NEREID

NanoElectronics Roadmap for Europe: Identification and Dissemination

2nd General Workshop

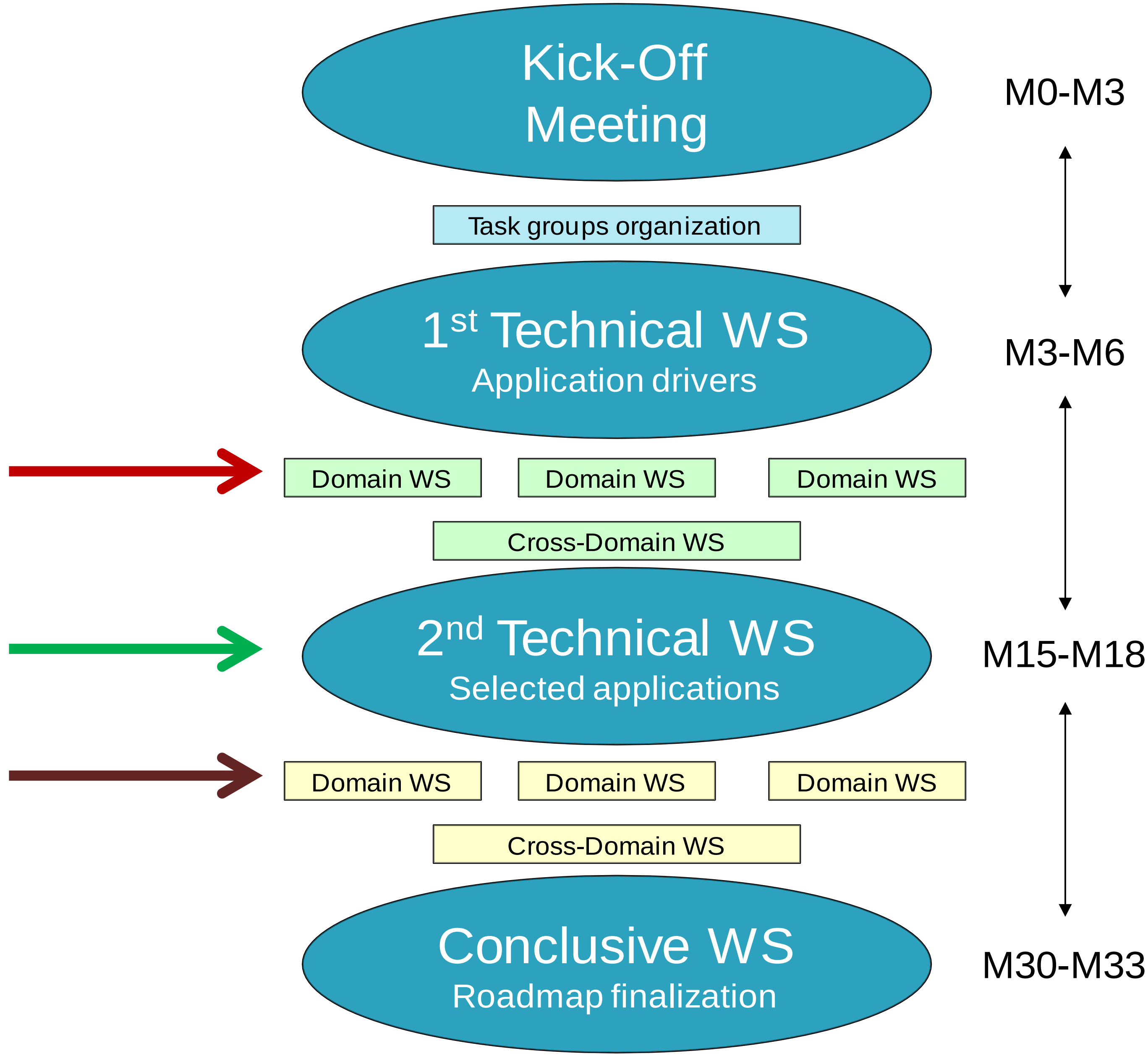
Athens, April 6-7, 2017

Heterogeneous System Integration Chapter

WP5/Task 2

HORIZON 2020

- 16 Sep 2016
Grenoble, France
- 6th-7th April
Athens, Greece
- Sep/Oct 2017

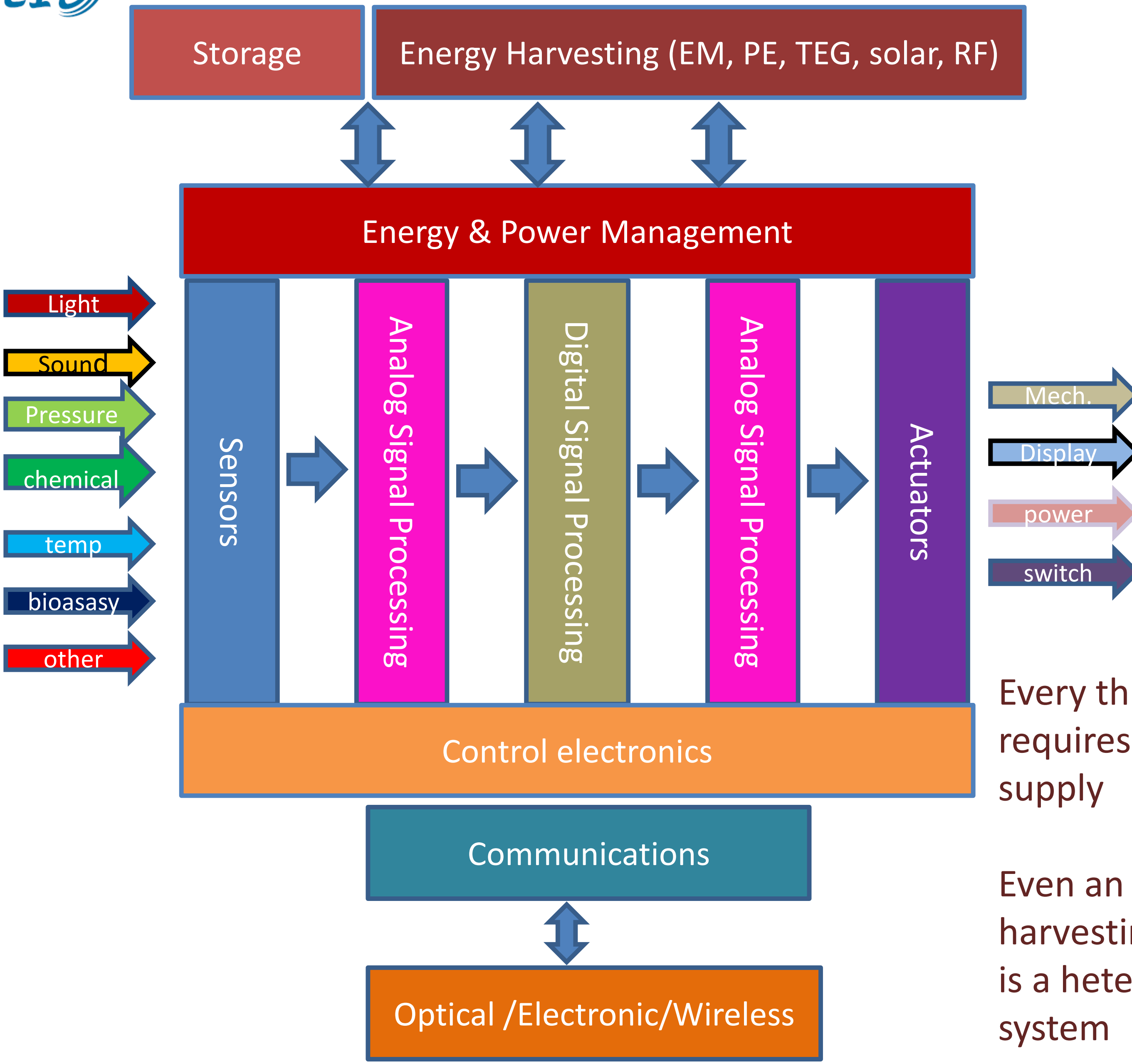


Experts Pool

- Main resource and engine of the project
- Academic and industrial representatives

Ralf Pferdmenges (Infineon, DE)
Peter Ramm (Fraunhofer EMFT)
Maaike Takklo (SINTEF)
Eric Beyne (imec)
Giovanni De Michelli (EPFL)
Piotr Grabiec (consultant, former at ITE)
Gabriel Pares (CEA-Leti)
Androula Nassiopoulou (NCSRD-INN)
Fred Roozeboom (TU Eindhoven)
Christian Silber (Bosch)

Generic micro-system



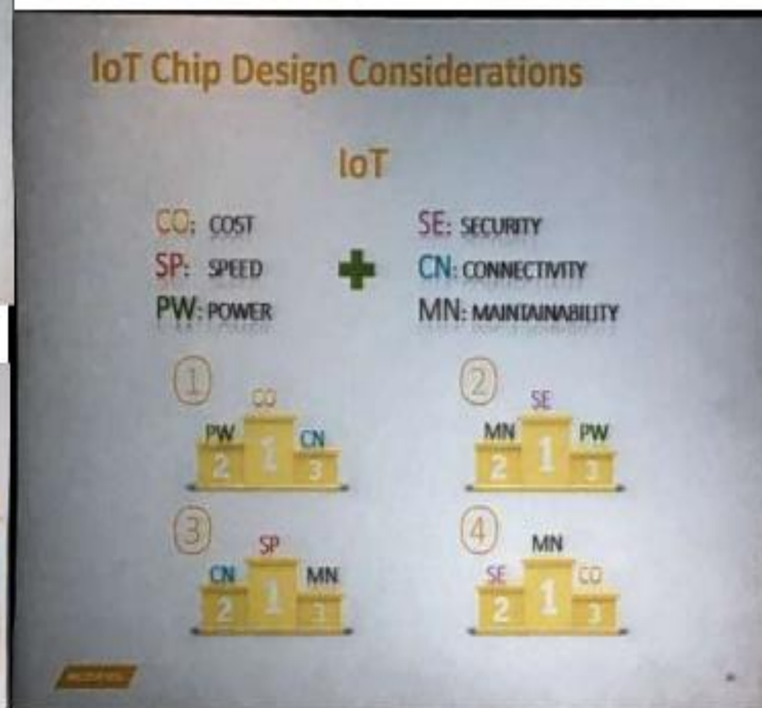
Every thing requires a power supply

Even an energy harvesting device is a heterogeneous system

Outcome from 1st general workshop

Top Down approach

The real challenge for HSI



Source: SA Huang, Mediatek

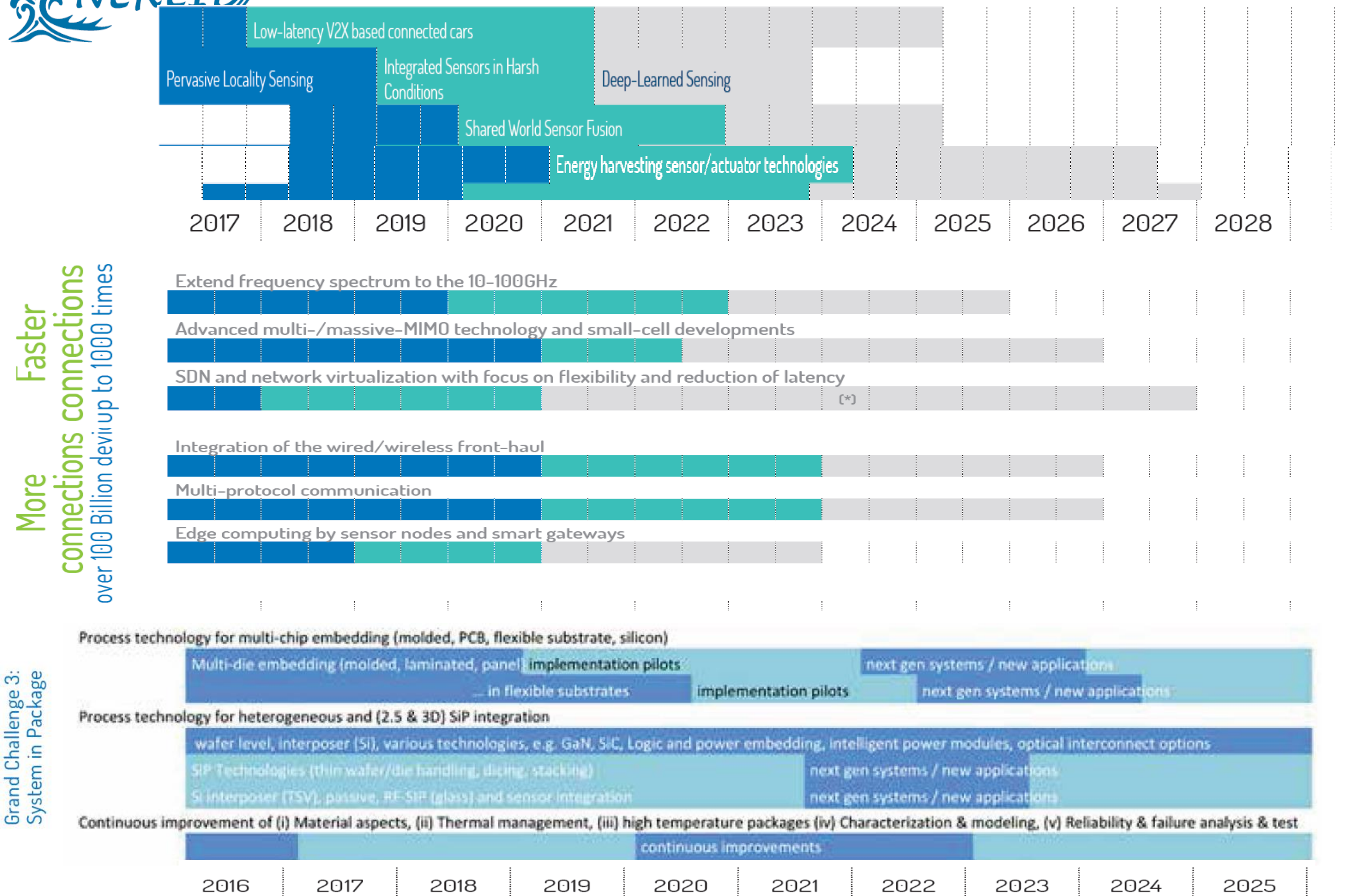
Outcome from 1st domain workshop

Functionality	Challenges (drivers)
Connectivity RF-enabled devices	form factor, performance/quality of antennas, shielding
Mobile/autonomous/off-grid	Low-power design, battery integration, energy harvesting, power management, voltage regulators
Sensor fusion	Form factor, cost, functional partitioning → unified modularity, calibration procedure, voltage supply
Biosensing	Temperature control, corrosion resistance, insulation, biocompatibility, integrable
Actuation	Power, accuracy, stroke, lead free
Implantable	Cost, Regulatory/Legal, constraints: connectivity, size, durability, power autonomy, form factor (e.g., flexibility)
Smartness	Latency, heat dissipation, bandwidth, customized computation efficiency, machine learning
Environmental resistance	Hermeticity, temperature, humidity, biofouling, vibrations, radiation, light
Functional Safety & Security	Fault tolerance, reliability, self-repair, resilience against physical and cyber attacks, self-awareness
Stimulus response	Optical, fluidic, mechanical, thermal, magnetic, inertia, chemical, radiation

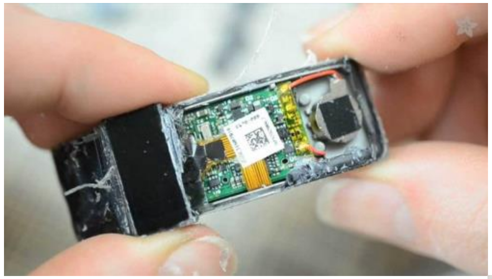
NEREID roadmap structure...

Concept	Medium term: 5+	Long term: 10+
a) Key research questions or issues		
b) Potential for application or Application needs and Impact for Europe		
c) Technology and design challenges		
d) Definition of FoMs (quantative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)		
	....	...
e) Other issues and challenges, and interaction with other Tasks/WPs.		

Positioning with respect to AENEAS Roadmap

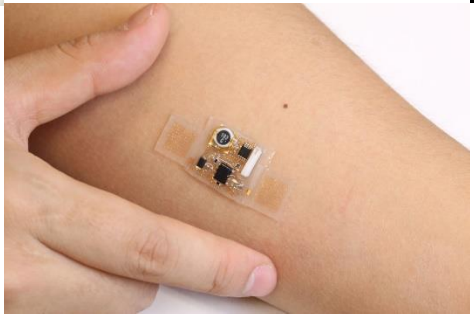


Target *very* demanding applications



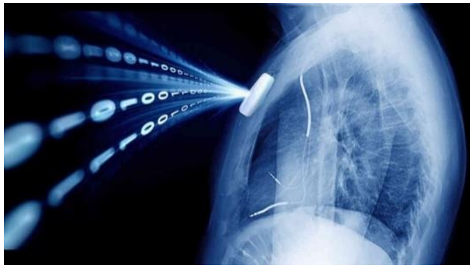
PCB

Multi-chip module



System on flex

Implantable
medical devices



Functionality as a HSI 'concept' for the NEREID roadmap

Generic requirements

- To be autonomous in terms of energy for mobile, wearable, off-grid, portable use
- To be connected
- To collect data from multiple sources and be smart, i.e., integrate and analyse inputs from diverse stimulus response incl. biosensing
- To be safe for critical use, i.e., reliable and resistive to the environment
- To be pervasive → Smart Anything Everywhere (from implantable, to wearable, to things you attach to cars, robots and industrial machines)

Functionality	Medium term: 5+	Long term: 10+
Energy autonomy		
Connectivity		
Sensor Fusion		
Functional Safety & Security		
Ubiquitous/Pervasive		

Energy autonomy

a) Key research questions or issues
Low-power electronics, long-lifetime storage and energy harvesting capability for systems providing mobility, portability, wearable use, off-grid, real-time local analysis
b) Potential for application or Application needs and Impact for Europe
From “smart-xx” (xx for cities, building, transport…) to “benevolent-xx” Societal needs not only so-called “silver domain”, but also all groups of people with special needs Medical monitoring and “patients-at-home” are huge markets Food, water and agriculture at large Water quality, water treatment, water re-treatment
c) Technology and design challenges
How to close the gap between energy generated/stored and the energy needed to implement application specs • Low-power architectures and power management • Battery integration (e.g. as function of system volume, form factor conformity, discharge properties) • Energy harvesting (e.g. for eternal off-grid devices) • Power-efficient algorithms (see sensor fusion) Flexible solutions needed for wearables and thin, large area electronics

Energy autonomy

	Medium term: 5+	Long term: 10+
d) Definition of FoMs (quantitative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)		
• energy consumed & dissipated per duty cycle divided by volume	….	…
• power management efficiency		
• energy (power) density of storage device	>10Wh/kg(10^5 W/kg)	> 30Wh/kg(10^6 W/kg)
• energy generated per unit volume per duty cycle		
• leakage current of storage device	<0.1mA	<0.001mA
• series resistance of storage device	<10mOhm	<1mOhm
• forward voltage (diodes)	< 0.5V	< 0.3V
• compatibility with system on flex	++	+++
• solid state storage	+++	+++
e) Other issues and challenges, and interaction with other Tasks/WPs.		
Task 4.2 on Smart Energy		

Connectivity

	Medium term: 5+	Long term: 10+
a) Key research questions or issues		
To enable low-power connectivity (WiFi, LiFi, Bluetooth etc.) in small form factor systems and high-data rate applications		
b) Potential for application or Application needs and Impact for Europe		
Welfare, first-responders Healthcare IoT for cars Industry 4.0		
c) Technology and design challenges		
RF-enabled devices need logic dies for BLE or NFC, how to make these low cost and power efficient Antennas for low power consumption, new designs/materials will be needed Antennas for massive multiple frequencies, and multiple antennas (M-MIMO)		

Connectivity

	Medium term: 5+	Long term: 10+
d) Definition of FoMs (quantitative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)		
• Increase antenna performance per area • Antenna area reduction (based on performance and frequency increase) • New materials for antennas (e.g. CNTs, graphene) • New materials for low-loss substrates integrating high-conductivity metal interconnects (e.g., PZT, AlN, porous Si) • New designs (e.g. fractal) and modelling tools	10% x 0.5 +++ ++ +++	20% x 0.1 +++ +++ ++
e) Other issues and challenges, and interaction with other Tasks/WPs.		
WP3 How to exploit optically based communication (LiFi) WP3 Connectivity between devices that are off-line WP3 APIs open to third parties, interoperable APIs		

Sensor fusion

	Medium term: 5+	Long term: 10+
d) Definition of FoMs (quantitative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)	…	…
• Latency • Bandwidth • Calibration procedure • Voltage supply • Functional partitioning • Redundancy • Power efficient algorithms • AI, machine learning		
e) Other issues and challenges, and interaction with other Tasks/WPs.	…	…
Task 4.1 on Smart Sensors		

Functional Safety & Security

	Medium term: 5+	Long term: 10+
d) Definition of FoMs (quantitative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)	…	…
• Hermeticity/insulation • Temperature control, avoidance of explosions • Operating temperature (harsh environment) • Humidity • Biofouling • Corrosion resistance • Fault tolerance • Hardware security, tamper protection • Cyber Security		
e) Other issues and challenges, and interaction with other Tasks/WPs.	…	…

Ubiquitous/Pervasive

	Medium term: 5+	Long term: 10+
d) Definition of FoMs (quantitative or qualitative) or planned evolution (based on SoA @ 2017 and evolution vs time)		
• Handling thin die • Flip chip placement accuracy • TSV aspect ratio (diameter) • Inspection tools for 2.5D and 3D devices and reliability tests • Biocompatible and invisible sustainable materials • Thin and large area electronics • Lifecycle analysis (duration, recyclable)	10µm ±0.1µm >10 (<10µm) +++ +++ +++ +++	<5µm less than ±0.1µm >? (<?µm) +++ +++ ++ +++
e) Other issues and challenges, and interaction with other Tasks/WPs.		
WP6 Equipment and Manufacturing Science		

Next Steps

- Work in progress
  - Update impact for Europe
  - Iterate FoMs
  - Include recommendations
- May 2017: release of 1st draft
- Q4 2017: 2nd Domain Workshop on Heterogeneous System Integration
- Nov. 2018: final Roadmap

Inputs are very welcome

Georgios.Fagas@Tyndall.ie