL2008-02818, and CGL2013-46736. He has been member of the management committee of 2 European COST Actions (ES1002, ES1004) as a Spanish representative, and of the Scientific Committee of the International Technical Meeting on Air Pollution Modelling and its Application.

4. VICTOR GUALLAR - Group Leader of the Electronic and Atomic Protein Modelling (EAPM) Group
ICREA Prof. Guallar was awarded a European Research Council Advanced Grant (ERC-AdG) in 2010, one of the youngest researchers in Europe to receive this award. He leads the EAPM Group, comprising 21 researchers from 8 different nationalities, which develops and applies computational algorithms for understanding and predicting biochemistry and biophysics at a molecular level.
In the biophysical field, the main contribution is the code PELE (Protein Energy Landscape Exploration), a software developed in-house at BSC, which outperforms commercial solutions in protein-ligand induced fit. Its public server (https://pele.bsc.es), with ~8000 visitors (till July 2015) from 75 different countries, was highlighted in the top 5% by the editors in the Servers special issue in NAR. In the biochemical field, the research focuses on developing methods to study biological electron transfer processes and, more recently, in enzyme engineering. Combining PELE conformational sampling, QM/MM methods and electronic coupling calculations the Group has produced one of the most complete protein-protein electron transfer computational studies to date. This extensive combination of modeling techniques enabled the Group to enter the field of enzyme engineering, as a partner of the largest KBBE (FP7) European consortium (INDOX project).

Prof. Guallar is also active in technology transfer, undertaking collaborative projects with companies such as AstraZeneca, Lilly, Novozymes, and others. He was recently awarded an ERC Proof of Concept (ERC-PoC) grant, and a BSC spin-off company including PELE technology will launch in 2015.

5. DAVID TORRENTS - Group Leader of Computational Genomics Research Group
ICREA Prof. Torrents has led his group during recent years to become a key player within the field of Biomedical Genomics, in particular by generating and applying new protocols for the analysis of genomic mutations in relation to complex diseases and cancer. He has published 14 articles in high impact journals, 6 with impact factor higher than 30. He has participated in 10 funded projects, 5 from the FP7 program. Currently, he participates in proposals to H2020 already in the second stage of evaluation. A significant achievement is the publication in Nature Biotechnology of a new method, SMuFin, which offers important improvements in the search of disease causing mutations in genomes. This study caught the attention of major Spanish newspapers and TV channels, provided high visibility also in society. This research enabled the group to participate in several world-leading projects in Cancer Genomics. In this context, Prof. Torrents has participated in the largest study of Chronic Lymphocytic Leukaemia, recently published in Nature; and is coordinating the participation of BSC in the ICGC-PanCancer, the largest initiative in Cancer Genomics in the world. He has also contributed to the study of complex diseases, coordinating the development of tools for the analysis of human variation and susceptibility to disease. Two manuscripts on these studies have been submitted, one to Nature Genetics. In this area, collaborations have been established with key centres, such as the Broad Stem Cell Research Center (USA), or the Sanger Institute (UK).

6. JESUS LABARTA - Director of Computer Science Department
Prof. Labarta has focused in 2011-15 in developing and promoting an important series of features in the OmpSs programming model, including asynchronous accelerator support (CUDA and OpenCL). OmpSs is having a tremendous impact in the OpenMP standardisation body and is mentioned and cited at most conferences on High Performance Computing. In this period he has presented in 25 different international conferences, published 28 journals, 26 peer-reviewed international conferences and 14 workshops, supervised 13 Phd theses and is currently supervising 6 PhD students. He is member of ACM.

Due to the impact of his research results, Prof. Labarta recently established a collaboration research contract with Intel and set up the Intel-BSC Exascale lab. He is the coordinator of the POP Center of Excellence granted by the EU in the recent call H2020-EINFRA-2015. The project aims to offer assessment services to academia and industry all over Europe on analysing the behavior of applications, suggesting the best directions to improve their performance and show how the new features of OpenMP4.0 can be used to achieve this in a clean and productive manner.

EDUARD AYGUADE - Associate Director of Computer Science Department
Prof. Ayguade has published in 21 journals, 53 peer-reviewed international conferences and 13 workshops during 2011-15. In this period he participated in 3 EU projects (Mont-Blanc, Mont-Blanc 2 and HiPEAC) and 2 contracts with companies (IBM and Intel). He is the technical coordinator of the research agreement between BSC and IBM research, with 10 joint study agreements defined during the duration of the collaboration, and is the scientific coordinator of the BSCs 2011-15 Severo Ochoa program. In 2014 he obtained the Consolidated Research Group assignation from the Catalan government. He will participate in 4 new EU projects to start during 2015 (Axiom, Mont-Blanc 3, ExaNode, INTERTWINE), being IP of ExaNode, and 1 EU Center of Excellence (PoP).

Prof. Ayguade contributes to the evolution of the OpenMP standard, with additional features added to the tasking model (including task dependences and reductions). The INTERWINE (Programming Model INTERoperability ToWards Exascale) project will demonstrate aspects related with interoperability of programming models with OpenMP, with features proposed by BSC to be integrated to the standard.

He also leads a new research line on Domain Specific Languages, with a specific implementation over BSC runtime platforms, to support efficient execution on clusters of multicore architectures with accelerators. The current prototype development (Saiph) supports the specification of problems in partial differential equations. The multinational company Repsol has shown real interest in this research is supporting the development and exploitation through the REPSOLVER project.

7. JORDI TORRES - Group Leader of Autonomic Systems and e-Business Platforms
Dr. Torres leads a group of 25 researchers, and has some 150 research publications (50 in 2011-15) in journals, conferences and book chapters. He is member of IEEE, ACM and ISOC. He has supervised 7 PhD Students. He works in the Aloja collaboration with Microsoft Research to provide automated optimisation to Hadoop's performance under different hardware deployment options, and is also member of the European Project RenewIT (FP7-SMARTCITIES-2013). He acts as an expert for various organisations and companies and mentors entrepreneurs. He is also a writer and collaborates with Spanish mass media and maintains an online blog. As Researcher he has a successful career with more than 150 research publications. He has been involved in the organisation of several conferences and also serves as a reviewer for relevant journals in the area.

8. DAVID CARRERA Senior Scientist
Dr. Carrera was awarded with an ERC Starting Grant for his project project HiEST: Holistic Integration of Emerging Supercomputing Technologies (2015-2020). He has deep experience on task placement and performance modelling for heterogeneous sets of workloads as he authored the first published work that addressed the problem of heterogeneous workload placement in virtualised environments and leveraging Utility Functions to model the performance of the workloads. He also has large experience on data placement strategies for data analytics runtimes, having authored the first known development of a deadline-driven scheduler for MapReduce in shared environments. In previous work, he proved that machine learning techniques can be used to learn web user intentions for visiting a Web site as well as the expected Quality-of-Service delivered to users. The results of his research have attracted the interest of IBM Research, Microsoft and Cisco, through 4 different direct funded projects in which Dr. Carrera is the lead scientist. He is also a WorkPackage Leader at the COMPOSE EU project (2012-2015). In 2012, Dr. Carrera was granted a José Castillejo Mobility Grant from the Spanish Ministry of Education, and spent 6

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months as a Visiting Scientist at IBM Research TJ Watson lab in NY, US. He has been the PhD advisor for 9 PhD students over the period, of which 3 have already graduated. He is an IEEE member, and has served as Program Committee member in several top International Conferences, as well as reviewer for numerous prestigious Scientific Journals.

9. JOSE MARIA CELA - Director of Computer Applications in Science and Engineering Department
Prof. Cela's research activity is centered in parallel numerical simulations related with oil & gas industry, specifically in the area of explorations geophysics. The most important result to date is the Kaleidoscope project. This project develops the first Reverse Time Migration (RTM) algorithm that could be deployed in an industrial framework due to the reduction of computational cost achieved. The RTM developed by his group was 14 times faster than any other in the industry. RTM is the algorithm used to create seismic images in oil & gas industry, and dramatically reduces the economic risk in hydrocarbon exploration. Kaleidoscope led to the formations of the Repsol-BSC joint research center, developing state-of-the-art tools for seismic imaging, including full wave form inversion of elastic and electromagnetic waves. Among others achievements, they developed a new algorithm for boundary conditions with elastic waves in a mesh including topography and anisotropy that reduces by a factor 100 the cost of the simulation.

10. ARNAU FOLCH Group Leader Environmental Simulations Group
Dr. Folch leads a group comprising 3 post-doctoral researhcer, 2 junior researchers, and 5 PhD students. He has 25 peer-reviewed publications (87% in Q1) and 42 proceedings and presentations in international meetings (2011-2015), 12 as invited. He participates in 6 EU-funded projects and has been the Principal Investigator of two national projects and of a CYTED international thematic network.
He is permanent member of the Advisory Board of the Volcanic Ash Scientific Advisory Group (VASAG) of the International Civil Aviation Organization (ICAO) and the World Meteorological Organization (WMO). He also acts as liaison officer between the International Union of Geophysics and Geodesy (IUGG) and the World Meteorological Organization (WMO) (from 2011 to present), he is leader of the Commission on Tephra Hazard Modelling of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). He has been Invited Editor of 2 special issues. He is the co-leader of a private project with Iberdrola Renovables since 2011, collaborating in a project on industrial innovation with the wind energy industry.

7.3.2. Research Facilities

Please brief on research infrastructures and facilities that the center shares or makes use of along 2011-2015. Refer especially to the access of national or international large research infrastructures or facilities.

BSC hosts MareNostrum (Spains largest supercomputer and one of the six Tier-0 nodes of PRACE) and other HPC specialist machines and research prototypes. BSC also coordinates the Spanish Supercomputing Network (RES), comprising 12 nodes throughout Spain, many linked to major scientific infrastructures such as the Canary Islands telescope and Spains major universities. Since its founding, over 30 million in HPC facilities have been invested at BSC. In addition, BSC has invested 15 million euros during 2011-15 in the construction of a new building (completion due 2017) to house BSC staff and new supercomputing facilities.

Both BSC and RES facilities are accessed by internal scientists as well as external users throughout Spain and Europe. BSC researchers in Life and Earth Sciences departments also make extensive use of key facilities at collaborating centres.

MareNostrum 3 (MN3): Commissioned in January 2013, 70% of capacity is competitively assigned to external users by the PRACE Access Committee, 24% by the BSC/RES Access Committee and 6% is dedicated to BSC internal scientists. MN3 has a compute capacity of 1.1 PFlops, based on 48896 Intel cores and 84 Xeon Phi, connected by Infiniband FDR10 low latency network. Total GPFS storage capacity is 2.3 Pbytes, connected with 10Gigabit Ethernet. Some 100 projects at European and Spanish level are active at any one time, from all scientific domains and disciplines.

MareNostrum 2 (MN2): MN3's predecessor was installed in 2006 and was operational until September 2012. It had a compute capacity of 94.28 TFlops, with total GPFS storage capacity 280 TBytes. External users were assigned 80% of capacity by the BSC/RES Access Committee and 20% was reserved for BSC researchers.

MinoTauro: commissioned in October 2011, with a compute capacity of 182TFlops, based on 1536 Intel Cores and 256 NVIDIA M2090 GPUs, connected with Infiniband network. Up to 80% is available to Spanish users using the RES Access Committee.

Prototypes: Several supercomputer prototypes were installed to support research, including MontBlanc prototypes based on ARM and accelerators technology; and Cell based prototypes.

SGI Altix: A 128 Intel core shared-memory system with 2.5 TBytes main memory, in operation from 2006 until 2014.

Shared memory: A total of three systems for data pre and post-processing, or workloads that require a huge number of memory. First, with 128 cores and 1.5 TB of main memory, the second with 80 cores and 2 TB of main memory and the third with 80 cores shared machine with 2 TBytes main memory, installed in February 2014.

Active Archive: installed in 2012, with a total storage capacity of 4.2 PBytes and 72 Intel cores for services, including capabilities for Big Data and Data analytics, and sharing of scientific data among scientists.

During 2011-15, BSC researchers made regular use of the following external infrastructures:
* Sequencing facilities at the National Centre for Genomic Analysis (CNAG), including 2 Illumina HiSeq 2500, 9 Illumina HiSeq 2000 and 1 Illumina MiSeq, all with a sequencing capacity in excess of 800 Gbases per day
* Experimental facilities at the Institute for Biomedical Research in Barcelona (IRB), used in the context of Joint Research Program for validating models. Fully-equipped 100sqm experimental laboratory
* AErosol RObotic NETwork (AERONET), a federation of ground-based remote sensing aerosol networks. BSC researchers particularly use the Barcelona site
* The UPC-Barcelona lidar station is part of the European AeRosol LIdar NETwork (EARLINET) to Establish an Aerosol Climatology, comprising over 25 stations in the EU
* E-EIONET, an extensive information technology infrastructure of the European Environment Information and Observation Network
* Instruments aboard the Terra and Aqua satellites: Moderate Resolution Imaging Spectroradiometer (MODIS)
* Instruments aboard the Meteosat Second Generation (MSG-2) satellite

7.4. Training and Recruiting

Please describe doctoral and post-doctoral training programes and related activities carried out during 2011-2015 and its international dimension. Refer also to the specific recruitment practices and activities for the 2011-2015 period. Describe the center' facilities and resources available to trainees as well as the mechanisms in place to foster research career (e.g. tenure track) and the practices for talent attaction and retention.

1. Career Development and Training 2011-2015
1.1. Career Development
In order to manage the BSC staff Professional Development a tool was designed and launched in 2013, named PDP (Professional Development Plan) facilitating the annual set of objectives, its evaluation, the monitoring of the each member of BSC on their career development plan and help us to find out and agree the new trainings needs. The platform also allows the reporting of global information by departments/groups and also on an individual level.

During this period 2011-2015, following the strategic plan of BSC-CNS, centres objectives have been defined every year. All managers were able to define and agree with their collaborators the specific individual objectives of each year. A part from the evaluation of the objectives, the system evaluated the complementary skills and engagement with the values of the Institution.

1.2. Training 2011-2015
Following and going hand by hand the career development plan, the internal training protocol was launched in 2014, including Training policy, the training actions catalogue and its regulations.

The main goals of this internal training plan are: to reinforce the BSC lines of action and knowledge for professional development, to establish a monitoring system to assess its impact in it and to provide individuals with the tools and resources to encourage the exchange of ideas, knowledge and experiences.

When developing the training plan, we have considered the professional roles and requirements of each job, individual needs, and the requirements arising from changes in their working environment. Its basic characteristics are: Diverse, Plural, Permanent, Dynamic, Open, Progressive, Applied and Committed.

The BSC also offers a programme of grants for student personnel and young researchers to foster and facilitate professional advancement in research careers, by means of academic-educational initiatives in collaboration with associated universities. BSC researchers actively participate in the following master degrees:
* Master degree in Supercomputing (HPC specialization on MIRI program at UPC). A referenced two-year postgraduate masters course in parallel programming and design of computer architecture taught by BSC experts. To facilitate talent capture and retention and support local universities in the development of postgraduate programs tuned to the needs of the HPC industry and supercomputing as research area, BSC is providing annual scholarships for academic excellence.
* Master degree on Biomedicine (University of Barcelona), associated with the BSC Life Sciences Department.
* Master degree in Environmental Engineering (UPC), associated with BSC Earth Science department.

BSC also offers courses internally organized, in collaboration with other research centres or within the framework of European research projects. This includes:
* Specialized Advanced Training courses in HPC related subjects and seminars organized by the Education and Training team, including the PRACE Advanced Training Center (PATC) courses enabling European research community to utilize the PRACE computational infrastructure.
* RES training sessions.
* The PUMPS summer school organized by the BSC GPU Center of Excellence.
* The Institution wide Research Seminar program that reflects one of the main objective of the Severo Ochoa project, namely collaborative research. The seminar series promote the active collaboration between the research groups of the BSC-CNS, involving all of the departments. It gives a broad perspective of the state-of-the-art in the field of HPC.
* Annual BSC International Doctoral Symposium.

In addition, the BSC mobility program managed by the Education and Training team, is available to Researchers, Postdoc and PhD students at BSC as well as researchers from institutions collaborating with BSC to visit us. This programme supports collaboration and short term visits (up to 3 months) worldwide in leading research and academic institutions and provides grants for visitors collaborating with BSC research groups.

Finally, BSC also offers a catalogue of career development courses oriented to BSC staff and students. The catalogue includes courses to develop functional skills (research, Information technologies, management, office computer and languages), leadership skills (managing people, creativity and innovation) and corporate skills (stress and time management, self-knowledge, communication, public speaking, managing meetings). During 2012 to 2015, a total number of 794 participants have attended to 96 training actions.

2. Recruitment 2011-2015
During this period a Recruitment process has been stablished and developed. This process consists in different stages starting with the Job Description definition and finishing with the Contract Proposal for the final candidate. Following are the stages of the process:
* Phase 1: Job description/Job Advert
* Phase 2: Dissemination Strategy (more than 58 specific recruitment sources have been used)
* Phase 3: CV Screening
* Phase 4: Interview and presentation in front of recruitment panel
* Phase 5: Final Decision and Validation and Contract proposal

In terms of attraction of talent, during the reported period BSC (2011 2015) BSC-CNS has recruited 75 pre-doctoral students, 51 Postdocs and Senior Scientist, 83 technical support staff members and 31 management staff, 146 from Spain, 39 coming from EU countries and 55 from outside Europe. All selection procedures have been performed in compliance with the disclosure requirements, merit and competition with gender equality.

3. Talent management
Regarding the fostering of Research careers we have developed and implemented several policies and procedures and the main one was the acknowledgement of the HRS4R logo.
BSC fully endorsed the principles and requirements of the Code of Conduct and committed to adhere to the Code of Conduct "European Charter for Researchers", during the first semester of 2013, which provides a means to achieving a transparent and open labour market for researchers, better job opportunities and more rewarding careers for researchers, and establishing a well-functioning and borderless European Research Area.

Built on the principles of the European Charter and for Researchers and The Code of conduct for recruitment a new tool has been developed in order to help employers and funders to put the principles of the Charter & Code into practice, this tool is the award in Human Resources Excellence in research, logo that BSC-CNS receive the acknowledgement by the EU in April 2015.

The HRS4R logo has an action plan for 2015 to 2019; this action plan has been defined in an inclusive and open process involving an internal Working Group with representatives from all research professional categories, areas and roles.

The BSC-CNS action plan was approved by consensus by the Executive Board on February 2015. It is an extensive and ambitious project which highlights are the following ones:
* The creation of advisory committees formed by researchers, which will help to generate strategies, policies and procedures more effective and close to the researchers needs.
* Boost the equal opportunities and gender policies, providing effective actions in order to ensure the policies.
* Strengthen of the activities in outreach and public engagement, as these activities are one the main goals of the Centre and give the opportunity to show to the society our work and highlights and engage the non-scientific audience, to get more relevance outside the BSC and outside science.
* The maintenance of our career development system, improving it and including more relevant aspects in the research career, in or outside BSC, as the Folks Project.

One of the projects of this action plan was the Folks BSC. It is conceived as a web project which could become a platform for all of the researchers and employees who have been part of the BSC at some point in their professional careers, where they can share both professional and personal experiences. It will allow us to keep track of BSC ex-employees careers. Folks BSC was launched in April 2015.

At the same time we have implemented some changes in the recruitment process, like the inclusion of gender Adding actions to ensure that all the recruitment process respects the Gender issues. For instance the percentage of female representation in each Recruitment Panel should be at least the same percentage of women at BSC-CNS and when KPIs such number of publications are evaluated, take into account the break of maternity introducing some compensatory elements so the women who have had children during their careers are not penalized in the evaluation.

During these years we have included in all policies, projects and strategies the BSC Values which are: Ethics and honesty, Responsibility and commitment, Excellence and quality, Enthusiasm and anticipation, Innovation and Collective Identity and Teamwork.

4. Additional information
Table in Annex 1 Supporting 2011-2015_BSC provide additional information about:
* The number of pre-doctoral trainees (i.e. doctoral students enrolled in PhD programmes and conducting their thesis under the supervision of research staff of the center), dissagregated by sex and nationality for the 2011-2015 period, and doctoral thesis carried out and finished at BSC.
* The number of post-doctoral fellows indicating the expiration date of their contractual relationship with BSC.

7.5. International Leadership

Please include a summary of the scientific relevance and impact of the international top class collaborations led by the researchers at the center over 2011-2015, including international and EU Framework Programme projects - with special attention to ERC projects- and any other international research activity and recognition revealing the leadership of the center.

During 2011-15, BSC participated in a wide range of international research consortiums, performing joint research and publishing with leading international HPC centres. Roadmapping activities with these centres ensured that BSCs research priorities were included in the most significant international research and technology roadmaps, helping assure future funding opportunities. The 2011-15 Severo Ochoa program facilitated essential actions in many activities:
* HPC technologies (JLESC, Mont-Blanc, ETP4HPC)
* Big Data and HPC (BDEC, BDVA)
* Embedded systems and HPC (HiPEAC)
* Standardisation (OpenMP)
* International Data Policy (RDA)
* International HPC Infrastructure (PRACE)
* Bioinformatics and HPC (PanCancer)
* Brain simulation using HPC (Human Brain Project)
* HPC for earth science (IS-ENES, WMO Dust Centres)
* HPC for astrophysics (SKA, GAIA)
* Collaboration with Latin America (RISC)

JLESC (Joint-Laboratory on Extreme Scale Computing). BSC was selected to join 5 world leading supercomputing centres (Argonne National Laboratory, NCSA, INRIA, Jülich Supercomputing Centre, Riken Advanced Institute for Computational Science). Research areas include: Scientific applications (big compute and big data), Modeling and optimizing numerical libraries, Novel programming models and runtime systems, Resilience and Fault-tolerance research, I/O and visualization, and HPC Clouds.

Mont-Blanc - Since 2011, the Mont-Blanc project has been working to design new computer architectures built from energy efficient solutions used in commodity mobile devices. In January 2015, the largest HPC prototype based on mobile chips was deployed at BSC. The results have been used to model future innovative architectures.

ETP4HPC European Technology Platform for High Performance Computing is an industry-led association, whose aim is to produce and maintain a Strategic Research Agenda for HPC, whose priorities drive the EU's funding programs (700M committed for H2020). BSC is a founding member of ETP4HPC and member of its steering board.

Big Data and Extreme-scale Computing (BDEC) aims to systematically map how major issues associated with Big Data impinge upon national (and international) plans for achieving exascale computing. The goal is to develop a multinational partnership to provide the next generation of HPC software to support big data and extreme computing for scientific discovery. BSC plays a key role, including organising a workshop of 100 people in Barcelona in 2015.

BDVA (Big Data Value Association) - BDVAs main aim is to produce a multi-year Strategic Research and Innovation Agenda for Big Data related research. BSC is an active member and helped to shape its evolution through the BSC-led European funded RETHINKBig project.

HiPEAC (High Performance and Embedded Architecture and Compilation) - HiPEAC's mission is to steer and intensify European research activity in the area of high-performance and embedded computing systems. This network of excellence was initiated by Mateo Valero and BSC has played an active role ever since. In the 2011-2015 period, BSC helped produce the highly influencial HiPEAC Vision document, which includes many of BSC's research priorities.

OpenMP through the standardisation body, BSC researchers are closely collaborating with language, compiler and runtime developers in member companies, including Intel, IBM, Nvidia, Oracle and ARM. BSC's vision, research outcomes and prototype implementations of the OmpSs programming model have had a huge impact in the evolution of versions 3.0 and 4.0 of the OpenMP standard.

Research Data Alliance (RDA) is an international forum involving actors from the US, Australia and EU which aims to accelerate international data-driven innovation and discovery by facilitating research data sharing and exchange, use and re-use, standards harmonisation, and discoverability. BSC participates in the RDA-EUROPE project since 2012.

PRACE the Partnership for Advanced Computing in Europe, is the European Infrastructure for the provision of HPC services to the academic and industrial research communities. BSC is one of the four hosting members of PRACE, providing access to the Tier-0 MareNostrum supercomputer and also leads the Work Package related to organisational aspects of the implementation phase. Established in May 2010, PRACE has mobilized more than 500M to deploy six HPC Tier-0 nodes, provided more than 10 billion hours to more than 400 competitive projects. Almost 5000 researchers have benefited from the PRACE Advanced Training Centres.

ICGC-Pan-Cancer project - the largest and most complete initiative in biomedicine with a specific focus in cancer genomics, with the aim of gathering and analysing more than 2000 tumour samples covering over 20 different tumour types. BSC plays a central role as one of the few analysis centers selected for the storage, primary analysis, and distribution of data among the more than 50 groups involved in the project. BSC also contributes to investigating the role of large genomic aberrations in tumour formation and progression by applying the program SMUFIN, developed in the frame of the Severo Ochoa project at the BSC.

Human Brain Project - BSC is one of over 140 partners in the 10-year, 1000M Human Brain Project (HBP) whose aim is to compile all existing knowledge about the human brain and eventually to reconstruct the brain in supercomputer-based models and simulations. Expected outcomes include new treatments for brain disease and new brain-like computing technologies. BSCs role is the provision and optimisation of programming models, performance analysis tools and the MareNostrum supercomputer.

IS-ENES, Infrastructure for the European Network for Earth System Modeling, is the distributed e-infrastructure of models, model data and metadata of the European Network for earth system modelling (ENES). BSC runs a number of climate experiments on its HPC and performs detailed analysis to enhance climate model performance.

WMO Dust Centers: The World Meteorological Organization (WMO) Sand and Dust Storm Warning and Assessment and Advisory System (SDS-WAS) Regional Centre for Northern Africa, Middle East and Europe (NA-ME-E), is hosted by Spanish Weather Agency (AEMET) and BSC. The web portal (sds-was.aemet.es) provides national meteorological and hydrological services with information to issue operational predictions and warnings related to the dust content in the atmosphere. This success led to the creation of the WMO-Barcelona Dust Forecast Center in June 2014, which generates and distributes predictions for the NAMEE region. The dust forecasts are based on the NMMB/BSC-Dust model developed at BSC.

SKA (Square Kilometre Array) project is a global scientific initiative to design, construct, and operate an advanced radio telescope in Australia and South Africa. BSC provides essential supercomputing resources, user support and tools for the performance analysis of parallel applications as well as programming models and runtimes.

GAIA project of the European Space Agency aims to make a detailed map of the Milky Way in 3D using data simulation on BSC's facilities (millions of hours) with the Grid Superscalar and COMPSS programming models developed by BSC.

RISC (Iberian American Supercomputing Network) - the BSC-led network for HPC Research between Europe and Latin America includes partners from Mexico, Argentina, Brazil, Columbia and Chile and aims to help coordinate supercomputing research between Europe and Latin America. An EU-funded project (2011-2014) identified research clusters and key areas for collaboration such as computational biology and natural disaster modelling and simulation.

During 2011-15, BSC participated in 84 EU-funded projects with total funding over 41M. BSC is strongest in the areas of Research Infrastructures, ICT and Future and Emerging Technologies with projects on Computer Architecture, real time critical systems, co-design of HPC hardware and software, distributed HPC, low power server technology, genomics, smart cities and earth system modelling. BSC participated in 5 ERC projects in 2011-15:
PELE. Dr. Guallar¿s Advanced-ERC Grant developed PELE (Protein Energy Landscape Exploration), used to model molecular interactions in a timely manner. This technology is accessible worldwide through the pele.bsc.es, with ~10,500 visits from 79 countries, and has led to numerous high impact publications, external collaborations and derived projects including with AstraZeneca and Novozymes.

Riding on Moore's Law (RoMoL), Prof. Mateo Valero¿s Advanced ERC Grant is focused on designing future high performance computing systems by developing new hardware components to support activities of runtime systems and accelerate the execution of parallel applications. The project has developed active collaborations with the Lawrence Livermore National Laboratory (LLNL) and the IBM T. J. Watson Research Center.

HiEST, Dr. David Carreras ERC Starting Grant aims to address a new class of the placement problem of mapping workloads on hardware resources to maximise the performance. The project will conduct frontier research in four research pillars: supervised learning of the placement properties, placement algorithms for tasks, placement algorithms for data, and software defined environments for placement enforcement.

eDRUG. Derived from the PELE ERC, this Proof of Concept develops a commercial application including high performance computing, state of the art visualization techniques and the PELE molecular modelling software. It is expected to lead to BSCs first spin-off company, with AstraZeneca as industrial partner.

EPNet (Production and Distribution of Food during the Roman Empire: Economic and Political Dynamics) is an external ERC Advanced Grant in which BSC researcher X. Rubio contributes to the project using the BSCs Pandora agent-based framework.

7.6. Funding Sources

Please refer to the funding model of the center during 2011-2015. Disaggregate by non-competitive public funding received by the center through transfers of the State Administration, the relevant regional government or the beneficiary organization to which it belongs; competitive funding from national and international sources, and non-competitive funding from the business sector.

1. Overview funding Sources and Evolution 2011-15
BSCs funding (detailed table in Annex 1 attached) comes from the following main sources:
a) Public Funding, including 1) Competitive Sources: being funds derived from competitive project grants from various Spanish and Catalan Ministries, the European Commission and some international organisations; and 2) Non-Competitive Sources: being funds provided by BSC's Patrons; the Spanish government (MINECO), and the Catalan government (Generalitat), and other funds derived from interest on bank deposits or other minor sources.
b) Private Funding, primarily from private companies to fund joint research activities through collaborative research contracts.
c) Strategic Investments: periodic injections of funds for major investments, such as the new BSC building or the regular upgrades (on average every 3-4 years) of BSC's supercomputing facilities. The majority of these funds come from the Spanish government, with smaller amounts from the Catalan government, the European Commission, and occasionally from private non-profit foundations.

It is worth mentioning that a significant portion (around 50%) of the non-competitive operational funding BSC receives from its patrons goes towards providing the supercomputing service to users (primarily the Spanish scientific community) who access these services for free via the regular public calls run by the RES and PRACE access committees.

During 2011-15, due to Spain's grave economic crisis, many Spanish public research centres and infrastructures had their core budget cut. Fortunately, BSCs patrons believed that cuts to the centres budget would be extremely detrimental to Spanish and European science, and the core budget was maintained up to 2014 (note: variations in income from 2011-2014 reflect some delays in payments). Core funding was even increased in 2015 in order to help fund strategic investments, and the patrons have committed to maintain this higher level in the coming 2016-19 period.

In 2011, BSC commenced construction of a new building to house all BSC staff, who are currently dispersed over several separate facilities in and around the UPC campus. The new building is located adjacent to the Torre Girona Chapel which houses the MareNostrum supercomputer, and will be connected to it via a subterranean passage. In addition to enabling all BSC staff to be housed under one roof, it will also host a future supercomputer even more powerful than the current MareNostrum. The construction is planned in several phases according to budget availability and official permits for works. During 2015, the contract for stage 2A2 was issued thanks to a generous grant from the Repsol Foundation. Complementary funds from ERDF (European Regional Development Funds) are currently being negotiated and if forthcoming, the building should be ready by 2017.

Also in 2011, a specialised supercomputer with heterogeneous architecture using graphics processors was installed, enabling BSC to offer specialised services to certain research groups who could run applications with much better performance and lower energy costs than they would otherwise achieve on a general purpose supercomputer. As part of an initiative to improve BSCs Exascale and Big Data facilities, this heterogeneous processor system will be expanded at the end of 2015, taking advantage of existing communications, power supply and management systems.

Finally, we would like to highlight that with extra funding from MINECO, the Generalitat and the ERDF, in 2013 BSC was able to complete the latest upgrade of the MareNostrum III supercomputer, thereby maintaining its position in the top rank of European supercomputers and with 1.1 PFlops of capacity, meeting its performance requirements as one of the six Tier-0 nodes of the European PRACE network.

2. European Competitive Funding
During 2011-15, BSC participated in an impressive 112 projects funded by the Framework programs of the European Union, with grants to BSC totalling almost 50.7M. Of note, in Framework Program 7 (2007-13), BSC had the 12th largest financial return of any organisation in Spain. Those ahead of BSC in the ranking were large companies, universities and technology centres. When analysed as financial return per researcher employed by organisation, BSC came 2nd. Even in absolute terms, BSC was the 2nd ranked public research institution in financial return, only beaten by CSIC (Spanish Research Council), which has over 14,000 researchers. The FP7 program areas where BSC performed best were Infrastructures (where BSC had the highest return of any organisation in Spain) and ICT (BSC had 7th highest return in Spain).

Some of the most significant projects in terms of financing are the five ERC projects, PELE, EPNet, ROMOL, eDRUG and Hi-EST, representing combined incomes of almost 6M; the PRACE Implementation Phase projects running from 2010 to 2017 with 5.4M; and the three Mont-Blanc projects, running from 2011-2018 with a combined income of 5.2M.

In the current funding program, Horizon 2020, BSC has had excellent results in the first calls, with 36 project proposals approved for a combined grant of 14.7M and with further proposals still under evaluation. The Centre has been particularly successful in the Future and Emerging Technology (FET) calls, in which High Performance Computing is a priority, as well as in the Centre of Excellence (CoE) for HPC Applications call, which was part of the Infrastructures sub-program, where BSC achieved funding for 6 projects (out of only 8 projects awarded).

Part of BSC's success can be attributed to BSCs active participation (supported by the 2011-15 Severo Ochoa program) in the European Technology Platform for High Performance Computing (ETP4HPC). This organisation plays a key role in setting the research priorities that underpin the topics and priorities of H2020 HPC-related calls, and was instrumental in securing from the European Commission a commitment of 700M budget for HPC related research in H2020.

Another important factor in this success rate was improved proposal coordination due to better internal communication as a result of the 2011-15 Severo Ochoa program.

3. Funding for collaboration with Private Industry
Since 2011, in addition to existing centres with Microsoft and Iberdrola, BSC has established joint research centres with Intel (programming models and tools for Exascale), NVIDIA (CUDA) and Repsol (seismic imaging) and has signed an agreement with IBM to renew collaboration on Exascale research. Repsol will have invested over 9M in the 2009-2016 period on both seismic imaging research and research into other areas such as optimisation of refining processes. IBM invested a total of 1.2M from 2013-2015; Intel have committed over 2M to the BSC over the 2011-2017 period; NVIDIA will invest almost 0.5M in the CUDA Centre of Excellence in the 2011-2016 period; Microsoft will have invested more than 2M in the joint research centre during the 2011-2016 period.

4. Impact of Severo Ochoa Funding
As a direct result of receiving the Severo Ochoa award, BSC was awarded in the order of 744,000 by La Caixa Foundation for five PhD Scholarships over a period of 4 years. Furthermore, the funding provided by Severo Ochoa allowed BSC to fill gaps not covered by other grants. In particular, the biomechanics, Big Data and personalised medicine strategic research lines were reinforced. In addition, funding for communication, human resources, mobility and training has contributed to significantly improved capabilities in these areas which are crucial for international competitiveness; this will have a significant effect on the future of BSC.

8. Strategic plan 2016-2019

8.0. Introduction

Please provide an overview of the strategic scientific vision of the center for 2016-2019. Include an analysis of major strengths, weaknesses, opportunities and threats (SWOT) of the center to consolidate its international leadership. When referring to the period 2016-2019 you should make specific reference to those actions within the Strategic Plan that will be implemented specifically as part of the Severo Ochoa award.

BSC has had formal Strategic Plans in place since 2009 (current plan runs till 2016), externally evaluated as excellent by MINECO and Scientific Advisory Board. The plans provide continuity of vision and core objectives whilst updating specific areas of focus and activity to reflect the changing environment.

BSC's vision, as Spains National Laboratory for Supercomputing, is to be of service to the rapidly changing needs of its users and to assist the countrys scientific and industrial communities to transition to and participate in the convergence of computation platforms and the emergence of new paradigms around Big Data. To do this it synergistically combines its capacities as a European Tier 0 HPC infrastructure and a world-class HPC research centre, positioning itself as a key international leader in developing and providing the next generation HPC technologies and knowledge and pro-actively assisting Spanish and European science and industry to integrate these technologies into their activities, boosting competitiveness and productivity in a broad spectrum of fields.

Summarising the SWOT analysis in BSC's Strategic Plan:
Strengths
* Holistic role as HPC provider and R&D Centre, with multidisciplinary expertise in Computer (hardware and software), Life and Earth Sciences and Engineering
* Internally developed technologies that influence standards and lead state-of-the-art
* Success in European Framework Programs, including H2020 (37% success rate in 2014 calls)
* Coordination (1) and participation (5) in H2020 Centres of Excellence
* Success in attracting R&D projects from major IT corporations
* Success collaborating with large Spanish industries
* Fast response and flexibility to external change
* PRACE founder and Hosting Member
* Leading role in international fora defining roadmaps and influencing EU priorities
* International prestige and leadership of the Centre and its Directorate
* National profile and prestige, including Severo Ochoa recognition
* Critical mass (4 scientific departments comprising 31 research groups, an Operations Department responsible for infrastructures, and a Management/Administration structure. 388 people in total)
* Multicultural, multidisciplinary, motivated team with many young researchers
* Comprehensive training programs, both technical & scientific, and link to academia
* Location in a unique environment: campus of the UPC, with UB adjacent, in Barcelona city

Weaknesses
* Restrictive hiring conditions imposed by law
* Lack of Spanish HPC industry
* Insufficient strategic collaborations with large EU entities
* Insufficient collaboration with SMEs and European firms
* Lack of entrepreneurial actions and culture

Opportunities
* Convergence of HPC with Big Data and embedded systems, and rising application needs in Health and Environment
* Consolidate research lines in emerging multidisciplinary fields of potential high impact
* Urgent need for energy-efficient HPC
* Participate in the EU vision of a wholly European HPC component, software and systems supply chain
* Further enhance internal, national and international collaborations
* Strengthening of entrepreneurial culture and incubation of spin-offs
* Expansion of HPC in Latin America

Threats
* Continuous need to update expertise to adapt to fast evolution of HPC
* Highly dependent on competitive funding - hard to plan a long-term strategy
* Increased competition for competitive research funding
* Difficulties in continuing to attract highly skilled people internationally
* Complexities in maintaining high motivation of staff
* Continued uncertain/unfavourable legal and administrative context for Spanish public research organisations
* Issue of senior management renewal over time

In formulating BSC's strategic objectives, consideration was taken of the priorities in the EUs Horizon 2020 and the Spanish governments 2013-2016 Research Plan:
1) Excellent science (World class science; Develop, attract and retain research talent; Best infrastructures)
2) Industrial leadership (Key technologies underpin innovation; more private investment in research and innovation; more innovative SMEs to create growth and jobs)
3) Societal challenges (Concerns of citizens and society (climate, environment, energy, transport, etc) cannot be achieved without innovation; Breakthrough solutions come from multidisciplinary collaborations; Promising solutions need to be tested, demonstrated and scaled up)
4) Promotion of talent and generation of employment (Youth unemployment presents a serious social problem, particularly in Spain; A prolonged brain drain of scientific talent away from Spain could have significant long term negative consequences)

In addition, consideration was given to BSC being a founding member and host node in PRACE, whose role is to make HPC resources available to leading scientists throughout Europe, and provide critical support to strategic European projects. Consideration also was given to the vision and objectives for development of European HPC of the European High-Performance Computing Technology Platform (ETP4HPC, www.etp4hpc.eu), of which BSC is a founding member and active participant.

BSC's Strategic Objectives were formulated taking all the above as guiding foundations:
Objective 1: Backbone of e-Science in Europe and Spain
i. Provide HPC resources to European and Spanish R&D&i groups, competitive at the global scale:

8.0. Introduction

* operate MareNostrum and maintain Tier-0 status
* coordinate the Spanish Supercomputing Network (RES)
ii. Lead the European and Spanish support infrastructure for intensive computation in a manner that is efficient, competitive and transparent to the user:
* promote the use of PRACE and RES resources to the broader scientific and industrial communities
* add value to other key European ESFRI infrastructures, and Spanish scientific endeavours and infrastructures
* participate in initiatives to further develop Spains Knowledge Society
* provide pro-active user support in adapting codes for optimal performance on MareNostrum and RES systems
* train postgraduates in fields of knowledge related to supercomputing
* train highly qualified technicians for both scientific and industrial settings
Objective 2: Research Excellence at the International Level
i. Expand BSC as a centre of excellence at the international level in:
* computer and computational sciences, with target on energy-efficiency and data-centric HPC
* fields of science highly dependent on HPC (life, earth, engineering)
* innovative application of HPC to unconventional fields (social sciences, humanities)
ii. Stimulate collaboration between pluridisciplinary teams, from scientific and industrial, public and private, internal and external communities:
* maintain existing and develop new collaborative R&D&i programs with IT industry leaders and leading Spanish institutes, in particular Severo Ochoa centres
* collaborate with industry and public agencies to apply HPC to add competitive value in important sectors (health, environmental, energy)
iii. Attract leading international talent:
* develop prestige and reputation for educational, scientific and technological excellence
* offer competitive salaries and opportunities for strong career advancement
* provide high levels of support to facilitate mobility
* develop a multicultural and dynamic workplace, with emphasis on addressing gender and equality issues
Objective 3: Societal and Economic Impact
i. Actively transfer technology to industry and contribute to the growth of the Spanish high tech industry:
* impact on global computing technologies by collaborating with industry leaders
* license proprietary technologies and incubate spin-offs
* contribute to open source software tools, and provide advanced complimentary services
* assist local entities to create and develop novel technologies
* prepare highly qualified people (researchers and technicians) for the workplace
ii. Promote the development of a Knowledge Society:
* disseminate new knowledge through publication
* pro-actively promote science and technology to society, both locally and internationally

Recognising the strong contribution of BSC's first Severo Ochoa program in advancing multidisciplinary research via both internal and external collaborations, and the resulting strengthening of BSC's international leadership credentials, the new SO program aims to further promote multidisciplinarity within BSC's broader Research Excellence objective by promoting frontier, multidisciplinary research via specific projects relevant to three key Social Challenges:
1) Energy: clean and sustainable energy with companies (Repsol, Iberdrola, DLR, Siemens) and consortia (ITER and DEMO);
2) Environment: climate prediction, atmospheric compositions, and coupling models to smart city networks and Internet of Things;
3) Health: precision medicine, next generation drugs, and bio-simulators.
But also to the convergence of HPC and BigData proposing new technologies to support the compute-and data-intensive workloads necessary to advance in the above mentioned social challenges.

In support of BSC's Societal Impact objective, SO will support further development of flagship software (OmpSs, Paraver, Alya, Pandora, Siesta), and also foment new entrepreneurial and technology transfer skills and capabilities amongst its staff via dedicated trainings and industry exchanges.

The SO program will further strengthen BSC's talent attraction initiatives, facilitating comprehensive induction, career planning, mobility and training, including both scientific and complementary topics such as entrepreneurship, communication, etc.

Funds will also facilitate participation in strategic international forums, including HPC Centers of Excellence, JLESC, platforms on the HPC/Big Data convergence and their applications and RISC (Latin American HPC network).

8.1. Scientific and Strategic Goals linked to the scientific activities of the center 2016-2019

Please describe the specific strategic objectives of the center for the 2016-2019 period, including any reference to the actions towards improving governance; research priorities and rationale; improvement of research outcomes'publications and other research outputs-; knowledge transfer and collaboration with third parties; scientific infrastructure; increasing collaboration and synergies across the center' units or external research units; etc. Emphasize the relationship between the planned strategic actions and the center research capabilities and resources. You should provide a description of the main action lines and specific targets attached to each strategic goal.

As described previously, the overarching strategic objectives of BSC are: (1) Backbone of e-Science in Europe and Spain, (2) Research Excellence at the International Level, (3) Societal and Economic Impact. In overview, the main strategic actions for 2016-2019 to advance these objectives are:

1. Backbone of eScience:
1.1 Reinforce the strategic position of BSC as a reference in High-Performance Computing and Big Data worldwide:
1.1.1 Continue participation as a leading member and Tier-0 node in PRACE
1.1.2 Coordination of the only European H2020 Centre of Excellence (CoE) on software technologies (programming models and tools) to advance in the performance/energy-efficiency challenge towards Exascale; and participation in 5 other CoEs on HPC applications (out of 8 selected in the first call), showing the key role of BSC in contributing to solving societal challenges
1.1.3 Continue driving the architecture/runtime co-design initiative towards lowering the programmability, memory, power and resiliency walls raised by the multicore revolution
1.1.4 Continue to play a key role in the Joint Laboratory on Extreme Scale Computing (JLESC) and other large-scale initiatives such as BDEC and ETP4HPC
1.1.5 Locally, lead further development and enrichment of the Spanish Supercomputing Network (RES)
1.1.6 Secure the financial resources, provide the technical expertise and manage the periodic upgrades of the MareNostrum supercomputer and RES nodes to ensure BSC facilities remain at the cutting-edge
1.1.7 Showcase BSC as an exemplary model of combined Research Infrastructure and Research Centre with strong governance, world-class academic credentials and industrial and societal relevance at the international scale
1.2 Be a key enabler in international cooperation towards grand scientific challenges:
1.2.1 Actively participate in key European and global projects in Health, Energy and Environment, providing HPC resources and expertise to support multidisciplinary international initiatives
1.2.2 Take an active, organisational role in the Research Data Alliance (RDA) which aims to enable researchers and innovators worldwide to openly share Big Data across platforms and disciplines to address the grand societal challenges

2 Research Excellence at the International Level:
2.1 Focus research efforts on key challenges in HPC and its applications for Health, Energy and Environmental challenges:
BSCs research priorities focus on a range of software technologies and application areas critical to the development of HPC solutions in key Societal Challenge areas. Achieving major breakthroughs in any of these is challenging, but, if successful, will have a significant societal impact at a global level.
2.1.1 In Computing, play a key role at the international level in the convergence of HPC and Big Data
2.1.2 In Health, develop tools to dramatically improve precision medicine, target and drug design, and human organ modelling
2.1.3 In Environment, develop models to simulate and predict climate change and air pollution
2.1.4 In Energy, create tools to support the advancement of renewable energies and new energy sources
2.1.5 Stimulate collaboration between multidisciplinary teams, from scientific and industrial, public and private, internal and external communities
2.2 Attract and develop talent:
2.2.1 Offer world-class training programs for postgraduates and technicians, attracting talent from around the world
2.2.2 Further develop BSC's career development program and management skills
2.2.3 Further develop mobility and secondment programs, with particular emphasis on interdisciplinary placements

3 Societal and Economic Impact:
3.1 Actively transfer technology to industry and contribute to the growth of the Spanish high tech industry
3.1.1 Impact on computing technologies in the global market by collaborating with international firms in R&D&i projects
3.1.2 Contribute to open source software platforms and tools, and provide advanced complementary services
3.1.3 Incubate and patent proprietary technologies for licensing and/or generating spin-offs
3.1.4 Serve as a competitive tool for local academia and industry, assisting local entities to create and develop novel technologies
3.1.5 Prepare highly qualified people for the workplace
3.2 Promote the development of a Knowledge Society
3.2.1 Disseminate new knowledge through publications and conferences
3.2.2 Pro-actively promote science and technology in the society through a comprehensive outreach program

These actions are further detailed below. Concerning governance, BSC mechanisms are well established, with regular reviews and high-level external evaluations. As described earlier, under the 2011-15 Severo Ochoa a number of senior coordinating positions (Severo Ochoa, EU relations, Latin American relations) were established. This has functioned very well and during 2016-19 additional actions will be taken to improve coordination between departments and maintain focus on key strategic aims. Also, a senior management succession plan will be developed to ensure the continuity of BSC should key figures depart or retire, and efforts will be made to reduce bureaucracy, especially in the area of technology transfer.

1.1 Reinforce the strategic positioning of BSC as a reference centre in High-Performance Computing worldwide
1.1.1 BSC is a Hosting Member of PRACE, the HPC European infrastructure which enables European and Spanish scientists to access world-class HPC systems. BSC drove its establishment and still leads initiatives to improve its functioning. A key focus in the coming period is expanding PRACE utilisation by SMEs.

1.1.2 BSC leads one of the newly awarded European H2020 Centres of Excellence (CoE) on HPC applications and technologies, and participates in other 5. No other supercomputing centre is involved in so many CoEs, vindicating BSC's efforts over the past 10 years in bringing computer and computational science together:
* The Performance Optimization and Productivity (POP) CoE coordinated by BSC will diagnose performance bottlenecks using the Extrae/Paraver/Dimemas tools and point to improvements to be made using OmpSs, all mature technologies developed by BSC. A rigorous performance optimization methodology will be developed including performance analytics to extract knowledge from the huge amounts of data generated by instrumented production runs.
* ESiWACE CoE aims to improve the efficiency and productivity of numerical weather predictions and climate simulation on HPC platforms by supporting the end-to-end workflow of global Earth system modelling in HPC environments. BSC will contribute with software developments and all the performance tools and techniques developed at BSC to analyse and optimise operational weather and climate applications.
* BioExcel CoE focuses on developing computational biology simulations. BSC will help define workflows, refine codes and develop simulation engines and databases.
* NoMAD CoE aims to create the largest data base storing the DFT simulation of hundreds of thousands of different materials. BSC will contribute with Big Data techniques allowing fast access and querying.
* MAX CoE will develop DFT simulations for very large molecules exploiting new algorithmic capabilities that allow a high scalability of such codes. Important

industrial impacts are expected, with BSC contribution on novel algorithms and performance issues.
* EoCoE will develop HPC tools for solving energy-oriented problems. BSC will contribute with codes adapted to solve atmospheric boundary layer flow problems of the wind energy community, and also data visualisation tools.
BSC will be the cross-pollinating institution with a broad view on the challenges, requirements and solutions in the different CoEs. This activity will also place BSC in the international vanguard of performance tools and programming models and their applicability to codes for solving societal challenges in Energy, Environment and Health.

1.1.3 The RoMoL (Riding on Moores Law) ERC project by Mateo Valero proposes an architecture/runtime co-design approach to drive the evolution of multicore evolution in future energy-efficient Exascale designs. The programmability, memory, power and resiliency walls raised by the multicore explosion will continue being explored with a holistic approach that includes computer architects and runtime designers, with focus on both compute- and data-intensive workloads, in an era of rapid and disruptive changes anticipated in processors and accelerators, novel stacked memory hierarchies combining volatile and non-volatile technologies.

1.1.4 BSC will actively contribute to the success of JLESC, the elite grouping of leading supercomputing centres including also Argonne National Laboratory, The University of Illinois at Urbana-Champaign (NCSA), INRIA in France, Jülich Supercomputing Centre and the Riken Advanced Institute for Computational Science. JLESC focuses on software challenges found in extreme scale high-performance computers, such as Big Data, Big Compute, novel programming models, numerical libraries, visualisation and HPC Clouds.
BSC will continue playing a very active role in the ETP4HPC (European Technology Platform for HPC) and the BDEC (Big Data and Extreme Computing international initiative). Membership of all these forums, which has been driven and promoted by Severo Ochoa, has a direct impact on setting roadmaps and research priorities at the international level, and has been an important factor in BSC's success rate in international competitive calls.

1.1.5 BSC proposed, initiated and coordinates the Spanish Supercomputing Network (RES), which has grown to 12 linked supercomputers throughout Spain, with 5 new nodes incorporated just in 2015. BSC's Operations Department is responsible for the maintenance and operation of BSC's facilities, as well as coordinating access to these HPC facilities via PRACE and RES access committees, supporting users in porting code and running their simulations, holding informational sessions to promote use of the RES services amongst the scientific community, running training sessions for RES personnel, and coordinating and assisting in the regular upgrades of MareNostrum and the RES nodes. The growth of the RES is testament to BSC's management and the inherent value derived from centralising access, support, optimising investments and resources, and leveraging training and experience. Additional support is planned from Severo Ochoa during 2016-19 to further cohesive supercomputing in Spain, proactively supporting researchers from across the scientific spectrum to apply HPC resources and to help translate results of strategic projects run on RES nodes into applications for scientists and industry,.

1.1.6 BSC hosts MareNostrum, one of the six Tier-0 supercomputers of PRACE, which must be regularly upgraded to maintain its world-leading capabilities. These upgrades tend to cascade to upgrades of the RES nodes, utilising equipment discarded from the old MareNostrum.
Maintaining BSC facilities at the cutting edge and ensuring they are well used to support frontier science across a broad range of disciplines is a key pillar of BSC's strategy to both consolidate its international leadership as a global flagship infrastructure, and ensure that its scientific divisions work with the very latest hardware and systems. A key strategic objective during 2016-2019 is to secure institutional funding for the necessary upgrades, which are expected to total in the order of 50 million.

1.1.7 BSC was founded in 2005 with (at its time) a unique vision, Unique in its origin and in its field, both for its conception and its form of usage; With its own research, that would provide the added value necessary to maintain it in the vanguard of technology; Of use to the national scientific community in a manner in which the services that it offers would be indispensable for the development of scientific and technological research with an experimental character, of high quality and internationally competitive. Ten years later, BSC is a well-established, worldwide-recognised centre of excellence whose operational model will continue influencing the development of HPC centres in Europe, Asia and Latin America. BSC aims to promote its model of synergistically combing infrastructure and research, and also to replicate the success of RES and PRACE by stimulating the development of similar networks, for example in Latin America via RISC, www.risc-project.eu.

1.2 Be a key enabler in the International cooperation towards scientific challenges,
1.2.1 BSC plans to actively participate in key European and global projects that require international cooperation and HPC support, in particular those involving Big Data and Data Analytics. BSC is already involved in a number of consortiums whose activities will develop during 2016 and beyond: EU projects PanCancer and EGA in the area of Health, where BSC provides computing capacities to store, curate, annotate, and offer data access; EU project Excellerate, linked to the ELIXIR infrastructure on BioData, where BSC will be the key computational partner, involved in workflow definition and benchmarking of bioinformatic programs and pipelines; developing and hosting air quality and dust models for forecasting, in collaboration with the World Meteorological Organization; EU projects PRIMAVERA and IMPREX to produce climate simulations and predictions at resolutions never before achieved, with direct impacts on management of renewable energy infrastructures and environmental protection. In addition to these already existing initiatives, BSC plans to submit at least 15 proposals to the Societal Challenges pillar of H2020 over 2016-19.

1.2.2 RDA is a global alliance to develop platforms for researchers and innovators to openly share data across technologies, disciplines, and countries to address the grand challenges of society. It is a project of strategic significance and impact, and BSC as an Organisational member has invested heavily in time and resources to advance RDA principles at the Spanish and European levels. BSC will host the 2017 RDA conference in Barcelona.

2.1 Focus research efforts on key challenges in HPC and its applications for Health, Energy and Environmental challenges:
2.1.1 Play a key role at the international level in the convergence of HPC and Big Data, proposing and developing new components in the software stack to support productive programming and efficient execution of hybrid compute-/data-intensive workloads. This includes i) programming models with rich semantics based on widely used languages such as Python; ii) novel resource management techniques with non-standard usage of HPC infrastructures; iii) use of light-weight virtualized HPC infrastructures with support for dynamic adaptation to demands of both kind of workloads; and iv) support for the upcoming active storage technologies (with support for in-memory computation) and novel key-value and persistent storages. BSC plans to gather a critical mass of researchers able to contribute to the future evolution of the new analytics and cognitive algorithmic layers and to give support in the exploration and use of these technologies in different scientific domains. These topics are of high priority in roadmaps of EU (ReTHINKbig) and industry leaders such as IBM, Intel, AMD, and Lenovo, with whom joint research initiatives already exist or are planned. BSC will also contribute to understanding this convergence with real applications:
* In the PRIMAVERA project, BSC will deliver novel, advanced and well-evaluated high-resolution global climate models capable of simulating and predicting regional climate with unprecedented fidelity, while in the CMIP6 climate change simulations, an unprecedented amount of data will be generated. BSC proposes to design new architectures to improve storing, analysing and sharing these huge amounts of data and making them readily available to both society and the private sector.
* MuG (multidimensional genomics) consortium is an EU-funded Virtual Research Environment to structure the computational aspect of research in the field of three-dimensional genomics. BSC will be a crucial partner responsible for the generation of a repository of programs organised in robust workflows, and in storage and mining of the data.
The emerging Internet of Things (IoT) will make Big Data much bigger, more valuable and useful in new ways further embedding Big Data and data-intensive computing into HPC. BSC will leverage initiatives in the EU COMPOSE project in order to play a key role at the international level in the convergence of IoT and BigData, the so-called BigIoT.

2.1.2 Health: precision medicine, target and drug design, and human organ modelling.
Precision Medicine: the popularization of genomics is producing an avalanche of population genome and phenome data which needs to be processed to lead to improvements of health. Many large consortia, typically linked to genetic-based pathologies (such as the PanCancer consortium) are now providing

information on hundreds or thousands of individuals with well-documented clinical records. All these data, as well as reference population information stored in large repositories such as EGA, hosted at the European Bioinformatics Institute and BSC. Challenges for next generation medicine will be linked to: i) the ability to process individual genomic data to quickly and reliably identify possible individual genomic alterations, ii) put the individual genomic data in context of population information to find correlations between genomic alterations and pathology, iii) analyse the data in the context of biological networks to determine potential targets for treatment, and iv) store, organise and maintain the data to allow community revision, and integrate data in the context of time-course experiments. BSC's inter-disciplinary teams have developed programs to perform fast annotation of genomic variants and new genome-wide association strategies, and in collaboration with the Barcelona Institute for Biomedical Research (IRB), in annotating the pathological nature of mutations. These tools will be optimised to integrate them into production workflows for flagship projects such as PanCancer.

Target and Drug Design: the combination of omics and structural data is opening new avenues for identifying new pharmacological targets and for the rational design of drugs, expanding the repertoire of potential treatments and speeding-up drug design, but requires investments of billions of euros over coming years. Challenges include: i) definition and optimisation of computational methods, including chemo-informatics for polypharmacology and drug repurposing, ii) creation and optimisation of computational approaches for analysis of biomacromolecules, iii) creation and optimisation of structure-based drug design, iv) development of integrated tools for integrating different rational drug design tools. BSC, in close collaboration with IRB, is actively developing structure-based and chemoinformatic-based software for rational drug design. These tools will be integrated in frameworks that allow real-time user interaction and visualisation. As a new multi-disciplinary initiative, Life Sciences and CASE will collaborate to explore using ultra efficient quantum mechanical codes based on the Density Functional Theory for the description of mutagenic damage and electronic damage in DNA, which might seed light into the origin of some kinds of neoplasia.

Human Organ Modelling: BSC is very active in developing simulation tools at organ level for biomechanical research, a highly multidisciplinary field, where medical doctors work with computational scientists on simulation codes to help diagnosis and treatment. The models are very complex, full of uncertainties, highly non-linear and transient, spanning multiple physics and scales. In recent years, BSC has greatly improved its simulation tools, especially in the cardiovascular and respiratory domains, by creating an in-house multidisciplinary team with very strong research links to top-ranked biomedical researchers around the world. Key areas of focus in 2016-19 related to already started initiatives during the current SO programme include carotids simulations with Mount Sinai Hospital in New York; ventricular arrhythmias with the National Centre for Cardiology Research (CNIC); full cardiovascular simulations from the heart up to the cerebral arteries by coupling Alya with the ADAN arterial system model, with LNCC in Brazil.

2.1.3 Environment: climate change and air pollution. BSC aims at better understanding these closely coupled subjects: air quality is strongly dependent on weather and is sensitive to climate change while the greenhouse gases impact global climate change.

Air quality: the objective is a better understanding of the chemical composition of the atmosphere and its effects upon air quality and weather, while improving predictions from local to global scales. BSC develops the NMMB/BSC Chemical Transport Model which runs operationally at the Regional Specialized Meteorological Center for Atmospheric Sand and Dust Forecast, hosted at BSC in collaboration with the World Meteorological Organization. BSC also develops and operates the CALIOPE air quality system which provides high-resolution short-term air quality forecasts for Europe and Spain. In a new multi-disciplinary initiative, Earth Sciences, CASE and Computer Sciences will collaborate to develop a new platform to assess urban related air quality problems. Improved understanding of local scales processes within urban environments would allow the assessment of healthy and sustainable environments. Air-quality forecasts will be linked to Smart Cities systems through the unprecedented coupling of micro-scale atmospheric and air chemistry models and observations from smart sensor-based Internet-of-Things infrastructures. New methodologies such as Floating Car Data (FCD) for modelling vehicular emissions will be explored. A prototype will be developed and tested in Barcelona co-designed with stakeholders such as Barcelona City council and the regional government, in order to develop a methodology applicable in other urban areas worldwide.

Climate Change: BSC aims to develop climate prediction capability for time scales ranging from a few weeks to a few decades (sub-seasonal to decadal predictions) and from regional to global scales. BSC coordinates the SPECS (2012) project and is a core member of the PRIMAVERA (2015) project, which aim to develop climate simulations and predictions at resolutions never before attempted (10 km globally). Earth Sciences will collaborate closely with Computer Sciences on model efficiency, workflow definitions, data compression beyond current levels, and data dissemination by adapting novel Big Data tools to climate services methodology. This role positions BSC as the key provider of both HPC and Big Data solutions for the European EC-Earth climate model, the central workhorse of this initiative.
2.1.4 Energy: renewable energies and new energy sources. Intensive numerical simulations and prototyping are needed to assess potential value of new energy sources and renewable energy installations, and improve their operational management and performance. Renewable energy from wind is one of the fastest growing and most volatile forms of electric power generation. Climate predictions of future wind over months to decades can provide vital information. Earth Sciences will participate in several European projects where this problem is addressed with the aim of producing first prototypes of climate predictions for the renewable energy private sector.

Biogas is attractive because of its wide availability, renewability and reduction of CO2 emissions, contribution to diversification of energy supply and rural development. However, its use is still limited since the complex fuel composition might lead to unpredictable combustion performance and instabilities in industrial combustors. BSC aims to develop combustion simulations designed for next generation Exascale HPC systems that can solve industrial problems for these alternative fuels, with huge potential impact on furnaces, engines, clean burning vehicles and power plants.

Hydrocarbons are still the world's main energy source, and exploration and production has become increasingly expensive and environmentally damaging. In order to reduce costs, oil and gas companies such as ENI, TOTAL and PGS have installed the largest privately owned supercomputers to analyze seismic data for geophysical exploration. BSC will continue its longstanding collaborations with REPSOL to further develop, optimize and enhance geophysical visualization and analysis tools.

2.1.5 Stimulate collaboration between pluridisciplinary teams, from scientific and industrial, public and private, internal and external communities: as described in 7.1, the 2011-15 Severo Ochoa program contributed greatly to fostering internal and external collaborations. This will be further developed in 2016-19 by focusing resources on pluridisciplinary projects and a comprehensive mobility program.

2.2 BSC regards the attraction and retention of talent as absolutely essential. As described in 8.2, BSC has a comprehensive plan of actions to:
2.2.1 Develop world-class training programs for postgraduates and technicians, and create a welcoming environment in order to attract talented people from around the world.

2.2.2 Further develop BSC's career development program and management tools, in order that the very best talent is happy to remain at BSC, and that when they do decide to leave they are able to secure career-advancing positions at top institutes and companies.

2.2.3 Further develop mobility and secondment programs, with particular emphasis on multidisciplinary, international and inter-sectorial placements.

3.1 Actively transfer technology to industry and contribute to the growth of the Spanish high tech industry
3.1.1 BSC already has extensive industrial collaborations and knowledge transfer activities with key global companies (IBM, Intel, Microsoft, NVIDIA, Repsol, Iberdrola, Xilinx, Samsung) and public agencies (ESA, NOAA, Governments of Catalonia, Andalucia and Canary Islands) with some 30% of its competitive income in 2014 derived from industry. Strong efforts will be made in 2016-19 to maintain these collaborations and stimulate the formation of new ones.

3.1.2 Through its participation in major international initiatives such as RDA (described earlier) and numerous EU projects, BSC is not only placing much of its own-generated technologies and data in the open sphere, but is also developing standards and platforms to enable others to do so too. BSC is committed to

driving more open source software and open access data developments in 2016-19.

3.1.3 Incubate proprietary technologies for licensing and/or generating technology based spin-offs
Although much of the knowledge BSC generates is either directly transferred to industry through one-to-one collaborations, or place in the public sphere through open source platforms, to date little has been produced in the way of spin-offs and direct entrepreneurial activity. This will be of particular focus in 2016-2019, with support from Severo Ochoa via training of BSC scientists in IP and commercialisation issues, and some stimulus funding to assist projects with high potential develop prototypes suitable to attract investment.

3.1.4 Under the 2011-15 Severo Ochoa program, BSC successfully initiated a number of strong collaborations with other leading Spanish research institutes, among them numerous Severo Ochoa centres. In 2016-19 BSC will continue to reach out to form new collaborations with research centres, but also plans a strong effort to engage local industry through dedicated sectorial focus groups and invited high-level visits to the MareNostrum.

3.1.5 An extremely important mode of knowledge transfer is training highly qualified researchers and technicians who then go to work in industry. As described in detail in 8.2 and 8.4, BSC plans a number of actions in this area, including increasing the number of industrial PhDs, developing new training modules in HPC systems and applications, to be disseminated through the both PRACE (European), RES (Spanish) and RISC (Latin America) networks, and through increased mobility and secondments with industry.

3.2 Promote the development of a Knowledge Society
3.2.1 BSC has an excellent record of high impact publications and conference presentations, the result of comprehensive internal support mechanisms to promote and assist researchers (especially younger researchers) in disseminating their research findings. These include actions at a personal level; strong mentoring, assistance in preparing presentations and papers, encouragement to participate in conferences, and also actions at an institutional level; the extremely active involvement of BSC in multinational forums and its leadership in key projects and congresses create a very high visibility for the centre, resulting in invited talks and strong dissemination of its research results. During 2016-19 these actions will be further strengthened with additional support for researchers in producing bibliometrics, and increased online dissemination and access of publications and research results.

3.2.2 As described in detail in 8.4, during 2016-19, BSC will engage a dedicated Outreach professional to significantly increase the breadth and scope of its outreach activities, to engage youth, teachers, industry and the general public through actions at national and international level

8.2. Training and Recruiting strategic objectives 2016-2019

Please describe the Strategic Plan' actions to: i) improve the center's doctoral and post doctoral capabilities-training courses, training and support facilities, etc.-; ii) to recruit research staff including international researchers during the period; and iii) finally describe actions that address the gender gap and/or promote women in science within the center (gender action plan). Please give cuantitative numbers and targets attached to each action.

BSC recognizes that its staff, including researchers from all areas and levels, managerial and support personnel, are all essential contributors to BSC's scientific and organisational success at national and international levels. BSC therefore aims to provide a motivating and intellectually challenging work environment along with best-practice working conditions, training and career planning, always respecting equal opportunities, work-life balance, ethics and integrity.

In 2015, BSC received the European Commission's Human Resources Strategy for Researchers (HRS4R) award, which recognises BSC's commitment to the principles of the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers, and furthermore commits BSC to an Action Plan for improving its capabilities and performance across a wide range of training, recruitment and gender issues. This Action Plan provides the core strategic actions for 2016-2019, which are further detailed below.

BSC is committed to provide an international high-level education and training program, which will be formulated around the Digital Agenda for Europe defined by the European Commission as a H2020 initiative (http://ec.europa.eu/digital-agenda/en). This initiative considers that the increased use of digital technologies drives innovation in more productive and more efficient production processes, and in new business models. It defines Education and Training for skills in HPC, Cloud and Big Data as a central plank of the effort to successfully achieve the Digital Agenda objectives.

BSC's Education and Training program is coordinated by the Education and Training team which reports directly to the Director, reflecting the high priority BSC places on these issues. The team comprises specialists in teaching methodology, course design, learning analytics and HPC and collaborative tools and the responsible of the unit has a strong background in HPC research as well as in the management of Academic affairs.

Recruitment, career development and gender actions are coordinated by the Human Resources (HR) team, within the Management Department. The HR team is led by an experienced HR professional, supported by a Career Development specialist, and two other HR professionals. The team utilizes specialized tools, including an HR management and database module linked to BSC's financial system, and the BSC Staff Professional Development Plan with a supporting web tool, which was implemented in 2013 as part of the previous Severo Ochoa program to improve career development mechanisms within BSC, and will continue to be improved and developed as part of the new 2016-19 Severo Ochoa.

Another important action developed under the previous Severo Ochoa is the BSC alumni association, BSC Folks, which will increasingly play a role in talent attraction initiatives in the 2016-19 period.

All new Education, Training and HR policies and actions are planned by specific advisory committees comprising researchers together with management staff, to ensure that actions are effective, address student and staff needs, and are reviewed with respect to equal opportunities and gender issues as part of BSC's strong commitment to improve in these areas.

1. Actions to improve the centre's training capabilities:
1.1. Implement the BSC Diploma of Excellence in Research Skills for all BSC personnel: as mentioned above BSC will launch a unique internal accreditation program with various grades relevant for all research levels, from PhD student through to Group Leaders.
BSC has developed its own in-house model of research excellence for the different career stages in sciences. The model is based in the leadership model of Transformational Leadership style from Bass-Burns, 1981, who described the Transformational Leader as a person who is able to change the motivational basis of their team from an ordinary motivation to one of engagement, by employing four factors: Ideality Influence (Charismatic Leader), Individual Consideration, Intellectual Stimulation and finally Inspirational Leadership.

The Bass-Burns model has been adjusted to the BSC context and to reflect BSC values and strategy. The resulting model consists of four different profiles reflecting different stages in the scientific career (Group Leaders, Coordinators, Postdoctoral Researchers / Senior Technicians. PhD Students) who each have varying levels of six core skillsets or factors:
* BSC knowledge: Values, engagement to BSC, experience in the Centre.
* Outreach skills: Abilities to communicate to the general audience.
* Knowledge Management: Technology Transfer skills and knowledge.
* Technical competencies: Scientific writing, Project management, networking, SCRUM & KAIZEN methodologies.
* Personal Competencies (Soft Skills): People Management skills, Organization and planning, time management, team management.
* Education, Experience and Background Profile: These reflect the minimum requirement to be in each career stage, they will not be directly trained.

The number of PhD and post-doctoral researchers has been growing impressively in the last years. Currently there are 73 post-doctoral researchers and 111 PhD Students at BSC, at different stages of their training and research. In order to support the correct development of their careers, BSC plans the following specific actions to reinforce its education and training capabilities by different means
* Special Lectures program: excellent researchers of international reputation, that will be invited to present to BSC young and senior researchers the most advanced results in the fields of HPC and its applications (4/6 per year)
* On the base of the successful experience of the prior Severo Ochoa program, BSC will keep the regular series of interdisciplinary Research Seminars (SORS) with internal and external speakers, once a month: BSC PhD and PostDoctoral students will present their results at least once during their stay at BSC.
* Organization of seminars on complementary skills, like IPR issues, patents etc; how to create a spin-off, etc: Students will participate to these sessions at least once during their PhD or Postdoctoral time.
* Organisation of the BSC Annual International Doctoral Symposium to provide a forum in which PhD students can present the results of their research work, sharing their experience and findings through talks, poster sessions and discussions.

For Post-doctoral researchers, BSC plans to apply for a European Marie SKlodowska Curie COFUND program. Successful fellows shall work on interdisciplinary research projects. They will benefit of the interdisciplinary research environment of the Center, as well as of exposure to collaborating with industrial and private institution, through the multiple international collaborations and contracts in which BSC participates with industry or SMEs: this will strengthen their CV and will open new job opportunities for their future. They will be offered the possibility to participate in outreach activities for presenting science to society, thus improving their communication skills and strengthening public interest and engagement for science.

In addition to these actions, the Unit of Training and Education will reinforce the participation in European Masters (Erasmus+) and in European Research Networks (Marie Sklodowska Curie Innovative Training Networks), for increasing the mobility of young researchers and attracting young talents from other countries, by submitting proposals in future calls.

1.2. Implement international best-practice in HPC training HPC facilities face the challenge of serving a diverse user base with different skill levels and

needs. Therefore, HPC training must include a variety of topics at different levels to cater to a range of skillsets. As HPC centres worldwide install increasingly heterogeneous architectures, training becomes even more important. BSC has been co-organising workshops to determine best practices for delivering HPC training.
Actions for 2016-19 include:
* Development of on-line courses on topics related to the BSC strategic research on local (UCATx) and international platforms (edX).
* Design new teaching methodologies for technology-rich learning environments appropriate for BSC courses, such as xMOOC (institution relevant Massive Open Online Courses), SPOC (Small Private Online Courses) and SOOC (Selective Open Online Courses).
* Design and develop digital training resources to be shared in the context of national and international collaborations (PRACE MOOC collaboration, JSC-BSC-CaSToRC EC twining project).
* Piloting XSEDE developed Digital Open Badges for certification of achievement for learners demonstrating competency in HPC related skills as part of an international effort to develop quality assessments for HPC training.
* Increasing BSC involvement in the international research on HPC education and training through active engagement with the community and through active participation in relevant projects and events.

1.3. Develop and promote the HPC training offer to industries - Training industrial staff in new technologies and the application of HPC resources is a key element in BSC's societal impact objective. Building on the BSC course portfolio and in-house developed technologies, BSC will offer courses addressing HPC skills gap of industrial user communities.

2. Actions to recruit research staff including international researchers:
The best advertisement for a Research Center is its results: with an average of 180 presentations at Conferences per year, BSC is very present in the international landscape. Still specific additional measures can be implemented in order to reinforce the visibility of BSC jobs offers and ensure the recruitments of the best candidates.
Support and promote fellowship programs In order to help attract top local and international talent to BSC special effort will be dedicated to increase participation in prestigious fellowships programs that offer attractive compensation packages, international visibility and help to attain tenured positions in the longer term. Therefore BSC plans to strengthen applications to ICREA professorships (Catalan Institute for Research and Advanced Studies tenured position) aiming at submitting at least 8 new candidatures in the next 4 years, at least 6 Marie Curie Individual Fellowships and to provide support to researchers for participating in 6 Marie Curie European Innovation Training Networks
Specific additional actions will be
* Broadening the number of dissemination channels used in order to reach a larger pool of candidates (see international talent attraction below).
* Training in interview techniques for staff involved in selection interviews.
* Improvement in candidate management, ensuring regular contact so that candidates remain engaged and do not commit elsewhere while still under evaluation.

2.1. Focus on international talent attraction BSC will undertake a two-pronged approach; (i) develop and enhance BSC's reputation for excellent science and strong career development, and (ii) increase the breadth and effectiveness of dissemination of open positions. Actions under these objectives include:
* Generating promotional brochures highlighting BSC's scientific achievements, top-class working environment and excellent career development programs, for distribution in summer schools, outreach activities, and conferences.
* Involving BSC staff seconded internationally through mobility programs in promotion and dissemination activities.
* Motivating research staff to promote BSC and disseminate job opportunities via their networks, with particular focus in key international platforms (JLESC, RISC, etc), the EU Centres of Excellence, and PRACE partners.
* Further developing and activating BSC's alumni network BSC Folks
* Launching an employee referral scheme.
* Enhancing use of social networks, the Euraxess portal, and other online dissemination tools.

2.2. Further development of BSC's Career Development program
Career development while at BSC is a critical factor in attracting and retaining talent. During the 2011-15 period, BSC launched a formal career development program for all staff, supported by a specialized program management module in the HR system. Improvement actions include:
* Provide young researchers with more mobility opportunities linked with BSC's internationalisation strategy.
* For PhD and PostDocs: multidisciplinary research seminar series. SORS (Severo Ochoa Research Seminars (Target - an average of 24 lectures annually (2:1 ratio of visiting local speakers) and ad-hoc summer lecture series. Currently 20% of the lecturers are female researchers and under BSC's gender action plan this should increase to 30%).
* The management module interface is currently available only in Spanish. It will be translated to English and made more user-friendly for managers and evaluators, implementing adjustments recommended by the users in our service surveys.
* Reformulating the evaluation of competencies, to better relate them to the values and needs of BSC.
* Increase the number of BSC staff who utilize the system (target 80%).

3. Actions that address the gender gap and/or promote women in science within BSC:
3.1. Implement a BSC Equal Opportunities and Diversity Plan BSC is already committed to a number of gender and equal opportunity actions via the HRS4R action plan (see next point below). However, during the 2016-19 period, BSC plans to develop a comprehensive Equal Opportunities and Diversity plan. This will commence with a detailed evaluation of BSC's current situation in terms of equal opportunities and diversity through surveys and analysis of HR data. Following this analysis a special working group will be established with diverse representation of professions, ethnic, religious and family backgrounds, in order to generate an action plan, which will then be implemented and audited.

3.2. HRS4R Action Plan Gender and Equal Opportunity actions as defined within BSC's HRS4R action plan, a number of actions will be implemented to promote women in science and improve other weaknesses identified in respect of gender and equal opportunity issues. These include:
* Organising a free annual seminar from a prominent female researcher, primarily directed to BSC staff, but open and announced to the general scientific community.
* Publishing information on courses, trainings, seminars and other education and training events at web sites such as ACM-W (http://women.acm.org/) and Women in HPC (http://www.womeninhpc.org.uk).
* Implementing more gender, equality and disability considerations in BSC recruitment processes, for instance, introducing compensatory elements to take into account maternity breaks and other familial obligations so that women who have had children during their careers are not penalised in the evaluation.
* Integrating gender and equal opportunity issues into BSC's conflict management protocol.
* Fostering the participation of female research staff in school visits to the BSC Supercomputer facilities, so that young female children who visit BSC can meet and be inspired by female scientist role models, thereby helping to break stereotypes and other early barriers in children.
* Promote BSC women scientists participating in education and training initiatives such as Every Girl Digital, a European campaign to find and celebrate digital role models who could encourage young women and girls to study and to pursue careers in IT.
* Develop the BSC Women in HPC digital badge to highlight education and training events and programs organised and delivered with the active involvement of female lecturers and researchers.

8.3. Internationalization

Please describe the Strategic Plan' actions designed to improve the center's international scientific leadership with a specific reference among other actions to those aimed at strengthening collaboration with top research centers, universities and international networks of excellence; to improve the center's returns from Horizon 2020, and related actions within the European Research Area. Please give targets attached to each action.

In this section we present BSCs strategic actions to increase its international scientific leadership for 2016-19. This international leadership should be demonstrated through: 1) the active participation of the Centre and its researchers in large and important international consortiums (e.g. JLESC, BDEC, PRACE, RDA, ETP4HPC and PanCancer) that define strategies and research agendas; 2) the establishment of bilateral collaborations with the best research groups worldwide to complement BSCs research capabilities; and 3) BSC assuming the coordinating and/or other key roles in international consortium projects, which usually require strong alliances with key international groups.

The activities and actions to achieve this international leadership are not usually supported by external funding and must therefore be financed with internal funding. BSC's 2011-15 Severo Ochoa program defined and funded the implementation of a set of instruments that enabled BSC to expand its participation in the international arena, foremost of which were the incoming and outgoing mobility actions to reinforce collaborations, and direct support for participation in certain initiatives of high strategic priority. BSC's 2016-19 Severo Ochoa program continues and reinforces these instruments, with numerous target actions to be taken to consolidate international scientific leadership in the four challenges presented in section 8.1.

1. Continue the active participation in large international research consortiums, as an essential measure to be at the forefront of global science in disciplines relevant to BSC.
1.1. Drive and be active in the collaborations to be established in the framework of the H2020 Centers of Excellence (CoE) and Virtual Research Environments (VRE).
* POP. This CoE is led by BSC and brings together the European world-class expertise in the area (HLRS, JSC, RTWH, NAG and TERATEC), combining excellent academic tools and programming models, methodologies and a practical hands-on approach.
* BioExcel. BSC will contribute to this CoE with the deployment, verification and benchmarking of the CoE software stack, creating opportunities to implement and optimise workflows related to the docking/virtual screening necessary to perform structural and functional studies of the main building blocks of living organisms.
* ESiWACE. BSC will collaborate with CoE partners by using and evolving programming models and performance tools to enhance the performance of climate and weather simulations in HPC ecosystems, as well as increasing the usability of weather and climate models across multiple platforms.
* NoMaD. BSC will contribute to this CoE with HPC infrastructures, big data analytics, visualisation support, and its competence in material science codes in general, opening the door to other initiatives (e.g. CECAM).
* MAX. This CoE brings together domain scientists, software scientists and HPC centres in order to provide towards Exascale computing services to industrial and academic end users. BSC will coordinate the actions related to new workflow programming models, providing HPC support and training.
* MUG. BSC will contribute to the software stack of this genomics VRE with technologies for database and storage management, workflow design and management, benchmarking and optimisation.

1.2. Consolidate BSCs participation in international alliances oriented to foster joint research and infrastructures, by providing the human resources necessary to influence the visibility and evolution of HPC technologies developed at BSC.
* In JLESC (Joint-Laboratory on Extreme Scale Computing), BSC will continue recently initiated collaborations, including the study of techniques to identify the memory access pattern of applications and its use in the optimisation of data placement in future memory hierarchies; cooperation with ANL to address the resiliency issues in Exascale systems; and integration and interoperability of runtime systems developed at BSC, UIUC and ANL.
* In ICGC-PanCancer, BSC will contribute with its recent advances in genome analysis (Smufin). This will consolidate BSCs position in the Biomedical Genomics community, opening new research opportunities to develop healthcare HPC systems, involving important hospitals and centres, such as Hospital Clínic de Barcelona, European Molecular Biology Laboratory (EMBL), Sanger institute, and others.
* In ELIXIR, BSC will continue its contribution 1) to set the basis for a platform to support community centred benchmarking efforts of bioinformatics tools and algorithms; and 2) standardisation, data publishing, and data connectivity of the resources offered in the community. BSC also participates in two Elixir use cases: The Rare-diseases infrastructure, and the Access to controlled data (EGA).
* In the Human Brain Flagship Project (HBP), BSCs role is the provision and optimisation of programming models to allow simulations to be developed efficiently, performance analysis and diagnostic tools, as well as the use of the MareNostrum supercomputer as part of the HPC platform for simulations. The main outcome of the project will be six ICT Platforms dedicated to different Neuroscience topics.
* In IS-ENES2, the infrastructure for the European Network for Earth System Modeling, BSC will contribute with the improvement of climate models across a number of HPC platforms, making use of performance and analysis tools to improve model efficiency.
* For the EC-Earth model, through the H2020 PRIMAVERA project, BSC will deliver novel, advanced and well-evaluated climate models and predictions at resolutions never tried before, with an unprecedented fidelity and amount of data to be processed.
* In SKA (The Square Kilometre Array), BSC will contribute to the Science Data Processor (SDP), focussing on the design of the computing hardware platforms, software, and algorithms needed to process the data generated. BSCs role in this initiative is strategically important since it will showcase BSC technologies in one of the most challenging Big Data projects of the moment.
* In EUROfusion, the European Consortium for the Development of Fusion Energy to manage and fund European fusion research activities on behalf of Euratom, BSC contributions include the scientific leadership of specific fusion experiments at the commonly operated fusion devices, i.e. the world largest Tokamak JET located in the UK and the ASDEX Upgrade Tokamak in Germany, together with their analysis and modelling.
* As part of the EuroLab-4-HPC project, BSC will coordinate the research work package with the aim of stimulating cross-cutting research collaborations, contributing to the goal of building a connected and sustainable leadership in HPC systems by bringing together the various leading performance-orientated communities in Europe, working across all layers of the system stack and, at the same time, fuelling new applications of HPC.
* In the OpenMP Architecture Review Board, formed by hardware and software vendors and research organisations leading the evolution of the OpenMP standard programming language, BSC researchers will closely collaborate with language, compiler and runtime developers in companies (Intel, IBM, Nvidia, Oracle, ARM,) in order to better integrate the currently supported execution models and refine support for accelerators.

1.3. Be an active player in the HPC/BigData convergence challenge, through the active participation and organisation of international forums, workshops and plenary events. BSC will actively participate in:
* BDEC (Big Data and Extreme-scale Computing), with the goal of helping the international community to develop a plan to provide the next generation of HPC software to support big data and extreme computing for scientific discovery.
* HiPEAC, with the goal of steering and intensifying European research in the area of high-performance and embedded computing systems, stimulating the cooperation between academia and industry and computer architects and tool builders, and producing the highly influential HiPEAC vision document.
* Research Data Alliance (RDA), with the goal of accelerating international data-driven innovation and discovery by facilitating research data sharing and exchange, use and re-use, standards harmonization, and discoverability.
* EXDCI (European Extreme Data and Computing Initiative), coordinating the strategy of the entire European HPC Eco-system (i.e. Technology Provision, Research Infrastructure and Application Expertise) by delivering the tools, measurements and other mechanisms needed to deliver that strategy. EXDCI will produce the next ETP4HPC Strategic Research Agenda (HPC Technology Roadmap), the next PRACE Scientific Case, together with key performance indicators to monitor the progress of the Eco-system, training and education initiatives aimed at attracting young talent and job creation and mechanisms for international collaboration and SME development.

1.4. Closely collaborate with Organisations, Agencies and Centres in deploying operational services:
* WMO Dust Centers. BSC, in collaboration with the World Meteorological Organization (WMO) and the Spanish Meteorological Agency (AEMET), created the Regional Centre for Sand and Dust Storm Warning System (SDS-WAS) covering Europe, northern Africa and the Middle-East and also launched the Barcelona Dust Forecast Center (BDFC), the first WMO Regional Meteorological Center Specialized on Atmospheric Sand and Dust Forecasting.
* Forum for Air Quality Modelling (FAIRMODE), a joint response initiative of the European Environment Agency (EEA) and the European Commission Joint Research Centre (JRC) that sets quality assurance rules for air quality modelling. The aim is to bring together air quality modellers and users in order to promote and support the harmonised use of models by EU Member States. BSC will co-chair the group on emissions and be an active member of both the assessment and source apportionment groups taking part in inter-comparison exercises.
* Task Force on Measurement and Modelling (TFMM) of the UNECE (United Nations - Economic Commission for Europe) under the European Monitoring and Evaluation Programme (EMEP) to assess the efficiency of air pollution mitigation strategies over the past 20 years. BSC is the only Spanish institution contributing to this international effort.

2. Support existing and promote new collaborations with international partners both within smaller projects and bilaterally. These collaborations are absolutely necessary to cover the expertise in areas that BSC is not leading or to complement with alternative approaches. A number of collaborations currently exist or are planned for the near future. We list some of them grouped by challenge:
2.1. Convergence of HPC and Big Data Challenge: including processor and memory technologies for HPC (Chalmers U., Technion, UC Berkeley, U. of Texas Austin, U. of Wisconsin) and embedded (ESA, ETH Zurich), programming models (EPCC, KAUST, U. Brasilia), storage technologies (FORTH) and scalable algorithms (Chinese Academy of Sciences, Oak Ridge).

2.2. Health Challenge: including collaborations in protein interactions and docking (U. Paris Diderot and Weizmann Institute), electronic and atomic protein modelling (Ulm University, Washington U. in Seattle, Washington U. in St. Louis), computational genomics (Ontario Institute Cancer Research, Sanger Institute, Broad Institute), fluid dynamics of the respiratory system and particle deposition (St Marys Hospital, Imperial College Healthcare Trust), and fluid-electro-mechanics simulations of a heart (U. of Oxford, George Mason U.).

2.3. Environment Challenge: including collaborations to optimise metereological codes (European Centre for Medium Weather Forecast, Institut Pierre Simon Laplace des Sciences de l'Environnement Global, Max-Planck-Institut für Meteorologie), development of new models for NMMB/BSC-CTM (National Centers of Environmental Prediction NASA Goddard Institute for Space Studies, University of Oxford) and development of climate services (MetOffice, Netherlands Organisation for Applied Scientific Research).

2.4. Energy Challenge: including collaborations to develop high-order mimetic methods (U. of California at San Diego), compression algorithms for geophysical applications (ETH Zürich) and modelling of waves in strongly anisotropic media (U. of Delft).

3. Promote Participation in H2020, continuing the success rate (35%; well above the average for the program) achieved during the first year and a half of the H2020 programme (with 36 projects approved with a total funding of 14.7M).
3.1. Ensure the support provided to researchers through BSCs Project Management Office (PMO), proactively detecting and communicating research funding opportunities; coordinating and contributing to project proposals; managing contract negotiations and managing all legal, financial and administrative aspects of contracts and projects.

3.2. Ensure BSCs influence on Europe's future HPC research funding priorities through continuing to have one BSC employee exclusively dedicated to the Public Private Partnership on HPC (ETP4HPC) and the Public Private Partnership for Big Data.

3.3. Promote and consolidate the European Research Area, the unified research area open to the world, based on the Internal Market, in which researchers, scientific knowledge and technology circulate freely and through which the Union and its Member States strengthen their scientific and technological bases, their competitiveness and their capacity to collectively address grand challenges. BSC contributes to this in various ways:
* Through its role as a hosting member of the PRACE research infrastructure, where it makes 70% of the MareNostrum supercomputer available, free of charge, to the best European scientists, helping them to address grand scientific and societal challenges
* Through its extensive collaboration in EU funded projects with a multitude of partners from many different countries and through its collaboration with companies
* Through the transfer of its knowledge and technology, supported by a dedicated Technology Transfer Manager since December 2014, advising researchers on the exploitation potential of the technologies which they propose to develop within H2020 projects
* Through its adherence to the Charter for Researchers and Code of Conduct for Recruitment, as demonstrated through it being awarded the HR Excellence in Research Badge (HRS4R) in 2015
* Through its commitment to free circulation of researchers, evidenced by its extensive mobility program and that over 40% of BSC researchers are from outside Spain
* Through its commitment to communicating research results, with a dedicated Project Dissemination team with experience coordinating dissemination in a number of Framework Program projects.

8.4. Exploitation and diffusion of research outcomes 2016-2019

Please refer to the specific actions of the Strategic Plan aimed at fostering the exploitation and dissemination of the center' research outcomes by referring to: the management of IPR; knowledge transfer and collaborative linkages with the business sector and other relevant stakeholders; outreach activities and knowledge diffusion by encouraging open access to scientific publications and underlying research data accordingly to international standards.

BSC has a long track record of knowledge transfer through collaboration with industry, dissemination of results and training. In 2014, BSCs Technology Transfer Office (TTO) was created in order to centralise tasks which had formerly been distributed around the centre. The five main aims of the TTO are: to intensify relations with industry (especially SMEs); to effectively manage BSCs portfolio of technology and IPR; to obtain funding for transfer activities; to help create spin-offs; and to promote an entrepreneurial and tech transfer culture in the centre. In 2016-19, BSC will consolidate internal support structures and increase the centres capacity to transfer knowledge and technology at local, national and international levels, by employing a fully dedicated outreach officer and through the other specific actions detailed below:

1. Improving IP Management:
a) BSCs IP protection and dissemination processes will be further refined by:
* extending and formalising BSCs internal processes for managing IP assets, thereby improving the quality and commercialisation potential of the IP portfolio.
* using database tools to analyse the scope and hidden opportunities of the IP portfolio.
* developing and disseminating a BSC IP catalogue including software, tools and patents.
These should be in place by early 2017.

b) Exploiting BSCs technology portfolio: by identifying BSC technologies with the highest TRL (Technology Readiness Level) and quantifying the resources needed in order to bring them to market. This will be done for one technology in each department, per year.

c) Fostering start-up creation and development: by formulating a start-up creation strategy for BSC, using methodologies such as the lean start-up, and designing and delivering in-house training modules to researchers covering topics such as IP protection, innovation processes and entrepreneurship. Training will commence in 2016, and the start-up strategy will begin implementation in 2017.

2. Knowledge transfer to business and others:
a) The long-term relationships that BSC has with key industrial partners like Repsol, Iberdrola, IBM, NVIDIA, Samsung, Intel and Microsoft will be consolidated and extended. Specific targeted actions include:
* Work towards a new 3-year collaboration initiative with IBMs international research laboratories. Topics being discussed include highly multithreaded processors and GPU accelerators directly connected through NVLINK.
* Maintain and extend beyond 2017 the activities of the INTEL-BSC Exascale Laboratory with special emphasis on the new processor architectures based on Xeon Phi and hybrid memories stacking volatile and non-volatile technologies.
* MICROSOFT - Continue to develop automated optimisation for the performance of Hadoop infrastructure deployments.
* NVIDIA Continue collaborating on the optimisation of Data analytics and Deep Learning algorithms using GPU, as well as training activities.
* SAMSUNG - Continue BSCs collaboration with Samsung on memory systems for high-performance computing beyond its renewal date of 2017.
* REPSOL Continue the Repsol-BSC Research Center up to at least 2019. The target is to develop a robust method for the join inversion of the seismic and electromagnetic wave equations.
* IBERDROLA - Extend the Iberdrola-BSC Research Collaboration up to 2019, to develop mathematical models to improve the design of Iberdrola's wind farms.
* New major collaborations Identify and contact major multinational companies with capacity to fund joint R&D units, and whose business activities could directly benefit from the application of BSC know-how and technologies.

b) Proactively seek Spanish companies to participate with BSC in consortiums applying for publicly funded projects (H2020, Spanish, Catalan, RIS3, etc), incorporating technology transfer. Target is to submit at least 3 proposals with Spanish companies per year.

c) BSC will develop a specific program to foster the use of HPC by SMEs, particularly in the following sectors:
* Bio-sciences: Drug discovery, disease detection/prevention
* Computer aided engineering (CAE): computational mechanics, design and testing
* Chemical engineering: process and molecular design
* Geo-engineering: oil and gas exploration modelling
* Climate change: Big Data analytics for efficient access to the distributed climate data
This program will be progressively implemented from 2016, with full implementation due by 2018.

d) Company visits to the MareNostrum supercomputer will be continued to encourage companies to use HPC tools and resources. Target is 24 visits to BSC facilities each year, with 400 companies taking part.

3. Communication and Dissemination:
BSC aims to further consolidate the centres reputation as an internationally recognised producer of cutting-edge HPC technology, educator and HPC service provider. Specific communication campaigns focused on BSCs main strategic areas (HPC and Big Data, precision medicine, renewable energy, climate change, air pollution, etc.) will be designed and implemented. Other general actions include:
a) Relationship with the Media - a close relationship with media (print, radio, TV and digital) is essential for BSC to raise awareness of its research activity. BSC will produce and distribute content in all relevant formats and distribute to local, national and international media.

b) Organise and Participate in Events BSC plans to continue hosting large-scale, strategic international events and workshops (BDEC workshop, RDA plenary meeting, JLESC workshop and summer school and ACM ECRC). BSC also aims to increase its presence and visibility in relevant non-scientific events (e.g. Mobile World Congress).

c) Digital communication In 2016, BSC will launch a new website that will be more dynamic and accessible from all devices. It will also offer more visibility to key areas such as technology transfer, outreach activities, European projects, and strategic research areas, among others. BSC will also continue to have an active presence on media channels (Facebook, Twitter, Youtube and Linkedin).

d) Dissemination of Project Results BSC participates in over 80 EU and international projects. BSC aims, where possible, to lead the dissemination activities in those projects it coordinates and to actively participate in dissemination actions even when it is not leading. BSC's communication team will provide comprehensive support to researchers in producing and distributing dissemination materials for projects.

e) Outreach BSC plans to significantly increase its outreach activities during 2016-19. A full-time outreach expert will be engaged by the Severo Ochoa

program develop an Outreach Plan and coordinate all BSC outreach activities. The Outreach Coordinator will be supported by a permanent working group formed by BSC researchers and other relevant staff in order to provide suggestions and advice. Specific outreach actions will include:
* Increase researchers communication skills in accordance with the HRS4R Action Plan. Target is 80% of BSC's pre-doctoral researchers trained to communicate efficiently with general public and media by 2019, and 50% of school visits to include a talk by a BSC researcher.
* Promote HPC Success stories talks in national and European industry forums, exploiting synergies with ETP4HPC, RES, PRACE and other stakeholders.
* Develop and run workshops on HPC for Spanish high-school teachers providing them with resources to explain HPC in the classroom.
* Improve the BSCs Museum, particularly the information provided about the exhibits, and build a cluster for HPC demonstrations for visitors. Target is to install the cluster by end of 2017 and attract 6,000 visitors yearly to BSC facilities.
* Promote talks by BSC researchers in science museums, fairs and TED-type events.
* Create opportunities to exchange best practice, experiences and ideas with other Severo Ochoa and PRACE centres and by joining outreach networks such as Ecsite.

f) Promote the role of Women in Science specific actions to promote women will include the organisation of seminars of relevant female researchers, increasing the presence of female researchers in MareNostrum visits, supporting the Women in HPC program activities, inclusion of the female figures in multimedia material (where possible), and others.

4. Open Access:
In order to foster the dissemination and exploitation of the results of BSCs research, the centre has implemented measures to guarantee that all its publications will be accessible free of charge via the Polytechnic University of Catalonia (UPC) institutional research repository.

In addition, BSC has obtained funding to recruit a Documentalist, to commence in 2015, who will assist researchers in tasks related to publication, bibliometrics and management of data.

In terms of research open data, BSC participates in international initiatives such as the Research Data Alliance (BSC is both an organisational member of RDA and a partner in the EU funded project RDA-Europe), which are analysing and enabling the mechanisms to share research data. BSC with the RES is helping in the creation of RDA Spain.

Finally, BSC develops and improves many Open Source softwares, and even hosts some of them on its own servers, with access free to the scientific community and the general public. Key examples include Caliope air quality forecasting, OmpSs programming model, Siesta atomic level materials simulator, PELE protein analysis tool, SMUFIN genetic analysis tool, among others.

8.5. Strategic Opportunity and Social Impact

Please provide a clear description on how the specific actions of the Center's Strategic Plan 2016-2019 will contribute to strengthen the center's scientific base and the potential impact of its outcomes. Please include the estimates of the total funding needs of the center for the period 2016-2019, including the expected sources of funding, with special emphasis on block (non-competitive) funding from public Administration. In this section you should also describe the 2016-2019 Strategic Plan monitoring system and its corresponding indicators.

As described in 8.0 and 8.1, BSC's 2016-19 Strategic Plan is based on 3 core objectives.

The first, Backbone of eScience in Spain and Europe, is the foundation upon which all BSC's endeavors are built. Maintaining an infrastructure that is at the cutting-edge globally of supercomputing technology enables BSC scientists to develop next-generation hardware and software, which in turn then influences the next round of upgrades in a synergistic cycle with positive impacts on all facets of BSC activities, in particular the quality of its scientific output and its ability to attract top talent.

These impacts are not limited just to BSC scientists through PRACE and RES, scientists across all disciplines from Spain, Europe and beyond are able to access these infrastructures and are provided world-class support to enable cutting-edge research outcomes. Via the 2016-19 Severo Ochoa program, BSC will further augment these value-added services with dedicated support to place selected strategic projects into production for the benefit of the wider scientific community.

These facilities, and BSC's leadership position in PRACE (Europe), RES (Spain), RISC (Latin America) and other major international infrastructure initiatives would not be possible without the long-term commitment and support of BSC's patrons, who have maintained core funding and investments in upgrades even during Spain's deep economic crisis.

BSC's management of these facilities and its coordination of the 12 RES nodes provide a unique base not replicated by any other international HPC centre for technical training, facilitating formal and hands-on training across a broad range of HPC-related professions and levels.

Via PRACE and RES selection of projects, the very best Spanish and European researchers come into contact with BSC, providing a rich pool of potential collaborators selected for excellence. The high quality of BSC's collaborations in turn has significant impact on BSC's international reputation and is a key factor in its consistent success in competitive funding calls.

Building on this backbone, BSC's second core objective, Research Excellence at the International Level, derives a comprehensive series of inter-related actions designed to ensure that BSC's research lines adapt to the rapidly changing panorama of HPC technologies and the needs of traditional and emerging HPC user communities, while maintaining overall coordination and focus on long-term objectives to build-up critical mass of know-how, tools, expertise, IP and collaborators in order to impact next generation HPC technologies and applications to tackle the most difficult problems in Europe's main societal challenges.

As described in 8.1, 8.2 and 8.3, key actions in 2016-19 to strengthen BSC's scientific base include:
* Expanding and deepening internal and external collaborations, in particular through BSC's participation in the ETP4HPC and the six Centres of Excellence (CoEs) and other strategic EU projects, emphasising multidisciplinary actions with special focus on the development and application of HPC technologies to solve barrier challenges in other disciplines (biology, climate, engineering, etc)
* Supporting the direct participation of BSC scientists in key international consortia and platforms, involving them in setting technology roadmaps and the definition of next generation infrastructures and softwares
* Strengthening institutional links with leading international reference HPC centres by promoting joint events, collaborative projects and staff interchanges
* Seeding and incubating strategic actions in emerging fields, in particular those at the cutting edge of applying HPC technologies in non-traditional ways
* Attracting new talent by offering competitive working conditions and strong career development opportunities
* Investing in researcher training at all levels, including in complimentary skills such as presentation skills, entrepreneurship, etc.
* Promoting and facilitating mobility between both academia and industry
* Addressing gender and equality issues to ensure that all BSC staff can realise their maximum potential

Based on consolidated world-class infrastructure and research excellence, BSC's 3rd objective, Societal and Economic Impact, ensures that all possible mechanisms are exploited to derive societal benefit from BSC facilities and research results. This is a very complex objective with many difficulties, but one in which BSC has already demonstrated very strong capabilities, as described in 7.2 and 7.5. The 2016-19 program aims to consolidate and strengthen established mechanisms, with a particular focus on empowering the broader research community and industry with cutting-edge technologies to address societal challenges in Health, Energy and Environment. As described in 8.1 and 8.4, these include:
* providing enabling technologies to substantially improve healthcare and environmental issues
* direct technology transfer via joint research laboratories with IT technology leaders driving next generation computing technologies
* joint development of HPC applications with multinational energy companies to improve competitiveness and reduce environmental impact
* development of open source platforms to support scientific and industrial activities, in particular in collaboration with public agencies
* dissemination of research results via high impact publications and conferences
* development of open access systems and tools to support dissemination of research data and results
* pro-active co-development with scientists from other disciplines of new HPC tools and applications to help them progress their research
* education and training of predoctoral and postdoctoral researchers, as well as technical staff from academic and industrial settings
* outreach to youth and the general public
* development of HPC networks (PRACE, RES, RISC) to optimize effectiveness and impact with limited resources

The program also has actions to develop new mechanisms:
* Promote HPC technologies to small and medium enterprise
* Develop an entrepreneurial culture at BSC with the aim of generating more licensed IP and spin-off companies
* Expand outreach with special programs for teachers and industry (focus on SMEs)
* Expand training programs internationally via PRACE and RISC

Funding of BSC over 2016-19 is expected to remain fairly constant and of similar composition to recent years. Core non-competitive public funding for operations from BSC's patrons is expected to remain steady at the higher rate of 8.6 million per year which commenced in 2015. Competitive public sources (regional, national and European) are expected to grow slightly (around 5-10% per year) from the current 8 million per year to around 10 million by 2019. This growth expectation is based on recent strong successes in public calls with projects scheduled to start over the coming year, and a successful renovation of the Severo Ochoa program. Private funding deriving from industrial collaborations is the most difficult to predict, but is expected to also grow around 5-10% per annum from the current level of 1.5 million based on current negotiations for renewals and new collaborations. Current technology transfer initiatives are expected to start generating small returns within several years.

BSC acts conservatively in committing resources; the new activities detailed in the 2016-19 program in research, support, technology transfer, training and

outreach will be funded primarily through realised growth in incomes, and some redirection of existing resources resulting from BSC's continual revision of non-performing research activities and improvements in internal efficiencies via implementation of improved IT systems and administrative processes.

Strategic investments totaling some 50 million will need to be made during 2016-19 to perform a major upgrade of MareNostrum and to complete the BSC building.

BSC has well established governance and management procedures to implement its strategic plans. Overall management and decision-making rests with the Director, Mateo Valero, and the Associate Director, Francesc Subirada. As described in Organisational Structure Annex 7.1, these are supported by BSC's Management Board comprising the scientific and operational departmental directors and a small number of senior adjuncts responsible for strategic initiatives including Severo Ochoa Program Coordination, European Relations Coordinator, Latin American Relations Coordinator, and Education & Academic Programs Coordinator.

Legal, financial and administrative issues associated with the Severo Ochoa award will be handled by the BSCs dedicated project management office. The detailed documents of the Strategic Plan are available to all senior staff via the BSC intranet, including the technical, management and communication activities needed to realise the programs objectives, and a detailed description of work with tasks, deliverables and milestones and clear processes for quality control.

The Management Board meets monthly and one of its key tasks is to monitor the programs progress with particular regard to milestones and budget. Where necessary, further committees are defined at the sub-program level.

In addition to the required reporting to MINECO, regular reporting will be made to BSCs Board of Trustees and its Scientific Advisory Board.

Details of milestones and indicators are given in the annex, but in summary:
Backbone of e-Science in Europe and Spain:
1) Secure funding and implement supercomputing infrastructure upgrades as per PRACE commitments
2) Enhance Big Data - acquisition, curation, management and storage capabilities in BSC facilities
3) Lead the expansion of the RES and further develop its management, technical, training and dissemination capabilities
4) Continue active participation in PRACE, and in particular drive initiatives for stimulating access by SMEs
5) Consolidate the RISC network in Latin America
6) Complete funding and construction of the new BSC building

Research Excellence at the International Level:
1) Expand on existing collaborations with leading computing companies (IBM, Microsoft, Intel, NVIDIA, Samsung, etc) and develop new collaborations, to contribute to the development of the next generation of supercomputing hardware, interfaces and applications (number of collaborations; funding levels; number of BSC researchers involved)
2) Promote and lead projects at European and international levels to converge Exascale HPC, Big Data and Big Compute to develop HPC applications for societal challenges in Health, Energy and Environment (renew funding for PoP CoE, present proposals to EU FET HPC call)
3) In Computer Sciences, play a key role in the convergence of HPC and Big Data Technologies and their use to tackle societal challenges (Participation in JLESC and BDEC workshops; Roadmap for Big Data Hardware; Networking in EU)
4) Within Health, position BSC as one of the key European reference centers for computational biology, bioinformatics and biomechanical modelling
5) Within Environment, position BSC as a key international partner for global climate change modelling efforts. In particular, continue development of BSC tools in atmospheric dust modelling to provide world-leading tools in dust-storm and pollution modelling
6) Within Energy, position BSC as the international reference for developing data analysis and simulation tools for solving complex industrial problems in traditional and new energy sources
7) Continue development of BSC and open source software platforms to increase fields of application and especially to increase the range of industrial applicability. Key platforms include ALYA, PANDORA, SIESTA, OMPsS, COMPsS, SMUFIN, PELE, CALIOPE, NMMB/BSC-CTM.
8) Consolidate and grow leadership activity in key international platforms
9) Strengthen institutional links with leading international reference HPC centres
10) Talent attraction (number of prestigious fellowships and personal grant applications ERC, ICREA, Marie Curie)
11) Implement the HR4SR plan for training and career development (milestones and indicators defined in the action plan)
12) Foster mobility, in particular with industry (number of mobility actions)
13) Implement the Gender and Equal Opportunities plan (milestones and indicators defined in HRS4R action plan)

Societal and Economical Impact:
1) Disseminate BSC¿s scientific results
2) Renew and/or establish strategic multi-annual projects with companies (contracts signed)
3) Diversify and expand technology transfer activities
4) Develop an entrepreneurial culture within BSC (number of participants in trainings; development of internal IP commercialization processes)
5) Development of open source platforms (number and scope of platforms; diversity of applications)
6) Open access (% of BSC outputs placed in open access repositories)
7) Development of applications for HPC
8) Develop a matrix of indicators for verifiable measurement of BSC¿s societal and economic impacts
9) Training of people (number of PhD graduates; number of people participating in technical trainings and scientific workshops)
10) National and international outreach actions (number of actions with industry; number of new industrial participants; number of actions with teachers; number of new international outreach actions)

8.6. Tabla de Presupuesto

Tabla de Presupuesto		Anualidades			
		2016	2017	2018	2019
COSTES DE PERSONAL	NUEVA CONTRATACIÓN	640.000,00	640.000,00	640.000,00	640.000,00
	COMPLEMENTO SALARIAL	50.000,00	50.000,00	50.000,00	50.000,00
COSTES DE EJECUCIÓN	OTROS COSTES	150.000,00	150.000,00	150.000,00	150.000,00
	Equipamiento e infraestructuras	10.000,00	10.000,00	10.000,00	10.000,00
COSTES INDIRECTOS	COSTES INDIRECTOS	150.000,00	150.000,00	150.000,00	150.000,00

8.6.1. Resumen del Presupuesto

	2016	2017	2018	2019
Costes Directos (Costes de Personal + Costes de Ejecucion + Costes de equipamiento e infraestructuras)	850000	850000	850000	850000
Costes Indirectos	150000	150000	150000	150000
TOTAL	1000000	1000000	1000000	1000000

8.7. Documentos anexados

Tipo Documento	Nombre	Código
Acreditación de la vinculación del Director Científico e Investigadores al Centro	Vinculacion Laboral del Director y Garantes_BSC.pdf	00000000000000000726
Calculations of normalized impact of researchers and scientific director	Impacto Normalizado Garantes_BSC.pdf	00000000000000000724
C.V Jordi Torres Viñal	JordiTorresVinals.pdf	00000000000000000648
C.V Jesus Labarta Mancho	JesusLabartaMancho.pdf	00000000000000000647
C.V Francisco Doblas Reyes	FranciscoDoblasReyes.pdf	00000000000000000645
C.V David Torrents Arenales	DavidTorrentsArenales.pdf	00000000000000000644
C.V David Carrera Perez	DavidCarreraPerez.pdf	00000000000000000643
C.V Arnau Folch	ArnauFolchDuran.pdf	00000000000000000642
C.V Eduard Ayguade Parra	Eduard Ayguade Parra.pdf	00000000000000000424
C.V Jose Maria Cela Espin	JoseMariaCelaEspin.pdf	00000000000000000649
C.V Victor Guallar Tasies	VictorGuallarTasies.pdf	00000000000000000651
C.V Oriol Jorba Casellas	OriolJorbaCasellas.pdf	00000000000000000650
Documentación acreditativa de la constitución del Centro	Acreditacion de Constitucion_BSC.pdf	00000000000000000722
Nombramiento y vinculación del personal gerencial	Nombramiento Director y substitutos gerenciales_BSC.pdf	00000000000000000720
Other documents/Otros documentos	ANNEX 1 SO Supporting 2011-2015_BSC.pdf	00000000000000000730
Other documents/Otros documentos	Annex2_Supporting 2016_2019_BSC.pdf	00000000000000000733
Other documents/Otros documentos	Compromiso Director e Investigadores_BSC.pdf	00000000000000000715
Other documents/Otros documentos	Annex b) Severo Ochoa Tables and Figures_BSC.pdf	00000000000000000711
Other documents/Otros documentos	Annex a) Scientific Report Severo Ochoa 2011_BSC.pdf	00000000000000000714
Other documents/Otros documentos	Annex c) Severo Ochoa Garantes Report_BSC.pdf	00000000000000000712
Scientific Director CV	MateoValeroCortes.pdf	00000000000000000422
Unidades administrativas, directivas y gerenciales	Estructura Organizativa de Gestion_BSC.pdf	00000000000000000718