1. Final Publishable Summary Report

Ramp-Up Phase (M1-M41)

1.1 Executive summary

The goal of the Human Brain Project (HBP) is: "to build a completely new ICT infrastructure for neuroscience, and for brain-related research in medicine and computing, catalysing a global collaborative effort to understand the human brain and its diseases and ultimately to emulate its computational capabilities."

During this Ramp-Up Phase (RUP), the HBP was divided into 13 Subprojects (called SPs): four neuroscience SPs focusing on data and theory (SPs 1-4), six information and communication technology (ICT) Platforms (SPs 5-10), Applications (SP11), Ethics and Society (SP12) and Management (SP13).

The neuroscience Subprojects contribute "strategic data" that was used to refine the theoretical understanding of the brain, to develop models and to populate specialised ICT Platforms for neuroinformatics (including brain atlases and a “brainpedia”), brain simulation, medical informatics (centralising information on brain diseases), neuromorphic computing (ICT which mimics the functioning of the brain) and neurorobotics (allowing virtual testing of brain models and simulations). Platforms and neuroscience Subprojects are supported by the High-Performance Computing Platform (SP7).

HBP has achieved the goals set for the RUP.

The Platforms were made available to the international scientific community via the "Collaboratory" web interface. The six ICT Platforms were released to the public on 30 March 2016 by a physical event at the Biotech Campus in Geneva, which reached a large community via web streaming techniques. The launch itself was accompanied by in-depth workshops, presentations and tutorials, all accessible to online audiences. A total of 339 scientific articles, with several in leading journals, plus numerous presentations at conferences and invited lectures, helped to highlight the scientific strength and impact of the HBP.

The European Institute for Theoretical Neuroscience began operation in April 2014. Members of SP4 created detailed plans for modelling work and began to implement the plans.

The Subproject dedicated to High-Performance Computing (SP7) completed the first phase of the Pre-Commercial Procurement (PCP) Process, which will lead to the purchase of a large supercomputer supporting the other HBP Platforms.

An Ethics Advisory Board (EAB) was set-up, which is handling ethical issues arising within the project.

The set-up of the Project’s governance was completed, providing an effective project management and coordinating relations with the European Commission.

The planned HBP Competitive Call was carried out, leading to the introduction of 32 new Partners to the Project in M6.

During the RUP, HBP also underwent significant changes from its original plan, to help it to achieve its high-level scientific goals better, to implement modifications requested by the European Commission's independent, international review board (evaluation in January 2015), and those suggested by the Mediation Process (led by Wolfgang MARQUARDT, head of the Forschungszentrum Jülich, Germany). The proposed changes concerned neuroscience and governance (March 2013) in the frame of the subsequent phase (FPA and the SGA1), accompanied by transitions in the funding conditions (from FP7 to Horizon 2020) as well as in HBP governance towards a legal entity.

Major changes made in response to these recommendations included:

1. A User Recruitment and Infrastructure (URIS) working group was established to provide a detailed work plan of how the HBP's Platforms will be transformed into a community-driven infrastructure for brain research. Their activity resulted in a White Paper, which became part of the Framework Partnership Agreement (FPA) governing the remainder of the Project after completion of the RUP.

2. In order to overcome shortcomings in integrating research work with Platform development, Co-Design Projects (CDPs) have been established that involve transdisciplinary cross-SP teams, which combine expertise in (neuro-) science and in technical implementation. Detailed work plans and data flows have been developed, to enable a smooth start for the CDPs in SGA1. The five CDPs are: CDP1 (Development of the whole brain mouse brain model and atlas), CDP2 (Mouse-based cellular cortical microcircuit models), CDP3 (Multi-level human brain atlas), CDP4 (Visuo-motor integration) and CDP5 (Functional plasticity for learning in large-scale systems).

3. The Mediation Report requested that Cognitive Neuroscience be reintegrated into the HBP Core Project. The HBP issued a Call for Expressions of Interest (CEoI) on Systems and Cognitive Neuroscience to recruit Partners to form a new SP3. An independent, international review board selected four proposals, which formed the new SP3 with 10% of the HBP's SGA1 budget.

1.2 Project context and objectives

1.2.1 Subproject (SP) objectives

During the RUP, the HBP was divided in 13 subprojects with the following objectives.

1.2.1.1 SP1: Strategic Mouse Brain Data

The aim of SP1 was to acquire strategic datasets on the molecules, cells, and cognitive capabilities of the mouse brain, and to align these with information on the human brain. Assembled data on the cellular and molecular organisation of the brain set a precedent for the comparison of mouse-human systems, allowing the reconstruction of models and simulations of the brain across all its levels and functions. At the onset of the HBP RUP, the technologies enabling these strategic datasets were in their infancy.

1.2.1.2 SP2: Strategic Human Brain Data

SP2's aim was to generate human brain data that parallels the mouse brain data collected in SP1. Integrating SP2's data into Cognitive Architectures from SP3 make it possible to derive general principles of brain organisation. Other HBP Subprojects were enabled to use these principles to predict features of the human brain that have not been measured experimentally, or that are not experimentally accessible. SP2 derived general principles describing the structural organisation of the human brain, allowing predictive reconstruction of human brain models. To reach this goal in the Operational Phase, the aim for the RUP was to develop the workflows required to generate, analyse and share the data, as well as ensuring that both methods and data meet the highest quality standards and HBP requirements.

1.2.1.3 SP3: Cognitive Architectures

The aim of SP3 was to select challenging dimains in cognitive neuroscience that have already been partially studied, and to define strategic experimental protocols ("localisers") to dissect associated patterns of brain activation and response dynamics in well-specified conditions, thus making it possible to identify the "cognitive architectures" underlying specific capabilities of the brain.The observed patterns of activation and dynamics make it

possible to identify: a) the brain regions involved in the task; b) the likely circuitry connecting these brain regions; and c) principles of information processing within and between these brain regions. This information is referred to collectively as the cognitive architecture for the task.

SP3 was framed in an international context of massive diversification of research on the neural mechanisms of cognitive functions, both in humans and in non-human species. SP3 chose to focus on the following challenging cognitive functions for which a theory is not yet available:

- Perception: How does the brain integrate multiple pieces of sensory information to construct invariant representations of its environment? (Given the breadth of this question, SP3 has chosen to focus on the perception of visual objects, other people's actions, and the body).
- Decision: How does the brain generate its own motivation, make decisions, and assess the confidence in its own decisions?
- Memory: How do the different forms of memory operate, differ and interact?
- Quantitative computations: How does the brain encode quantities, coordinate systems, and compute with them?
- Singularity of the human brain: What functions are uniquely developed in humans—Symbol processing? Language? Recursion? Social competence?

1.2.1.4 SP4: Mathematical and Theoretical Foundations of Brain Research

The goals of SP4 were: 1) to investigate mathematical techniques to link models used or developed in other modelling and simulation-oriented Subprojects; 2) to investigate different scales that are observed in experimental data and that need to be present in the simulation Platforms; 3) to develop plasticity rules for brain circuits that continually change during development and learning; and 4) to theoretically characterise different cognitive functions that are compiled in other Subprojects. A further aim was to set up the European Institute of Theoretical Neuroscience (EITN), which was achieved in M8.

1.2.1.5 SP5: Neuroinformatics Platform

The goal of the Neuroinformatics Platform (NIP) was to offer new tools for the construction of multi-level brain atlases and for the analysis and interpretation of large volumes of structural and functional data. The HBP planned to use these tools to develop detailed multi-level atlases of the rodent and human brains, bringing together data from the literature and ongoing research. It aimed to provide a single source of annotated, high quality data for the HBP modelling effort and for the international neuroscience community. Another key feature of the Platform was to support Predictive Neuroinformatics: the mining of large volumes of data, and the analysis of activity data to identify patterns and relationships between data from different levels of biological organisation. The objective for the RUP was to launch the first functional version of the NIP and populate it with data, models and ontologies for ion channels, cell types, synapse types and microcircuits.

1.2.1.6 SP6: Brain Simulation Platform

SP6 was focused on: 1) the development of tools for automated brain modelling and *in silico* experimentation; and 2) the use of tools to build initial brain models and scout multi-scale modelling biochemistry in the brain. SP6 was developing the HBP Brain Simulation Platform (BSP), that was made accessible over the internet via the Collaboratory. The simulation platform allows collaborative reconstruction and simulation of biologically detailed multi-level models of the brain, at different levels of description, and supports continuous integration of biological data, allowing models to become progressively more accurate and detailed, up to multiscale (simple to complex), multi-level (genes to whole brain) models of mouse and human brains.

Since SP6 plays a central role in the HBP ICT Platform system, it was the first Platform to be integrated into the Collaboratory and the development of the two is closely tied. The Collaboratory facilitates seamless interaction with the ICT Platforms and other HBP online resources, while maintaining sufficient simplicity to encourage use by less technically adept users. The Collaboratory is designed to catalyse research at all levels of the HBP by allowing: a) instantaneous sharing of data, models, tools, theories, configurations, methods and applications as developed and served by the platforms; b) tracking and crediting researchers for their contributions (provenance); and c) launching collaborative projects on any level. The Collaboratory was also designed to be the primary gateway by which the HBP shares its scientific and technological advances with the scientific, medical and engineering communities.

1.2.1.7 SP7: High-Performance Computing Platform

SP7's mission was to build, integrate and operate the hardware and software components of the supercomputing and data infrastructure required to run large-scale, data intensive, interactive brain simulations up to the size of a full human brain; to manage the large amounts of data used and produced by the simulations, and to concurrently manage workloads and workflows, data processing and visualisation. This infrastructure as a whole was planned to form the HBP High-Performance Computing (HPC) Platform. In the RUP phase, SP7 made version 1.0 of the HPC Platform available to the HBP Consortium in M18, and to the wider scientific community in M30. The HPC Platform is accessible in a seamless and intuitive manner through the HBP's Collaboratory.

1.2.1.8 SP8: Medical Informatics Platform

SP8 had three major objectives: 1) to build the key components of the Medical Informatics Platform (MIP); 2) to federate clinical data (imaging, genetics and physiological data), recruit hospitals and gather brain patient data; and 3) to identify tools to extract unique biological signatures of brain diseases. The MIP will allow researchers to identify biological mechanisms that explain the complex nature of brain disease. The MIP was designed to provide end-to-end solutions ranging from data to advanced analytical tools. Researchers are able to investigate questions requiring data correlations, distributions and interactions in the context of disease processes and epidemiological factors. Simultaneously, as data accrue and new hospitals and data generators are recruited, data mining tools were designed to explore all data to detect recurrent patterns and identify biological signatures of disease. The biological signatures of disease are set up to form the basis for a new disease space that neuroscientists and clinicians can explore.

The MIP was built on public and research databases and hospital data federated by novel data management and query techniques. This federation software and hardware was designed to allow researchers to query and analyse a very large volume of data without moving it from local servers and without compromising data privacy.

1.2.1.9 SP9: Neuromorphic Computing Platform

The HBP Neuromorphic (NM) Platform was set up to enable users to run simulation/emulation experiments on two neuromorphic computing systems: the Heidelberg system (NM-PM); and the Manchester system (NM-MC). The NM Platform is an integral part of the HBP Platform ecosystem. It is operated through the Collaboratory, which offers access to all users of the HBP infrastructure. The NM Platform machines are part of the HBP's overall computing infrastructure. High-performance computers can be used to perform placing and routing for the neuromorphic machines, and experience with construction of neuromorphic machines helped to guide the design of future, energy-efficient high-performance computers. HBP's neuromorphic computing services has the following key features:

- Complementarity;
- Configurability;

- Low energy and high speed;
- Scalability;
- Hybrid operation;
- Non-expert user access;
- Upgradability.

1.2.1.10 SP10: The Neurorobotics Platform

The SP10 Neurorobotics Platform (NRP) is a high-fidelity simulation system for virtual robotics that allows neuroscientists to perform *in silico* cognitive and behavioural neuroscience experiments, and roboticists to experiment with brain-model-controlled robots. The NRP thus connects HBP brain models to simulated robot bodies. The level of abstraction of the brain models ranges from micro- via meso- to macroscale connectomes: they could be models of a particular neuronal circuit, a region like a Brodmann area, or even the whole brain. Using a simulation approach with a variable degree of model abstraction allows SP10 to replicate classical experimental paradigms, and eventually develop new ones. The goal was to gain new insights into the causal relationships linking basic neural constituents to perception, cognition and behaviour. Simulating an experiment also implies simulating a robot's brain. After running a brain simulation on a dedicated computer node, it is only a small step to transfer this software from a simulated robot to a real robot. The NRP also aimed to develop and establish a sustainable and open source software solution. Software modules were derived from established tools with a strong developer community, and from software already developed in the Blue Brain Project.

1.2.1.11 SP11: Applications

The overall goal of Subproject 11 was to prepare, evaluate and test the early applications of the six HBP Platforms. The Subproject was structured into three Work Packages, covering applications of the HBP Platforms in Future Neuroscience, Future Medicine and Future Computing. Because the Platforms were scheduled to become operational at the end of the HBP's RUP (M30), the main application work can only take place afterwards, during the Operational Phase, as defined by the HBP FPA. This will run from M31 to M120.

1.2.1.12 SP12: Ethics and Society

The Ethics and Society Programme had five main goals for the HBP RUP:

- Establish and support two independent, management-level committees to provide ethical governance within the Project:
  - An Ethical, Legal and Social Aspects Committee to monitor and provide guidance on the Project's long-term ethical and social implications
  - A Research Ethics Committee to manage and provide advice on issues related to practical and procedural research ethics (studies using human volunteers, animal research, use of clinical data collected for other purposes, applications to ethics committees, etc.)
- Set up and start operating the Foresight Lab, which is responsible for monitoring HBP research and investigating its social and ethical implications for European citizens, industry, economy and society.
- Investigate conceptual and philosophical implications of brain simulation and the emergence of new insights into the relationship between brain and mind.
- Launch the HBP online deliberation, a European Citizens' Convention and a stakeholders' forum – all part of the HBP's broader programme of public dialogue and engagement.

- Launch a survey of ethical views among HBP researchers. This forms the basis for a broader programme of researcher awareness during the Operational Phase.

1.2.1.13 SP13: Management

SP13 provides the HBP with its governance and management structures and manages the project administration and HBP relationships with the European Commission. SP13 manages the project's dissemination activities, its technology infrastructure (internal and external web sites), the HBP Education Programme, and the European Research Programme Office.

1.2.2 Strategic objectives

During the RUP, the research undertaken in each SP was guided by six strategic objectives:

1. Design, develop and deploy ICT Platforms
2. Demonstrate the scientific value of the Platforms
3. Research future versions of the Platforms
4. Ethical research and responsible innovation
5. Transdisciplinary education
6. Develop a framework for collaboration

These HBP strategic objectives were clarified and sharpened during the course of the project in the light of the scientific discussions that followed the first Periodic Review, the Mediation Process and the preparation of the FPA.

1.3 Main Science & Technology results / foregrounds

1.3.1 Strategic objectives (SO) results

1.3.1.1 SO-1: Design, develop and deploy ICT Platforms

During the first Periodic Review, the HBP Consortium unveiled first versions of the six ICT Platforms, dedicated respectively to Neuroinformatics (SP5), Brain Simulation (SP6), High-Performance Computing (SP7), Medical Informatics (SP8), Neuromorphic Computing (SP9) and Neurorobotics (SP10). The Collaboratory was presented as the central access point to these Platforms.

In M18, the UP was renamed "the Collaboratory", to emphasise that it is a powerful tool for internet-based collaboration. The first Periodic Review recommended that HBP's ICT Platforms be evolved to become a reliable research infrastructure that is accessible to the entire scientific community. To address this recommendation, the Project-wide objectives, as well as the Subproject objectives, were adjusted. The HBP also sharpened its objectives regarding tighter integration and coordination of the Platforms. A Technical Coordinator position was created to support the implementation of these objectives. All updated objectives became part of the FPA, negotiated between the European Commission and the HBP Consortium.

For each of the six ICT Platforms, the goal has been to advance significantly the frontiers of research in their respective ICT fields during the RUP. During the reporting period, the Platform Subprojects focused on extending their Platforms' capabilities, transforming them into more broadly accessible research infrastructure and integrating them with the HBP Collaboratory. As suggested by the Periodic Review, the Platform SPs have worked to build user communities and make their core tools (e.g. NEURON and NEST in SP6) available to the wider scientific community.

These activities culminated in the public release of the 6 ICT Platforms on 30 March 2016.

1.3.1.2 SO-2: Demonstrate the scientific value of the Platforms

During the RUP, the Project used two mechanisms to achieve this objective. Firstly, many SPs hosted Work Packages and Tasks that were dedicated to using the Platforms. Secondly, SP11 hosted cross-cutting research, often using more than one Platform (e.g. combining neurorobotics (SP10) with neuromorphic hardware (SP9)). In the second half of the RUP, it became apparent that this strategy may have been premature, as the Platforms were not yet operational (for example, see SP3 Progress Summary M13-30). Moreover, the first Periodic Review and the Mediation report suggested that prospective users of the Platforms should be more strongly involved in the design of the Platforms.

To address these comments, a working group led by Thomas SCHULTHESS developed a strategy for transforming the HBP Platforms into a Community-Driven Infrastructure for Brain Research. The details of this new strategy were laid out in a White Paper that became part of the FPA. A key element is an approach adopted from the world of hardware development, where future versions of hardware are designed with strong participation of its prospective users (see e.g. https://en.wikipedia.org/wiki/Participatory_design). As a result, the HBP Platform design and implementation during the Operational Phase will be guided by CDPs that will start in SGA1. In addition, to demonstrate the scientific value of the Platforms during the RUP, a number of small pilot studies were designed, spanning key areas of neuroscience, medicine, and computing and robotics.

1.3.1.3 SO-3: Research for future versions of the Platforms

The RUP research plan discusses this objective under three separate headings: Data, Theory and Platforms. Research for future versions of the Platforms was to be realised through the collection of so-called "strategic experimental data" feeding via the NIP directly into the data-driven reconstruction of brain models. Both mouse and human data were to be

collected. Here, it was considered important not to duplicate efforts being undertaken outside HBP, but rather to generate data, which are not expected to be produced by other initiatives. These strategic data, together with external data, will be used to constrain and validate brain models at different levels of biological detail. However, it is far from obvious how to use and represent data when building models. In addition, modelling need not be exclusively data-driven; it can also be hypothesis-driven. A Theory Subproject (SP4) was defined to bridge these aspects and to identify strategies for eventually understanding the neural bases of behaviour and cognition.

Both the first Periodic Review and the Mediation identified the need for a more integrated approach to Platform development, and recommended that research for future versions of the Platforms should be driven by the needs of the prospective platform users. The HBP consortium has taken these recommendations extremely seriously and transitioned to driving the Platform development by "co-design". During SGA1, research supporting the Platforms will therefore be guided by a number of transdisciplinary, cross-SP CDPs. Already during the RUP, the Consortium has, where possible, tried to adjust its research to the new strategy. To support and coordinate the scientific activities in and between SPs 1-4, and between them and the Platform SPs 6-10, a new position as Scientific Coordinator was created.

1.3.1.4 SO-4: Ethical research and responsible innovation

The HBP strives to implement a strategy of responsible innovation, monitoring science and technological results as they emerge, analysing their social and philosophical implications, raising awareness of these issues among researchers and among citizens, and involving them in a far-reaching conversation about future directions of research. This objective is implemented by SP12, in collaboration with all other SPs. For Months 12-30, the objectives were to produce Foresight Reports for the different research areas of the HBP (neuroscience, medicine, computing, robotics), to identify how the new knowledge and technologies may impact research and society. Another objective was to establish a constructive dialogue between the HBP, its stakeholders and the general public to identify emerging HBP-related questions that may cause concern in society and to formulate recommendations for HBP research. Other specific issues relevant to the HBP included the ethical implications of collecting data from individuals belonging to different ethnic and age groups, to discuss areas like cognitive enhancers and the implications of creating a successively more and more detailed brain model *in silico*.

1.3.1.5 SO-5 Transdisciplinary education

During both the RUP and the Operational Phase, the HBP is implementing a programme of transdisciplinary education, training young European scientists to exploit the convergence between ICT and neuroscience, and creating new capabilities for European industry and academia. This objective is implemented in several ways. Firstly, the HBP aims to create research communities built around its Research Platforms. To this end, the Platform SPs organise user and community workshops, which are (by definition) transdisciplinary. Secondly, the HBP's education programme supports transdisciplinary education activities across all SPs; in particular, it emphasises the cross-training of students from one discipline in the skills and mind-sets of other disciplines present in HBP.

1.3.1.6 SO-6: Develop a framework for collaboration

The HBP will continue to develop a framework for collaboration during the Operational Phase that links the Partners through strong scientific leadership and professional project management, which will provide a coherent European approach and will promote effective alignment of regional, national and European research and programmes. As anticipated, this objective was difficult to pursue, given the diversity of the European research funding landscape. A pragmatic approach was followed during the RUP to develop collaborations around HBP's Research Platforms.

1.3.2 Subprojects results / foregrounds

1.3.2.1 SP1: Strategic Mouse Brain Data

SP1 has established methods to be used for mapping the mouse brain. A first strategic mouse brain dataset draft has been obtained across the key domains of transcriptome, proteome, neuroanatomy, channel function and behaviour, as well as data aggregation, integration and dissemination of data, according to the objectives set up in RUP. These initial studies have established a strong foundation for initiating the development of the different HBP Platforms, in particular those of Neuroinformatics and Brain Simulation. New protocols were developed for many applications, including freeze fracture replication, FIB/SEM immunogold channel labelling and acquisition of 3D electron microscope data on the cortical neuropil. From the hippocampus, 88 cells have been fully reconstructed, supplemented by 36 cortical neurons and 10 cells from the striatum. In addition, first versions of vascular maps of the mouse brain were generated, based on various high-resolution imaging methods. Two strategic mouse data packages have been generated and data have been characterised in data information cards, a prerequisite for data sharing.

1.3.2.2 SP2: Strategic Human Brain Data

SP2 provided multi-level data concerning the human brain. This effort included analysing the relationships between different aspects of brain organisation, and selecting strategically relevant data for building models and for developing a multi-level human brain atlas on the NIP. Whereas the cellular structure of the rodent, non-human primate and the human brain shares many facets, cognitive ability associated with circuits for language, symbolic representation and number processing, seems to be specifically human. For many parameters, however, inter-species similarities and differences have not been systematically analysed. Research undertaken involved the development of tools and methods to acquire data, link them to the atlas, and to modelling and simulation. SP2 developed the workflows required to generate, analyse and share the data, and to ensure that the methods used and data generated meet the highest possible quality standards and HBP requirements. A key publication provided a novel concept for a new understanding of cortical organisation in the human brain, highlighting the different spatial levels.[1]

1.3.2.3 SP 3: Cognitive Architecture

SP3 delivered localisers for all cognitive functions under study. Members of the SP3 team reviewed the literature and ran new experiments to identify and document the best fMRI or MEG experiments to achieve the goals of the Subproject. Results from this work are now being transferred to SP2.

A major achievement was the publication of Dehaene *et al.*, 2015, a special issue devoted to cognition work undertaken by SP3 researchers.[2] In addition, several international workshops were organised, to provide the link between cognitive neuroscience, data-driven models and theoretical approaches. For example, a first hippocampus model that uses one-shot learning, and a striatum model that uses reinforcement learning were introduced. Key datasets have been delivered to the HBP. Furthermore, functional analysis of fMRI data revealing the role of bilateral temporo-parietal junctions (TPJs) and insular cortex for the sense of self, and classified anatomically of the right temporo-parietal junction (rTPJ) and left temporo-parietal junction (lTPJ) were performed. However, the implementation of data-driven models related to the sense of bodily-self will not be further pursued within the HBP. The very successful research undertaken by the RUP SP3 will unfortunately not be continued in SGA1 since the responsible researchers will not continue their engagement

[1] Amunts K, Zilles K. (2015). Architectonic mapping of the human brain beyond Brodmann. *Neuron* **88**:1068-1107.
[2] Dehaene, S. et al., eds. (2015). Cognitive architectures (special issue). *Neuron* **88**:1–236. Available (viewed 2017-06-07) at: http://www.sciencedirect.com/science/journal/08966273/88/1.

within HBP. The topic of cognitive and systems neuroscience will be addressed by a new SP3, recruited through a CEoI on Cognitive and Systems Neuroscience, which was performed and finalised in 2015.

1.3.2.4 SP1, 2 and 3: from Molecular to Cognitive Neuroscience

Data collected in SP1 and SP2 made a vital contribution to the newly developed multi-level atlas of the rat brain based on the Waxholm space and the Human Brain Atlas of SP5, which is being increasingly filled with data for internal access, but also for the scientific community outside HBP. Researchers created the first high-level 3D reconstruction of the fibre architecture of the rat brain [e.g. Schubert, and integrated it into the framework of the Waxholm space (Bjaalie)]. This project serves as a Use Case to integrate progressively more data modalities, and to create a comprehensive rodent brain atlas. Together with the partners from SP5 and SP7, concepts and tools were developed to create a user friendly, multi-level atlas of the human brain, combining maps of different aspects of brain organisation such as cytoarchitecture, receptor architecture, structural MR-imaging, and maps of cortical and subcortical regions. The BigBrain[3] was introduced as a new template and resource for the international research community.

Experiments carried out in SP1 enabled the use of gene expression data to predict features of the brain that have not been measured experimentally, thus reducing the number of experiments necessary to build high-fidelity reconstructions of the brain.[4] The data provided the initial scaffolding and validation test for high-fidelity reconstructions and simulations of the mouse brain to be filled with data from the HBP's European and international collaborations and with predictions from reconstructions. Within SP1, the SP Leader, Javier DEFELIPE, has set up an interaction with the Cajal Blue Brain Project UPM-CSIC, based on their complementary research activities, as well as on the sharing of resources. In addition, other national projects share equipment with the HBP (e.g. microanatomical and neurochemical alterations of the cerebral cortex in Alzheimer's disease (MINECO, Ref.: BFU2012-34963), Distribución espacial y conexiones sinápticas de los terminales gabaérgicos y glutamatérgicos de la corteza somatosensorial de la rata [MICINN, Ref.: SAF2010- 18218)].

Comparative assessment of the data collected in SP1 and SP2 identified principles allowing the use of mouse data to predict features of the human brain for which experimental data are not available. This concerned, for example, studies of Huib MANSVELDER and team, who generated a first strategic dataset of full quantitative reconstructions of over 90 human pyramidal neurons across neocortical layers (Mohan et al., 2015), fed it into SP5 (the NIP) and shared it with SP4 (modelling) and SP6 (simulations). These data were used to generate the first data-driven models of human neurons and to simulate functional properties of human pyramidal neurons. The data, tools and methods generated in SP2 provided the initial scaffolding and validation tests for high-fidelity reconstructions and simulation of the human brain in collaboration with Idan SEGEV from SP4, i.e. this collaboration resulted in "productive loops" between experimental approaches, theory, and simulation, resulting in new input for experiments.

Rainer GOEBEL, Pieter ROELFSEMA and Wim VANDUFFEL joined SP2 via the competitive call, "Large-scale and sub-millimetre functional comparisons between human and non-human primates". This research is the first to compare functional topographies of the human and monkey visual and auditory cortex using sub-millimetre fMRI data collected in the two species with identical natural stimuli and analysed with identical state-of-the-art methods. Importantly, because both human and monkey fMRI data are obtained at sub-millimetre resolution, the project has the unprecedented possibility to perform an inter-species

[3] Amunts K et al. (2013). BigBrain: an ultrahigh-resolution 3D human brain model. *Science*; 340:1472-1475.
[4] Broadhead MJ et al. (2016). PSD95 nanoclusters are postsynaptic building blocks in hippocampus circuits. *Sci Rep* **6**:24626.

comparison of the functional architecture and the tuning to multiple stimulus features in the cortex down to near-columnar and near-laminar levels.

Jean-Philippe LACHAUX, Olivier BERTRAND and Philippe KAHAENE joined SP2 via the competitive call "Human Intracerebral Database", which added expertise in brain physiology, and contributed a unique database of patients, which is being integrated into the human brain atlas.

SP3 generated new theoretical insights into issues of key importance to neuroscience. These include the link between different levels of biological organisation in the brain, the dynamics of single neurons, plasticity mechanisms and their impact, network dynamics and the mechanisms underlying specific cognitive functions. SP3 implemented theoretical insights in high-level operational models, suitable for implementation in neuromorphic computing and in SP4. The fundamental approach of SP3 to elucidate the cognitive architecture is documented in a special issue of the high-level journal Neuron. The issue was published in October 2015 and contains several contributions from the consortium.

Partners and leadership (Stanislas DEHAENE) of SP3 left the Project after finishing the RUP. To continue research on cognitive architecture, to link the growing information from cognitive science with simulation, and to more effectively contribute to the developments of the HBP platforms, a CEoI invited new high-level partners in the field of cognitive and systems neuroscience. A total of 70 applications were received, and a group of external, independent reviewers selected the winning proposals in August 2015. As a result, four new consortia were integrated to start their work in SGA1.

The collected and shared database of the human brain represents a unique contribution, and significantly exceeds existing mapping approaches through its multimodality. Analysis and brain modelling based on such data will inevitably lead to breakthroughs in our understanding or the human brain, and major publications promoting the HBP even further.

Several meetings were held to start or strengthen collaboration with international initiatives and institutions - the Allen Institute in Seattle (to exchange data and images), the US Initiative Human Connectome Project (to experiment with datasets released by the HCP); the Centre for Magnetic Resonance Research at the University of Minneapolis (to optimise the MR acquisition protocols and sequences for the collection of 7 Tesla fMRI human data); the Montreal Neurological Institute (to improve the quality of the 3D reconstruction of the Big Brain dataset and to label the different tissue compartments); and the Biomedical Computer Vision (BMCV) Group at the University of Heidelberg (to develop image analysis methods for geometric alignment and 3D reconstruction). Moreover, intense discussions on strategies and protocols to harmonise research efforts took place with researchers from all other the world, initiated by Huib MANSVELDER (VU, P50).

1.3.2.5 SP4: Theory

SP4 has an important role in providing theoretically and experimentally based models at the cellular, systems and cognitive levels. This top-down approach to modelling complements the detailed simulations of SP6. SP4 has delivered the first version of an internet-accessible collaborative platform for data-driven predictive reconstruction and simulation of brain models. It did so by a close co-design setup between neuroscience, modelling, computer science, and software engineering. The accomplished work spans the underlying tools to the online Platform integrated with the HBP Collaboratory, as well as the science needed to develop the Platform in the first place and the application of the Platform to accelerate the building of scaffold models of various brain regions and to tackle novel research questions.

SP4 has also initiated the European Institute for Theoretical Neuroscience (EITN) for the benefit of the entire HBP and also the community. It was set up during the RUP, to serve as an incubator of ideas, where independent neuroscientists following different approaches can work together to understand the fundamental computational principles underlying brain

function and to work towards a unifying theory. SP6 will be a key adopter of advances in SP4.

1.3.2.6 SP5: Neuroinformatics Platform

SP5 is responsible for the Brain Atlasing and Data Analysis for the HBP. The NIP was released for public use on 30 March 2016. The release included ESPINA, Elephant toolkits, several strategic datasets including the JuBrain cytoarchitectonic atlas, improvements to the Big Brain model, probabilistic maps of major white matter bundles, and quantitative measures as well as spatial distributions of concentrations of different receptor binding sites for selected cytoarchitectonic areas.

The NIP developed in SP5 has a central position and is designed to be used by most parts of the HBP, as well as the neuroscience community in general.

The overarching goals of the NIP are to provide the neuroscience community and HBP with integrated multilevel data and enriched atlases of both the rodent and the human brain. The purpose is to provide an integrated view and the possibility to search both models and data related to neuroscience concepts.

- To provide all information gathered through the MIP (SP8) regarding diseases of the brain
- Tools to curate and spatially register datasets to standard reference atlases
- Tools to annotate data with metadata necessary to enable search and integration
- 2D and 3D viewers to navigate and query the atlases
- Data-mining tools for feature extraction from neuroscience datasets

The need for the NIP was conceived at the time of the application of the HBP in 2013, but its design was developed gradually during the RUP, and the architecture developed is based on three key components:

- The KnowledgeGraph provides the heart of the NIP, and provides the key metadata for all entries, with regard to both neuroscience and for simulations. The KnowledgeGraph is built around a provenance standard, and provides a basis for tracking all data operations, and the related datasets, as well as specific tools and algorithms and the attribution to all contributing sources. The KnowledgeGraph enables search across key dimensions, provided by the standardised metadata.
- The Data Space provides archival repositories and active data repositories that can be searched from the KnowledgeGraph and also the atlas viewers. This is the source for the different atlases.
- The Knowledge Space provides integrated knowledge and concepts to a federated data search. The data in neuroscience if often very diverse, distributed and challenging to integrate, moreover, the data is fragmented from the subcellular level to the integrated or cognitive neuroscience level, and the related spectrum of neurological and psychiatric diseases. One aim is to establish a common vocabulary for neuroscience, organised as taxonomies and ontologies. This is a critical condition for the ability to have a well-structured and searchable NIP.

The design with the KnowledgeGraph, Knowledge Space and the Data Space, developed from scratch during the RUP, will provide the backbone of the organisation of the NIP during SGA1, and some aspects have been further developed and modified as NIP has been developed during the SGA1. In particular, the organisation of the repositories has been shifted to a closer relationship with SP7.

Data collected in SP1 and SP2 have been integrated into the newly developed rodent atlas representing different organisational levels based on the Waxholm space (developed within

INCF) and a high-level 3D reconstruction of the fibre architecture of the rat brain (Bjaalie). The Human Brain Atlas of SP5 is being filled with data for internal access, but also intended for the scientific community. Together with the partners from SPs 1, 2 and 7 concepts and tools have been developed resulting in a user-friendly, multi-level atlas of the human brain, combining maps of different aspects of brain organisation such as cytoarchitecture, receptor architecture, structural MR-imaging, and maps of cortical and subcortical regions.

Following criticism levelled at the M30 NIP release and the rejection of two of its M30 written Deliverables, as well as the initial SP5 plan for SGA1, HBP put in place the Data Planning and Implementation Team (DPIT) to extensively revise SP5. DPIT's mission was to reposition SP5's approach, develop Use Cases, and produce a detailed product breakdown structure linked to costs and activities, as well as associated specifications. DPIT identified what strategic data is, which tools will be used to manage it, what data should be provided by the Neuroscience Cluster, and what data would have to be sought and imported from elsewhere. The result of DPIT's work was a complete new SGA1 work plan for SP5, introducing an important curation aspect and clarifying responsibilities for atlas building and Platform building and operation. This was accompanied by a change of leadership. SP5 is now led by Prof. Jan Bjaalie of Uni. Oslo, who has since then taken a major role in the HBP infrastructure.

1.3.2.7 SP6: Brain Simulation Platform

SP6 modelling work in STEPS, NEST and NEURON. A major achievement has been the creation of a model of the whole human cortical pyramidal (L2/3) neuron models. This included: cable properties; dendritic spines; synaptic potential (from other L2/3 cells); NMDA/AMPA properties and axonal spiking activity. In addition, a major validation of the reconstruction and simulation strategy, which underlies the BSP, was published in Markram *et al*. (2015), and represents an unparalleled collaborative effort of 82 authors.[5] The results have been made available via the Collaboratory. The BSP was released for public use on 31 March 2016.

SP6 focused on developing a data-driven strategy to reconstruct and simulate the organisation of the brain at multiple levels of biological scales from the subcellular to the systems level. As there is no practical way to measure every aspect of the brain experimentally, and it is extremely unlikely that this will become possible at any time in the foreseeable future, SP6 offers a novel solution to this seemingly intractable problem, leveraging interdependencies within and between levels, allowing well founded predictions, thereby avoiding the need to measure inaccessible details.

At the end of the RUP, SP6 delivered a first version of the BSP, which is a core of the HBP's data integration strategy and incorporates the standardised workflows shown to be successful[6]. This strategy has already been shown to dramatically accelerate modelling of human neurons and the modelling of mouse visual cortex neurons in collaboration with the Allen Institute for Brain Science or the collaborative modelling of the Hippocampus CA1 with the community. Innovation opportunities in relation to this are found in Annex H of Deliverable D6.7.4, which lists IPR status, ownership and the innovation potential for the products/software packages/services of the Platform.

SP6 has also provided improved versions of the BSP, incorporating algorithms and workflows for the reconstruction and simulation of subcellular, cellular, microcircuit, and meso-circuit (brain region/system) levels, and tools and protocols for image analysis and for *in silico* experimentation and model validation. Initially these modelling workflows will focus on mouse due to data availability. But even at these early stages of brain model development,

[5] Markram *et al*. (2015). Reconstruction and simulation of neocortical microcircuitry. *Cell* **163**:456-492.
[6] Markram *et al*. (2015). Reconstruction and simulation of neocortical microcircuitry. *Cell* **163**:456-492.

mouse simulation will have a significant impact due to the prevalence of rodents (mostly mouse) animal models in laboratory disease experiments (SP8).

1.3.2.8 SP7: High-Performance Computing

SP7 provides the core HPC infrastructure on to which most other platforms are built. Major successes were: completion of the PCP of interactive supercomputing resource and completion of an agreement with the Partnership for Advanced Computing in Europe (PRACE). New versions of NEST and NEURON have been released, and work on visualisation and provenance tracking has been undertaken.

PCP is a relatively new instrument, particularly in the HPC market. Both public procurers and solution providers are still in the process of collecting experience, and thus communication played an important role during the implementation of this PCP.

Throughout the PCP, the general public was informed about its progress by means of press releases, including the final one announcing the installation of the pilot system. These pilot systems are prominently featured on a dedicated webpage on the Forschungszentrum Jülich web portal.[7] In addition, PCP activities were presented at seven HPC related workshops and conferences, including especially SuperComputing (SC15).

1.3.2.9 SP8: Medical Informatics Platform

SP8 provides a platform for clinicians, neuroscientists, statisticians, pharmaceutical, and biotech companies to use big-data analytics to look for disease signatures in clinical trials data. Of special significance is the ability to use the Bayesian approach to hunt for disease signatures in the otherwise-discarded data from patients receiving placebo treatment in double-blind clinical trials. SP8 has recruited five hospitals to participate in the evaluation of an innovative data analytics system.

In order to fully address the needs of clinicians and researchers, SP8 signed initial agreements with five hospitals - Lausanne (CHUV), Lille (CHRUL), Milan (Grande Ospedale Metropolitano), Freiburg (Universitätsklinikum Freiburg) and Tel Aviv (Sourasky Medical Center) – to closely collaborate on the developments and first stage of deployment.

As part of the Platform, SP8 developed a set of tools to manage data acquisition, treatment and analysis; these tools are gathered in three main building blocks: Data Capture, Data Factory, Hospital Database Bundle and Algorithm Factory.

Data mining tools have been developed and applied to patient cohorts described in several publications:

- A 3-C strategy to address the challenges related to hospital data (missing values, biased populations, and diagnosis process biases). We developed a simulation framework for assessing 3-C and applied the methods to an Alzheimer's disease dataset (ADNI), identifying a number of interesting subtypes.
- Development of a multi-threaded implementation based on a simplified tSNE method (using Barnes-Hut approximation) that works for cloud computing, allowing fast on-the-fly whole-genome analyses to be performed. We applied the approach to the Allen Brain Atlas in order to discover relations between patterns of gene expression and brain function, and correlations among gene expression in different brain regions. In addition, we developed the HDCluster algorithm, which enables extraction of gene expression disease signatures based on the Allen Brainspan atlas.
- Development of a new multi-layer clustering algorithm that can include multiple and diverse data layers, which was tested on the ADNI dataset to identify patient subpopulations

[7] News on the installation of the systems were also posted on Twitter.

- Development of rule-based models for distributed and privacy-preserving data mining, and with the aim of disease signature discovery.

Overall, the RUP has seen the implementation of the architecture of the MIP, the major tools in their first versions, and the first algorithms' development. As set in the strategy, SP8's goals of implementing an infrastructure, tools and algorithms to share and access, analyse, and process data at a global level are under way. Collaboration with clinicians brings up needs, feedback and strong expectations and interest, and the first pre-processing results on research datasets reveal promising results for the following phase of the Project.

As remarked by the reviewers during the second technical review, user involvement has not occurred to the extent anticipated and the quality of the results remained uncertain due to lack of user exposure. Indeed, only one hospital, CHUV, has integrated the Medical Informatics Platform (MIP), and the bottom part of the hospital bundle software stack has been implemented in another hospital. The MIP has yet to be made available for research by the scientific and clinical community in the sense anticipated in the initial planning of the HBP.

In addition, the SP changed its strategy during the Ramp-Up Phase regarding the architecture of the MIP, aiming for a less centralized approach. This then required new in-house software development compared to the commercial/sub-contracted product initially selected.

To address these issues, SP8 developed and negotiated deployment agreements with five hospitals. The agreements define in detail the role of the parties involved in the deployment of the MIP to client hospitals. They state the strategy and delivery approach, the functionality included, the detailed deployment plan, an estimation of timeline and resources needed, and other requirements necessary for the successful deployment and adoption of the MIP system. The signature of these agreements and their implementation during SGA1 should lead to the expected user engagement with the MIP.

1.3.2.10 SP9: Neuromorphic Platform

SP9 builds and operates specialised hardware systems that make point neuron simulations such as PyNN and NEST both faster and more energy efficient.

SP9 designed all the NM-PM printed circuits boards and assembled a NM-PM hardware prototype, complete with rack, power and cooling infrastructure. This is now ready for the installation of 20 wafer modules. For the NM-MC system, a complete rack with 100,000 ARM cores has been assembled and is now being tested. The Platform's unified software framework was demonstrated in September 2014, providing non-expert users with seamless access to both the PM and MC systems – a unique achievement in neuromorphic computing. SP9 is collecting benchmark computing tasks that can be used to quantify neuromorphic computing performance and relate it to traditional supercomputing. In preparation for post-RUP development, designs for prototype Phase 2 PM and MC chips have been completed, with the involvement of many Partners. This broadens SP7's technological base beyond the SpiNNaker and BrainScaleS architectures used in RUP machines SP9 has produced prototypes of the next generation chips required by the platform roadmap, and delivered the world's first publically available, large-scale neuromorphic facility, thereby beating IBM's TrueNorth to the punch.

Besides the usual academic papers, significant attention has been taken to make the technology available and usable by typical users; this is achieved by running training courses on the technologies involved throughout the RUP of the HBP. One general audience publication to which attention needs to be drawn is Furber (2012)[8].

[8] Furber, S. (2012). Low power chips to model a billion neurons. *IEEE Spectrum*.

Figure 1: The SpiNNaker neuromorphic many-core system

All of the technology (both software and hardware) has received interest from industrialists. Whilst talks have been held with all of the usual potential partners (ARM, google, etc.), the technology is still in the early, pre-commercial phase.

1.3.2.11 SP10: Neurorobotics Platform

SP10 provides a unique combination of tools to connect spiking neural network models to robots that operate in a realistically modelled environment. It provided pre-configured experiments illustrating the main features available for users. As the interface to the BSP is under active development, all experiments relied on highly simplified neural controllers simulated by the point-neuron simulator NEST. These were the simulation of a humanoid robot together with a retina model, a proof-of-concept implementation of a Braitenberg vehicle based on a Husky robot, an experiment with legged locomotion interfaced with external controllers and the HBP mouse model including soft body simulation.

Any new branch of science requires a community that supports it and carries it into the future. From the beginning, SP10 has tried to build a community around neurorobotics and has been successful in doing so. Since the start of the RUP, SP10 has organised nine Neurorobotics Workshops (Performance Shows) during which we discussed and planned our research. The last day of these Workshops was open and we used this day to share and discuss our progress with influential peers from outside the HBP. These open discussions lead to a large number of invitations to workshops and conferences, but also had lasting impact such as the regular Europe-Japan Neurorobotics Meeting series where HBP Neurorobotics researchers meet and discuss with renowned Japanese groups.

The final pillar of our dissemination strategy is the neurorobotics community website https://neurorobotics.net which not only offers access to the NRP and combines all documentation material (including videos), but also links to a blog where we report regularly about events and new research in SP10.

1.3.2.12 SP11: Applications

SP11 was dedicated to guiding Platform development during the HBP RUP with applications in the areas of neuroscience, medicine and computing. The work performed was largely successful with several applications being developed in close collaboration with the Platform teams. SP11 was discontinued after termination of the RUP, but its work will continue in other SPs in SGA1. For example, in SGA1, SP8 will incorporate the disease signature work

undertaken by WP11.2 in the RUP into its big data analysis WP; similarly, some of the teams in WP11.3 will be absorbed into SP9.

1.3.2.13 SP12: Ethics

The HBP is committed to upholding and implementing the principles of Responsible Research and Innovation (RRI) in all its research and development, and SP12 is the hub of RRI in the HBP.

SP12 undertook foresight research on social, ethical, legal and cultural implications of HBP research (WP12.1), explored conceptual and philosophical issues and challenges raised by HBP research (WP12.2), engaged HBP researchers with external stakeholders and the general public (WP12.3), built awareness and capacity for social and ethical reflection among HBP researchers (WP12.4), and supported the robust management of ethical issues of the HBP as a whole (WP12.5). Three reports, on future medicine, neuroscience, and computing and robotics were produced in collaboration with other SPs, notably SPs 8 and 10.

The aims of SP12 also include theoretical reflection within WP12.2, which focuses on theoretical/philosophical and ethical concepts related to simulation, consciousness, human nature and identity, and problems in philosophy of mind, epistemology, moral philosophy and ethics.

The general goal of ethics management in SP12 (WP12.5) was to support HBP decision-making on issues with significant social and/or ethical implications and to ensure that the Project fully complies with European and national legal and regulatory requirements. It also provided management and support of the EAB, an independent body that advises the HBP on ethical, regulatory, social and philosophical issues. The EAB was formed by combining the Research Ethics Committee and the Ethical, Legal and Social Aspects Committee. The merger of these two committees happened in March-June 2015. The Ethics Rapporteur Programme was created, which identified individuals in all SPs who are designated points of contact for ethical issues. EAB members and Ethics Rapporteurs were paired up to ensure that there is a two-way communication between EAB and all parts of the HBP. The EAB was officially constituted in September 2015 during the Madrid Summit. Its contribution to the development of the Conflict of Interest standard operating procedure (SOP) was crucial to dealing with such issues. The EAB proposed principles for the appointment of an Ombudsperson to be implemented during SGA1.

SP12 organised a number of seminars, conferences, workshops, webinars, surveys and interviews, joining researchers from within and outside the HBP. Jointly with the EAB, SP12 formulated an Opinion on Data Protection and Privacy that has been officially adopted.

1.3.2.14 SP13: Management

SP13 set up the HBP's Governance bodies, drew up plans for the HBP beyond the RUP, and managed a Competitive Call which brought in 32 new Partners and a broad range of new research. It also produced a number of key planning documents, detailing actions to be undertaken in the RUP, including a Dissemination Plan, a Plan for the Use of Results, a Data Management Plan and a curriculum for the HBP Education Programme.

SP13 was responsible for the finalisation and signing of a heavily modified FPA in October 2015 and submission of the HBP's first Specific Grant Agreement (SGA1) proposal in November of the same year. Implementation of a new governance structure set out in the FPA began with the election of new SP Leaders and deputies in April 2016. Risk Management was strengthened by the creation of a new Risk Management Group. The Science and Technology Coordination function delivered a substantial Systems Engineering Package and largely completed a comprehensive mapping of data flows across the whole Project. The Collaboratory web interface for HBP Platform users was delivered, and two HBP Summits Co-funded by the European Union were organised, in Heidelberg (2014) and Madrid (2015). The

Education Programme conducted several Workshops and Schools, plus a Young Researchers' event in Budapest in April 2016.

1.3.3 Exploitable foreground

The HBP product catalogue can be reached at the following link (after having obtained a user account): https://collab.humanbrainproject.eu/#/collab/19/nav/2108

Exploitable foreground in SP5

SP5 has newly developed several API tools, listed in their Month 30 Deliverable D5.8.4 (Annex G), and for which use cases have been described in the same Deliverable.

Exploitable foreground in SP6

Foreground from SP6 includes:

- Newly developed tools (mainly BluePyOpt, Brain Builder, ValidationToolkit, PostsimulationWorkflows)
- Major contributions to pre-existing open source tools (such as coreNeuron, NEST, STEPS)
- Open sourcing of pre-existing Background tools (e.g. eFEL, BRION)
- Contributions to many other tools to support HBP use cases (e.g. OptimizerFramework, Neurodamus, MorphologyRepair, MorphologySynthesis, NeuroM)
- Wrapping of all these tools for the BSP (in TaskService)
- The BSP

The new software BluePyOpt is used in informal collaborations with institutions and universities (the Allen Institute, UCL, Krasnow Institute, University of Toronto, UCL, CNR (Consiglio Nazionale delle Ricerche), Boston University) to build single cell models;

The new framework BrainBuilder is being used to create Hippocampus CA1 circuits in informal collaborations with universities [Krasnow Institute, University of Toronto, UCL, CNR (Consiglio Nazionale delle Ricerche), Boston University];

The further development of an open source software (NeuroM - initially created by EPFL-BBP) has been made in the framework of a collaboration with the Allen Institute to support modelling efforts such as the hippocampus or cerebellum of the HBP (HBP RUP foreground on neuron synthesis may be disseminated through this open source path in the future);

Tools that have been open sourced through the work of the HBP RUP (such as the feature of extraction library (eFEL, https://github.com/BlueBrain/eFEL/)) are also being used in an institutional collaboration (with the Allen Institute).

Foreground from SP6 also includes the Collab functionality of the HBP Collaboratory and several Collabs (private and public) which allow collaboration with other universities and institutions to use tools from the SP6 BSP and tools for morphology curation and simulation launch;

SP6 modelling of glia cells, methods of morphology synthesis have been parameterized to work for glia cells in the framework of an informal collaboration with a university (KAUST).

Exploitable foreground in SP7

The following software from SP7 was entirely developed as part of the HBP RUP:

- InDiProv, an open source software for the creation of provenance tracks in the context of interactive analysis tools and visualisation applications. Currently no usage outside of the HBP.

- An S3 storage interface for UNICORE, integrated and publicly released with the open source UNICORE software. Currently no known usage outside of the HBP.
- The following software from SP7 was partly developed as part of the HBP RUP:
- Deflect, an open source C++ client library to develop applications that can send and receive pixel streams from other Deflect-based applications, e.g. DisplayCluster. Outside of the HBP it is used non-commercially by the EPFL-BBP, KAUST and TACC.
- DisplayCluster, an open source software environment for interactively driving large-scale tiled displays. Outside of the HBP it is used non-commercially by the EPFL-BBP, KAUST and TACC.
- Equalizer, an open source parallel rendering framework to create and deploy parallel, scalable OpenGL applications. Outside of the HBP it is used by commercial and scientific users worldwide, e.g. Dassault, University of Zurich, Electronic Visualization Lab at UIC.
- Livre, an open source out-of-core rendering engine. Outside of the HBP it is used non-commercially by the EPFL-BBP and the University of Zurich.
- Monsteer, an open source software library for Interactive Supercomputing in the neuroscience domain, facilitating the coupling of running simulations (currently NEST) with interactive visualization and analysis applications. Outside of the HBP it is used non-commercially by the EPFL-BBP.
- RTNeuron, a proprietary software tool for the interactive visualisation and media production of cortical column simulation results. Outside of the HBP it is used non-commercially by the EPFL-BBP.
- VIOLA, an open source software tool to visualise activity in multiple 2D layers in an interactive and efficient way. It is used non-commercially also outside of the HBP.
- VisNEST, a closed source software tool for visualising neural network simulations of the macaque visual cortex. Outside of the HBP it is used non-commercially in a joint research project between RWTH and Jülich.
- ZeroBuf, an open source software that implements zero-copy, zero-serialize, zero-hassle protocol buffers. Currently no known usage outside of the HBP.
- ZeroEQ, an open source software cross-platform C++ library to publish and subscribe for events. Outside of the HBP it is used non-commercially by the EPFL-BBP.
- OmpSs, a fine-grained programming model for shared memory environments, with a powerful runtime that leverages low-level APIs (e.g. CUDA/OpenCL) and manages data dependencies (memory regions). Outside of the HBP it is used by many different private and public companies as well as project partners of BSC.
- PyCOMPSs, the open source Python binding of COMPSs (COMP Superscalar), a coarse-grained programming model for distributed environments, with a powerful runtime that leverages low-level APIs (e.g. Amazon EC2) and manages data dependencies (objects and files). Outside of the HBP it is used by many different private and public companies as well as project partners of BSC.
- DLB, an open source dynamic load balancing library devoted to speeding up hybrid parallel applications. Outside of the HBP it is used non-commercially in other research projects with BSC participation.
- Score-P, an open source highly scalable and easy-to-use tool suite for profiling, event tracing, and online analysis of HPC applications. Outside of the HBP it is installed and used at dozens of HPC centres and companies worldwide.

- Scalasca, an open source software tool that supports the performance optimisation of parallel programs by measuring and analysing their runtime behaviour. Outside of the HBP it is installed and used at dozens of HPC centres and companies worldwide.
- Extrae, an open source instrumentation and measurement system gathering time stamped information of the events of an application. Outside of the HBP it is used by many different private and public companies as well as project partners of BSC.
- Paraver, an open source flexible data browser for performance analysis results. Outside of the HBP it is used by many different private and public companies as well as project partners of BSC.
- A REST API for UNICORE, integrated and publicly released with the open source UNICORE software and non-commercially used e.g. at TU Dresden.

Between M31 and M41 no exploitable Foreground that belongs to SP7 partners was generated. Intellectual Property created under the PCP remains under the ownership of the PCP contractors, with SP7 partners who are infrastructure providers (BSC, CINECA, EPFL, ETHZ, Jülich, KIT) having a license to use such Intellectual Property. The PCP contractors will make part of their R&D results available under an open source license.

Further information can be found in Deliverable D7.7.7, under "4.3 Maximising impact of PCP outcomes".

Exploitable foreground in SP8

SP8 has developed among other the following Foreground, with commercial potential:

- General data mining tools (MIP Function - Multi-Target Regression on Data Streams, MIP Function - Predictive Clustering Trees, MIP Function - Rule Ensembles, MIP Function - Feature Ranking for Structured Targets, MIP Function - Subgroup Discovery from Multi-Resolution Data, MIP Function - Subgroup Discovery from Heterogeneous Data, MIP Function -Visual Performance Evaluation), as well as a general medical informatics methodology (3C (categorize, cluster, classify) methodology for medical informatics), all with industrial application potential, that can be applied to data analysis tasks in many different sectors;
- Web applications (MIP Web Interface, entirely developed as part of the HBP RUP, Personal dashboard (with real time statistics on the data available), Model app (select variables, create models, estimates models, visualisation), Article redaction app (write article, reports with results and data provenance tracking), My data App (contain the articles and model created), Variables grouping ontology (data mining standard with PFA) that can be used in science or industry entirely developed as part of the HBP RUP
- The MIP Knowledge Base (KB) platform entirely developed as part of the HBP RUP:
  - https://hbpmedical.github.io/documentation/
  - https://hbpmedical.github.io/media/
- A schema mapping and data exchange tool (MIPMap) specifically tailored for the needs of the HBP, in which the user, given a source and target schema, can define correspondences/mappings by simply drawing arrow lines between the elements of the two tree-form representations, complemented by a service (MIPMapRew) rewriting queries posed at the Web Portal so that the nomenclature used by its predicates conforms to the schema of the hospital/research centres, entirely developed as part of the HBP RUP;
- A distributed and privacy preserving processing engine (Exareme) which can analyse a very large volume of data and tackle with constraints, such as computer node size limitations and privacy protection of data nodes, as it is based on a distributed non-

disclosive summary statistics concept. Exareme has been developed outside the HBP RUP but Privacy Preserving algorithms running on Exareme (used for research purposes only) have been partly developed as part of the HBP RUP. The following have been entirely developed as part of HBP RUP and are not used outside the scope of HBP: a) List_variables, statistics and variable_profile algorithms, b) connector for the integration with RAW, c) integration with the unified web portal.

- An automated diagnosis of brain disease based on biological data (Diagnostic and disease severity methods based on pathology and MRI), developed entirely as part of the HBP RUP.
- A hospital schema created with an open source software (Postgres raw), support for new datatypes and medical analysis, as well as interfaces based on iPython notebooks and the web, developed entirely as part of the HBP RUP and used exclusively within the scope of HBP.

Exploitable foreground in SP9

Foreground from SP9 includes:

- Online, local self-learning neuromorphic computing - CDP-5 will help drive this forward, by combining theoretical advances with practical implementation work.
- Wafer and chip embedding in multi-layer printed circuit boards, currently in a prototyping phase.
- Finishing first generation of low-energy, fast, configurable neuromorphic computing systems, in large-scale and portable implementations.

Exploitable foreground in SP10

SP10 has newly produced among other the following Foreground:

- Neurorobotics web app - this is the main software package from SP10 provided to the users. It enables to create or edit neurorobotics experiments, and includes the Environment Designer, Brain Body & Body Integrator and Experiment Designer components.
- Neurorobotics World Simulation Engine, a software that is a fork of the Gazebo simulator for physical and world simulation with additional support of deformable objects and tactile sensors.
- Closed loop engines (CLE) - this synchronises the brain simulation and the World Simulation Engine. It provides a REST backend interface to control the simulation.
- Neurorobotics experiments and models library – this is a library of 3D robot and environment models, and a Library of template and example experiments.
- Neurorobotics Experiment Simulation Viewer – this is a high-fidelity rendering client application for the use on DisplayWall, CAVE and desktops. It gives an immersive 3D representation of neurorobotics experiments with navigation capabilities.
- Neurorobotics Robot Designer – this is a blender plugin that enables to design and edit robot models and export and import them to and from the Neurorobotics platform.

SP10 Foreground is currently used within HBP only, except for the Neurorobotics web app, which is also used outside the HBP (for performance of own neurorobotics experiments for research). All software will be published as open source.

1.4 Potential impact and communication

1.4.1 Overarching strategy of HBP and Impact

The overarching strategy of the HBP is that it should lead to an unmatched understanding of the operation of the human brain and also promote the development brain-inspired technology, such as neuromorphic engineering and robotics. The human brain represents one of the most complex structures that biological evolution has created and to find out how it operates, a battery of different approaches to brain function need to be combined. Researchers with very different backgrounds, ranging from the molecular and neurophysiological levels to cognitive neuroscience, psychology, physics, informatics and computer science, need to combine their efforts. During the first 30 months, it has required a substantial effort for the Subprojects to function in their specific domain and to interact as planned, towards the development of knowledge within HBP. The challenges brought about by interdisciplinarity is inherent in such a project, but also the important possibilities. With regard to the different Platforms (SP5-10), the RUP has been a period of developing the required infrastructure that will become important in the subsequent phases of HBP and for the neuroscience community in general.

The data-driven simulations (SP6) and top down modelling (SP4) as a way of understanding the brain are at the centre of the HBP strategy – a specific feature compared to other brain initiatives in the US, Japan and the plans in China, Korea and Australia. The simulations require access to all relevant information worldwide for each type of process simulated, whether on the subcellular and cellular level or at the level of microcircuits (e.g. cortical columns) or other circuits in the brain. SP6 is currently using biological data from rodents since only very limited information is available for humans at this level; however, within SP1, researchers have used brain material obtained during operations and have made detailed biophysical descriptions of the human pyramidal neurons, showing larger differences with rodents than predicted in specific membrane properties. They have been simulated by researchers within SP4. This finding in itself will have a prominent impact.

For SP4 and SP6, it is critical to get access to all relevant biological facts for making the simulations and models as accurate as possible. Therefore, the NIP has been implemented and the focus of SP5 is to develop atlases for both humans and rodents. The NIP should store information from the subcellular to the macroscopic level and, in collaboration with SP8, also about the mechanisms underlying the many diseases of the brain from the molecular to the systems level. The biological information stored in SP5 should come from SPs 1-3 and from the community. SP1 provides information on the molecular and cellular level about in particular circuits of interest for the simulations in SP6 and also in SP4. A major contribution of SP2 is data from human imaging represented in the NIP. SP3 has provided high level information to elucidate the cognitive architecture relevant for the top down modelling in SP4 (see below).

A long-term plan for the HBP is first to simulate major subsystems of the brain based on biological data at the cellular synaptic and microcircuit level and ultimately the human brain, which clearly requires exceedingly effective computer technology, provided by SP7. In addition, SP9 aims to provide very efficient fast data processing, allowing for the simulation of complex circuits in real time based on simplified but comparatively complex neurons. Neuromorphic engineering in SP9 has progressed rapidly within the RUP and the techniques developed are not only very fast, but also energy efficient.

Robots interacting with the environment have essentially the same problem as biological creatures, they need to perceive the environment, and interpret whatever information they get to subsequently decide what action to take and do so successfully. The inspiration of the HBP robotics (SP10) is to use the information from biology (SP1 to 6) to build robots on biological principles. For this, fast processing in real time is required, and for that the neuromorphic chips of SP9 will be used. Conversely, robots based on biological principles can play an important role for the HBP aim of understanding the brain and its dependence on the dynamic sensory-motor integration of our actions.

1.4.2 Long-term impact

The Ramp-Up Phase was focused on setting up the Consortium, its management and its governance, and developing prototypes. There was therefore only indirect progress towards achieving the long-term impacts of HBP. The impact of HBP according to these indicators will be mostly visible during the second part of the operational phase and after the end of the FPA.

EC work programme target	Instantiation	Status	Ramp-up contribution	Ramp-up support	Support from dissemination and use planning
Transformational impact on neuroscience	LTI1: Better understanding of learning and memory; emotion, thinking and creativity; capabilities highly specific to the human brain (e.g. language)	Progress made by SP1-4, more impactin the operational phase	SO-1 SO-2	SO-3, SO-4, SO-5	Dissemination, standardisation
Transformational impact on health practice	LTI2: Biological signatures of brain disease, new classification of disease, disease simulation, drug simulation, personalised-medicine	Proof of concept with limited datasets in SP8 but no other significant progress in the ramp-up phase	SO-1, SO-2	SO-3. SO-4 and SO-5	Dissemination
Transformational impact on technology	LTI3: New brain-inspired paradigms of computing; advanced High Performance Computing, Neuromorphic Computing Systems; Neurorobotics	. The first release of the Platforms is a proof-of-concept for these new technologies	SO-1, SO-2, SO-3	SO-3, SO-4 SO-5	Dissemination, standardisation, use plan/rights
Substantial benefits for European industry and the European economy	LTI4: The pharmaceutical industry, new markets for high performance computing, neuromorphic computing and neurorobotics	No specific progress. visible mainly after the conclusion of project	SO-1, SO-2, SO-3	SO-5 and innovation support	Dissemination, standardisation, use plan/rights
Substantial benefits for European society	LTI5: Social benefits from better healthcare, new computing technologies, new robotics technologies	No specific progress. Visible mainly after the conclusion of project	SO-1, SO-2, SO-3	SO-5 and innovation support	Dissemination, standardisation, use plan/rights
European leadership in key scientific areas	LTI6: Advanced HPC, Future medicine (diagnostics, pharma, personalised	SP7 and SP9 have shown that their researchers are at the leading edge of HPC and neuromorphic	SO-1, SO-2, SO-3	SO-4 and SO-5	Dissemination

	medicine), Neuromorphic computing	computing technologies			
Strengthening of the interfaces between ICT and other disciplines	LTI7: ICT and neuro-science, ICT and medicine, ICT and cognition	Progress made via the Education Programme in SP13 and the organization of interdisciplinary workshops.	SO-1, SO-2, SO-3	SO-5	Dissemination, standardisation

Table 1: Long-term impact status

1.4.3 Results obtained during the Ramp-Up Phase

EC work programme target	Instantiation	Status	Ramp-up contribution	Ramp-up support	Support from dissemination and use planning
Progress towards the realisation of the fully operational phase of the FET Flagship, following the ramp-up phase	RES1: Demonstration of scientific feasibility for data, theory, models, specs	Results obtained by SP1 to 11	SO-1, SO-2. SO-3	SO-4. SO-5	Dissemination, consultation, cooperation,
	RES2: Extending the HBP Consortium	Achieved through the Competitive Call	SO-6	SO-4, SO-5	Dissemination
	RES3: Financial sustainability of the HBP	FPA signed between EC and Consortium, Legal Entity work started	SO-6	SO-5	Dissemination, lobbying
	RES4: Catalysing public support for the project	To be monitored during project. To be achieved by end of ramp-up phase	SO-6	SO-4, SO-5	Dissemination, lobbying
Leveraging effect through alignment and collaboration with regional, national, European and international programmes and activities	RES5: Governance, agreements, Joint Programmes of Activity etc.	Joint programme with FLAGERA Consortium, Joint programme with US brain initiative in negotiation	SO-6	SO-5	Dissemination, consultation, cooperation, data open-access
	RES6: Collaboration with European and international research initiatives	Collaborations initiated and some formalized by MoUs and agreements.	SO-6	SO-5	Dissemination, consultation, cooperation, data open-access
	RES7: Catalysing new research	6 FLAGERA-funded projects have been initiated	SO-6	SO-5	Dissemination, consultation, cooperation, data open-access

Table 2: Results status table

1.4.4 Impact at Subproject level

1.4.4.1 Impact of SP1, 2 and 3: from Molecular to Cognitive Neuroscience (LTI1, RES1)

Neuroscientific knowledge, data and tools have been developed in SPs 1-3, which have been made publicly available. While SP1 focused on mouse brain organisation, SP2 and SP3 focused on the human brain with an emphasis of SP2 on structural data, and SP3 on functional data concerning the cognitive architecture of the human brain. All three SPs collaborated with their colleagues in the Platform project.

The impact of SPs 1-3 was demonstrated by a high number of publications (80), including top journals (e.g. Neuron, Nature journals, PNAS, Current Biology, and Brain) and through its contribution to the development of the Platforms, in particular to the human and rodent brain atlases (SP5), the development of new models and simulation (SP4+6), and big data analytics (SP7) representing the basis for the future European research infrastructure of the HBP.

1.4.4.2 Impact of SP 4 and 6: Theory and Brain Simulation (LTI1, LTI7, RES1)

One important aim of the HBP is to use modelling and simulations to speed up the understanding of the brain. A top-down or hypothesis-driven modelling approach has dominated for decades within the field of computational neuroscience. Here one typically selects and identifies specific features assumed to be important to represent in the model. Models have then been used to generate predictions or describe phenomena of interest. This type of work is represented by SP4 within HBP. Simulations based on data-driven bottom-up modelling work are represented in SP6.

The research infrastructure will have significant social and economic impacts. For example, the research conducted in SP6 will make it possible to create brain simulation services available through the HBP research infrastructure for commercial research in neuroscience, computing, medicine, and pharmacology, improving European competitiveness in those areas. Models of the specific diseases at different levels of detail from the subcellular to the systems level will contribute significantly to clinical and pharmacological research also through SP8 (Medical Informatics Platform). Simplified versions of detailed brain models developed based on theories developed in SP4 will be a necessary precondition to fully exploiting the potential of neuromorphic computing platforms. A synergy between SPs 4 and 6 will be to combine top-down and bottom-up approaches addressing the same function within the brain.

1.4.4.3 Impact of SP5: Neuroinformatics platform (LTI1, LTI7, RES1)

The NIP developed in SP5 has a central position and is designed to be used by most parts of the HBP, as well as the neuroscience community in general. The NIP will allow neuroscientists to get access to information available from the different databases regarding neuroscience data in both basic and clinical neuroscience and to facilitate researchers to extend between organisational levels from ultrastructure to the systems and cognitive levels. At the end of the RUP a successful first release of the NIP took place in Geneva on 30 March 2016 together with the presentations of the other Platforms.

1.4.4.4 Impact of SP7: High-Performance Computing (LTI3, LTI6, LTI7, RES1)

Figure 2: The PCP pilot systems

SP7 provides the hardware underlying many of the other Platforms. As such it has an especially important impact on much of the rest of HBP. In addition to the hardware itself, much of the critical software required in the rest of the Project is supplied by SP7.

Thus SP7 has a clear and direct impact for developers of neuroscience software, making their job easier when dealing with supercomputers, or allowing them to be much more efficient when using these computing infrastructures. Moreover, due to the cross-cutting nature of computer science, these results not only impact neuroscience, but also any other science that may need to use them.

Finally, it is important to note that supercomputers are big energy consumers. This means that doing things more efficiently when using them has a clear impact in the energy consumption of the machine, which results in a decreasing carbon footprint.

1.4.4.5 Impact of SP8: Medical Informatics (LTI2, LTI7, RES1)

During the RUP, SP8 built the MIP, one component of the core infrastructure of the HBP. The MIP is a global collaborative open-source platform that allows hospitals and research centres worldwide to share medical data enabling online users to efficiently access accurate and relevant information on brain-related diseases while strictly preserving patient confidentiality, by smart use of big data and machine learning. On the infrastructure side, the first public version of the MIP was released in March 2016. Through the web application, the users can create, build and estimate models. It promotes collaboration between users, enables them to share tools and the results of their analyses, increases the replicability of the results, and drives the alignment of ontologies and standards.

1.4.4.6 Impact of SP9: Neuromorphic Engineering (LTI3, LTI6, LTI7, RES1)

During the RUP of HBP the neuromorphic Subproject developed, constructed and commissioned the world's first internet platform for the scientific use of neuromorphic technology. To achieve this both SpiNNaker and BrainScales hardware platforms were significantly extended from the situations they found themselves in at the beginning of the HBP. In addition, to make the systems accessible, portal software was delivered by CNRS to link to the overarching portal software emanating from EPFL.

Figure 3: The BrainScaleS neuromorphic physical system

1.4.4.7 Impact of SP10: Robotics (LTI3, LTI6, LTI7, RES1)

The HBP NRP is an enabling technology for an emerging branch of science at the intersection of neuroscience, robotics and medicine. When SP10 started in 2013, the NRP was the first project that tried to develop an integrated simulation platform for robots and neurorobots that allows researchers to collaborate over the internet, share their work and build on the experience of others. Meanwhile other groups and companies have started working on similar platforms (e.g. the Construct and open-AI gym), but so far none has the scope and ambition of the NRP. At the same time, we have received a lot of positive feedback from peers outside the HBP ensuring us of our original vision. If our vision and strategy is ultimately successful, the NRP will establish *in silico* experimentation as a valid technique for exploring the causal relationships between the multi-level structure of the brain, cognition and behaviour in complex environments.

The NRP is also the only platform that will allow researchers to explore the capabilities of neuromorphic hardware in neurorobotics applications.

Leveraging advances made in neuromorphic hardware, SP10 will build physical robots with neuromorphic controllers, which will have functional capabilities, such as learning and effective handling of multimodal real-time input. These capabilities are not present in current robotic technologies and will have a major impact over a broad range of domains, including manufacturing, transport, healthcare, and home assistance. The NRP will enable the HBP to offer commercial services, giving medical and industrial researchers the opportunity to experiment with state-of-the-art neurorobotics setups and applications that are developed using this technology.

1.4.5 Conclusions on first impact

During the RUP the different SPs have been developed from scratch with new types of collaborations and goals, and at the same time the SPs have had to find their role for contributing to the overarching goals of HBP through collaboration with each other. The impact of all the integrated work done during the RUP will be manifested particularly during the years to come, when each and every one of the SPs will contribute in their specific way to the understanding of the human brain, brain-inspired technology and the infrastructure

development not only within HBP but for the benefit of the entire neuroscience community worldwide.

1.4.6 Communication, dissemination and exploitation of results

1.4.6.1 Communication activities

HBP communication activities include diversified channels and methods for different audiences to achieve various communication goals, including media coverage, press and news activities, social media, brochures, video, and press materials.

The HBP website and HBP social media channels (Facebook, Twitter, YouTube, Tumblr, etc.) were widely used to communicate information and to interact with the general public.

Internal and external newsletters were also implemented together with specific Communications workshops organised at each HBP Summit. The Communications workshops were centred on the following topics: overview on the Communications Team activities and services, communications material available to the Consortium, and HBP identity and communication guidelines (e.g. use of the logo).

The HBP was present at many related conferences with booths, posters and various printed materials, including brochures on the various Subprojects and main achievements.

Overview of HBP communication activities:

- **Media coverage:** There were 7,244 media reports and press articles (traditional media) and 27,235 engagements from users on social media. Due to the large numbers, detailed tables will not be provided in this Report, but can be provided on demand.
- **Communications Materials.** This included production of
    - Videos: 13 Subproject videos, 3 research area videos, 1 introduction video, 2 HBP people videos, 1 HBP Magazine video, 3 for the HBP Summit, 1 to communication on a publication, 13 on scientific highlights, 3 for science competition, 1 for N-magazine, 1 for SIB elections, 1 instructional video for video selfie campaign, 2 for the Platform Release, 2 documentaries, revised HBP overview video, HBP 3D video and HBP 2D video.
    - Press kits: 2 press kits were developed. They consist of a validated list of images and captions to support press articles.
    - Project Identity materials: Identity guidelines, logo design (primary and secondary), letterhead designs, High-level standard presentation, HBP PowerPoint templates, 13 Subproject brochures (describing each of the 13 HBP Subprojects), 1 HBP introduction brochure, 1 HBP Management brochure, 1 HBP achievements brochure, 3 banner designs, 1 HBP infographic (the infographic consists of one page representation of HBP information in a clear and graphical way), poster templates (scientific and event), 3 conference booth designs.
- **HBP Social Media**: main social media statistics were 17,337 likes on Facebook, 13,486 followers on Twitter, and 216,347 total views of all HBP videos on YouTube.
- **Communication Activities:**
    - There were a total of 1,073 communication activities. The two busiest months were October 2013 (with 106 communication activities), which coincided with the launch of the Project, and September 2015 (with 87 communication activities), which coincided with the 2015 HBP Summit in Madrid.

- Four press conferences were hosted by the HBP, two at each of the two HBP Summits (in M1 and M12) and two for the announcement of the FPA, and for the Platform Release event, respectively, and there were ten press releases.
- The Largest Audience is 29,234,736 unique views per month (of Walsh, 2013)[9]
- The communication activities took place in over 30 different countries on six continents (Europe, Africa, Asia, Oceania, North America and South America). The largest live audience addressed for a communication activity was 30,000 people at the Society for Neuroscience 2015 conference in Chicago, 17-21 October 2015. The most common audience type for the communication activities was a scientific audience.

1.4.6.2 Dissemination and results exploitation

1.4.6.2.1 Publications

During the Ramp-Up Phase 419 publications were published by the Consortium. Of these, 340 were peer-reviewed.

With respect to detecting trends in academic collaborations, we found a number of noteworthy trends. When taking the publication as the focus of interest, using Subprojects as standing for Academic (Sub)-Domains, it is clear that many publications are published that highlight the work of individual SPs, while there is also a reasonable number of cross SP publications (Figure 4). While some of these cross-SP publications may be position publications and opinion articles, the release of the Platforms at the end of the Ramp-Up Phase should allow for more and more results-driven publications to emerge in their place in SGA1.

When considering authorship, Figure 5 shows that the number of co-authors per publication was relatively low, but comparable to publications accessible in Pubmed during the same time period. There are only a small number of multi-author (e.g. 20+) publications. This will be different in the next phase as Platform-developing SPs have been urged to explore the possibility of regular "release publications". These "release publications" are meant to introduce to the research community the latest features available, while acknowledging the contribution of all contributors towards achieving the release.

When collapsing co-author graphs it is apparent that, while large publishing cliques exist in the HBP, a number of isolated groups are also present. One analysis of these clusters focused on identifying authors critical to these larger clusters based on the centrality and connectivity they represent in the graph. When overlaying co-author networks with information about the role of authors in HBP, an interesting picture emerges. Authors who hold a leadership function in a SP (green circles in **Error! Reference source not found.** and Figure 7) and authors holding leadership functions in multiple SPs (red circles in **Error! Reference source not found.** and Figure 7) appear to be greater connectors of co-author cliques than authors who do not hold leadership roles (example Figure 7a). While some super clusters (Figure 7b and c) can be connected to multiple multi-SP leadership authors, it is not clear whether this is an artefact of the setup of the phase or whether this trend persists, and could serve as a predictor for areas where intense collaborations result in significant engagement of the community or a leap forward in terms of insight. Follow up analyses are underway to determine if such co-author clusters pre-date the launch of the flagship and to determine how a model derived from the clustering properties holds up when compared to publication data from the next phase.

[9] Walsh, F. (2013). Billion pound brain project under way [viewed 2017-06-07]. *BBC News*

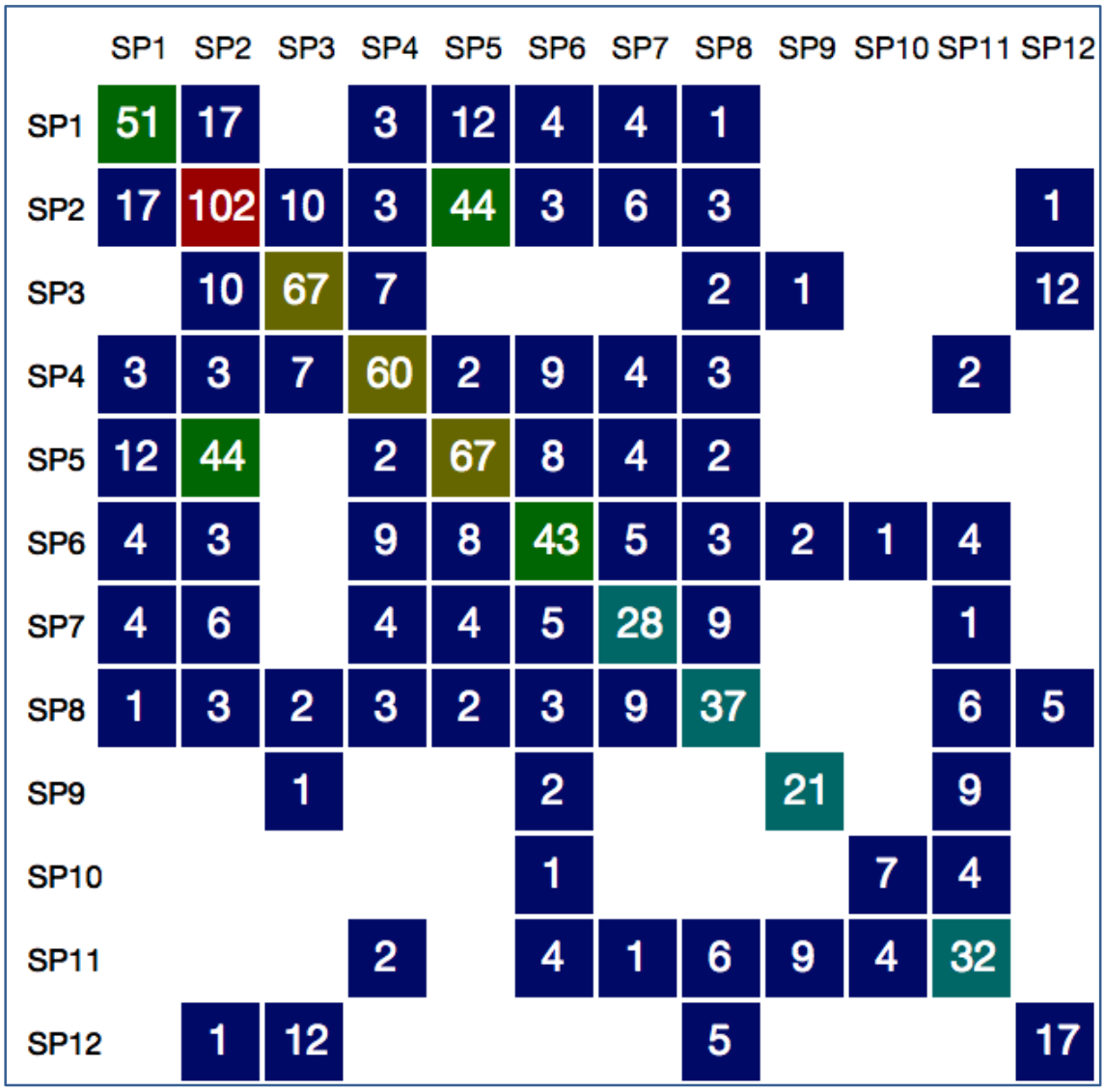


Figure 4: Matrix of SP and cross SP publications in the Ramp-Up Phase, based on the SP affiliations of the publications authors.

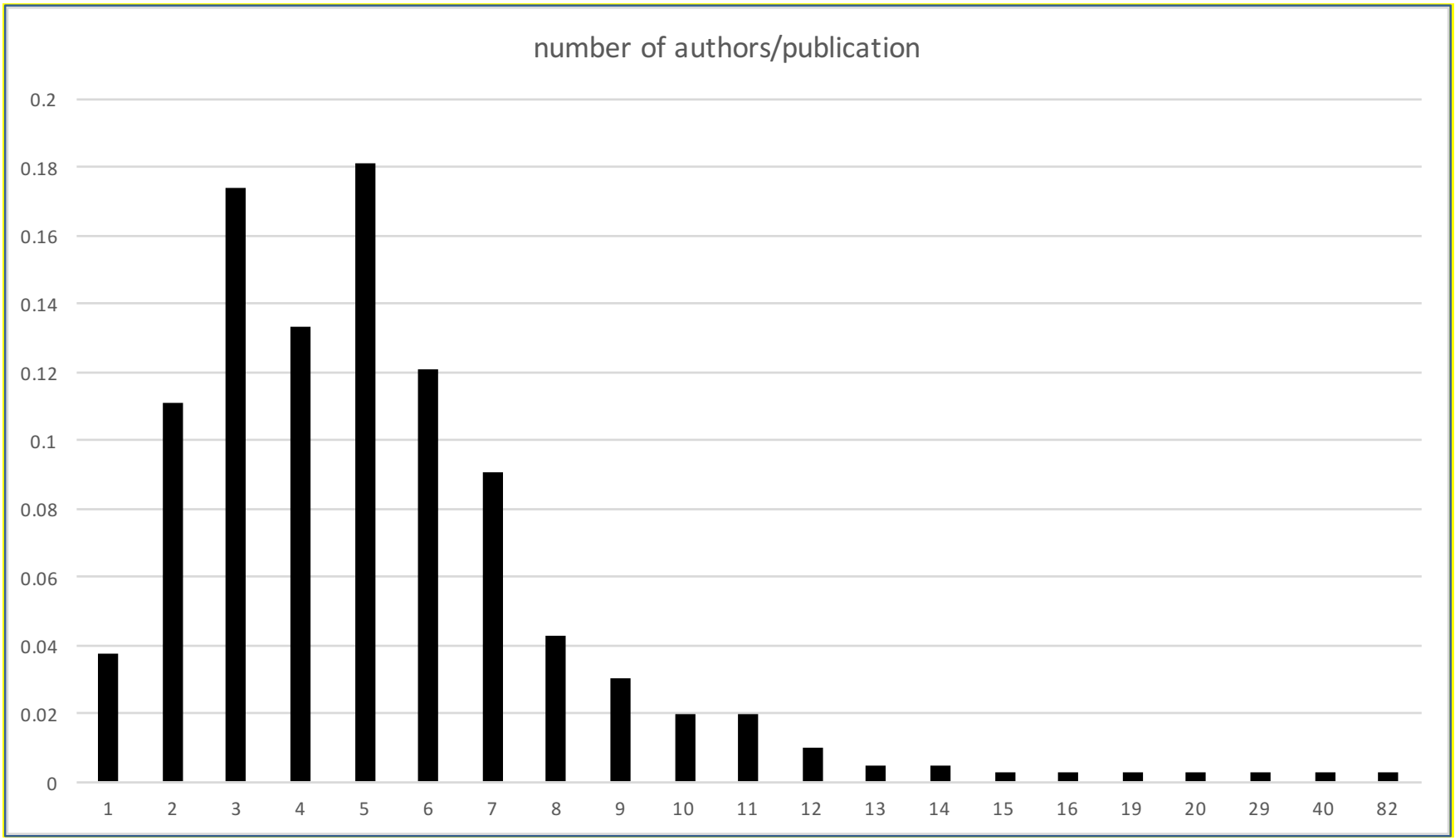


Figure 5: Fractions (y-axis) of publications with a given number of co-authors (x-axis).

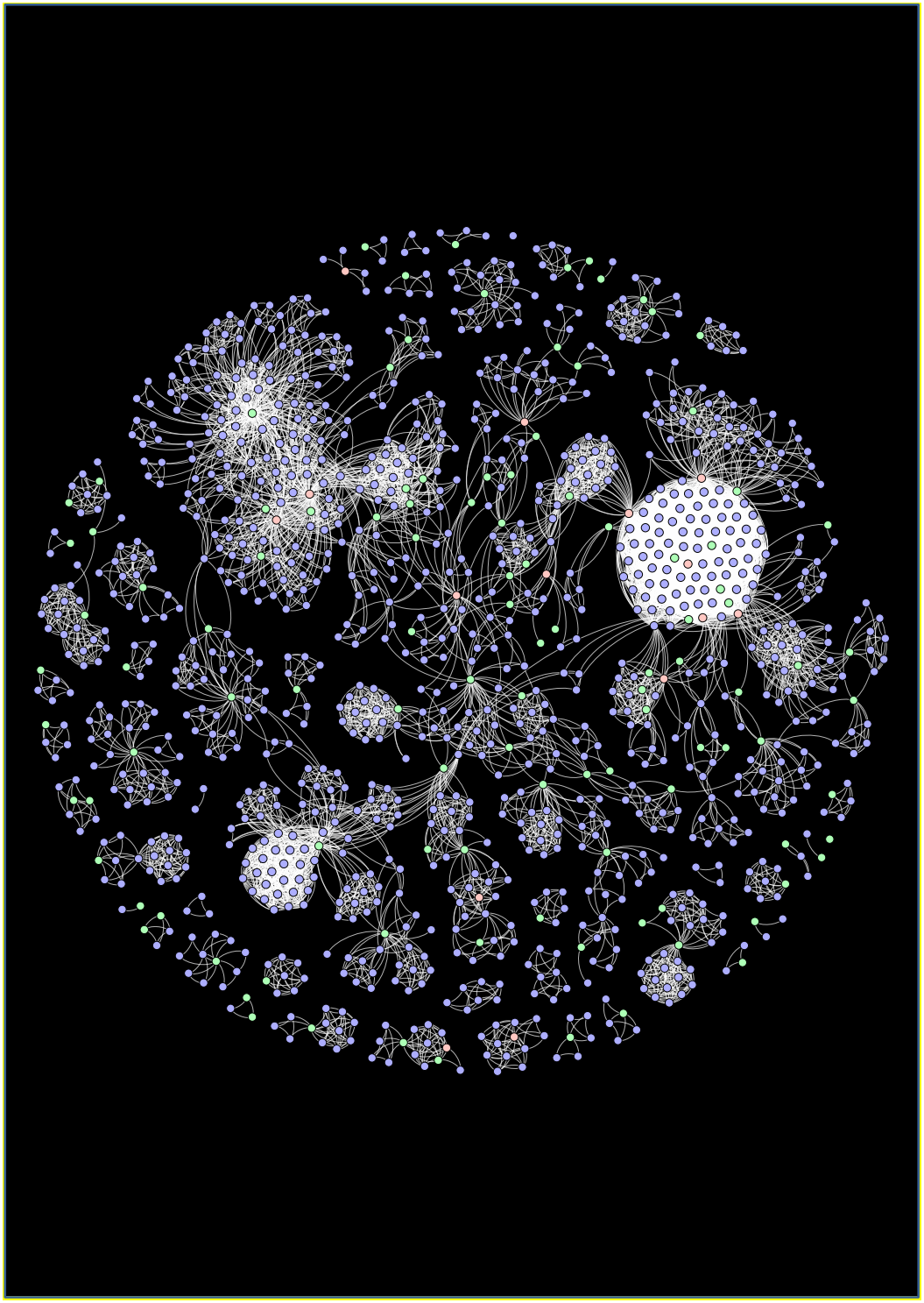


Figure 6: Collapsed co-author networks of publications.

Colours of circles (authors) are based on SP leadership function of the author, while the lines show co-authorship. Red circles represent leadership (Subproject, Work Package, Task) of the author in multiple SPs, green represent leadership of the author in a single SP, and blue circles represent authors that do not have leadership responsibilities in HBP.

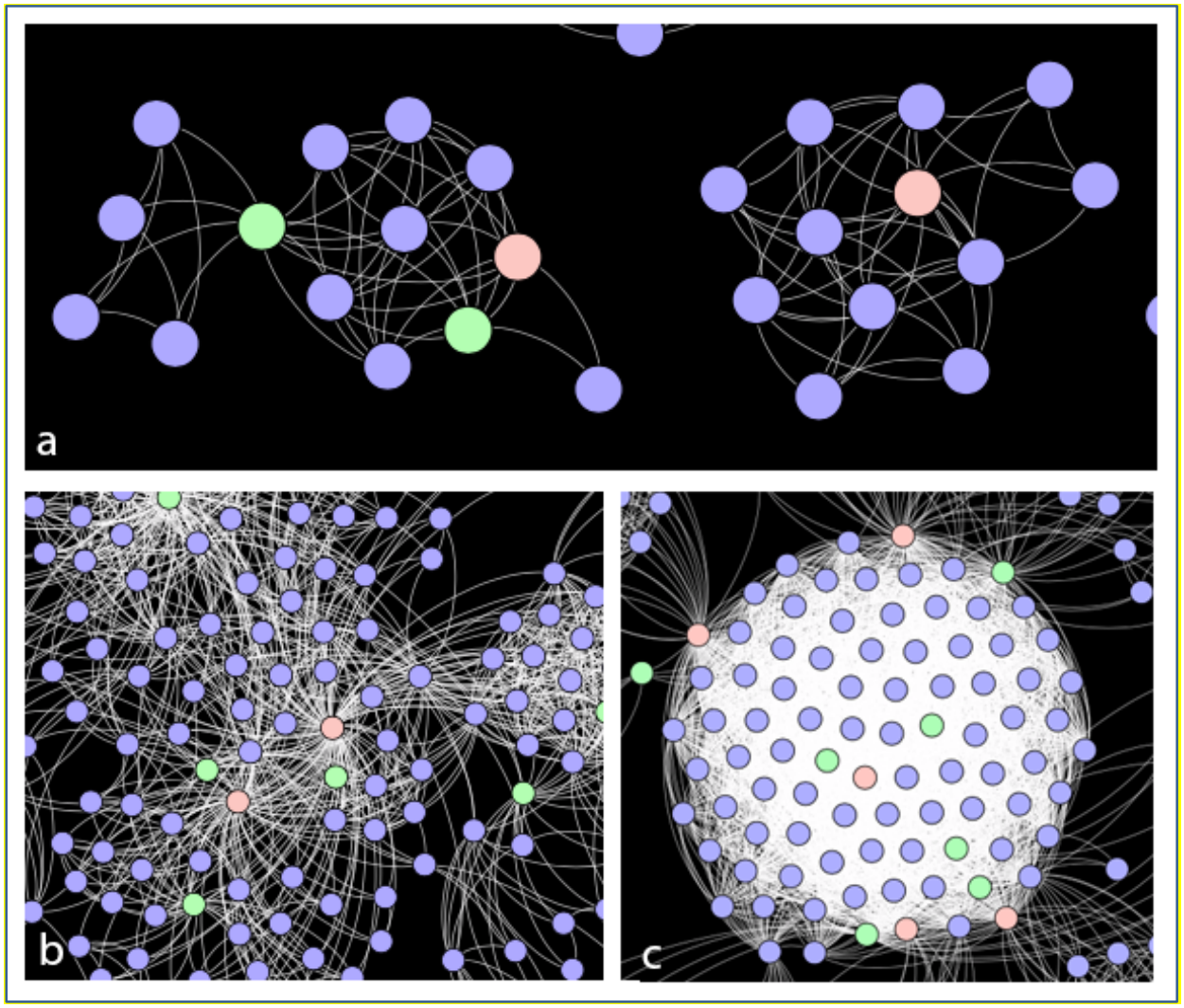


Figure 7: Close-up of examples of co-author cliques and super clusters shown in Error! Reference source not found..

1.4.6.2.2 Dissemination

Researchers in the Consortium release data to the community using a range of different options due to delays in the delivery of SP5 data repository and search capacities. For details on sites/repositories used please refer to Deliverables D1.4.4, D2.3.4, D3.7.4, D4.6.4, D5.8.4, D6.7.4, D7.7.5, D8.6.4, D9.7.4, and D10.4.4.

Of the 1'227 Consortium registered Dissemination Events/Activities a large number (1'002) were local events. The majority of these events were located in Europe (838), followed by North America (110), Asia (33), South America (12), Australia (6) and Africa (3). The remainder of activities took place online or via media channels that had global reach. For Dissemination Activity to country mapping please see Table 3 below.

Country	Events	Country	Events	Country	Events
Morocco	2	Finland	16	Serbia	6
South Africa	1	France	77	Slovakia	1
China	14	Germany	238	Slovenia	3
India	2	Greece	2	Spain	137
Japan	13	Hungary	4	Sweden	21

South Korea	2	Ireland	3	Switzerland	53
Singapore	1	Israel	19	Turkey	9
Taiwan	1	Italy	41	UK	59
Australia	6	Lithuania	7	Ukraine	1
Austria	41	Macedonia	1	Canada	11
Belgium	17	Netherlands	32	USA	99
Bulgaria	2	Norway	8	Argentina	1
Czech Rep	10	Poland	3	Brazil	3
Denmark	6	Portugal	11	Mexico	8
Estonia	2	Russia	8		

Table 3: Number of dissemination events per country.

Open source and software dissemination

The HBP has engaged in significant software construction and utilization activities over the Ramp-Up Phase. This activity stream is visible in the HBP Software Catalogue, hosted in the HBP Collaboratory.

The 212 software packages listed in the Software Catalogue are licensed under a variety of licenses, in each case chosen to reflect a community building and/or commercialization strategy of the originating institution. In some cases, modifications and enhancements are being made to software that predates the HBP. In these cases, the enhanced versions typically inherit the license of their predecessor.

License type	Number	%
Copyleft Opensource (GPL v2+, LGPL v2+, CeCILL)	43	20.28%
Liberal Opensource (MIT, Apache, BSD or variants)	26	12.26%
HBP Consortium only or to be negotiated	143	67.45%
Total	212	100.00%

Table 4: Number and types of software packages in the Software Catalogue

This shows that a significant number of Software Catalogue packages have been open-sourced, thereby contributing to adoption and standardization of various HBP-enhanced software packages and their respective data file formats.

Open Data: Collaboratory and Neuroinformatics Platforms

Similarly, the HBP started to put data online in the process of building the Neuroinformatics Platform. The bulk of the data released by the HBP in the Ramp-Up Phase was released with an NIP metadata search and with the actual datasets stored in the HBP Collaboratory. Where datasets had atlas viewers, the data was also available for interactive exploration through the first version of the HBP Atlas viewer. Currently the NIP search index holds metadata records for 2,094 datasets. This data requires an HBP Collaboratory account but these accounts are granted to anyone requesting an account by email.

https://nip.humanbrainproject.eu/

Open Data: Zenodo - HBP

In the Ramp-Up Phase, 44 datasets, presentations and publications were made available through Zenodo, a domain agnostic data-sharing tool which allocates DOIs to shared data. Of these published entities, 12 are open and 32 are restricted. The restricted datasets require an access request to the HBP prior to accessing.

https://zenodo.org/communities/hbp/

However, it became clear during the Ramp-Up Phase implementation that there were a number of limitations to Zenodo which limit its utility as a primary working and archive data repository.

1) Current Terms of Use provided by Zenodo make it unsuitable for primary long term storage. Zenodo provides no guarantee of data integrity or accessibility. This invalidates it as a primary archive respository. As a result, SGA1 with the reviewer approved DPIT plan will focus on providing a more focused HBP internal effort to meet data integrity and accessibility requirements.
2) Zenodo does not store data co-located with the supercomputers. As a result, any users of the data will need to download from Zenodo prior to use. Since many working datasets in the simulation and Neuroinformatics workflows at greater than 1TB, Zenodo would require a transfer overhead which is unacceptable for HBP workflow support. This presents a significant challenge and will be a key focus of the HBP Joint Platform teams for SGA1.

1.4.7 Standardisations

HBP employs and contributes to a large number of standards throughout the various domains in which it works. Listed below are key standards, which have been adopted by HBP or have been advanced by work in the Ramp-Up Phase.

OpenID Connect (OIDC)

The HBP Collaboratory relies on OIDC (https://en.wikipedia.org/wiki/OpenID_Connect) as its authentication and authorization standard. This standard provides a well-defined, protocol for coarse-grained authentication and delegation of Web applications and Web service APIs in a federated service infrastructure. This allows the HBP Platforms to interoperate for service authentication and facilitates multi-platform workflows. OIDC is widely implemented in third party web applications with authentication support for the OIDC services of Google, Amazon and other major vendors. This allows the HBP to more easily integrate third party web applications into the service ecosystem provided by the HBP.

REST services

HBP deploys much of the Platform software functionality as REST services. This architectural standard is well supported by frameworks in a variety of programming languages and represents a proven architectural pattern for end-user and enterprise applications. This model allows the easy construction of Web UIs for Platform functionality. It also allows for easy construction of programming language specific client APIs to facilitate easy integration of REST Service functionality into scientific workflows. Additionally, this architecture allows a clearly defined API which itself can be a standardization target.

W3C PROV

NIP leverages the W3C PROV model to represent experimental provenance. The general consensus is that future work on experimental and workflow provenance will also be based on W3C PROV.

Simulation: NEST

NEST is the standard HBP large-scale network level neural simulator, as described on the project website http://nest-simulator.org/:

"NEST is a simulator for spiking neural network models that focuses on the dynamics, size and structure of neural systems rather than on the exact morphology of individual neurons."

This simulator is the basis for simulation projects in SP4, SP6, SP9 and SP10. It also forms the basis of key functions of the Neurorobotics Platform produced by SP10. The HBP's contribution has been to enhance the simulator for key Use Cases inside the HBP and to reintegrate these enhancements back into the community.

Simulation: NEURON

NEURON is the standard HBP large-scale cellular model simulator, as described on the NEURON website https://www.neuron.yale.edu/neuron/what_is_neuron:

"NEURON is a simulation environment for modelling individual neurons and networks of neurons. It provides tools for conveniently building, managing, and using models in a way that is numerically sound and computationally efficient. It is particularly well-suited to problems that are closely linked to experimental data, especially those that involve cells with complex anatomical and biophysical properties."

NEURON is heavily used in SP6 modelling workflows and is considered an essential tool for understanding cellular to network level phenomena.

Model representation: PyNN

PyNN is extensively used throughout the HBP and by various parts of the community for representing brain models in a simulator agnostic fashion. In particular, PyNN is used in SP4, SP6, SP9 and SP10. PyNN models can be used on NEST, NEURON and Brian simulators. With current and future developments, neuromorphic hardware platforms are targeted. This cross-simulator capability is key to cross-simulator and neuromorphic platform validation along with productive software and model engineering efforts.

Model Representation: NeuroML2

NeuroML2 is the latest incarnation of the XML-based model description language for computational neuroscience. Historically, models produced in SP6 include features which could not be represented in NeuroML2. In an attempt to close this gap, Padraig Gleeson of Opensource Brain and modellers from the Blue Brain Project worked to identify and add some of the key features needed by SP6 models. As a result of this collaboration, the NEURON models released in the Blue Brain Neocortical Microcircuit reconstruction have also been converted and released as NeuroML2. See https://bbpteam.epfl.ch/nmc-portal/web/guest/downloads for more details.

1.4.8 Collaborations with other projects/programmes

The HBP pursued a two-pronged approach for developing collaborations with ongoing research programmes and initiatives, which resulted in diverse collaborations aimed at supporting the HBP in achieving its core objectives.

At the SP level more than 100 collaborations with research groups were established, leading to publications and, in some cases, the development of prototypes. In numerous cases, these collaborations included cooperation with research groups in third countries including the US, and in Latin America and Asia. These collaborations are described in greater detail in D13.4.5.

For example, Jülich was part of a large collaboration on Atlasing that included research institutes from around the world including Asia, Europe and the US. The EITN hosted several visits that included PIs from third countries including the US. The BBP organised a workshop including PIs from the US and Canada to define a community roadmap for the development of open and unifying models of hippocampus. King's College London organised a 3-day workshop (11-13 June 2015) with Fondation Brocher to support cross-SP and external stakeholder engagement on the future of Neuroscience that included PIs from the US. UHEI

and UMAN jointly organised a workshop series entitled “NICE Workshop” involving academia, industry and funding agencies to develop a strategy document for neuromorphic computing. Discussions with the Innovative Medicines Initiative (IMI) resulted in an agreement to jointly organise a workshop on platform and data technologies that will involve the technical teams from the IMI projects EMIF, AETIONOMY and also EPAD to take place in June 2016. SP13 engaged in several discussions with the US BRAIN. While there is an interest to identify ways to collaborate a concrete plan needs still to be defined. SP13 also built solid and trustful relations with FLAG-ERA, paving the way to bring on board the first six Partnering Projects funded through FLAG-ERA.

1.5 Contact

Project public website: https://www.humanbrainproject.eu/en/

Main contact details:

Prof. Philippe Gillet
EPFL SB IPHYS EPSL
PH B2 392 (Bâtiment PH), Station 3
CH-1015 Lausanne
Switzerland

List of beneficiaries:

Beneficiary N.	Short name	Full name	Contact	Country
1	EPFL	École Polytechnique Fédérale de Lausanne	Prof Philippe GILLET	Switzerland
2	AALTO	Aalto-korkeakoulusäätiö	Prof Lauri PARKKONEN, Prof Riitta HARI	Finland
3	AUEB	Athens University of Economics and Business	Prof Vasilis VASSALOS	Greece
4	BSC	Barcelona Supercomputing Center - Centro Nacional de Supercomputacion	Prof Matteo VALERO	Spain
5	BUW	Bergische Universität Wuppertal	Prof Andreas FROMMER	Germany
6	BSMJ	Bloomfield Science Museum Jerusalem (BSMJ)	Maya HALEVY	Israel
7	CNRS	Centre National de la Recherche Scientifique	Prof Yves FRÉGNAC	France
8	UOXF	The Chancellor, Masters and Scholars of the University of Oxford	Prof Chris PONTING	United Kingdom
9	CEA	Commissariat a l'énergie atomique et aux énergies alternatives	Prof Stanislas DEHAENE	France

10	CINECA	Consorzio Interuniversitario Cineca	Dr Giovanni ERBACCI	Italy
11	DMU	De Montfort University	Prof Bernd Carsten STAHL	United Kingdom
12	EKUT	Eberhard-Karls-Universitat Tuebingen	Prof Jan BORN, Prof Martin GIESE	Germany
13	ENS	Ecole Normale Superieure	Prof Antoine TRILLER	France
14	ESI	Ernst Struengmann Institute GGMBH	Prof Pascal FRIES, Prof Wolf SINGER	Germany
15	ETHZ	Eidgenössische Technische Hochschule Zürich	Prof Thomas SCHULTHESS	Switzerland
16	FT	Fonden Teknologirådet	Mr Lars KluVER	Denmark
17	JUELICH	Forschungszentrum Jülich GmbH	Prof Thomas LIPPERT, Prof Katrin AMUNTS	Germany
18	FG	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	Prof Michael GRIEBEL	Germany
19	FCHAMP	Fundação D. Anna Sommer Champalimaud E Dr. Carlos Montez Champalimaud	Dr Rui COSTA	Portugal
20	GRS	German Research School for Simulation Sciences GmbH	Dr Paolo CARLONI	Germany
21	HUJI	Hebrew University of Jerusalem	Prof Idan SEGEV	Israel
22	UDUS	Heinrich Heine Universität Düsseldorf	Prof Katrin AMUNTS	Germany
23	CHUV	Hospices Cantonaux CHUV	Prof Richard FRACKOWIAK, Dr Ferath KHERIF	Switzerland
24	HITS	HITS GmbH	Prof Rebecca WADE	Germany
25	ICM	Institut de Cerveau et de la Moelle Epinière Fondation	Prof Mathias PESSIGLIONE	France
26	INRIA	Institut National de Recherche en Informatique et en Automatique	Olivier FAUGERAS, Bertrand THIRION	France
27	IP	Institut Pasteur	Prof Jean-Pierre CHANGEUX	France

28	IEM HAS	Institute of Experimental Medicine, Hungarian Academy of Sciences	Prof Tamás FREUND	Hungary
29	UFRA	Johann Wolfgang Goethe Universität Frankfurt am Main	Prof Gabriel WITTUM	Germany
30	KIT	Karlsruher Institut für Technologie	Dr Marcus HARDT	Germany
31	KI	Karolinska Institutet	Prof Sten GRILLNER	Sweden
32	KCL	King's College London	Prof Nikolas ROSE	United Kingdom
33	KTH	Kungliga Tekniska Högskolan	Prof Jeanette Hellgren KOTALESKI	Sweden
34	LENS	Laboratorio Europeo per la Spettroscopia Non Lineare	Prof Francesco PAVONE	Italy
35	LNU	Linnéuniversitetet	Prof Abdul MOHAMMED	Sweden
36	IMU	Medizinische Universität Innsbruck	Prof Alois SARIA	Austria
37	UoA	National and Kapodistrian University of Athens	Prof Yannis IOANNIDIS	Greece
38	OIST	Okinawa Institute of Science and Technology Graduate University	Prof Erik DE SCHUTTER	Japan
39	POLITO	Politecnico di Torino	Prof Enrico MACII	Italy
41	UCAL	The Regents of the University of California	Dr Maryann MARTONE	United States
42	RWTH	Rheinisch-Westfälische Technische Hochschule Aachen	Prof Torsten KUHLEN	Germany
43	RIKEN	Riken the Institute of Physical and Chemical Research	Dr Naotaka FUJII	Japan
44	MCGILL	Royal Institution for the advancement of learning McGill University	Prof Alan EVANS	Canada
45	UHEI	Ruprecht-Karls-Universität Heidelberg	Prof Karlheinz MEIER	Germany
46	SU	Sabanci University	Prof Volkan OZGUZ, Prof Yaşar GuRBUz	Turkey
47	SAP	SAP AG	Dr Frank GOTTFRIED	Germany

48	CWI	Stichting Centrum voor Wiskunde en Informatica	Prof Martin KERSTEN	Netherlands
49	SKU	Stichting Katholieke Universiteit	Prof Paul TIESINGA	Netherlands
50	VU	Stichting VU-VUMC	Prof Huib MANSVELDER	Netherlands
51	TUC	Technical University of Crete	Prof Minos GAROFALAKIS	Greece
52	TUD	Technische Universität Dresden	Dr.-Ing Rene SCHUFFNY	Germany
53	TUM (+FORTISS)	Technische Universität München	Prof Aloïs KNOLL	Germany
54	TUGRAZ	Technische Universität Graz	Prof Wolfgang MAASS	Austria
55	TAU	Tel Aviv University	Prof Yoav BINYAMINI	Israel
56	UMU	Umeå Universitet	Dr Lars NYBERG	Sweden
57	UAM	Universidad Autónoma de Madrid	Prof Francisco CLASCA	Spain
58	UGR	Universidad de Granada	Prof Eduardo ROS	Spain
59	UPM	Universidad Politécnica de Madrid	Prof Javier DE FELIPE	Spain
60	URJC	Universidad Rey Juan Carlos	Prof Luis PASTOR	Spain
61	UNIPV	Università degli Studi di Pavia	Prof Egidio D'ANGELO	Italy
62	UBERN	Universität Bern	Prof Walter SENN	Switzerland
63	UZH	Universität Zürich	Prof Bruno WEBER	Switzerland
64	UB	Universitat de Barcelona	Prof Mel SLATER	Spain
65	UPF	Universitat Pompeu Fabra	Prof Gustavo DECO	Spain
66	UGENT	Universiteit Gent	Prof Benjamin SCHRAUWEN	Belgium
67	UMB	Norges miljø- og biovitenskapelige universitet	Prof Gaute T. EINEVOLL	Norway

68	UIO	Universitetet i Oslo	Prof Jan BJAALIE	Norway
69	UCAM	University of Cambridge	Prof Barbara SAHAKIAN	United Kingdom
70	UCL	University College London	Prof Alex M. THOMSON, Prof Neil BURGESS, Prof John ASHBURNER	United Kingdom
71	UEDIN	The University of Edinburgh	Prof Seth GRANT	United Kingdom
72	UHAIFA	University of Haifa	Prof Avi KARNI	Israel
73	UMAN	University of Manchester	Prof Steve FURBER	United Kingdom
74	USC	University of Southern California Corp	Prof Arthur TOGA	United States
75	UTHSC	University of Tennessee Health Science Center	Prof Robert W. WILLIAMS	United States
76	UB2	Université de Bordeaux	Prof Jean-Marc ORGOGOZO	France
77	UU	Uppsala Universitet	Prof Kathinka EVERS	Sweden
78	WIS	Weizmann Institute of Science	Prof Yadin DUDAI	Israel
79	WMC	Wenzhou Medical College	Prof Yun WANG	China
80	YALE	Yale University	Prof Michael HINES	United States
81	LUMC	Academisch Ziekenhuis Leiden - Leids Universitair Medisch Centrum	Mr Paul BILARS	Netherlands
82	CSIC	Agencia Estatal Consejo Superior de Investigaciones Científicas	Prof Antonio FIGUERAS	Spain
83	CNR	Consiglio Nazionale delle Ricerche	Dr Michael PUSCH	Italy
84	UNIC	Edex-Educational Excellence Corporation Limited	Dr Nicos PERISTIANIS	Cyprus
85	EBRI	European Brain Research Institute Rita Levi-Montalcini fondazione - EBRI	Prof Giuseppe NISTICO'	Italy

86	UH	Helsingin yliopisto	Dr Eero CASTREN	Finland
87	JSI	Institut Jožef Stefan	Prof Jadran LENARCIC	Slovenia
88	IST	Institute of Science and Technology Austria	Prof Thomas A. HENZINGER	Austria
89	KUL	Katholieke Universiteit Leuven	Prof Paul VAN DUN	Belgium
90	KNAW	Koninklijke Nederlandse Akademie van Wetenschappen - Knaw	Prof Dr Pieter ROELFSEMA	Netherlands
91	MU	Middlesex University Higher Education Corporation	Prof Balbir BARN	United Kingdom
92	SNS	Scuola Normale Superiore di Pisa	Prof Fabio BELTRAM	Italy
93	SSSA	Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna	Prof Pierdomenico PERATA	Italy
94	FZI	Stiftung FZI Forschungszentrum Informatik am Karlsruher Institut für Technologie	Dipl. Wi.-Ing. Michael FLOR	Germany
95	SIB	Swiss Institute of Bioinformatics	Prof Ron APPEL	Switzerland
98	TASMC	The Foundation for Medical Research Infrastructural Development and Health Services next to the Medical Center Tel Aviv	Prof Talma HENDLER	Israel
99	TUT	TTY-Säätiö	President Markku KIVIKOSKI	Finland
100	UCLM	Universidad de Castilla – La Mancha	Prof José Julián Garde LOPEZ-BREA	Spain
101	UNIBAS	Universität Basel	Prof Dr Edwin CONSTABLE	Switzerland
102	UNIBI	Universität Bielefeld	Ms Iris LITTY	Germany
103	UKE	Universitätsklinikum Hamburg-Eppendorf	Prof Dr Uwe Koch GROMUS	Germany
104	AMU	Université d'Aix Marseille	Prof Yvon BERLAND	France
105	UJF	Université Joseph Fourier Grenoble 1	Mr Patrick LEVY	France
106	UCBL	Université Lyon 1 Claude Bernard	Mr Francois Noel GILLY	France

107	UPMC	Université Pierre et Marie Curie – Paris 6	Prof Jean CHAMBAZ	France
108	UM	Universiteit Maastricht	Prof Bernadette JANSMA	Netherlands
109	UvA	Universiteit van Amsterdam	Prof Dr Louise J. Gunning SCHEPERS	Netherlands
110	ULEEDS	University of Leeds	Mr Martin HAMILTON	United Kingdom
111	SURREY	University of Surrey	Ms Sue ANGULATTA	United Kingdom
112	UoS	University of Sussex	Ms Rossana DOWSETT	United Kingdom
113	HUG	Hôpitaux Universitaires de Genève	Prof Giovanni B. FRISONI	Switzerland

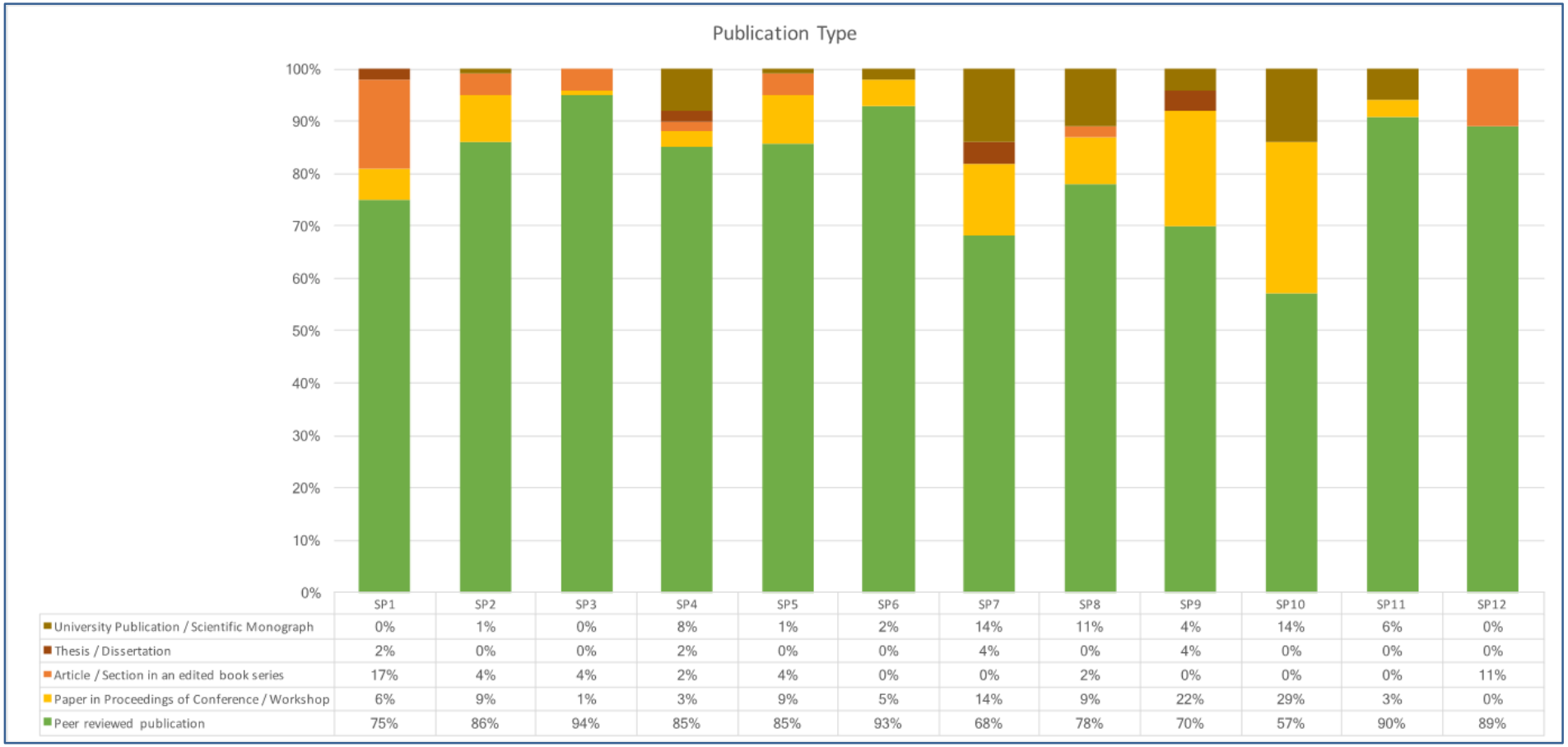
2. Use and dissemination of foreground

2.1 Section A: Dissemination measures

2.1.1 Scientific publications

During the Ramp-Up Phase 419 publications were published by the Consortium. Of these, 340 were peer-reviewed. When looking at the types of publications (Figure 8) and the ratio of open access/not open access (Figure 9) across the different SPs there is no obvious trend that would confirm any perceived separation of the Consortium into research SPs (SP1-4) and Platform SPs (SP5-10). The addition of Component/Use Case layer in SGA1 may allow a closer look at differences based on the type of result (data, model, software, service, hardware, report) produced.

The full list of publications is reported in **Annex 1**.



	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10	SP11	SP12
University Publication / Scientific Monograph	0%	1%	0%	8%	1%	2%	14%	11%	4%	14%	6%	0%
Thesis / Dissertation	2%	0%	0%	2%	0%	0%	4%	0%	4%	0%	0%	0%
Article / Section in an edited book series	17%	4%	4%	2%	4%	0%	0%	2%	0%	0%	0%	11%
Paper in Proceedings of Conference / Workshop	6%	9%	1%	3%	9%	5%	14%	9%	22%	29%	3%	0%
Peer reviewed publication	75%	86%	94%	85%	85%	93%	68%	78%	70%	57%	90%	89%

Figure 8: Percentage of different types of publications per SP.

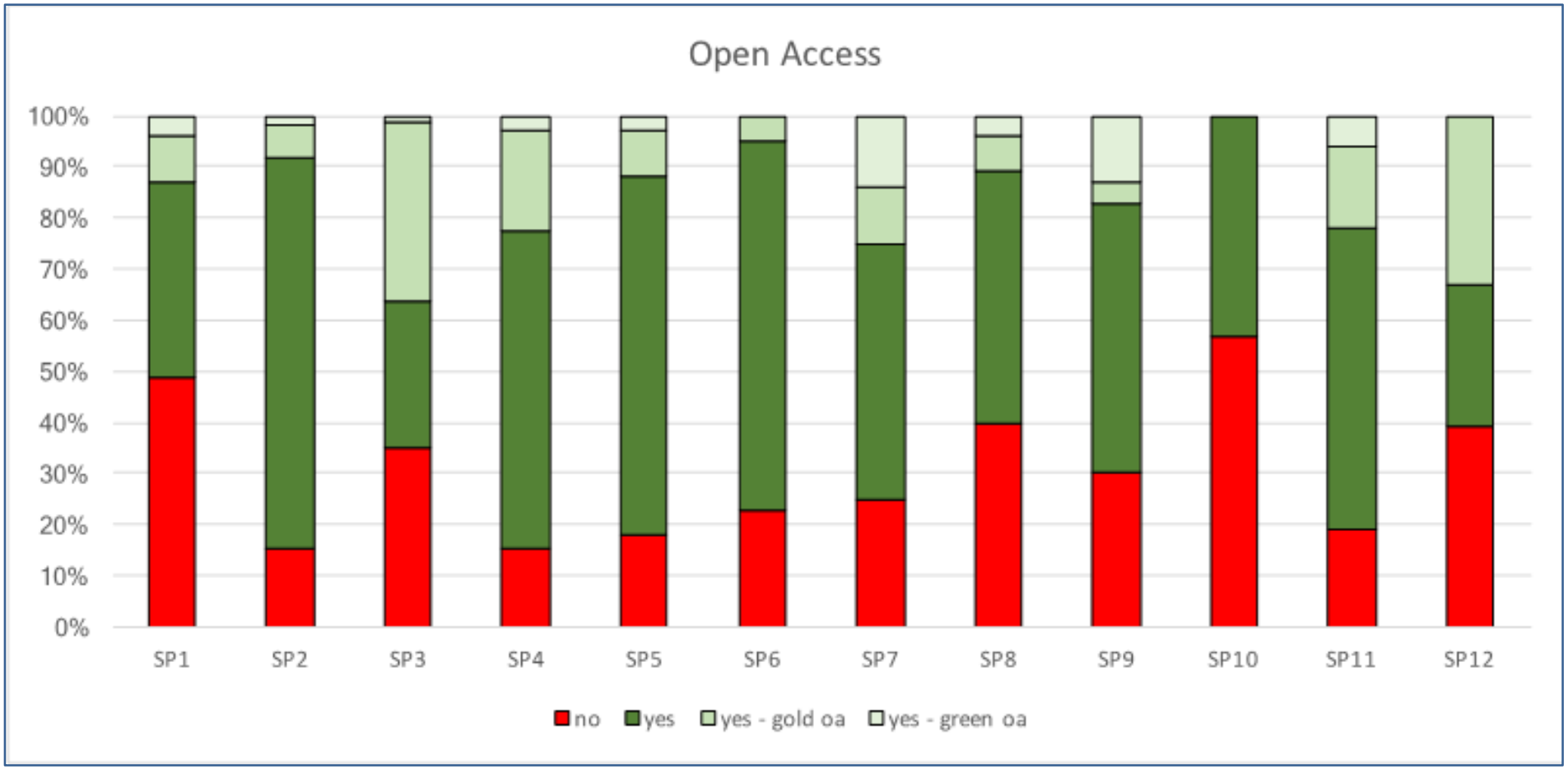


Figure 9: Percentage of open access/non open access publications per SP.

2.1.2 Dissemination events/activities

During the RUP phase 1'227 dissemination events/activities occured. The full dissemination list of is reported in Annex 2.

Figure 10 is providing an overview on the partners contributions to the disseminations events/activities. Not surprising but still interesting is that only a small number of Partners are responsible for a large percentage of all dissemination activities (Figure 10).

Country mapping of the dissemination events/activities is provided within section *1.4.6.2.2 Dissemination*.

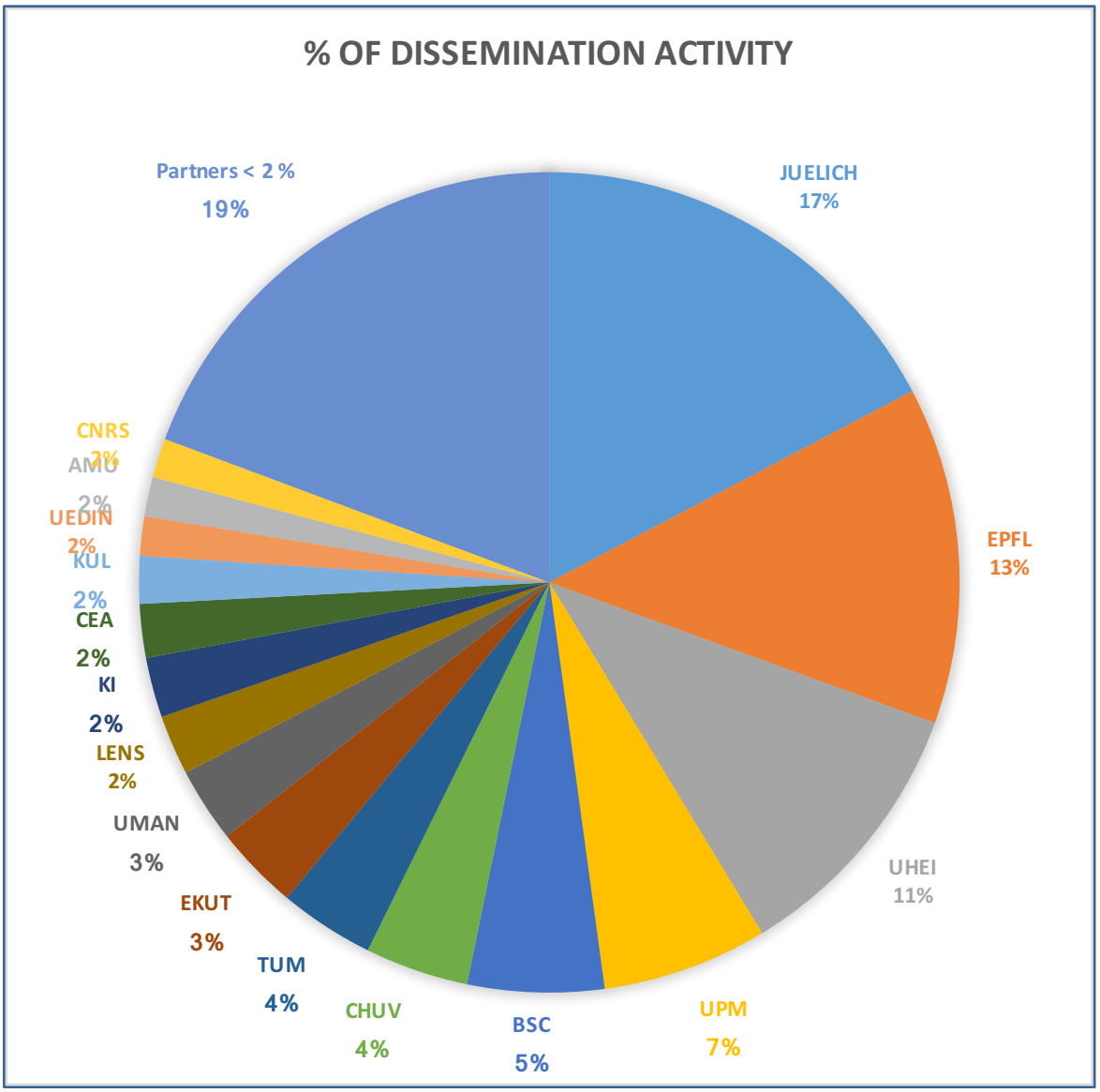


Figure 10: Partners and their relative contribution to Dissemination Events/Activities during the RUP.

2.1.3 Patents

In the Ramp-Up Phase, the HBP was primarily focused on the initial integration of scientific workflows with software and infrastructure developments. Since a key part of the strategy is community building, software developments are often contributed back to the community as open source projects, rather than being the subject of extensive patent activity. As a result, the patent activity of the HBP for the Ramp-Up Phase is limited. It is expected that this will increase with as formal innovation activities increase in SGA1 and beyond and as the infrastructure becomes a productive tool for HBP internal and external researchers. For specific patent activity in HBP, see Section B: Exploitable foreground and plans.

3. Report on societal implications

A General Information	
Grant Agreement Number:	604102
Title of Project:	Human Brain Project
Name and Title of Coordinator:	Prof. Philippe Gillet, EPFL (CH)

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	Yes
2. Please indicate whether your project involved any of the following issues	**YES**
RESEARCH ON HUMANS	
• Did the project involve children?	X
• Did the project involve patients?	X
• Did the project involve persons not able to give consent?	X
• Did the project involve adult healthy volunteers?	X
• Did the project involve Human genetic material?	X
• Did the project involve Human biological samples?	X
• Did the project involve Human data collection?	X
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (e.g. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	X
• Did the project involve tracking the location or observation of people?	X
RESEARCH ON ANIMALS	

• Did the project involve research on animals?	X
• Were those animals transgenic small laboratory animals?	X
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc.)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc.)?	
DUAL USE	
• Research having direct military use	X
• Research having the potential for terrorist abuse	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Scientific Coordinator (SP leader & Co-leaders)	4	18
Work package leaders	8	68
Experienced researchers (Task leaders)	29	187
PhD Students	Not available	Not available
Other	Not available	Not available
Scientific Coordinator (SP leader & Co-leaders)	4	18

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men:	Not available

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○	Yes
	X	No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
❑	Design and implement an equal opportunity policy	○	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
○	Other:					

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

X Yes- please specify: https://education.humanbrainproject.eu/web/hbp-education-portal/educationalevents

○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

X Yes- please specify: https://education.humanbrainproject.eu

○ No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

X Main discipline[10]: **neuroscience, clinical medicine, biological sciences, mathematics and computer sciences, computer engineering, robotics**

X Associated discipline[10]: **Health sciences**

X Associated discipline[10]: **Educational sciences**

G Engaging with Civil society and policy makers

[10] Insert number from list below (Frascati Manual).

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	X ○	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ○ No
- X Yes- in determining what research should be performed
- X Yes - in implementing the research
- X Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	X ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- X Yes- in framing the research agenda
- X Yes - in implementing the research agenda
- X Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- X Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- X Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights X **Information Society** Institutional affairs Internal Market Justice, freedom and security X **Public Health** Regional Policy X **Research and Innovation** Space Taxation Transport	

13c If Yes, at which level?

- X Local / regional levels
- X National level
- X European level
- X International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	339
To how many of these is open access[11] provided?	168
How many of these are published in open access journals?	Not known
How many of these are published in open repositories?	Not known
To how many of these is open access not provided?	91 (Confirmed number, but there could be more)
Please check all applicable reasons for not providing open access:	
X publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available X no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[12]: ……	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		One
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	None
	Registered design	None
	Other	
17. How many spin-off companies were created / are planned as a direct result of the project?		One
Indicate the approximate number of additional jobs in these companies:		

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	❑	In small & medium-sized enterprises
X	Safeguard employment, or	❑	In large companies

❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs: *Estimation assumption: (Tot n. of person months / 30)*1.25* Difficult to estimate / not possible to quantify	*Indicate figure:* 306.50 (Indicative figure) ❑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

X Yes ○ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

X Yes ○ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

X	Press Release	X	Coverage in specialist press
X	Media briefing	X	Coverage in general (non-specialist) press
X	TV coverage / report	X	Coverage in national press
X	Radio coverage / report	X	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
X	DVD /Film /Multimedia	X	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

X	Language of the coordinator	X	English
X	Other language(s)		

[11] Open Access is defined as free of charge access for anyone via the internet.
[12] For instance: classification for security project.