Visions of ECS beyond 2030

Analysis of Key Messages from the LTV and the 5 KDT Workshops

Sven Rzepka, EPoSS Scientific Council
Visions of ECS beyond 2030  
Joint Workshop of the 3A Scientific Councils on 14 Sep 21

**Agenda**

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<td>Introduction by the moderator: workshop guide and agenda</td>
<td>Patrick Cogez, AENEAS</td>
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<td>09:35</td>
<td>Main ideas under development in the Long Term Vision Chapter</td>
<td>Dimitrios Serpanos, Chair, ARTEMIS Scientific Council</td>
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<td>10:00</td>
<td>Inputs as derived from the KDT Workshops</td>
<td>Sven Rzepka, Chair of EPoSS Key Technology working group</td>
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<td>Future of Computing</td>
<td>Heike Riel, IBM Research</td>
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<td>Integrated Photonics</td>
<td>Dries Van Thourhout, Ghent University</td>
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<td>Flexible Electronics</td>
<td>Ralf Zichner, Fraunhofer ENAS/ OE-A</td>
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<td>Smart Networks and Services long term ECS requirements</td>
<td>Alexandros Kaloxylos, 5G Infrastructure Association</td>
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<td>11:20</td>
<td>Linking HW and SW for AI</td>
<td>Elisa Vianello, CEA-LETI</td>
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<td>11:35</td>
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<td>Michael Malms, mm-it4you</td>
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<td>11:50</td>
<td>Open Source HW and RISC-V</td>
<td>Luca Benini, University Bologna and ETHZ</td>
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<td>12:05</td>
<td>Q&amp;A and collecting inputs from the audience</td>
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<td>Wrap up by moderator</td>
<td>Patrick Cogez, AENEAS</td>
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Jointly organized by the 3As (Aeneas, Insight, EPoSS), the workshop had 170 registrants.
Heike Riel, *IBM Research*

**Future of Computing**

- **Key drivers**
  - Energy Efficiency
  - Data Explosion and AI
  - Security and Privacy

- **Whole array of research threads**
  - Towards perfect analog computing
    - Improve materials
    - Compensate imperfections with device architecture and algorithms
  - Technology for AI hardware
    - Traditional CMOS with algorithms and architectures for approximate computing
    - In-memory computing with algorithms and arrays for analog memory elements
    - Biologically plausible networks
  - Quantum computing
    - Many potential qubit technologies: superconductors, trapped ions, engineered defects, spin, quantum dots, topological devices
    - Challenges: cryo-electronics, nanoscale physics, engineering of nanostructures, exploitation of new phenomena

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• Areas of needed progress in SoI and SiN PIC platforms
  • Light source integration
  • Phase modulation (electronic and thermal)
  • Very low loss linear and non-linear waveguides also in SiN
  • Integrated detectors also in SiN
  • Optical isolators / circulators
  • Non-volatile programmable functions
  • Integration with electronics
Ralf Zichner, *Fraunhofer ENAS/ OE-A*
Hybrid, Flexible and Printed Electronics

- Circular economy of flexible electronics
  - Green production and green products

- Process technology
  - Towards more robust, lightweight, flexible and stretchable electronic systems
  - Printed flexible Q-dots and microLED
  - Seamless integration of printed hybrid electronics systems on top of any 3D object

- Applications
  - Printed flexible medical patches to detect body vital parameters, disease patterns and show aging rate

Courtesy of OE-A
Alexandros Kaloyxlos, 5G Infrastructure Association
Smart Networks and Services

• Fully distributed AI/ML solutions for network virtualisation
  • Cloud, deep edge, end devices…

• Transceivers for higher spectral efficiency, reduced power consumption, high density digital logic, chip-package-antenna co-design

• Human friendly radio systems - Safety
  • Handle increased density, higher frequency ranges, control EM fields

• Self-powered and energy harvesting devices
Elisa Vianello, CEA-LETI

Linking Hardware and Software for AI

• Need for Frugal Edge AI accelerators
• Brain-inspired computing
  • Massively parallel
  • Co-location of computation and memory
    • Resistive memory
  • Match circuit time scale with input signal dynamics
    • Spike coding
  • Embracing the statistical nature of emerging memories
    • Low precision neural networks
    • Bayesian neural networks
• Frugal AI devices - Combination of Algorithms, Technologies and Circuit Solutions

Courtesy of CEA-LETI
Michael Malms, *mm-it4you*

**Trans Continuum Initiative**

- From deep edge to cloud to HPC
- Case studies of digital twins in various settings
  - Industry, urban air pollution, extreme earth phenomenon predictions
- Research treads identified so far
  - Need for increase in computational power
    - New architectures: Quantum annealing
    - New paradigms: Stochastic computing
  - Automated digital twin development and application
    - Derive physics from data, train intelligence
    - Automatic detection of gaps between system and digital twin
  - AI/ML developments
    - Reinforcement learning
  - Distributed computing, distributed AI/ML solutions
    - Dynamic adjustment (of edge system) vs. backend
    - Overcome data transfer bottleneck

*Extremes prediction & the Digital TransContinuum*

**Technical dimension**

*The TransContinuum Initiative: exploiting the combined benefit of digital technologies for the prediction of weather and climate extremes*

*By Peter Bauer, Marc Ouyarten, Michael Malms*

*The Extremes Prediction Use Case*

Dealing responsibly with extreme events requires not only a drastic change in the ways society addresses its energy and population crises. It also requires a new capability for using present and future information on the Earth system to reliably predict the occurrence and impact of such events. A breakthrough in Europe's predictive capability can be made manifest through science and technology solutions delivering in yet unseen levels of predictive reliability with real value for society.

*Courtesy of the TransContinuum Initiative*
Luca Benini, *University Bologna and ETHZ*

**Open Source HW and RISC-V**

- Open source hardware as an innovation facilitator
- Requires access to advanced EDA tools with licencing compatible with open-source hardware
Findings from the 5 KDT workshops
Technology Fields

**Quantum Technologies:**
Q-Sensing, Q-Computing, Q-Communication

**AI Technologies:**
Hierarchical Architecture (AI at the edge ... SoS), Trustable / Certifiable, Digital Twins (full-scale ... very compact)

**Autonomous Systems:**
Multifunctional Integration and Functional Electronics, Trustworthiness (Reliability, Safety, Self-X, Security, Robustness)

**Materials:** Highly performant, Efficient fabrication, Inherently green, Hazard-free, Recyclable, Bio-based, Lifecycle optimized
Findings from the 5 KDT workshops

Application Fields

**Mobility**: Electrical, connected & autonomous vehicles

**Energy**: Multimodal bidirectional sustainable generation, distribution and use – across Europe

**Digital Industry**: Industry 4.0, Collaborative Robots

**Agrifood & Natural Resources**: Fully autonomous systems for smart farming, biodegradable materials, sustainable farming, animal welfare

**Health & Wellbeing**: Individualized / personalized medicine & care for inclusive self-determined life without dependence

**Digital Society**: Comprehensive services with full privacy
Summary: Joint Vision Beyond 2030

1. Foundational Technology Layers
   - Open Source HW as innovation enabler
   - Programmable photonic ICs
   - Autonomous Systems: Multifunctional Integration and Functional Electronics
   - Wafer-scale heterogeneous silicon photonics
   - New materials, devices, technology, infrastructure including measurement

2. Cross-Sectional Technologies
   - 1.1 Process Technology, Equipment, Materials and Manufacturing
   - 1.2 Components, Modules and Systems Integration
   - 1.3 Embedded Software and Beyond
   - 1.4 System of Systems

3. ECS Key Application Areas
   - AI HW from approximate to analogue computing
   - Frugal AI devices: Algorithms, technologies & Circuit solutions
   - Quantum Technologies: Q-Sensing, Q-Computing, Q-Communication
   - Smart Networks: Trustable AI everywhere, efficient use of spectrum
   - Trustable & Sustainable Electronics
   - Digital Industry: Industry 4.0, Collaborative Robots
   - Health & Wellbeing: Individualized/Personalized medicine & care
   - Digital Society: Comprehensive services with full privacy
   - Materials: Highly performant, Life-cycle optimized
   - Energy: Multi-modal bidirectional
   - Agrifood & Natural Resources: Smart, autonomous, sustainable farming, bio-degradable materials, animal welfare

4. Long Term Vision
   - Mobility: Electrical, connected & autonomous vehicles