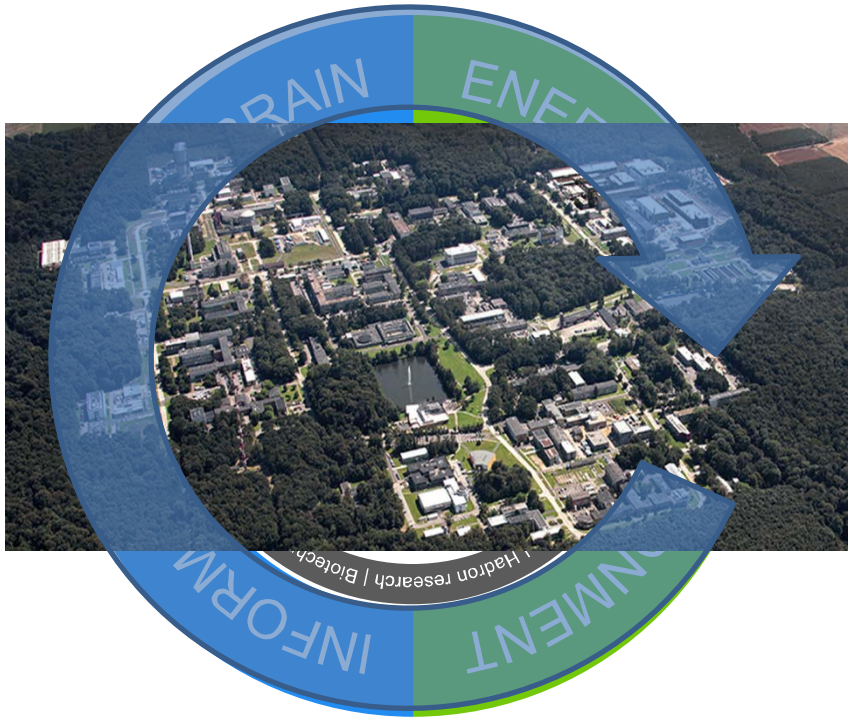
JÜLICH
FORSCHUNGSZENTRUM

Research at Forschungszentrum Jülich in the Era of Digitalisation

International Workshop on Quantum Annealing and its Application in Science and Industry (QuAASI‘16)

Prof. Dr.-Ing. Wolfgang Marquardt, 26/07/2016

Science Campus Jülich



~ 5,700 staff members

Budget (2015): **558 mio. €**

- Institutional funding: **320 mio. €**
- Third party funding: **238 mio. €**

Project management: **1,6 billion €**

Projektträger Jülich
Forschungszentrum Jülich

ETN
Projektträger
Energie • Technologie • Nachhaltigkeit

Teaching:

~ 900 Phd students (Campus Jülich)

~ 350 Trainees

Research for the future for
key technologies of the **next generation**

Strategy of Jülich : Use-Inspired Basic Research

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Research which has impact.

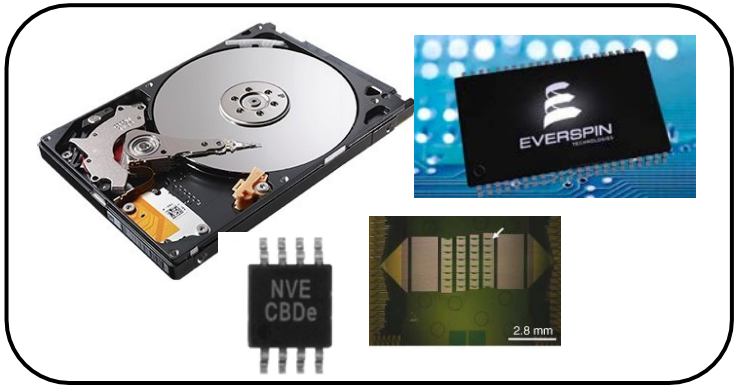
Impact is defined as 'any effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia'

Example of Use-Inspired Basic Research: DYNASORE

ERC Consolidator Grant DYNAmical magnetic excitations with Spin-Orbit interaction in REalistic nanostructures (Samir Lounis)

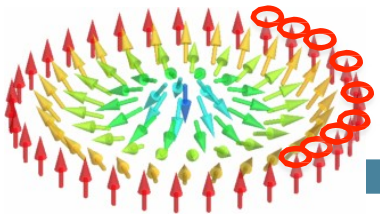
Today:
Information stored worldwide mainly using magnets

=



Challenges:
- Speed limit in writing & reading information
- Energy consumption

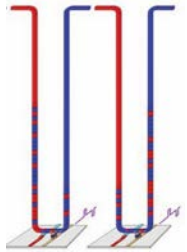
Tomorrow:
Establish localized magnetic textures as new magnetic bits for information technology



e.g. Skyrmion: hundreds atoms

$$\frac{\partial \psi}{\partial t} = -i\left(\frac{1}{\hbar}\hat{H}\psi\right)$$

Theory/method development for dynamic analysis



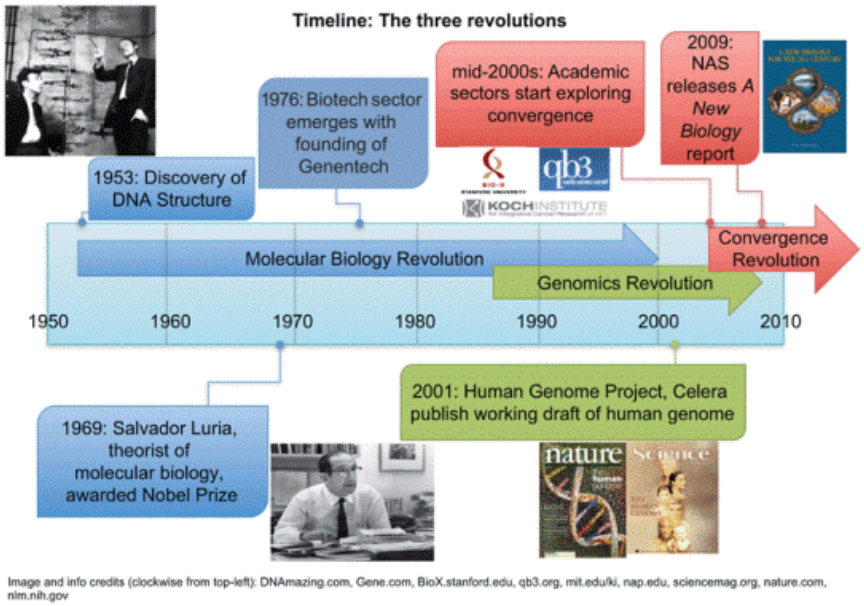
Use as race-track memory devices?

The „Convergence Paradigm“

„Convergence is a new paradigm that can yield critical advances in a broad array of sectors, from health care to energy, food, climate, and water!“

“The merging of distinct technologies, processing disciplines, or devices into a unified whole … It involves the coming together of different fields of study – particularly engineering, physical … and life sciences – through … the integration of approaches that were originally viewed as distinct and potentially contradictory.”

Convergence timeline



MIT White Paper 2011: The 3rd Revolution: The Convergence of the Life Sciences, Physical Sciences, and Engineering

Strategy of Jülich: Convergence & Coherence

Information

Bioinformatics;
Simulation across all scales

Modelling
Materials
Energy systems
Energy meteorology

Living Lab
Energy Campus

R&D platforms
EMPHASIS, DPPN, TERENO, AGRISM, …

Marginal Fields Lab

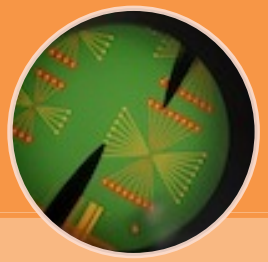
Energy

Emission processes with climate relevance

Bioeconomy

Our Vision

Information



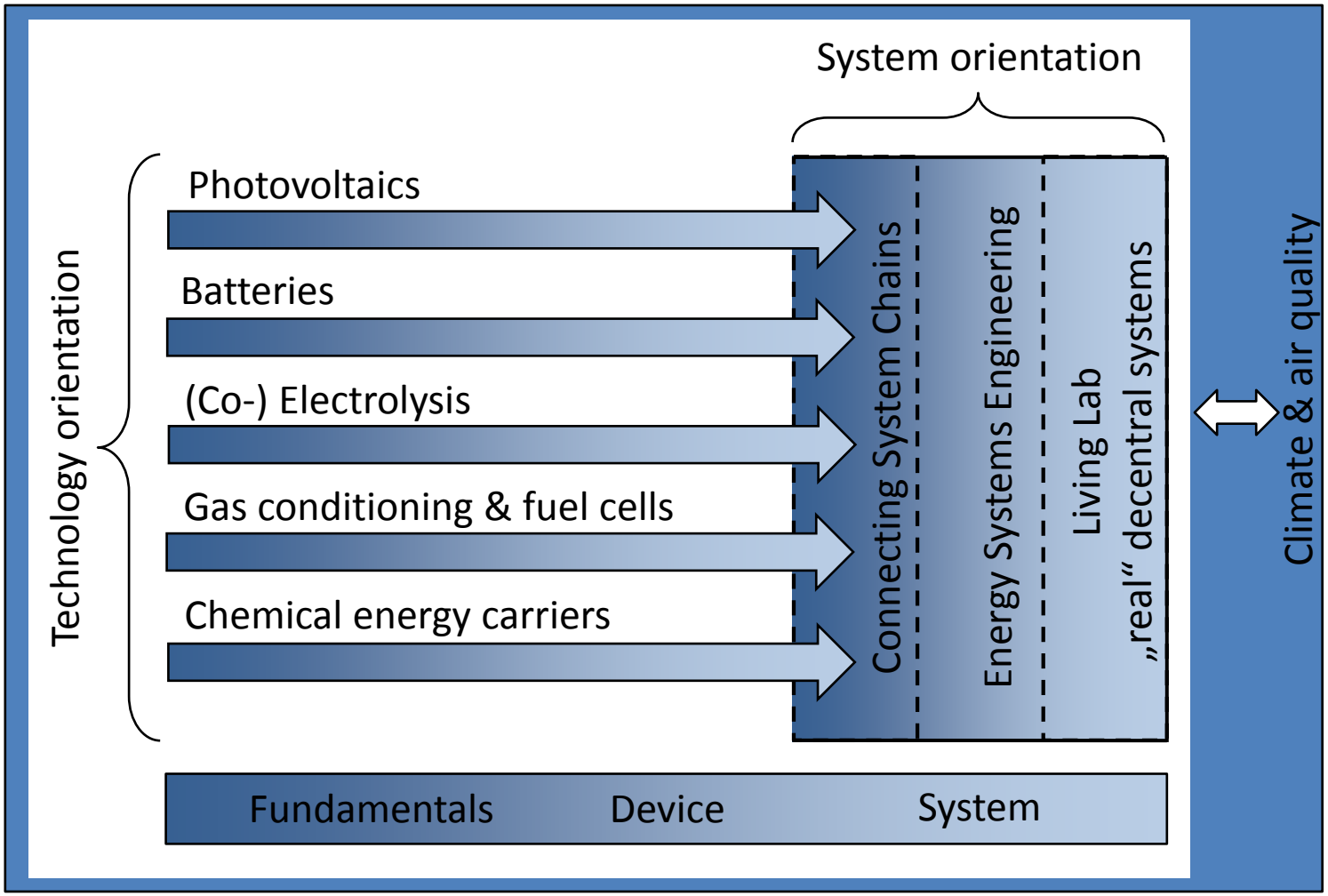
Energy

Bioeconomy

JÜLICH FORSCHUNGSZENTRUM **: Out of many, one.**

JÜLICH FORSCHUNGSZENTRUM

Energy Research in Jülich



Living Lab Energy Campus

Integrated Research Platform for Decentralised Urban Energy Systems

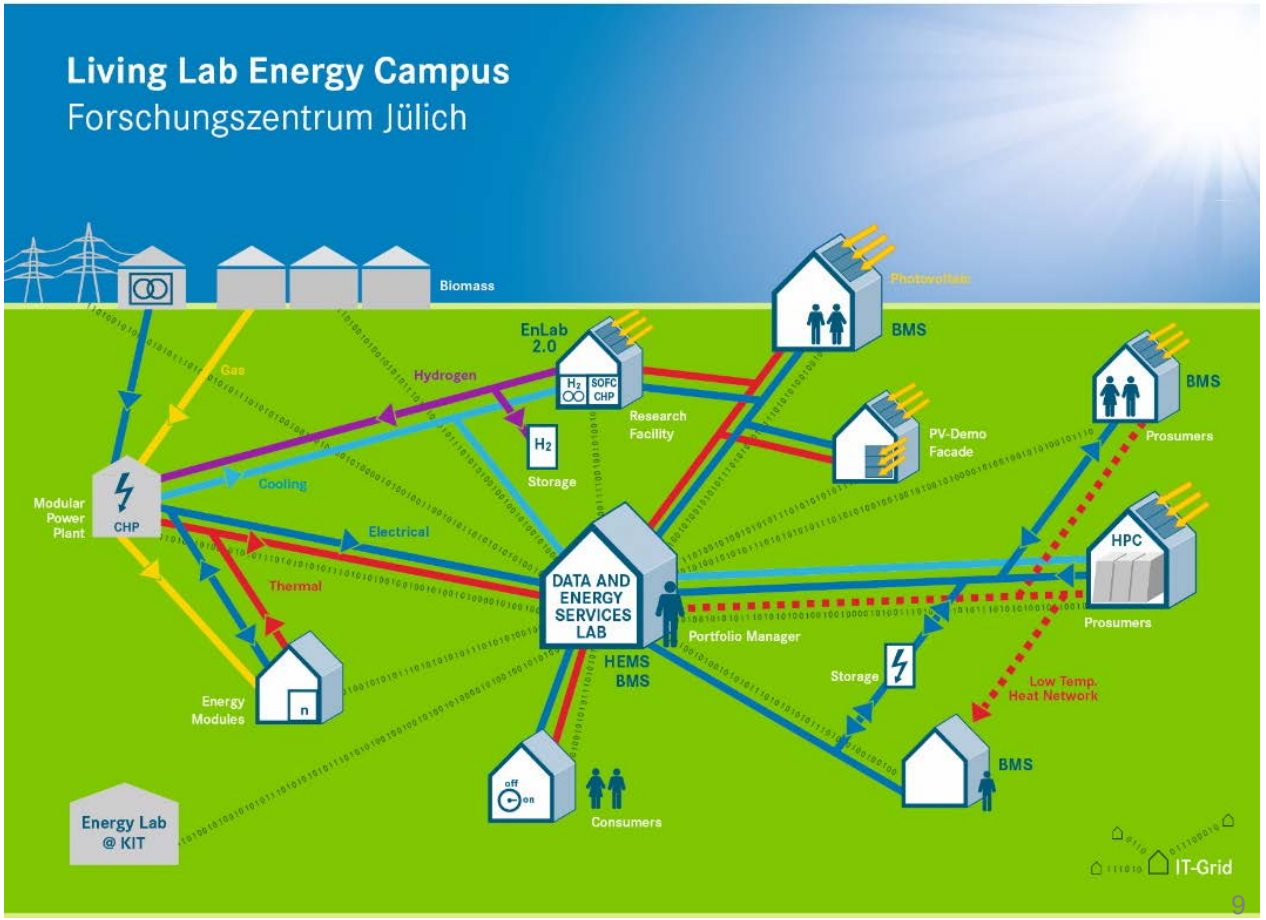
Implementation of:

- Measurement and control technology
- Demonstrators
- Data and Energy Services Lab

- Real time -

- Data acquisition
- Steering
- Optimization

using HPC technologies



Key Technologies for a Sustainable Bioeconomy

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

Economy and social implications

Innovative plants and microbial biotechnology

universitätbonn

Sustainable Plant Bioproduction and Resource Stewardship

Economy and Societal Implications

BioSC
Bioeconomy Science Center

Microbial and Molecular Transformation

JÜLICH FORSCHUNGSZENTRUM

Chemical Engineering and Processing

Sustainability and production

Biorefinery und conversion

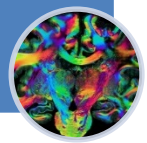
A B C/J geoverbund aachen bonn cologne jülich

RWTH AACHEN UNIVERSITY

Convergence in the Field „Information“

- Basic research
- Technology
- Translation

Neuroscience



- Quantum comput.
- Resistive memory
- Spintronics
- Bioelectronics
- Green IT

Information Technologies

Machine Learning

Neuronal Information Processing

Bioinspired Materials

Structural Biology

Neuromorphic Computing

Neural Networks

Brain Simulations

Neural Information Processing

- Exascale
- Big Data (Analytics)
- Modeling
- Simulation

High Performance Computing

Anorganic Components & Architectures

Materials Simulations

Energy Efficient Hardware

Virtual Design

JÜLICH FORSCHUNGSZENTRUM

Convergence of Neuroscience and HPC

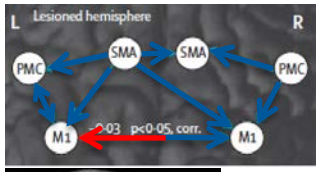
Human Brain Project / Decoding the Human Brain

Simulation-Lab
Jülich supercomputers
Visualization
BigData
Neuroinformatics

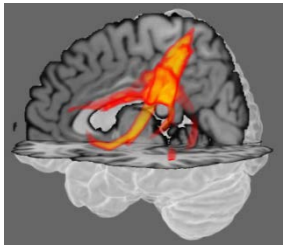
BIG DATA ANALYTICS & SIMULATION

Dynamic connectivity

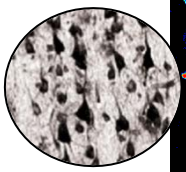
Fiber tracts

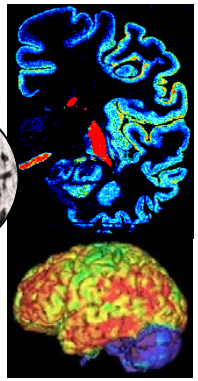


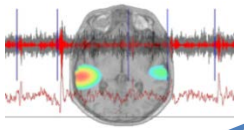
Local and global receptor distribution



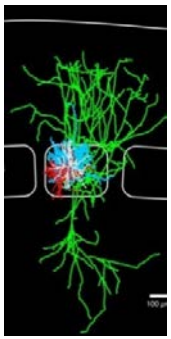
Small circuits

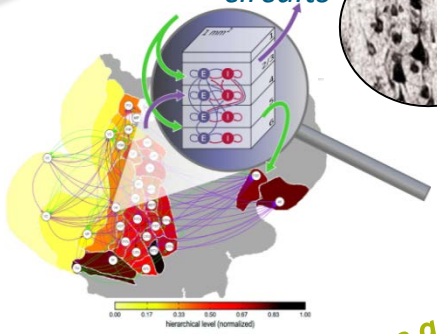




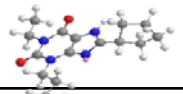


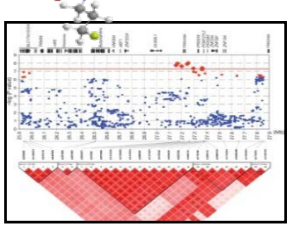
Cells



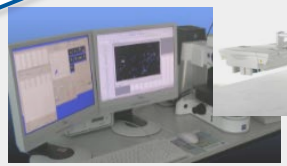


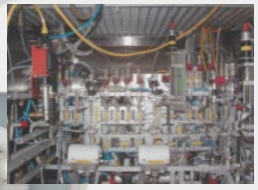
Molecules





Multiscale and multimodal in space and time





NEUROIMAGING

3T MR
9.4 MR-PET
3T MR-PET
Electron microscopy
Image analysis
9.4 T animal MR
Tracer development
Radiopharmacology
High-throughput microscopical Imaging
Electroencephalography
Magnetoencephalography

Human Brain Project

Contribution of Juelich

- Human Brain Organisation
- Neuroinformatics Platform
- Brain Simulation Platform
- High Performance Computing Platform

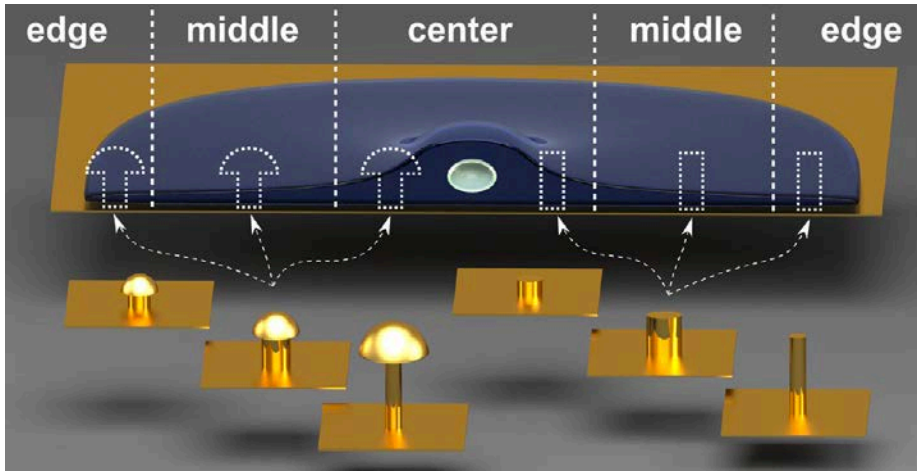
Example from Human Brain Organisation: Crossing Scales with 3D-Polarized Light Imaging

Mapping fiber architecture in white and gray matter

Amunts et al.; Institute of Neuroscience and Medicine

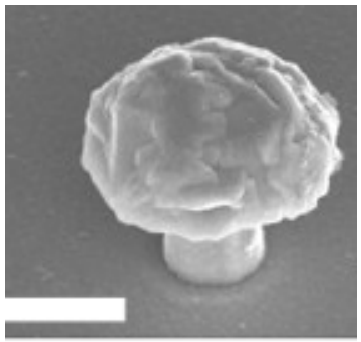
Convergence of Neuroscience and IT

Fundamental Understanding of the Integration of Biological Cells and Technical Nanostructures

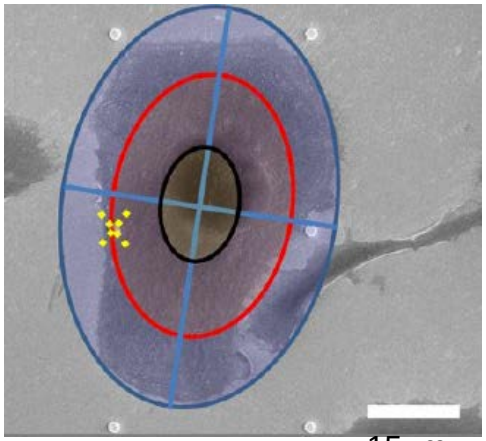


Challenge

Neuro-implants: How to establish a close contact between nanostructures and cells membranes?



15µm



15µm

Result

Distance between cell membrane and nanostructure can be optimised by an adaption of size and form of the nanostructure

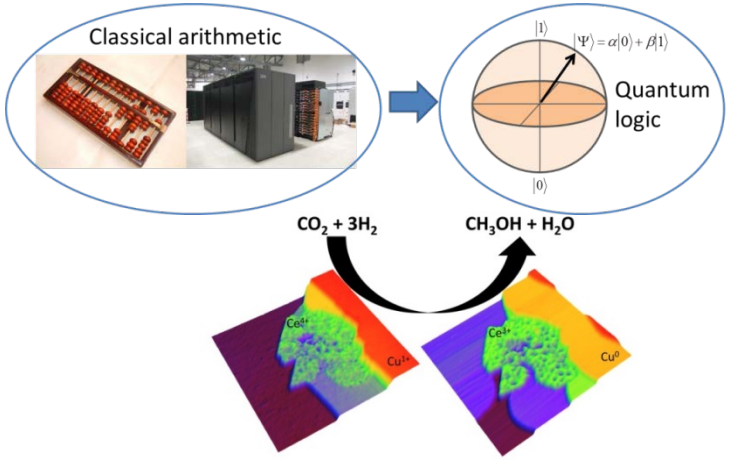
Santoro et al.; Institute for Complex Systems

Convergence of HPC and IT

HGF ”Zukunftsthema”: Scalable Solid State Quantum Computing

Vision

- New computational paradigm with exponential speedup

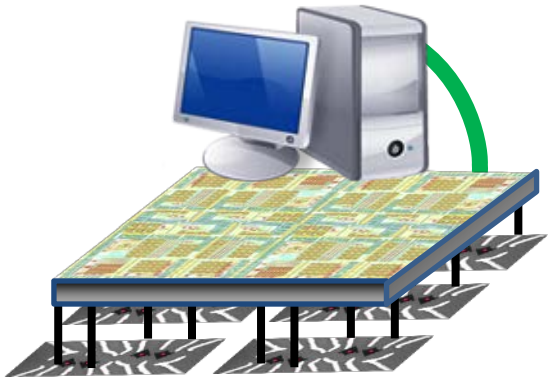


Applications and impact

- Simulation of quantum systems (e.g. new materials and catalysts)
- Decryption, optimization problems, …
- Physically secured communication

Challenge to realize useful system

- 10 qubits => >10^6 qubits
- Complex classical control system



Need critical mass, interdisciplinary, systems level approach, and long-term perspective

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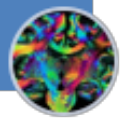
Development and Extension of Infrastructures

- Basic research
- Technology
- Translation

Neuroscience



- Quantum comput.
- Resistive memory
- Spintronics
- Bioelectronics
- Green IT

Information Technologies

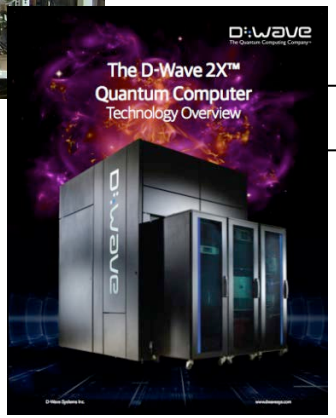
ER-C

- Exascale
- Big Data (Analytics)
- Modeling
- Simulation

High Performance Computing

JuSPARC

Helmholtz Nanoelectronics Facility



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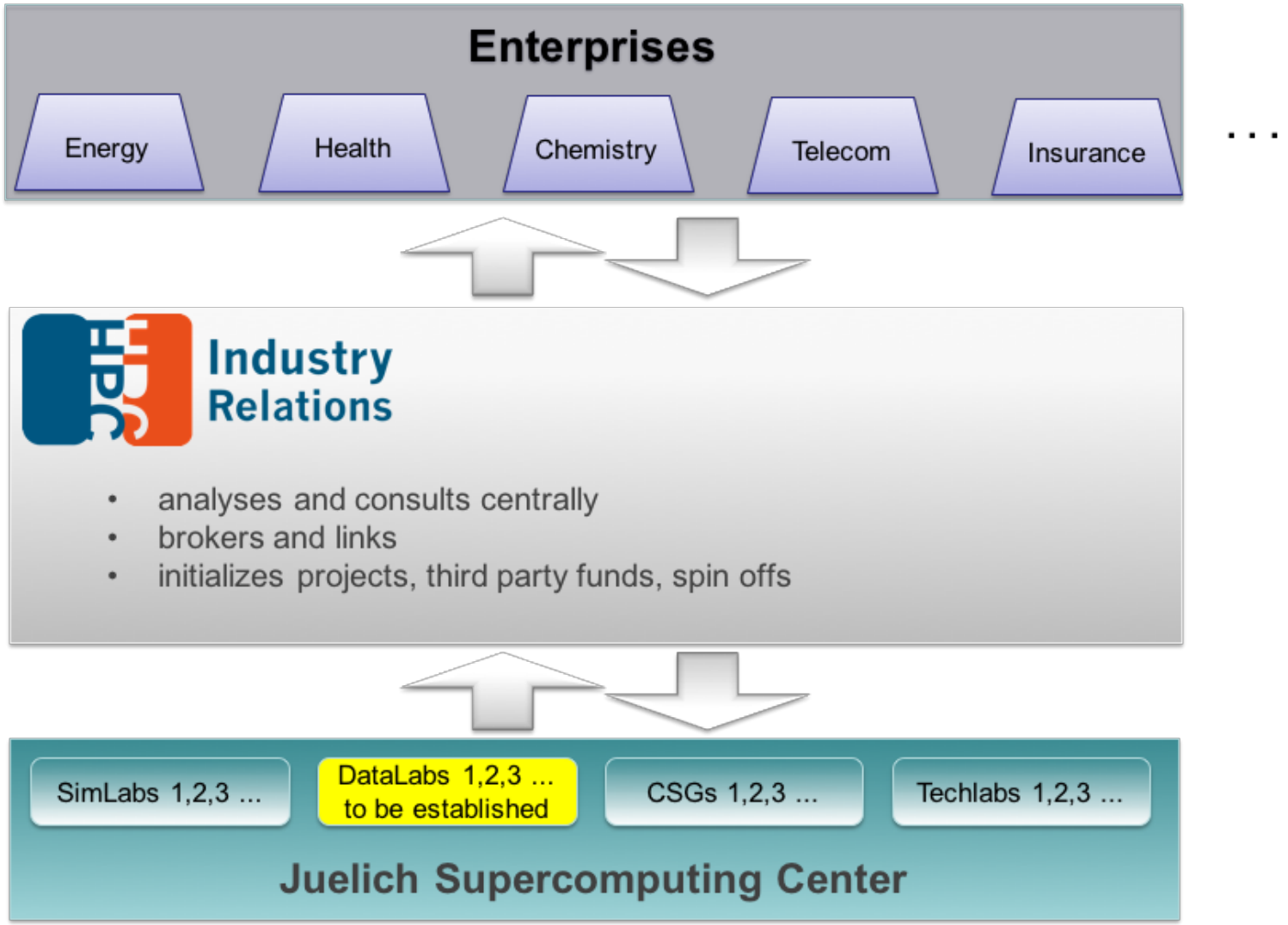
Jülich Supercomputing Center

Industry Support for HPC, Simulation and Big Data

Mission: “We generate connections”

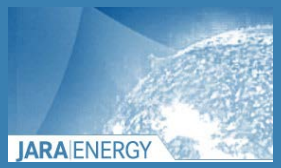


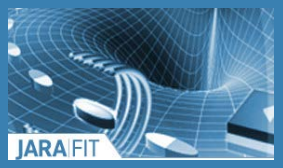
JARA Jülich Aachen Research Alliance

AN INITIATIVE OF

RWTH AACHEN UNIVERSITY

JÜLICH FORSCHUNGSZENTRUM





193 professorships – More than 4,000 scientists – Budget 500 Mio. €

JARA Institute Quantum Information

Hendrik Bluhm & David DiVincenzo

Development of concepts for quantum information processing on the basis of semiconductor-based qubits

Combining experimental and theoretical expertise for running highly coherent qubits and small groups of qubits in form of „spin quantum dots" and „superconducting qubits"

Implementation of complex multi-qubit devices

Vision:
Building a Quantum Computer

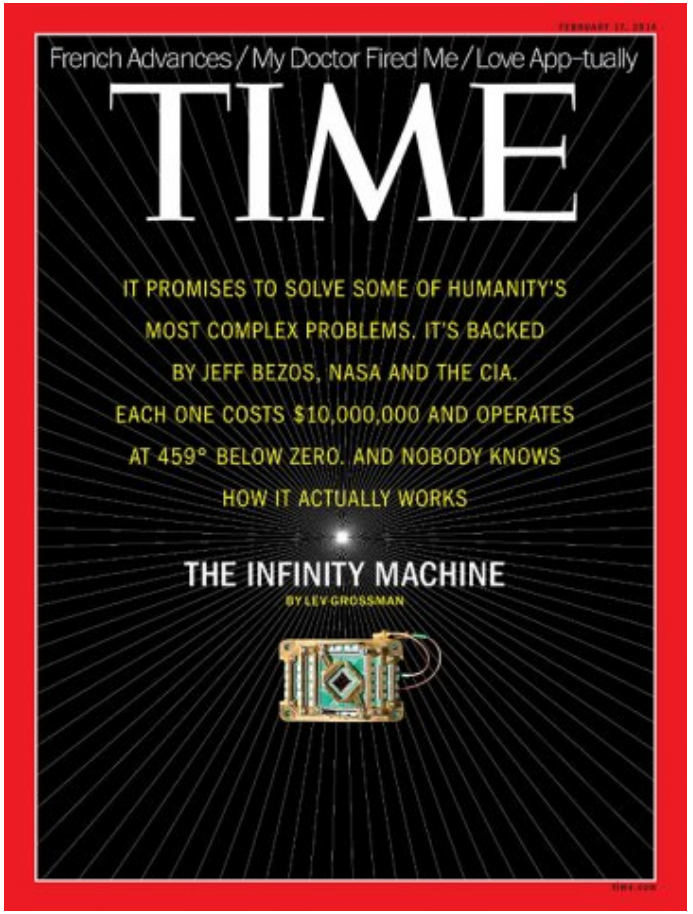
Aims of the Workshop QuAASI'16

Elucidation of the Potential of Quantum Annealing for Scientific and Applied Purposes

Topics

- Quantum Annealing / adiabatic quantum computing
- D-Wave architecture
- Applications of quantum annealing
- Training on a D-Wave device
- . . .

Let's make it work!



TIME: The Quantum Quest for a Revolutionary Computer. Feb 6, 2014

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FINDING TOMORROW TODAY