A European Center for Brain Simulation

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Goals & Ambition

**Build an ICT facility to simulate the brain across species, ages & diseases**

- **Neuroscience:**
  - Understand the brain at all levels of organization (genes to whole brain); simulate the brain in any species at any age with any disease; heal the diseases of the brain.
- **Industrial Screening:**
  - Screen the brain at all levels (genes to whole brain); develop new ICT for screening.
- **Neuroinformatics:**
  - Federate experimental data from all over the world; design and build an ever‐scale database for the brain and brain models; database the brain; Predictive Reverse Engineering to build detailed brain models from non‐invasive data.
- **Brain Probes:**
  - Build new ICT technologies to probe the structure and function of the brain and biological organisms in greater depth, with more detail and faster than ever before.
- **Disease:**
  - Federate clinical data on the Human Brain; study the Diseasome as a complex system.
- **Modeling:**
  - Generate mathematical models for all levels of biological organization of the brain (structure/geometry/function/computation); establish parameters, generate equations, build libraries, develop algorithms, enable multi-scale models.
- **Simulation:**
  - Build software applications to model, simulate, visualize and diagnose biologically detailed brain models; build simulation engines, libraries, procedures, workflows; build an internet accessible European facility for simulation based brain research.
- **Supercomputing:**
  - Establish an European Exascale HPC Facility for brain simulations; build a European HPC Design & Optimization Centre to design and optimize HPC for any simulation challenge; enable hardware/software co-design & co-development for supercomputers.
- **Visualization:**
  - Enable interactive, collaborative and visual steering of supercomputing (HPC as a desktop virtual environment); build remotely accessible virtual laboratories; build a simulation cocktail for the brain; create a European Facility for Scientific Multimodal Production (for science, education & society).
- **Analytics:**
  - Build a suite of analytics applications to process brain data (signal analytics, visual analytics, real‐time analytics, auto‐analytics); build data display applications for complex data (multidimensional data; visualizing complexity).
- **Computational Intelligence:**
  - Discover the essential mathematical, physical and chemical principles of neural information processing, emergent functions, complex behavior & cognition.
- **BrainIT:**
  - Build a European Facility for Neurocomputing Engineering; design and build neural computers, intelligent devices and software.
- **Neurorobotics:**
  - Enable a real‐time closed loop between virtual and physical robots and brain simulations on supercomputers.
- **Education:**
  - Create virtual centers for education; create 3D internet technologies; produce multimedia & internet based training programs & workshops.
Impact

- **Impact on ICT (Screening Life)**
  - Advanced ICT technologies for high throughput multiomics screening

- **Impact on ICT (Data Deluge)**
  - New strategies to store, manage, and mine exascale volumes of data
  - New strategies to predict unknown data from data at other levels of biological information or in other species (Predictive Reverse Engineering)

- **Impact on ICT (Computing)**
  - Boost Europe's role in global HPC
  - Create a European design & configuration center for exascale HPC
  - Intelligent software & hardware devices
  - Neuromorphic computers

- **Impact on ICT (Global Collaboration)**
  - A new generation of virtual laboratories for collaborative and interactive research
  - Remotely accessible immersive environments

- **Impact on Neuroscience**
  - A unifying agenda
  - A new way of integrating data and knowledge and of testing hypotheses
  - Insight into the structural and functional design of biological intelligence

- **Impact on mental health**
  - A systems view of all brain diseases
  - A strategy to study the causes of any brain disorder
  - Reduce the incidence and impact of brain disease; contribute to individual and family well-being, reduce the impact on national economies and health services.

- **Impact on Industry**
  - ICT methods for pharmaceutical companies (disease and drug simulation; simulation for drug screening and for rational design of new drugs)
  - ICT tools for high-tech SMEs offering high-throughput screening services.
  - Simulation of neuroprosthetics, and surgery
  - New Brainprobes for clinical diagnostics
  - New role for simulation-based science

- **Impact on education and skill base**
  - Development of key skills in life sciences (multiomics) and simulation-based science.
  - New immersive multimedia tools for education

Integration

- **Disciplines**
  - ICT (transform & enable),
  - Life Science (data & knowledge; computation),
  - Health & Medicine (mental health),
  - Materials (research & development; screening, diagnostics),
  - Physics, Mathematics, Chemistry (models of all levels of biology)
  - Science & Society (3D internet education, psychology, philosophy, ethics)

- **Countries**
  - All EU countries
  - USA, Japan, China, Russia, Australia, Latin America, Africa

- **EU Industries**
  - ICT (HPC, visualization and analytics, neuromorphic and brain-inspired computing, Internet)
  - Bio-tech,
  - Bio-services,
  - Medical devices
  - Pharmaceuticals
  - Robotics.
Plausibility

- Neuroscience:
  - 120,000 neuroscientists, vast amounts of fragmented data.
- Industrial Screening:
  - Rapidly falling costs
  - Data deluge from High Throughput technologies
- Neuroinformatics:
  - Already possible to database all past and current data
- Brain Probes:
  - Organic, nano-, micro- and other physical devices to probe the brain in more detail, in greater depth and faster than ever before
  - Rapidly growing industry
- The disease:
  - The brain disease pandemic: 560 diseases, 35% of the population affected, over €800 billion p.a. for Europe alone.
  - Huge need for understanding, diagnosis and treatment
  - Unique opportunities to examine brain disorders as a complex emergent system;
  - Identification of connections between diseases: genetic, protein, cellular, circuit, systems-level constraints on the functioning of the healthy brain
- Modeling:
  - Applied mathematics sufficiently advanced to describe structural (geometrical) and functional (computational) aspects of the brain with biological precision

Simulation:
- Software Engineering (engines, libraries, workflows; applications, internet technologies); ready to build simulators across all levels of biology
- Supercomputing:
  - Supercomputing power already sufficient for circuit-level simulation of whole rat brain
  - Exascale computers ready by 2018
  - Exascale power for multilevel simulation of whole human brain
- Visualization:
  - Supercomputers lack visual interactivity
  - Current PC-derived technologies inadequate
  - Supercomputing power for real-time interactive visualization, new rendering techniques, holography.
- Computational Intelligence:
  - Tools to extract the essence of neural information processing systems already available
  - Require accurate brain models
- BrainIT:
  - Neurocomputers and virtual reality
  - Brain IT computer systems ready for use
- Neurorobotics:
  - Virtual and physical environments for a brain
- Education:
  - The 3D internet is coming...
- Science & Society:
  - Society wants, can and should be closer to science and its implications...

Interest and Support

- Switzerland provides core infrastructure and operational support
- Each pillar & institution provides infrastructure and operational support
- Industry (Computing, Big Pharma, Bio-tech, Bio-services) is expressing interest & matching support