FET consultation 2014: a first analysis (working draft of 1/10/2014 – partial analysis)

The aim of the public consultation launched was to identify promising and potentially game-changing directions for future research in any technological domain. It was open for contributions during the months of May and June 2014.

The consultation was organised as a series of discussions, in which contributors can suggest **ideas for a new FET Proactive initiative** or **discuss the 9 research topics** identified in the previous consultation (2 years earlier) to determine whether they are still relevant today. The 10 discussion topics and the number of contributions received are listed below:

- Ideas for new topics (what's new that isn't in the other 9 topics?) – 272 contributions received
- Bottom-up intelligent construction – 10 contributions received
- Constructive symbiosis – 6 contributions received
- Ecological technology – 11 contributions received
- Global Systems Science – 39 contributions received
- Knowing, doing and being – 10 contributions received
- Nano-optomechanical technologies – 80 contributions received
- New possibilities at the nano-bio-chem interface – 17 contributions received
- Quantum technologies – 31 contributions received
- Time for time – 15 contributions received

The total number of contributions received was 491. Note that not all contributions are equally substantial, some stating more expressions of interest and support to submitted ideas.

Each of the previously identified topic was described with a few lines of teaser text, that describes the general challenge addressed. On these themes the consultation asked for adjustments and additions.

This document provides an overview of the material received, with short description of the ideas (as stated by their respective authors) and putting them in context of some others. Some ideas received have been moved under what seemed to be the most appropriate umbrella topics. When topics fit under several of those they are usually mentioned under all those relevant headings. Although it has been attempted to include all material in this overview, such completeness is not guaranteed.

Disclaimer: No claims are made or implied as to the relevance of these topics and ideas for Future and Emerging Technologies. Mention of ideas in this document does not imply any commitment whatsoever from the side of the Commission on their inclusion in future work programmes or any preferential treatment of the topic in any of its calls or other actions.

The consultation home page is here: https://ec.europa.eu/digital-agenda/en/content/consultation-new-fet-proactive-topics

PARTIAL ANALYSIS

All contributions are visible through this link.[1] Note however that the FET mailbox received various contributions directly. They are included in the analysis but not all accessible through the webpages.

Further analysis of these contributions and other material is ongoing and will lead to a list of new and adjusted umbrella topics (i.e., a new list compared to the previously identified topics listed above) for future research on future and emerging technologies.

Contact: Future and Emerging Technologies, European Commission
Email: cnect-fet@ec.europa.eu

PARTIAL ANALYSIS

[1] Several contributions, though not all of them, are linked from within this document.

In content

Ideas for new topics (what's new that isn't in the other 9 topics?)

Note: 'new' means that a topic does not obviously fit under the previously established 9 themes. It does not mean that the topic or theme is new *per se*.

The medical domain.

In-cell nano-technology for in-cell physics, is a visionary idea to bring artificial nano-constructs inside living cells as sensors or active components. See also Intracellular optical sensing under the nano-bio-chem theme. A more computation-oriented and bio-oriented variant of this is under BIOCOMP. Bio-inspired very fast computers which mentions a "bioinspired computer" inside a cell. This can be linked to the ideas on exosomes, and those on artificial cells with a focus on natural-artificial cell interaction (see Dear All).

The joint contribution on exosomes (FET Topic Suggestion Mobile Genetic Elements as Novel Biomarkers, Targeted Biological Homeostasis Control Units & Disease Biosensors in Future Medicine) is well developed and argued (speculative but far reaching). It could be a real paradigm shift in the way we think about medicine and disease transmission.

These themes form an interesting cluster of ideas around in-cell and inter-cell processes and technologies (cell-nano-bio-chem).

Particle therapy (specifically, high-precision delivery of the radiation dose in the patient under any circumstances), is a rather specific proposal to boost the main benefit of particle therapy over photon radiotherapy, namely more precise dosing and targeted delivery.(note this is different from the use of nanoparticles for therapy). See also Extreme Light from Science to Society for high power laser technology, mentioning some of these application aspects and thus enabling this vision in the future (see under New Devices). Molecular imaging is a proposal to develop imaging, diagnosis, therapy integration (so called theragnostics). This fits in a broader picture of personalized medicine. See also the separate idea of 4D-tracking, i.e., time-position detection, as a potential enabler for this.

These themes form a potential cluster of ideas around medical imaging and theragnostic tools.

Another theme crystalises around the notions of medicine-free therapy and bio-electronic medicines. The BCI ecosystem for stroke patients motor function improvement and restoration is potential paradigm shifter by working directly on the nervous system. This topic can be related to the one of Bio-electronic medicines, in which devices connected to groups of individual nerve fibres are used to control the patterns of electrical signals to restore health to organs and biological functions, has been suggested to have the potential to make major advances in the treatment of conditions resistant to drugs, including diabetes, obesity, hypertension and pulmonary diseases). According to the authors NIH is funding this at 250M$ over 6 years.[2] Some projects in FET-Open appear related, e.g. CLONS on closed-loop vestibular prosthetics, though the above ideas seem to be viewed less as prosthesis than as medicines working on more complex pathways throughout the body.

[2] See also the recent (26/8/14) announcement by DARPA on a similar theme (http://www.darpa.mil/NewsEvents/Releases/2014/08/26.aspx): '*ElectRx aims to explore neuromodulation of organ functions to help the human body heal itself*'.

PARTIAL ANALYSIS

TUNETH: tuning to healing, tuning to ethernal is an idea to study electromagnetic wave interactions with bio-molecular, cell and metabolic processes in healthy and diseased conditions to understand beneficial effects, thus paving the way for medicine-free therapies (similar in spirit to bio-electronic medicines).

A contribution on Hybrid memory system (submitted under the symbiosis topic) describes using memristors circuits interacting by sensors and actuators with biological hippocampal cells to create adaptive memory systems which can cope with memory loss in neurodegenerative illness, such as Parkinson and Alzheimer diseases. The implementation of such combined system (memristors, cells and selective membranes) can offer new insight as in vitro model for studying neurodegenerative processes as Alzeheimer's disease. Semi-permeable polymeric membranes, thanks to their highly selective structural, physico-chemical and transport properties, allow the successful in vitro reconstruction of neuronal tissue reproducing a tissue model for studying metabolic diseases and drug effects. Also importance of optogenetics and optoelectronics is suggested (see also various FET-Open projects on this topic, projects Enlightenment, 3DNeuron and Optoneuro in particular). See also the neuro-inspired photonic systems under bio-inspiration and mimicry, though the focus there is more on computing.

Another direction for this idea is to link it to the submissions on neural coding of knowledge, and on cognitive photonics. This would indicate a cluster around the idea of cognitive neural prosthesis (for memory but possibly also for other mental functions).

See also nano-medicine under the nano-bio-chem cluster and various more specific ideas for medical applications under that cluster, focused on specific illnesses and on regenerative medicine. The importance of moving towards clinical trials is also highlighted there (as fundable activity).[3]

Bio-Inspiration and mimicry remains a source of ideas in many areas, with the following standing out:

The micro and nanostructured mechanisms and materials of selected insects (ENEA, email of July 23) proposes to start a large scale multidisciplinary investigation of carefully selected insects, with expected fall-outs to materials, ICT, microfluidics, energy, behavior, neuroscience, ecology, new devices, etc. The spirit is kept intentionally quite exploratory.

Evolution underground: bio-inspired mining takes inspiration from animals and plants. Suggested extension to ecological technologies for less waste through in-situ selection and preprocessing.

Nature inspires new smart materials and technologies emphasizes the bottom-up hierarchical construction: the next frontier in the manufacturing of smart materials and devices able to take part to metabolic and transformation processes induced by specific environments. See also several related ideas under bottom-up intelligent construction.

Neuro-inspired photonic systems: While efforts to implement optical computing by mimicking the digital logic of electronics has had only limited success, the unconventional computing capabilities in the photonics domain are much more promising. In recent years, funded by the EU in the FET-Open domain, and via ERC grants and national projects, the potential of photonic implementations for unconventional computing, in particular reservoir computing, has been

[3] The mentioned DARPA initiative has it as a requirement that projects interact with NIH to make sure the conditions for a human trial are met at the end of the project.

PARTIAL ANALYSIS

demonstrated (published in Nature Scientific Reports, Feb 2012). The first proofs-of-concept have reached ultrafast computations, high classification performance, hardware efficiency, and the potential to drastically reduce energy consumption. Besides the applications in computing and artificial intelligence, a possibile fall-out could be in a better understanding of brain activity and neuronal organization in perception and information processing (see Cognitive neuro-prosthesis under Medical).

Seems closely linked to Cognitive photonics (integrated photonic circuits, photonic devices, integrated optics): reproduce complex patterns in compact on-chip optical circuits (classical and quantum) in order to study cognitive processes, solve computational tasks of various complexity, and understand failures related to diseases affecting the cognitive processes.

Interaction-based computing is a bio-inspired attempt to bridge computing, networking and interactivity in a single theoreatical/epistemological framework. (Paolo Dini, BIOMICS. Amos email of 30 June). The wide range of unpredictable interactions with their environmnent that biological cells can support, for example, is a source of mathematical and domain modelling ideas for computer science, This calls for collaboration among technology disciplines with cell biologists, biomedical researchers and pharmaceutical researchers, among others. (See under the RRI topic for another interpretation of this.) Several contributions in fact call for a new theoretical and conceptual foundation for computer science along such lines (e.g. Beyond Turing under Computing). A visionary extension to extend this to physical world of our living environments is discussed under the RRI cluster below.

Beyond mere inspiration for computer science is BIOCOMP. Bio-inspired very fast computers: beyond silicon based computers (biocomputers; wet computing; molecular computing; physical long-range electromagnetic interactions). A new class of computing and communication devices by using biomolecules instead cells and chemical reactions. Thanks to electromagnetic long distance communication among biomolecules (this seems to be the key novelty here) a complex information processing activity might be implemented by usiging heteropolymers (DNA and RNA), homopolymers (microtubules), and proteins. A "bioinspired computer" inside a cell could work as a wireless network of computational units (biomolecules, biopolymers) interconnected through their own electromagnetic field. The present research topic proposal will add at least three more prospective aspects that would represent real technological breakthrough: the speed of the switching process (transitions among vibrational states of the molecule), the speed of the communication among switches (via electromagnetic radiation), and the extended connectivity of the interactions among switches (long distance electromagnetic interaction). This approach is related to the topic of intelligent computing substrates.

RRI: A group of ideas around the human dimension, interaction, problems and opportunities of technology use, in a broad spectrum of disciplines (architecture, psychiatry,…)

Cognitive Insourcing - Technology beyond the era of Cognitive Outsourcing, Competition for Attention and Scarcity of Boredom (Digital Dementia, Cognitive Outsourcing, Digital Over-Use, Myopia, Depression, Anxiety, Stress, Sleeping Disorder, Improved Learning, Learning Modulators, Technology Enhanced Learning, Smartphones, Tablets, e-learning, Gaming, Game Addiction, Internet Addiction, Attention Deficit). Understanding the negative developmental effects of overexposure. Some fields of Medicine (e.g. Psychiatry, Ophthalmology),

PARTIAL ANALYSIS

Neurobiology, Education Science, Didactics, Software, Human-Machine-Interaction Technology, Manufacturer of End-User Consumer Devices, IT Service Providers in Public Sector.

Similar concerns are expressed in Humans and information-sharing (submitted under symbiosis) that considers the emerging relationship between humans and information (through digital hyperconnection). For example, our alignment with new and widespread technologies that facilitate information-sharing, may have repercussions upon our biology and evolution. These effects are real but have not yet been studied sufficiently. We know that interactions with a changing environment can act through epigenetic mechanisms in an attempt to adapt to these changes. When the environment becomes increasingly technological, it will profoundly affect our own social and biological characteristics. The mutualistic effects of ubiquitous technologies in healthcare and other contexts is also discussed in hybrid artificial-natural for healthcare (symbiosis topic).

The above is linked in an original way to work on privacy, as seen from an architect's perspective. The traditional home is a private place in the real, and a research programme is proposed to reinterpret this for the digital age, without however abandoning the physical and the built environment (Pot email contribution). Such discourse can also be linked to interaction-based computing where a new unifying dialogue between information, computing, communication and behavior (in a physical and partly designed and possibly intelligent environment or 'ambience' – home, building, organization, urban,…) is being sought. See also symbiosis.

Seeing things more as an opportunity than as a danger: Experience engineering: societies of technologized indviduals. Virtual Reality (VR) engineering, and has proved capable of supporting some specific behaviours and experiences. These are gradually becoming accessible to the everyday consumer. However, the next phase must involve engineering innovation and a better embedding of communication technologies into the activities and experiences of individuals. This will also lead to shifts in the structure of society that require extensive research, in order to ensure positive outcomes. We propose a framework with four areas spanning technology through to society, to address these research challenges: moving beyond a focus on devices, generalising reality engineering, extending the interface, and social embedding of technologized experience.

A proposed idea with more technological focus on Augmented reality (virtual into the real) could be integrated with this.

More down to earth and specific, but potentially foundational: new code systems for computer instruction (HCI related).

Information and media authentication for a dependable web (trust, forensics). How can we gather information and use it to exchange ideas, debate different opinions and take decisions, if no evidence can be trusted? Are we irremediably condemned to base our opinions, beliefs and social activity on information whose reliability cannot be determined? The need to restore and maintain trust in the web as one of our primary sources of information is evident. This includes social studies, information retrieval and mining in big data (e.g. to find an original in its original context to verify its meaning), multimedia forensics, social computing and legal aspects. Complements regulation to protect privacy by giving users themselves tools to establish and verify trust. Being linked to device fingerprinting and physical unclonability. Used also for law enforcement.

PARTIAL ANALYSIS

See also the discussion on data abuse under Global Systems Science (GSS).

Managing information over-abundance – shrink to fit: the idea is to invest in complexitiy reduction as a horizontal research for improving explainability interdisciplinary bridging, better risk assesment, submission of human requirements, etc. Linked to submission(s) on Text understanding – see also under knowing-doing-being.

Technology for Social & Social for Technology: proposes to study how social networking approaches can be better evaluated and used as additional elements in larger system designs, e.g., to provide additional community data on top of more curated official data, or to use user collaborations for network optimisation. The purpose seems to be mainly increased efficiency and green computing. However, the general idea of what could be called 'the power of social' is present in other contributions as well, in different contexts (GSS, knowing doing being).

New devices

Nanofluidics (and microfluidcs) for future generations of devices in variety of industry and lab applications. Strange phenomena at nanofluidic scales to be understood and controlled.

Nanoarchitectronics brings Electronics, Photonics, Material Science, Solid State, Quantum and Condensed Matter Physics, Chemistry under the same umbrella. The main objective is to overarch future researches in Electromagnetism from Microwaves to Optics through a visionary and synergic approach which is grounded on the extraordinary light-matter interactions at nanoscale. This is a throughly developed proposal with 4 seemingly ambitious subtopics and horizontal modelling and design approaches as well. The interesting point of this proposal is the effort to define a platform involving novel materials, new areas of applications and shared analytical-modeling tools. The topic seems to balance between fundamental science and industry readiness. Maybe the value is in bridging the worlds of nano tech and electromagnetism at all frequency ranges.

Note: the horizontal topic 'architecture by design' is related to one proposed by CEA under intelligent bottom-up construction. What binds these together is the insight that simulation studies are not enough to design optimally at the nano-scale, but that some form of physical exploration of designs is also needed.

Another specific direction is spin-wave based devices. It suggests that a FET proactive initiative should address the realization and test of spin-wave based multifunctional devices that can be operated with orders of magnitude power-saving if compared to current technology. The initiative could be in the form of a challenge to demonstrate figure of merits pre-defined by the call, relative to the construction of devices where the computing power and the data processing is by far more efficient than in existing devices.

See also specific ideas under the theme of Energy and zero-power (adiabatic logic, spin-wave, 3D-heterogeneous integration).

Extreme Light from Science to Society is about New paradigm leading to a laser system that can produce simultaneously Peak Power (TW-PW), Average power (~100kW)and efficiency (>30%), and its various applications (energy, imaging, therapy, space, cosmology,…). See also under Medical.

On chip optical frequency synthesizer. optical frequency synthesis is still in its infancy. The invention of optical frequency combs in 1999 has revolutionized frequency metrology, by providing a technique which enables to link a radio wave signal (at MHz or GHz frequency) to an optical carrier. A key outstanding challenge

PARTIAL ANALYSIS

is to make optical frequency synthesizes ubiquitous – that is make them lightweight, compact such that their teeth are spaced by the technologically important Microwave frequency range, and reduce their cost, size, complexity in such a way that they can be used in a much broader range of applications. Such chip-scale optical frequency synthesizers could be used as multiwavelength sources for coherent communications for short haul in datacenters, as sources for spectroscopy in both the near and mid IR as analytical tool, as supercontinuum generators for OCT, as well as for the generation of stable microwave signals from optical carriers as required for navigation and timing. Such chipscale frequency synthesizers – unimaginable a decade ago – have now become a real possibility. The scientific breakthrough of 2007 (Del Haye et al Nature) demonstrated that optical frequency combs can be generated using on chip microresonators.

(see also several quantum topics, as well as nano-optomechanics moved under the related topics)

4D Tracking describes the idea of radiation detectors, both for photons and for charged particles, that can detect time AND position accurately to achieve 4D tracking. This would be of extreme help in many fields, ranging from PET, to 3D cameras, mass spectroscopy to beam monitoring for hadron therapy. See also Therapy idea under medicine.

Computing

Foundational research in algorithms (HPC, big data, embedded systems, quantum algorithms, bottom-up constructed systems).

Beyond Adaptive Computing Architectures (BACA): This topic addresses all the questions that need to be answered in order to build a computing system that is capable of adapting itself to the changing requirements imposed on it while being operational. New languages, new run-time environments, new processing architectures and new hardware platforms beyond CMOS. See also Complex Computing Systems: Adaptive - Autonomous - Accepted (as new topic)

BIOCOMP. Bio-inspired very fast computers: see under bio-inpsiration. beyond silicon based computers (biocomputers; wet computing; molecular computing; physical long-range electromagnetic interactions). A new class of computing and communication devices by using biomolecules instead cells and chemical reactions. Thanks to electromagnetic long distance communication among biomolecules a complex information processing activity might be implemented by using heteropolymers (DNA and RNA), homopolymers (microtubules), and proteins. A "bioinspired computer" inside a cell could work as a wireless network of computational units (biomolecules, biopolymers) interconnected through their own electromagnetic field. The present research topic proposal will add at least three more prospective aspects that would represent real technological breakthrough: the speed of the switching process (transitions among vibrational states of the molecule), the speed of the communication among switches (via electromagnetic radiation), and the extended connectivity of the interactions among switches (long distance electromagnetic interaction).

Interaction-based computing (from BIOMICS, Dini). See under bio-inspiration. This can also be linked to smart cities and architecture, the notion of 'home' (Pot contribution), although this topic can also stand on its own.

Similar idea: Beyond Turing: defining new computational paradigms and specification languages able to manage the dialectic relations between structural and functional properties in the same way as the human brain interacts with

PARTIAL ANALYSIS

information and behaves as a set of embodied computers. The emergence of new insights in complex systems will stimulate the birth of a novel integrative science, that overcomes the limits of current computational models as well as models of computation and allows us both to understand the entangled socio-technical systems and to unravel the complexity of crucial biological systems such as those responsible of human brain or immune system dynamics (see also the discussion under RRI).

Innovation organization, ecosystems, methodologies, enablers, and training

Regenerative innovation ecosystems: Decision Support System for innovation ecosystem self-configuration based on managing EU wide development of regenerative Capabilities, Competencies, Collaboration and Knowledge. Open networked collaborational framework based on synthesis on EU wide (case relevant); Flows, Structures, Functionalities, Facilities and Events. (For instance innovation related) for self-configuring innovation networks on the level of Campus, Industry and Area development for investments in manufacturing. Industry 4.0 and 5.0. Regional and interregional arguments.

Circular economy: closing the waste-water-cycle (submitted under new ideas, probably to be ecological technology). See also European Water Platform contribution.

Value creation through mathematical modeling, simulation and optimisation (MSO): this aims to boost innovation and industry competitiveness through mathematics for a service platform for MSO, based on HPC and big-data capacity. Building on the international network EU-MATHS-IN, the European Service Network of Mathematics for Industry and Innovations (see http://www.eu-maths-in.eu/). US and national initiatives on this. This topic is closely related to the implementation of the HPC strategy.

ICT and Art (ICT ART CONNECT - Artistic Practices for Research in ICT): various contributions and support statements (see also time for time, see also quantum creativity email June 11). Mostly limited to ICT, building on the *ICT* and art CONNECT project under FET. Some contributions extend this to research more generally. Also being linked to participatory approaches and to DIY. Some specific topics for art-tech collaboration are suggested (thematic), like technologies for living matter, technologies for uncertainty, constructing a future human, technologies for non-human perspective. Seen as a way to achieve the RRI and SSH strategies. Suggested use of CSA. Maybe integration of this methodology in other topics is possible.

Another direction for this theme is to link Science and Art with ideas of creativity (under knowing-doing-being and a separate contribution on quantum creativity) and the nature and role of the non-rational (time for time and GSS), which could make for an interesting cluster on its own (see also enabler of creative research and innovation under knowing-doing-being).

Systems engineering curricula development and promotion (could be a CSA topic) on the non-functioning research value chain in Europe. Interdisciplinary science/technology/business curricula. This could be building block for a wider programme to build a more entrepreneurial mindset within FET-like research so that opportunities can be recognized and effectively developed.

Energy

PARTIAL ANALYSIS

A suggested new topic is Energy Society, from Renewables to Direct Conversion, very interdisciplinary (linking to food), building on artificial photosynthesis and solar conversion at the cell and plant level, direct conversion of CO2 into complex products. See also topic Direct photoconversion of CO2 proposed as new topic. 122M$ in US for a center on this. See also ref to this under quantum technologies. Another contribution (CEA, email of June 30) proposes hybrid systems for solar to chemical energy conversion (so called artificial photosynthesis).

Zero power is also a lead for the future, linking also to personalised medicine and monitoring. It is extended from computing to include sensing and communication, and the integration thereof in systems. This allows for energy scavenging to have zero-sum energy. The uses are seen for embedded systems, e.g., in smart cities and in- and on-body technologies, for IoT and for cyber-physical systems more generally. Claims of 5 to 8 orders of magnitude gain in power efficiency.

An important addition is that of energy-efficient software. E.g., hoar logics for computing bounds on energy consumption as part of software engineering.

A specific direction for this is ultra-low power for computing: adiabatic logic, NEMS logic switching).

Another specific direction for this is the use of 3D heterogeneous integration in CMOS.

Another specific direction is spin-wave based devices (see New devices). FET proactive initiative should address the realization and test of SWs based multifunctional devices that can be operated with orders of magnitude power-saving if compared to current technology. The initiative could be in the form of a challenge to demonstrate figure of merits pre-defined by the call, relative to the construction of devices where the computing power and the data processing is by far more efficient than in existing devices.

A valuable attempt to integrate these issue can be found under the 'energy efficient systems from software to hardware' proposed topic. Greatest savings expected from energy-aware-algorithms. Covers range from HPC to smart dust.

See also the discussion on energy under the topic of ecological technologies.

Some reference to energy issues under the nano-bio-chem cluster, where for example biocompatible fuel-cells to power implantable devices is mentioned.

Materials

Multifunctional and hierarchical soft and hard materials (a la metamaterials). Can be bio-inspired, bottom-up or top-down engineered, programmable or with all kinds of properties. Requirements: Interdisciplinary collaborations between theoretical, experimental and applied chemists, physicists, materials scientists, electrical and mechanical engineers, materials and product designers, etc. Includes electromechanical active polymers (Europe leading, already a community ESNAM network and EuroEap platform). Artifical mussels, soft machines, implants, etc.

Linked to this: multi-scale modeling of complex systems (materials): This initiative aims to explore the development and use of multi-scale simulation and modeling to design new materials with specifically tailored properties for the advancing new technologies.

Linked also to submission Nature inspires new smart materials and technologies, which emphasizes the bottom-up hierarchical construction: the next frontier in the manufacturing of smart materials and devices able to take part to metabolic and transformation processes induced by specific environments, is in the ability to

PARTIAL ANALYSIS

replace the conventional fabrication concepts with new bottom-up processes pinning on self-assembling and self-organizing molecular building blocks with complex chemistry and structure.

Innovative hierarchized three-dimensional hybrid nanomaterials and nanostructures for energy conversion and storage technologies is suggested also by CEA (email of 30/6) with a view of their integration in nano- and microelectronics (portable, embedded). This could include third generation solar cells, electrochemical storage devices, thermoelelectricity, micropower sources, etc. Techniques can be physical multistep or self-organised (relevant to bottom-up intelligent construction). Also ecological concerns are mentioned.

Some contribution in adaptive systems want to include a programming dimension here as well: how to program the emerging constructs (and how to program their emergence by design?).

Material science approach to energy production in deuterated metals (ENEA, email June 23) calls for the development of new materials for sustainable and renewable energy by finding out the origin of the isotope effect (Cold Fusion, Low Energy Nuclear Reactions, Fleischmann and Pons Effect FPE) with a sound materials science approach. The existence of the effect is sure, the controlled reproduction in materials can now be studied. Europe has critical mass of institutes on this.

There is also a strong materials dimension to artificial photosynthesis, mentioned in several contributions (see under ecological technologies and under nano-bio-chem).

Some outliers that do not easily cluster with other ideas:

3D-urban traffic (Elevating city transport from the ground), based on flying vehicles (cars, jetpacks, multicopters, possibly unmanned for transport of goods as well). Involves entire approach of vehicles, rules and regulation, infrastructure, city design,… (see e.g. French Pegasus flying car project).

Transport: nonCO_2 producing large aircraft (e.g. electrical, solar).

3D aqua farming (email june 11) with a.o. robotics. Can possibly be linked to underwater technology for in situ observation of phytoplankton, cytometry. Deep water (5000 meter).

Exploitation of Supercritical CO_2 Properties in power generation industry (ENEA, email of 23 June) could achieve low-carbon power plants with near-zero emission, high efficiency, low cost, high load flexibility and easy to integrate with renewable energy sources. This seems to take off from relatively well established knowledge and focusses on higher TRL and MRL levels.

Bottom-up intelligent construction
This initiative aims to explore techniques and methodologies for bottom-up design, manufacturing, and construction of materials and artefacts at various size scales, ranging from very small (molecular, cellular) to very large (meso and macro scales). The long term goal is to achieve growth or self-assembly of such artefacts, possibly in a scale-invariant way. Inspiration can be found from biological processes like morphogenesis or epigenetics, or in the study of self-organisation, adaptation or evolution in order to design and assemble complex functional materials, artefacts or larger complex structures in cost-effective, reliable and adaptive ways, under relatively affordable conditions (cost and others)

PARTIAL ANALYSIS

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

A contribution from TRUCE project (Susan Stepney. Amos email of 30 June) points out missing the programming dimension to bottom-up intelligent construction. This was left out originally to keep this open to more material science rather than ICT types of complex constructs. The contribujtion argues that the usual focus on hardware/wetware has to be complemented by a similar focus on the computational aspects, including simulation, design, programming languages, verification, safety properties, full "groware engineering".

The topic of intelligent computing substrates is proposed (NASCENCE, Julian Miller. Amos email of 30 June) as with specific emphasis to examine how material nanoscale and molecular properties could be exploited and new kinds of computational and or sensory devices could be constructed. Specific questions are how much computation a piece of matter can be engineered to do, at what speeds, scaling and automatic testing of many materials and mixtures.

This is also discussed under computer controlled evolution and exploration of nanoscale systems (physical evolution and exploration) for computation and sensing (NASCENCE and CEA). A similar message, specific for bottom-up functional devices and in particular the area of Bottom-Up NanoElectronics is formulated in another contribution under this topic: 'we should aim at emulating Nature and use computer-controlled Darwinian evolution to create sophisticated information processing systems using bottom-up construction and self-assembly.' This would allow bottom-up hybrid nanoelectronics, where inorganic (CMOS) and molecular components are integrated. Some prior work exists, but it is claimed no organised community around this.

Innovative hierarchized three-dimensional hybrid nanomaterials and nanostructures for energy conversion and storage technologies is suggested also by CEA (email of 30/6) with a view of their integration in nano- and microelectronics (portable, embedded) also mentions the possibility of supramolecular self-assembly bottom-up methods (along physical multistep deposition techniques).

Energy related: bottom-up intelligent construction of solar plant (Email June 11, Chris van Felius).

Understanding the principles of biological self-construction to provide new methods for industry and iCT in particular. (project SECO, Rodney Douglas,ethz). This is further expanded in the submission Nature inspires new smart materials and technologies, which emphasizes the bottom-up hierarchical construction: the next frontier in the manufacturing of smart materials and devices able to take part to metabolic and transformation processes induced by specific environments, is in the ability to replace the conventional fabrication concepts with new bottom-up processes pinning on self-assembling and self-organizing molecular building blocks with complex chemistry and structure.

Synthetic cells. Specific suggestion to couple synthetic cells with natural cells through bio-chemical communication. This reminds of the Exosomes proposed idea, and could also be combined with the in-cell physics proposal. Synthetic biology and synthetic cells is also proposed under Important topic: limit to organ scale; include synthetic cells (TUDelft). It is suggested to add synthetic cells and bio-inspired artefacts (to clearly expand just beyond materials), and to restrict the largest scale from 'very large (meso and macro scales)' to 'multicellular, and organ scale' and add 'bio' before artefacts.

Change in paradigm in numerical simulation points out the role and computational load for mesh computation in numerical simulations and proposes a new approach which is mesh free. Simulation is probably important for bottom-up constructed systems as well, and can

PARTIAL ANALYSIS

be included under a methodological angle to this topic. The topic is also relevant to the proposed topic of value creation through modelling, simulation and optimisation, SMO (see under HPC).

Complex Intelligent Fabrication – how to make the next generation of complex multicomponent biological, molecular, nanocrystalline devices or materials grow or self-assemble? This notes that heteroelement, atomic and nanoscopic complexity are not part of the blueprints behind the leading industry fabrication technologies, while Europe's emerging technologies vision is to establish technology beyond a single-component, Silicon Valley-like approach, and help in turn consolidate a Nanocrystalline, Cellular and/or Molecular Valley: nanomanufacturing hubs throughout the continent with the potential to reach the next generation of technologies - today. Concrete directions proposed are Molecularly precise device (MPD) fabrication, Steered biomolecular and cellular material (SCM) manufacturing, and Nanocrystalline and nanoparticle heteroarchitectonics (NPA). Scaleable fabrication techniques are suggested for each.

The integrated nanofactory (ENEA, email of June 23) also looks at future nanofabrication, both self-assembling on the basis of artificial design, and artificially assembling in a bottom-up and possible parallel fashion. Electron beam, ion beam and laser beam technology, SPM, microfluidics need to be brought tightly together. A particular focus is on nanoantennas exploiting plasmon emission to perform both fabrication and characterization. Online testing and characterization of the fabricated items is considered as well. The scope includes organic-inorganic and bio-inorganic devices and components.

from atomic to micro scales provides a concrete example: the very sophisticated, atomic-based anisotropies in epitaxial metallic nanolayers, can be applied in textile-based materials, with intentionally introduced anisotropies, where textile yarns and fibers can "follow" in this way the very high-resolved observations.

A very different take on this is in Experiments on the information propagation in collective behavior, that sees collective systems multi-agent systems as self-organising systems to solve complex problems. Although it is not entirely clear whether anything is being 'constructed' as a result of this, it can be hypothesized that such information propagation will play a role in other instances of bottom-up (intelligent) construction of functional artefacts. Thus, the topic of information exchange/propagation as an enabler for self assembly could be a valid umbrella for this (probably also linking to the programming dimension mentioned above). This might even be the role of the exosomes proposed as a topic elsewhere in cell differentiation and aggregation.

ENEA (email of 23 June) confirms orientation and points at important results in bio-organic nanotechnology, with a quickly developing community devoted to intelligent design bottom-up self-assemblage.

The National Energy Efficient Buildings Platform (a Prague based initiative) points out the lack of work on self-assembly on material level within the construction industry. The call could capitalise on successes with the use of robotics (e.g. in space) for self-construction in the building context. Two specific topics of focus are suggested: self-assembly components fro on-site construction, and self-assembly processes druing the manufacturing of components. In another context they also mention energy grids inspired by swarm intelligence and responsive to environment.

Constructive symbiosis

PARTIAL ANALYSIS

This initiative wants to go beyond inspiration from nature and bio-mimicry and seeks to explore hybrid artificial-natural systems in which the nature and complexity of interactions can be considered to be a kind of mutualistic symbiosis as it is found in nature. Projects would thus combine concepts and knowledge from different disciplines for creating a constructive ('win-win') symbiosis between the artificial and the natural, in a systemic way. This might, for example, prepare for the creation of entirely new habitats, for instance on other planets, in the ocean or in certain extreme conditions. Other visions, like in symbiosis with the human body, in urbanism, or ecology would also fit under this topic.

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

According to one commentary, this topic appears to be too broad because it addresses different scales of systems between which little might be sharable. Some bridges can be made though. Bio-inspired interaction-based computing from BIOMICS project (see under bio-inspiration) is described as a kind of symbiosis, inspired by cell-biology. At a different scale, the traditional home is a private place in the real, and a research programme is proposed to reinterpret this for the digital age, without however abandoning the physical and the built environment (Pot email contribution). In both cases (and there are others, e.g. on hybrid cellular constructs - see medicine and bottom-up intelligentconstruction) a new unifying dialogue between information, computing, communication and behavior (in a physical and partly designed and possibly intelligent environment or 'ambience' – cellular, body,home, building, organization, urban,…) is being sought.

In hybrid artificial-natural for healthcare it is argued that the topic as described does not emphasize enough an important case of ubiquitous integrated artificial and natural components in daily life in a technologically enhanced world. Healthcare is singled out as important (' The symbiosis of the artificial with the natural in the human body is becoming an issue in people's daily life, which should be investigated in depth.'), but also ecological monitoring, and the long term effects of using technologies in agriculture or with animals should be considered. (see also the RRI cluster).

A contribution on Hybrid memory system (under the symbiosis topic) describes using memristors circuits interacting by sensors and actuators with biological hippocampal cells to create adaptive memory systems which can cope with memory loss in neurodegenerative illness, such as Parkinson and Alzheimer diseases. The implementation of such combined system (memristors, cells and selective membranes) can offer new insight as in vitro model for studying neurodegenerative processes as Alzeheimer's disease. Semi-permeable polymeric membranes, thanks to their highly selective structural, physico-chemical and transport properties, allow the successful in vitro reconstruction of neuronal tissue reproducing a tissue model for studying metabolic diseases and drug effects.

Also the BCI ecosystem for stroke patients motor function improvement and restoration is a form of symbiosis at the level of the human organs or body. Might need some generationalisation, e.g. with the topic of Bio-electronic medicines, in which devices connected to groups of individual nerve fibres are used to control the patterns of electrical signals to restore health to organs and biological functions. (see under medical)

In-cell nano-technology for in-cell physics, is a visionary idea to bring artificial nano-constructs inside living cells as sensors or active components, in a symbiotic way. This can be linked to the ideas on exosomes, and one artificial cells and natural-artificial cell interaction. (see under medical)

PARTIAL ANALYSIS

Humans and information-sharing considers the emerging relationship between humans and information (through digital hyperconnection). For example, our alignment with new and widespread technologies that facilitate information-sharing, may have repercussions upon our biology and evolution. These effects are real but have not yet been studied sufficiently. We know that interactions with a changing environment can act through epigenetic mechanisms in an attempt to adapt to these changes. When the environment becomes increasingly technological, it will profoundly affect our own social and biological characteristics.

Another symbiotic relationship is described in Integrating Visualization and Automated Analysis Methods with a vision to truly integrate data-driven automated techniques with human-centered visualization techniques. As the VisMaster roadmap (http://www.vismaster.eu/book/) outlines, if Europe wants to advance current research on Big Data in a way that enables experts, not only machines, to work with massive amounts of data, a new initiative is needed. This requires bridging between the machine learning (ML) and information visualization (IV) communities through new theory and platforms.

ENEA (email of 23 June) sees importance at the molecular or cell level, as well as at the level of planning new urban-industrial ecosystems with symbiotic mechanisms and using lessons from bio-mimicry for the management of resources. New habitats are considered as probably too far out.

The National Energy Efficient Buildings Platform (a Prague based initiative) defends a bio-mimicry approach and points at several possible promising topics: advanced responsive nanomaterials for intelligent control of wellbeing in buildings as well as (in a second step) in symbiosis with the human body; 'minimum' construction technology (tools needed, energy and transport needed, easy of understanding,…); and energy grids inspired by swarm intelligence and responsive to environment.

Ecological technology

The aim is to explore new ways of avoiding overall environmental impact of technologies (and of ubiquitous ICT in particular), going beyond incrementally reducing impacts along a single dimension (like energy consumption) but rather seeking holistic paradigms for future zero-impact mass-consumed IT. The scope includes current and future hand-held and personal devices, but the vision appears most valuable for ubiquitous environmental sensors (land, oceans), various embedded technologies, implants as well as future injectable or digestible devices.

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

Whereas the topic as described in the teaser has a rather specific 'green technology' focus, the various contributions show a clear appetite to extend this topic to a broader 'sustainability' area of research.

A suggested new topic is 'Energy society, from renewables to direct conversion', very interdisciplinary (linking to food), building on artificial photosynthesis and solar conversion at the cell and plant level, direct conversion of CO2 into complex products. See also topic 'Direct photo conversion of CO2' proposed as new topic. 122M$ in US for a center on this. See also ref to this under quantum technologies. The topic of artificial photosynthesis is also suggested by CEA under nano-bio-chem (email contribution of June 30).

Sustainability Analytics is about big-data analytics with a focus on data analytical methods for balancing environmental, economic, and societal needs for a sustainable future. Specifically, it will consider the major problem domains that impact global sustainability, those technologies and processes that offer the greatest opportunity to increase sustainability in these domains, and the fundamental computational methods that support these technologies and processes.

Socio-ecological agent-based modeling: Understanding complex socio-ecological interactions by designing and releasing a society of plausible agents into a simulated ecology and assessing: (a) whether the agents survive and (b) if they do survive, what impact they have upon the diversity of other species in the simulation. Up to now there has been a lack of simulations that combine a complex model of the ecology with a multi-agent model of society – there have been complex models of society but with simple ecological representations and complex ecological models but with little of human social complexity in them. See also Socio-ecological models and a memetics revival from new tools that are becoming available.

Transport: nonCO2 producing large aircraft (e.g. electrical, solar).

Transport is also suggested by ENEA (email 23 june): development of technologies for transport which can reduce impacts using an approach of sharing the energetic and material resources. Multiple criterio evaluation methodologies can combine energetic aspects with the social aspects that bring to holistic evaluation of the transport system (see also under Time for Time).

Comments submitted under nano-bio-chem point to the potential to enlarge the field of application beyond bio-medical to include environmental technologies (e.g. design of remediation systems, valorization of bioresources), white biotech (e.g. self-regenerating co-factors and Enzyme cascades) and material sciences.

3D aqua farming (email june 11) with a.o. robotics. Can be linked to underwater technology for in situ observation of phytoplankton, cytometry. Deep water (5000 meter). A related specific problem: Impact on water bodies of technologies related to sensors is about the study of antifouling technologies for marine and riverine sensors. This is a "hot topic" in the field of environmental monitoring as available methods to prevent the settlement of organisms (biofouling community) on sensors, currently, are not satisfying the needs of end users.

The European Technology Platform for Water (www.wsstp.eu) is closely collaborating with the EIP Water on its Strategic Water Vision 2030 and SRA. It stresses the importance of FET for the water dependent sectors, and underlines the emerging needs to address water sector challenges. A comprehensive research agenda includes:

- nature based solutions (see also Biological Clearsing purification of waste waters)
- membrane technologies and biotechnologies (e.g. biogas technologies, anaerobic technology for sludge).
- sensors, modeling, monitoring, real-time management, smart use – developing eco-system services in urban water management, river basin management and water treatment.
- detection and risk assessment of emergent pollutants (pharma, nano, …), sanitation for drinking water and aquatic life reproductivity.
- extraction/recovery of critical material

There are links here with Global Systems Science and with Nano-Bio-Chem. Given the intertwining of water with many different sectors and aspects of life, opportunities for a more interdisciplinary approach could also be found at those overlaps (e.g. Water-Energy-Food-Biodiversity Nexus, Water&ICT,… on which WssTP has specific working groups).

PARTIAL ANALYSIS

Circular Economy – Closing the waste-water-energy cycles argues that we need attention and tools that make us see the big picture; to create new technology and business models to enable product life extension, better distribution of energy intensity over multiple lifecycles, and effective resource utilization for water purification.

The European Technology Platform Food for Life (etp.fooddrinkeurope.eu/asp/index.asp) identified a number of emerging technologies for the food industry, several of which reflect eco- and sustainability concerns, for instance:

- reduction of energy consumption, efficiency (and ecological footprint)
- smart green house (and crop?) management
- novel biodegradable and intelligent packaging materials
- membrane techniques, cleaning, disinfection

The more systemic issues of macroeconomics, global food supply chains, space management, small –large producers, new economic models etc are surprisingly absent (probably not seen as emerging technologies stricktly speaking).

The National Energy Efficient Buildings Platform (a Prague based initiative) would like energy efficiency (in buildings in particular) to appear explicitly in the topics of FET Proactive, in particular under Bottom-up Intelligent Construction, Constructive Symbiosis and Time for Time.

Smart buildings with renewable generators argues that the designing of smart buildings which combine the use of renewable suppliers and storage system could reduce the energy demanded to the utility, and so the environmental impact

Photonics and green photonics in particular are seen as an important contributer to ecology (pollution detection, environmental sensing, food quality and safety, etc.).

Reduction of energy requirements for IT by a combined hardware/software approach is an important topic. Some research topics for IT driven component energy reduction could be

- generic, hardware parametric, static system analysis techniques that take both hardware and software into account (e.g. static analysis techniques such as typing systems and abstract interpretations)
- creating a library of energy models of often used hardware such that researchers can use these model in studying IT driven components that are based on that hardware
- dynamic energy measurement tools for figuring out which parts of an IT driven component are using up the most energy (only few tools are available and no generic approach for effective user feedback has been developed)
- developing generic methods to provide feedback based on static and dynamic IT driven component analysis in such a way that effective feedback is given in order to reduce the energy consumption of the devices. These techniques may have to be different when the average user is targeted or the programmer or the device designer.

The aim should be to reduce the environmental impact by both reducing the footprint of the hardware components, including the production process, and by reducing the energy usage that is caused by how the software is defined. This can make a big difference as you can have noticed e.g. when a big smart phone company announces a quick update of its os since it drains the batteries of the system (see discussion with Beatrice (same authors/group)).

More generally the ecological footprint of technologies: see ecological technology and ecological technology contributions: 'From our point of view the main key points are linked (footprint, raw materials, products, uses, re-use, waste...). We think if we are encourage to promove greener products starting from the sources, we will start to decrease the

PARTIAL ANALYSIS

enviromental impact of technologies. It's a key point to include all just the production, if we don't start to study how we can decrease part the uses of the feedstock for a greener sources (re-use, waste and natural raw materials or raw materials from natural sources) we can not decrease in a reasonable time... Towards zero-impact in interdisciplinary and early technology asessment, where it is stated 'Research on this topic should be oriented on international inter- and transdisciplinary forward-looking studies on integrated technical, social and organisational innovations for the "zero-impact mass-consumed IT" vision'.

Innovative hierarchized three-dimensional hybrid nanomaterials and nanostructures for energy conversion and storage technologies is suggested also by CEA (email of 30/6) with a view of their integration in nano- and microelectronics (portable, embedded) also mentions ecological, energy and footprint concerns.

Global Systems Science

GSS addresses new ways of supporting policy decision making on globally interconnected challenges such as urbanism and migration, environmental issues and climate change, financial crises, or containment of pandemics. The ICT engines behind GSS are large-scale computing platforms to simulate highly interconnected systems including cross-cutting policy dependencies and interactions, data analytics for 'Big Data' to make full use of the abundance of high-dimensional and often uncertain data on social, economic, financial, and ecological systems available today, and novel participatory tools and processes for gathering and linking scientific evidence into the policy process and into societal dialogue. GSS will develop further the scientific and technological foundations in systems science, computer science, and mathematics.

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

Note: this was one of the proactive initiatives retained for the FET WP2014-15.

An attempt to define GSS is in Global Sytems Initiative: capitalize on opportunities Global systems science approach allows us understanding how different processes of various natures e.g. economical, social, political, technological, biological and physical interact in a specific area of a social system, e.g. smart energy grids. The main pillars of the global systems approach are: 1) Strong, precise theories 2) Computer simulation models of real-life phenomena 3) Analysis of big data 4) Relevance to technology 5) Practical applications for policymaking and business 6) Interfacing with art. Note here the limitation to a specific area of a social system, which is in contrast with others who would like either a generic scientific toolbox, or a modelling of everything target for GSS. Another perceived tension between some of the contributions is in the use of the words policy making and policy makers, or decision making. In many contributions the institutionalised policy making level seems to be targeted, whereas others point out that this should go much deeper into the 'operational' levels of society (firm, farmer, cconsumer,…)

Global Networks takes a critical view on how funding agencies deal with groups of stakeholders and advocates for sharing of such groups, and breaking out of silos between agencies to tackle GSS, building really global networks of science. GSS is about interlinking Global Solutions hints at something similar by illustrating with the 3 parallel interlinked GSS conference series (US, Europe, China), trying to create such global networks while retaining a 'local' view as well. The lesson here is recognizing that solutions are rarely globally implemented but local. Moreover no local network of researchers can claim to have hands on what is needed in this (for instance, in-situ knowledge of specifics, access to local data,..): you need a global system of science to do Global System Science.

This resonates further with GSS - Collective Intelligence - Citizen Science, including an even broader network of contributions and collaborations of the general public with expert researchers, fostering the trusted relationships required between all the societal actors.

Several contributions (e.g., GSS as a research community) highlight how GSS is already embedded in and complimented by other private and public initiatives such as the Institute for New Economic Thinking, the New Approaches to Economic Challenges initiative of the OECD or UNEP's financial initiative, the IMF conferences, the UN Global Pulse initiative, http://www.unglobalpulse.org/.

GSS on disciplines and methodologies

Global System Science and Policy argues that "a new generation of researchers is needed, they will need the modelling skills of statical physicists, a good knowledge of discrete mathematics, graph theory and algorithimcs, and finally the skills of computer scientists to handle a deluge of big data." Science for Policy : some issues goes further to include social and political scientists in the picture in order to have a handle on the policy formation and decision processes (up to the individual level of e.g., the farmer).

Global Systems Science is Social Science warns against the likely mistakes from drawing a-theoretical conclusions from bid-data mining and argues for " integration of serious social science as the foundation for causal hypotheses that can be analyzed in big data. These should be validated through the common good practices of social science, where dealing with human beings and misleading assumptions about them is the norm. This theme of non-rationality can be linked to others (see the discussion under innovation enablers).

A similar message comes from Global Systems Science, Art, RRI and Behavioural Issues, with a broader conclusion though: that GSS should be about reinventing science away from its mechanistic and reductionist reflexes. Art is also suggested as one way to stimulate this way of looking at things in different ways.

A more radical attempted summary of some contributions is stated in Global Systems Science - The Sum of Things: consider: the use of art as part of the methodology; inclusion of what is called citizen science; adding behavioural (social science) aspects to the recipe; introducing time as a central element of GSS; generalising GSS towards a new way of undertaking scientific research; integrating Responsible Research and Innovation as an integrated aspect of method; moving beyond interdisciplinary thinking to encompass transdisciplinary operation in the sense of transcending the traditional organisation of knowledge; and shifting the focus away from policy towards the design of new systems (see also New Design and Engineering of Socio-Technical Systems).

Specific application areas being discussed are the following:

GSS and urbanism/cities building on work by the EUNOIA consortium (http://eunoia-project.eu/media/uploads/publications/eunoia_report_gss_an...). From the same background, see also GSS and policy applications focused on urban development and arguing the importance of covering an integrative approach to data (acquisition, modeling,…) with good policy interfaces in transdisciplinary research teams can lead to good science and to good shorter term fall-outs, including commercial ones. A related and more specific context (rooted in a concrete reality) is suggested in GSS on Social governance and urbanization in China.

PRELIMINARY ANALYSIS

Example of Policy Application of Global System Science offers a specific agenda for GSS to contain systemic risks, namely to provide ways for simultaneously reducing interconnectedness, correlation and complexity of instruments. The arguments come mainly from the financial sector, building on results form 3 GSS projects (FOC, SIMPOL, MULTIPLEX). Similar arguments (from FOC, SIMPOL) are also re-stated in another contribution GSS - Inter- and Transdisciplinarity at Work.

GSS and Socio-ecological agent-based modeling: Understading complex socio-ecological interactions by designing and releasing a society of plausible agents into a simulated ecology and assessing: (a) whether the agents survive and (b) if they do survive, what impact they have upon the diversity of other species in the simulation. Up to now there has been a lack of simulations that combine a complex model of the ecology with a multi-agent model of society – there have been complex models of society but with simple ecological representations and complex ecological models but with little of human social complexity in them. See also Socio-ecological models and a memetics revival from new tools.

GSS and Macroeconomics comments "on how Global Systems Science can shed light on important macroeconomic issues related to the interplay between human mobility, international trade, and country performance." Unerlying this is an argument on how GSS, when properly done, can repair some of the flaws of pure macroeconomics modeling (as in Dynamic Stochastic General Equilibrium (DSGE) modelling). The same author in GSS and the Relation between Inequality, Credit and Crises shows the power of agent-based modeling as " the very possibility of providing alternative theoretical tools to policy makers, which are firmly grounded in a GSS approach to social sciences, and can endogenously account for crisis emergence within a general disequilibrium macroeconomic-dynamics rooted in an explicit empirically-grounded microfoundation of interactions and individual behaviors". GSS and Agent-based Macroeconomics develops this further, tracing over work from FP6 Eurace (www.eurace.org) and FP7 Symphony (www.projectsymphony.eu) . In terms of international collaboration an initial opportunity can be found in the Chinese National Science Foundation. Pointing to a similar topic (maybe less agent-based) is the suggestion in Global Sytems Initiative: capitalize on opportunities to look at ' Social mechanisms underlying finance and economy'. A more specific application of this is in Economics: forecast of energy price (mathematics) for scenario planning and research investment on energy.

GSS and Engineering: New Design and Engineering of Socio-Technical Systems requires still a fundamental merge in Economics, Engineering and Complex System science to come up with such a novel, groundbreaking set of system design results and methodologies. More from the perspective of organization design, similar discourse is in Tool to combine bottom-up and top-down approaches to organising. The contribution Systems Complexity: Evolving Systems and Systems of Systems applies a GSS perspective to complex systems engineering, in particular Structure Evolving Systems and Systems of Systems in a broad variety of domains but largely with a technological (ICT) perspective in mind.

Social Innovation is suggested in Global Sytems Initiative: capitalize on opportunities as one of the promising areas for GSS. See also the idea in Global Systems Science to develop supportive technology for the communication of global social entrepreneurs. social entrepreneurs facilitate the process of social emergence by empowering the societies and enabling bottom-up development. On top of that Global Systems Science could develop methodology and tools for measuring the social networks' process of emergence.

How to understand and increase effectiveness of actual bottom-up social processes is also suggested in Global Sytems Initiative: capitalize on opportunities, along with specific issues such as Social cohesion vs. radicalization, conflict and sustainable

PARTIAL ANALYSIS

peace that would obviously benefit from such an approach. See also GSS for participation suggesting that GSS should also provide theories & tools to support the actual formation, coordination and self-organization of social, economic and technological systems.

The NESS 2014 GSS Roadmap (non-equilibrium social science) should be ready end of 2014.

Specific technological ideas from these discussions are the following:

Big-data: In one authors opinion the main pillarof the global systems approach is analysis of Big Data (and empirical type of date). Using of Big Data allows to analysis and interpret advanced mechanisms of social sciences.

New mobile pervasive sensing technologies (cyber-physical) for the actual production of data (including e.g. drones) should also be emphasised. Data assimilation is another key enabler to be correctly addressed (ENEA, email of 23 June). Strong support for an SME focus linked to specific global challenges.

Global monitoring of information entails unresolved problems of information extraction, semantic integration, trust, reliability and reputation, streamed data, data fusion, visualsation, recommendation and summarization. Global monitoring = abuse warns against this and rejects the monitoring, control and power paradigm. However, on this topic Global Systems Science argues that GSS has an unprecedented possibility to prepare societies for possible data abuse, trying to understand not only the consequences of new technologies but also the consequences of abusing peoples' privacy in unrestricted pursuit of big data. This is developed in more concrete terms in GSS for participation: Advancements in GSS should lead to participatory social processes rather than top-down control. Instead of strictly enforced action plans GSS-based policies should become sets of global constraints on otherwise self-organizing, bottom-up, micro-governance processes. Users that generate data should remain in control of the content they contribute to ensure that Big Data becomes social capital rather than an asset of single parties.

GSS - Collective Intelligence - Citizen Science gives a technological twist to the idea of participation and collective intelligence: "Billions of people inter-connected may solve current global challenges in a collective manner by a) contributing with individual solutions b) selecting and evaluating existing approaches c) re-using and adapting others work; leading to the digitally-enabled evolution of emergent intelligence. It is a great challenge to conduct large-scale experiments in order to collect big-user-generated-data with the aim of model and conduct these complex behaviors." And "The development of new and open disruptive brain-based technologies and frameworks for the emergence of collective solutions should be also considered." A concrete proposal for such a collective intelligence as a specifically structured social net is in Artificial intellect.

Perhaps a specific instance of this in the context of an organization is Tool to combine bottom-up and top-down approaches to organising, capable of informing members of an organisation of possible paths of action, based on an understanding of the external and internal conditions at any moment, and even capable of making decisions and taking action on its own would be of high value for everyone involved in an organisation. The tool would take into account communication processes, structural factors, members' social networks, task processes and requirements, and

PARTIAL ANAL.

external forces influencing the organisation in order to provide solutions to different scenarios.

The Suggestion for an open platform to address GSS challenges calls for integrating data sources,-processing resources, -simulation models (like multi-million agents systems) with adequate multi-level support and-analytic tools. It is noted that big companies have already part of this. This is echoed in GSS and urbanism/cities: "Also an open platform to share data on urban studies would be instrumental for significant advances in the field and the participation of different stakeholders".

Communication tools. As stated in GSS - Inter- and Transdisciplinarity at Work: for communicating complex systemic features of the financial system to non-experts, we need new communication tools. GSS has, for example, the potential to develop innovative graphical interfaces for communicating the complexity of the financial system to non-experts. Moreover, GSS can and should engage with communication experts from the new media and with artists to reach out to civil society. However, Art in GSS should not be about communication sees this communication not as the right role for art, as further explained in Global Systems Science, Art, RRI and Behavioural Issues.

Knowing, doing and being

Technologists are often naïve when appropriating themselves of topics that have been studied for ages in other disciplines. Knowledge is an important case in point. The rational of this initiative is to renew ties between the different disciplines that are studying knowledge, the phenomena of knowing (especially beyond the 'declarative' kind of knowledge) and related issues (e.g., learning, context, knowledge transfer, knowledge as a social construct,…) from various perspectives (e.g., neural, behavioural, social, epistemological). This is an initiative for exploring the interdisciplinary fundamentals of knowledge, knowing, doing and being, tightly linked to the conception of future knowledge technologies

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

Note: this was one of the proactive initiatives retained for the FET WP2014-15.

Some emerging themes:

Distributed intelligence, emergent knowledge, the power of social

Related new topic submissions: center-periphery distributed intelligence, emergent knowledge in social networks (WWW+++, Also related to ICT and Art comment by Ascott in his cyber intelligence vision), self awareness and complexity. There is an emerging cluster ideas on distributed intelligence and emergent knowledge, linked also the power of social.

Text understanding (submitted as new topic) is close to some the above, relying on multimedial and distributed resources.

Visual/automated analytics

Integrating vision and language in a data-driven society brings this home in a coherent proposal, under an umbrella of data analytics rather than cognition (builds on a COST action).

Integrating Visualization and Automated Analysis Methods should enable the interactive but computer supported analytics of large and complex data sets. A

PARTIAL ANALYSIS

specific instance of this is described in Sustainability Analytics with a focus on data analytical methods for balancing environmental, economic, and societal needs for a sustainable future. Specifically, it will consider the major problem domains that impact global sustainability, those technologies and processes that offer the greatest opportunity to increase sustainability in these domains, and the fundamental computational methods that support these technologies and processes.

Visual analytics and hybrid analytics can be argued to fit into this context as well.

Creativity, art and non-rationality

In a recent workshop we had on creativity the topic of "computer as co-creator" was highlighted as promising research towards powerful new technologies. The vision is to significantly enhance human creators' abilities to produce rich and creative content is based on the idea of 'Computers as collaborators'; This research should lead to software capable of making intelligent suggestions to human creators based on embedded knowledge about how human creativity works. The idea of 'Computers as co-creators' goes beyond simple software supporting humans in optimisation of the creative process. It is a bold vision about giving computers an autonomous say in the creative process when working with humans. As you can understand such research involves several disciplines including neuro and cognitive science, human computer interaction, artificial intelligence and cognitive systems.

As indicated elsewhere, the opportunity from combining the themes of creativity, art and science, and the nature and role of non-rationality into a single initiative may be worth investigating. This would put the theme of creativity in a broader context than the production of content, and highlight its role as an enabler of creative research and innovation.

Nano-optomechanical technologies

The various interactions between light and the dynamical (oscillatory) states of matter are beginning to be understood, for instance from research in cavity optodynamics, and have been delivering a lot of basic science results, both in the classical and in the quantum regime (e.g. for realising a quantum ground state through optomechanical cooling). This initiatives asks the question what we can do with all this? What are the technological implications of all this? How can this lead to anything practical?

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

An extensive series of contributions and support statements, also several from outside Europe (MIT, NIST, RIKEN, CALTECH 'in my opinion the potential for this area to impact technology and science is far greater than any other now being studied').

The topic has a wide support with strong convergence on the core orientations, applications and benefits for science and technology.

A useful addition from Wrachtrup, amil June 29) is an example of GPS-free autonomous car navigation with a precision of 30cm per hour, which only this kind of technology seems capable to achieve.

Strong support from ENEA (email, June 23). Interactions with other scientific communities (energy, bio-medicine, safety and metrology) should be reinforced. Clearer link to Photonics21. Suggestion to change the title in nano-opto technologies in condensed matter (less 'mechanical' thus a broaer scope on light-matter interaction'?).

PARTIAL ANALYSIS

After closure of the consultation a letter was receive co-signed by 3 PIs in ongoing or past FET-Open projects to argue further on the value of an initiative on this theme.

The EUPHONON (www.euphonon.eu) coordination action submitted its position paper on creating a European nano-phononics community and research agenda. It encompasses nano-optomechanics as an area as well.

New possibilities at the nano-bio-chem interface

This explores new possibilities at the intersection of nanotechnology, (cell-)biology, chemistry and information science. This can be aimed at new tools and techniques for advancing research (e.g., in neuroscience or biology), at the conception of novel systems and materials (e.g., synthetic or hybrid ones) or at applications for new implants, drug delivery, generative medicine. We seek strong synergies between the different disciplines for jointly exploring such new technological possibilities.

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

The topic as stated is still seen as important and timely, with some suggestion to enlarge it, and some illustrative instances of what this work could look like in more concrete terms:

Nano-medicine: A new topic here is in-cell technology, nanostuff injected directly into the cell. Plaza and Perry call this in-cell physics (another reason to include physics here more explicitly?) and state that bridging between biological and physical disciplines is particularly needed.

Intracellular optical sensing is related: The advent of optical nanoprobes for the quantitative determination of bioanalytes at the intracellular level is one of the most fascinating achievements in the field of nanoparticle and nanomaterial technology. Among this, oligonucleotide optical switches can work not only as nanoprobes but also as drugs capable to address specific RNA messengers thus preventing the overexpression of proteins associated with pathologic diseases.

Somewhat opposit to this is the extensive proposal on exosomes study for progress in vivo with various implications for future nano-medicine and beyond.

Perhaps slightly more established is the combination of pulsed and CW near-infrared laser light with plasmonic particles such as gold nanorods is gaining relevance for the photoacoustic imaging and photothermal ablation of cancer. Selective targeting of malignant cells with these contrast agents may rely on complementary biochemical and biological strategies, including the use of specific probes or the exploitation of cellular vehicles (not sure what this refers to).

An additional suggested topic to consider in nano-medicine is the targeting of epigenetic mechanisms of chronic illness progression (for instance Cardio-Vascular Diseases) for developing any future therapeutic pipline and also to expand our understanding of these illnesses.

It is also suggested to add more than basic research on the existing pile, and instead emphasize a clear clinical orientation.

Concrete illustration is offered on what this could lead to: systems for clinical therapy, wound healing and precision nano/microfabrication, regenerative medicine, electroconducting materials and rehabilitation, to develop innovative implantable biomedical devices for the treatment of human injuries.

PARTIAL ANALYSIS

Another concrete scoping suggested is the shift from Si to C, namely the Organic/Bio Micro/Nano Electronics, in all of its scientific, materials, technological and application paths.

An illustrative approach could be the realization of a multifunctional scaffold through a more biologically and rationally based method. This can extend to controlled 3D tissue and organ development (including brain and body-on-chip). In another contribution, functionality by design is highlighted. Can we do better than trial and error? See also the contribution on computer controlled evolution and exploration of nanoscale systems (physical evolution and exploration) for computation and sensing (CEA).

Another illustrative approach is interfacing and exploiting bio-organic selfassembled nanoconstructs (ENEA, email of June 23)which aims to exploit the ability to design and selfassemble DNA architectures at the nanometric scale by interfacing them as functional constructs to solid state artificially fabricated devices. This requires new bottom-up fabrication techniques, reliable organic-inorganic couplings, control of 3D configuration and orientation, conductivity, etc. This also needs an ab initio modeling effort.

Potential to enlarge the field of application beyond bio-medical to include environmental technologies (e.g. design of remediation systems, valorization of bioresources), white biotech (e.g. self-regenerating co-factors and Enzyme cascades) and material sciences. – note that these were not included here because of the presence of Ecological Technologies and the Bottom-up construction initiative.

Suggestion to add (bio-)physics as a relevant discipline. The same post mentions some recent results in Nanotechnology for protein/DNA sequencing, active bio-inspired materials for regenerative medicine and organs on chips (Wyss) for human disease models, which links to FET-Open ongoing projects like BoC. Also points out existence of relevant communities, the requirement of interdisciplinary teams and the role of early industry interest and thus the need for attention to educational (training) aspects.

The use of photonics technologies, functionalities and materials can be of great impact in the nano-bio-chem field, both for diagnostic and therapeutic applications. Smart light-matter interaction at interfaces can open new possibilities. This could refer to optogenetics, optical resonator based bio-sensing, intracellular optical nanosensing or to plasmonic nanoparticles, for instance.

Another contribution (CEA, email of June 30) proposes hybrid systems for solar to chemical energy conversion (so called artificial photosynthesis) as also relevant to this topic. Various other topics fall under the realm of low TRL NMP research. Some of it related to bottom-up self organisation and functional new materials. A mention is also made of biocompatible fuel-cells, to power implantable devices.

PARTIAL ANALYSIS

Quantum technologies

Technologies that exploit quantum phenomena like superposition and entanglement will be a radical departure from current technologies. Several promising directions are now well known, for instance in computation, communication, security, metrology, sensing, simulation and material science. Europe has the scientific lead in many of these, and some European companies were first to market with some concrete applications of quantum technologies (quantum key distribution in particular). Building on such successes is it not time to bridge from the science to the engineering of some more concrete quantum technologies? For example, are we close to delivering a quantum simulation

technology, and if so what precisely will it simulate? Or can we start to concretise the necessary quantum-ware for large scale quantum networking? What about applications in biology and medicine?

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

Note: this was one of the proactive initiatives retained for the FET WP2014-15.

To start on some horizontal issue:

> one contribution points out the various national initiatives, and asks whether EU can add any value to this. An ERA-NETcofund on this topic could be an answer. The possibility and strategic usefulness to extend this to non-European funding should be investigated.
>
> Other contributions point out the need for long-term sustained support to a real quantum technology strategy that can rival with for instance the US (IBM Research, Yale, UCSB, HRL), investor backed initiatives like the Canadian Institute for Quantum Computing (IQC, Waterlooo, CA) or with private ventures like D-Wave. A QT-Flagship or similar is advocated for this to bring research, engineering and industry interest together in a long-term partnership. Whether the current de-facto strategy of virtual institutes provides enough coherence and joint momentum for this is unclear.
>
> Several contributions hint at the need for moving up the TRL scale and for including more and more engineering aspects, while soliciting more industry interest and some spin-off generation. A topic of quantum engineering as a proactive (see below) could provide an umbrella for such a theme, probably with an explicit aim to position the right variety of players in an emerging quantum innovation ecosystem. An innovation oriented call that explicitly asks for ventures in Quantum Technologies (e.g., on component technologies for quantum networking, or for quantum enhanced sensing and metrology) could be an alternative to get the ball rolling (a kind of Proof-of-Concept grant).

Quantum Communication (moving quantum states around, realizing distributed entangled states) remains a valid topic, be it in terms of improving the security aspects (Quantum Key Distribution – QKD), in terms of long-distance (>120km, which seems to be the current practical limit) capability (fiber, air, satellite,…) and capacity (high-bit rate) and in terms of complexity, e.g., moving beyond point-to-point towards a quantum internet vision (requiring single photon sources, repeaters, transducers, memories, high-quality mirrors and fibers, new quantum circuitry, new protocols,…).

Since precise technical targes can be formulated for many of these, the topic may be suitable for a prize-based initiative as well.

Quantum communication can also be positioned as an enabler for a long-term vision of quantum computation and simulation to implement heterogeneous (coupling and transducing between different physical modes) and distributed systems or a quantum cloud. While a multitude of physical realizations are possible, device independence will become increasingly important.

Note that Quantum Communication has been funded in the last through other parts of H2020 showing the maturity of the approach.

Quantum computation is recognized to be still a long way off, though hype and reality around D-Wave maintains this topic high on the agenda. Some groups in Europe (e.g., TNO

PARTIAL ANALYSIS

and TU Delft) are gearing up to take on the challenge of delivering a European (Dutch) quantum computer. These contributions emphasise the need for engineering and resources to scale current results to practical levels of complexity, as well as ways of integrating future quantum devices in classical environments. In parallel of course the theory will need to advance, e.g. on algorithms, error correction.

Topological insulators are useful in topological quantum computers and for fault tolerant quantum computing.

A key issue here remains the choice of platform. Most promising ones seem ions and superconducting circuits, but there are others. Some contributons to the consultation aim to keep on investigating several physical paths in parallel, whereas other seem to privilege a particular implementation, e.g., integrated optics, or nano-electronic circuits (themselves existing in many variations spintronic devices, molecular electronics, single-electronics, quantum dots and nanowires, superconducting circuits and hybrid supra / semi / magnetic systems). See also under 'quantum engineering'.

Possibly some of the more mature specific approaches could be supported through other parts of the programme (e.g., photonics, microelectronics, though probably not for full-fledged quantum computing), while newer, niche and more radical approaches can find a natural home in FET-Open.

Quantum Infromation Science provides the theoretical power house of all this. New (device independent) protocols, error-correction techniques, quantum algorithms and classes of problems and their applications in new fields should be investigated.

A specific topic proposed for theory is Quantum Hamiltonian complexity, investigating decidability and approximation results for various classes of Hamiltonians, both in theoretical and in computational terms. These results are important for the study of important properties (ground states and energies, phase transitions,…) of many-body physics, materials and 'natural' quantum systems. It seems to be an essential theoretical and modeling toolkit for (any?) current research in quantum technology.

Quantum Simulation (we had a call on this under FET proactive in 2014). – to be done.

Quantum (enhanced) Metrology, Sensing, and Imaging is a diverse area in which quantum effects are exploited for high precision measurements. A typical example is the use of Squeezed Light (with noise levels below shot noise because of entanglement of multiple photons). Imaging provides an interesting angle to open to biology and health care as potential outlets for this. A specific contribution on Quantum Healthcare focusses on medicial imaging and theranostics as an area where coherent and incoherent control of quantum dynamics, and optimal quantum control in general (such as the pulse sequences used in NMR experiments), could be deployed. See also the contribution on new molecular imaging and theranostics under new ideas.

See also a contribution on quantum-enhanced sensing from ICFO (sent by email, May 19). Most (all?) of them are based on the exploitation of entanglement to squeeze signals within noise levels that are below the expected bounds. In addition, however, the expand the realm for quantum technology applications to a wide range of settings (gravitational waves, biomagnetics of living organisms, protein measurements, atomic clock). Dedicated DARPA initiative on this theme is mentioned (QuASAR) and a previous one on "Quantum Sensors".

The same contributions suggest a prize-like initiative on sensing, setting a precise technological target to the community. It suggest 'the first quantum-enhanced, best-in-

PARTIAL ANALYSIS

class magnetic field sensor. This could for example be an optical magnetometer capable fo measuring iomagnetic fileds and employing squeezed light and/or spin queezing to oost the useful bandwith and the signal-to-noise ratio.'

Quantum engineering emerges as a new umbrella for several proposed directions that revolve around furthering the engineering aspects of quantum technologies (e.g. Engineering for advancing quantum science)**.** Often a bridge with silicon and well known solid state environments is made, in a programme of ultra-precise engineering at the nano-scale. Note that this is not only about the material science and fabrication aspects. Also a bridge with computer science would need to be made here.

Quantum engineering could be focused on a specific class of implementation to develop a coherent engineering approach. For instance New semiconductor-based quantum technologies: Spin qubits is a proposal for a specific technological platform that is within reach of state of the art engineering approaches. Also Quantum technologies based on superconducting quantum circuits and Flying qubits both explore a similar technological platform as most promising. Another contribution (Mottonen, by email 12/5) states quantum nanoelectronics as being the most promising platform (similar to spin qubits?), emphasizing its direct integrability with traditional electronics. Also the optomechanical devices could provide a useful focus (cavities, mirrors, reference implementations, resonators,…).

Fitting within quantum engineering is Quantum control as an enabler for new FET. Two specific directions are suggested: Quantum control in few-body quantum systems and technologies, and Quantum control in Chemistry and Life Science. Espcially the latter seems to build a (interesting?) bridge between disciplines that is fairly new and where important challenges remain (multiple molecules, weak laser fields for probing biological tissue). This is proposed by Virtual Institute of Quantum Control, funded by the FET Coordination Action on Optimal Control of Quantum Systems (QUAINT), https://quantumcontrol.eu/.

Quantum engineering could also comprise Quantum thermodynamics (nano refrigertors, a.o.) understanding the dynamics of nano-machines. (and quantum thermo electrics?).

First-principles materials design and discovery, which has a specific focus on quantum simulation of new materials. A similar aim with a different method is proposed under a topic on evolutionary exploration and exploitation of material design (see under bottom-up intelligent construction).

Quantum technologies and the Interaction of Light and Matter is a somewhat more specific focus, related closely to Nano-optomechanical technologies (see that cluster).

Specific topics that can probably find a space under a broader umbrella (photonics? Energy?).

> Further research and development is required on optical technologies including low loss optical fibres, low loss optical mirror coatings, as well as quantum-noise limited laser light sources, e.g. light sources for single photons, as well as squeezed and entangled light.
>
> Photons are an ideal tool for qu-bit encoding and integrated photonic circuits can give a real boost to the application of quantum technologies. Integrated photonic

PARTIAL ANALYSIS

circuits are also an ideal platform for the simulation of quantum processes and can help to understand underlying mechanism.

Topological insulators as elements for fault tolerant (topological) quantum computers.

Photosynthesis light harvesting (with reference to the role of quantum coherence in plants). Presumably this would aim to strengthen and exploit the mounting theoreatical and experimental evidence that coherence plays a role (essential or not is a matter of the debate) in the very efficient lightharvesting in natural systems (quantum efficiencies of above 80%). The exact role is not well understood.The process of excitation in single light sensitive molecules (chromophores) is somewhat understood, and a lot of work focuses on the energy transfer in larger systems of chromophores, which can be densely packed and allow for strong electronic couplings between them. New theory and experimental tools are needed to study the exciton dynamics.

See also energy society under ecological technology, giving a broader perspective on this. This could, among others, exploit the results on photosynthetic light harvesting with a broader picture of light energy and CO2 conversion.

The topics Quantum Hamiltonian complexity and Quantum control are usually building blocks of more specifically targeted projects. The question is whether it makes sense to give them an explicit status within a Quantum call, or even to have a dedicated call on such topics to advance the issues more in general (but maybe also then more *in abstracto*).

Time for time

We seek to explore multiple notions of time and the new technological possibilities that they inspire. Many disciplines are concerned with time –physics of course, but also history, geology, zoology, biology, chemistry, philosophy, psychology, epistemology, computer science, mathematics, neuroscience, literature, media and the arts. There are as many different motivations and methodologies to study and use time – often at vastly different scales and levels of interpretation. What can be learned from this in terms of future technologies to, for instance, understand, measure, represent, program, manipulate, stop, create, invert, multiply, perceive or differently experience and use time in its multiple manifestations?

(this 'teaser text' was the basis for the consultation on this topic. The consultation requested new elements for deepening or reorientations)

The consultation made links to people in anthropology, physics, arts, linguistics, transport. The contributions are very supportive and significantly enhanced the scope of the topic with some interesting directions. There are contradictory hints to keep the scope of such a topic widen open, or to focus it just on specific technology (metrology).

Timekeeping artifacts extensive contribution from New York anthropologist (on –line and separate email). How the model of clock time is only one (internal, psychological time, time ethnography, musical time,…) and its impact on society, health, science,…

Time understood as an element of re-appropriateion of the human dimension is then projected into the world of transport in terms of personal management of travel thanks to the development of advanced mobility systems. The development of space-time components must find identity with the new energy consumption

PARTIAL ANALYSIS

patterns. The step to change from 'end use of energy' to 'shred use of energy resource' (ENEA, email of 23 June).

The National Energy Efficient Buildings Platform (a Prague based initiative) finds this a very interesting and highly relevant subject, with focus on interaction of time policies, human biology and psychological aspects of human existence. It sees various applicative directions from fundamental studies such as transportation in the context of strategic urban and regional planning (e.g. self-organized robotic car system).

Time not so real? Is time the domain of ignorance, illusion and failure? Time can be seen as the way by which we deal with the imperfection of knowledge of our past, as well as our future. Time is what makes us live with that imperfection.

It's All About Time. Refering to this book Moments in Time, this is about the experience of living past-current-future in a single moment. This is the kind of manipulation that imagination can do (with effort) and that some technologies might help to achieve. Why? Because it has implications for our interventions on large slow changing systems such as those studied in GSS. Resonates also with the Oxford Martin School report on 'now for the long term' where the historical embedding of the now is a key point: decision now have to take into account past and future. The author links to what he calls 'behavioral agriculture' (ref behavioural economics) in what I suspect is a similar perspective. This contribution also links to Art and Science and the process of artistic enquiry, to inter- and transdisciplinarity. The author also suggests, rather than through a new topic, to bring the time perspective into the GSS topic (judged to be too narrow) and/or into the Art and Science topic. A related but much more pragmatics perspective is taken in Decision-Making, Government, Citizenry, and Time.Citizens use on-line tools to make decisions about their lives, extending in time (from planning trips, holidays, to pensions and heritage issues beyond their own life). We need a research program for assessing the way an interface influences thinking about time, and a program for guiding interface designers to improve the presentation of time.

Cognitive perspective: Representing time and space links to ontology in linguistics and cognition to come up with better representations and ways to programme time and space (claimed to be linked: 'summer is getting closer'). Several concrete scoping topics proposed. Similarly The experience of time takes time perception as a Darwinian outcome that can be studied and reproduced/stimulated through technology. Similarly Effects of new technologies on temporal experience and the creation of temporal experiences (in this contribution mostly duration) with applications in therapy, robotics, education and early child development, entertainment. An email contribution (Kornai, May 09) is also calling for taking into account temporal logics (representation) and linguistics, in line with the above. This maybe all links to what's on vogue in cognitive neuroscience, viewing the brain as a sophisticated prediction machine, where various time models (and horizons) need to coexist.

Physics perspective. Metrology for a focus on time metrology (possibly extending to mass as well). Time as a fundamental problem in physics and philosophy wants to link fundamental physics on time to epistemology and philosophy (but the focus seems to be on physics).

PARTIAL ANALYSIS

HPC

Some contributions with relevance to HPC. Note that the proactive on HPC is defined in close collaboration with the PPP4HPC. We mention these relationships for completion, though most (all?) of these ideas are also found under other umbrella topics.

Zero power: Energy related research. Also: Hoare logic for energy consumption analysis of algorithms (GoGreen project, the Netherlands).

Value creation through mathematical modeling, simulation and optimisation (MSO): this aims to boost innovation and industry competitiveness through mathematics for a service platform for MSO, based on HPC and big-data capacity. Building on the international network EU-MATHS-IN, the European Service Network of Mathematics for Industry and Innovations (see http://www.eu-maths-in.eu/). US and national initiatives on this.

See also Change in paradigm in numerical simulation which points out the role and computational load for mesh computation in numerical simulations and proposes a new approach which is mesh free.

The quantum theme also mentions HPC as a context for work on quantum processors, both as a tool to support the research and as a host for a quantum co-processor.

Neuro-inspired optical computing (reservoir computing, a kind of analog computing which can be implemented with photonics) is also seen as an HPC technology. It can indeed attain speeds ways beyond electron based systems. The technology is also positioned within a neuro-science context, much like what is being done within HBP.

PARTIAL ANALYSIS