

smarter

in response to 2nd (2011) call

Jean-Marie Dilhac



UNIVERSITY OF
EXETER



Université
de Toulouse



UNIVERSITAT DE
BARCELONA

Outline

- *Scientific background, potential impact & key challenges*
- *Presentation of consortium*
- *Structure of the project, work plan and deviation*
- *Project management:*
 - *internal project meetings*
 - *student/scientist exchange*
 - *financial reporting*
 - *Industrial advisory board*
- *Main results*
- *Dissemination*
- *Future achievements*

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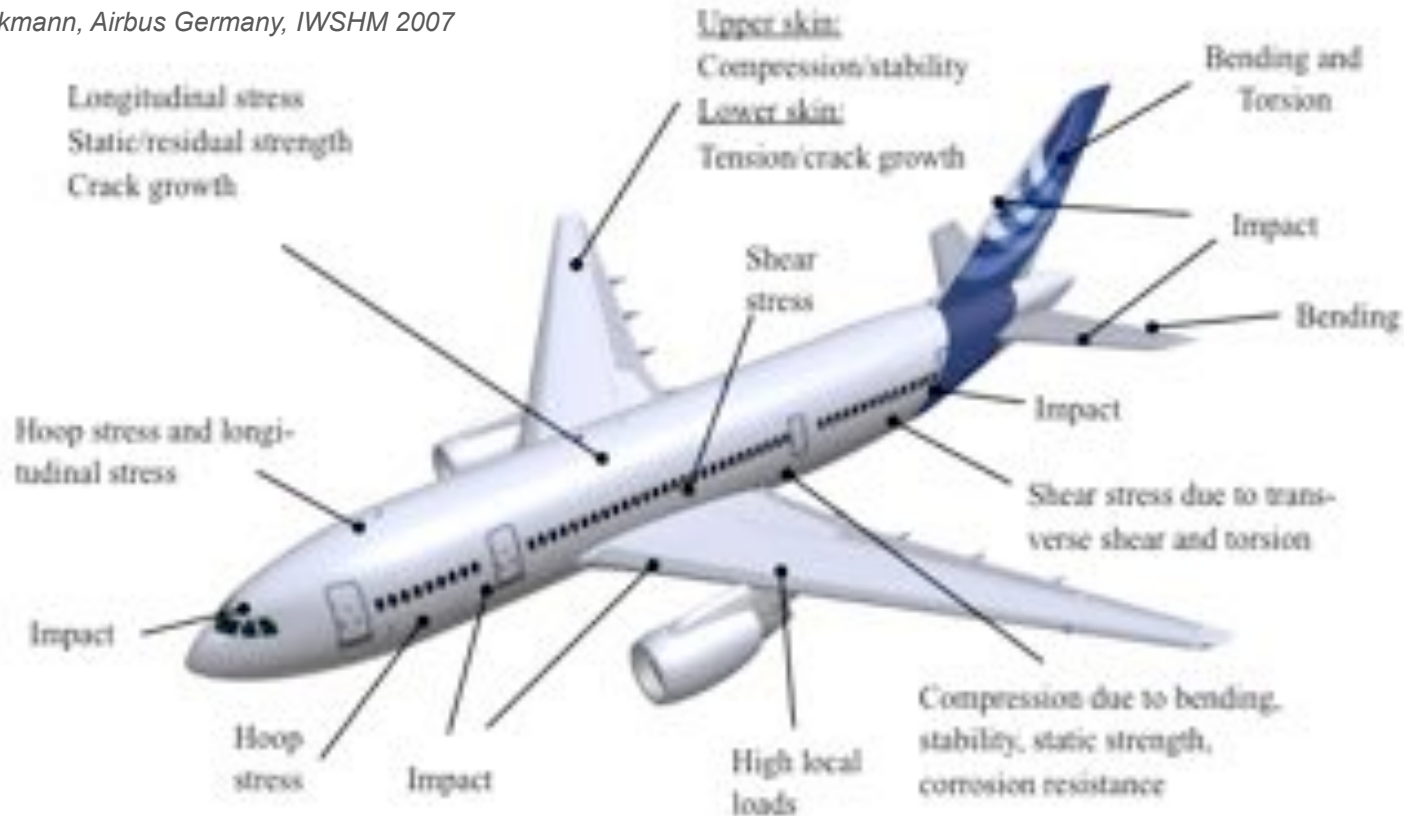
SMARTER

*Smart Multifunctional Architecture & Technology
for Energy-aware wireless sensoRs*

Structural Health Monitoring

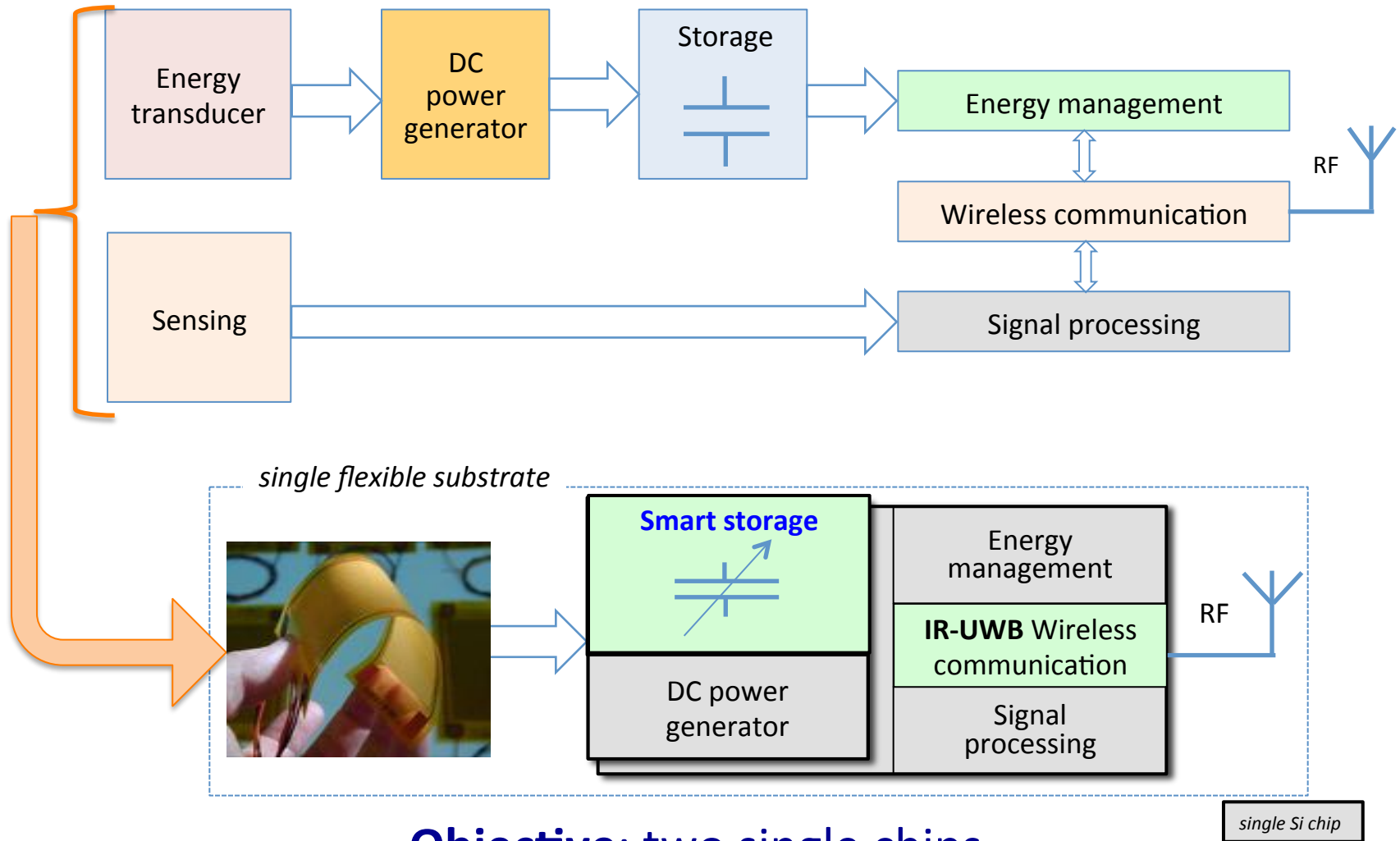
*through deployment of wireless
and battery-free sensor network*

© Holger Speckmann, Airbus Germany, IWISHM 2007



Potential impact: *predictive maintenance is a major challenge and is linked to Clean Sky, a Public Private Partnership between the European Commission and the Aeronautical Industry. It was set up to bring significant step changes regarding the environmental impact of aviation.*

Scientific background & key challenges



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Presentation of consortium

Participant	Main activities / skill	availability of chist-era funding
Exeter University <i>(formerly Cranfield University before November 2013)</i>	harvesting and sensing device, simulation, tests	1 st of October 2012
University of Barcelona	full-custom integrated circuit	1 st of January 2014
LAAS-CNRS	management, adaptive storage, communication	15 th of March 2013 <i>(eligible expenditure since Nov 2012)</i>

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LAAS

WPO – Project management

LAAS

WP1

Specifications
& architecture

Specifications

Device & architecture
optimization

Spec

Device & architecture
optimization

Specifications

WP4

Integration

Technology
Models

Technology
Models

WP2

Multifunctional
device

WP3

Smart adaptive
storage

Prototypes

Device & architecture
optimization

Prototypes

Prototypes

WP5

Demonstrator

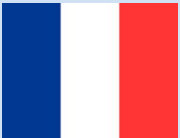
U
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LAAS

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Project synchronisation issues

2012	2013	2014	2015	2016
10				30/04
11				
				

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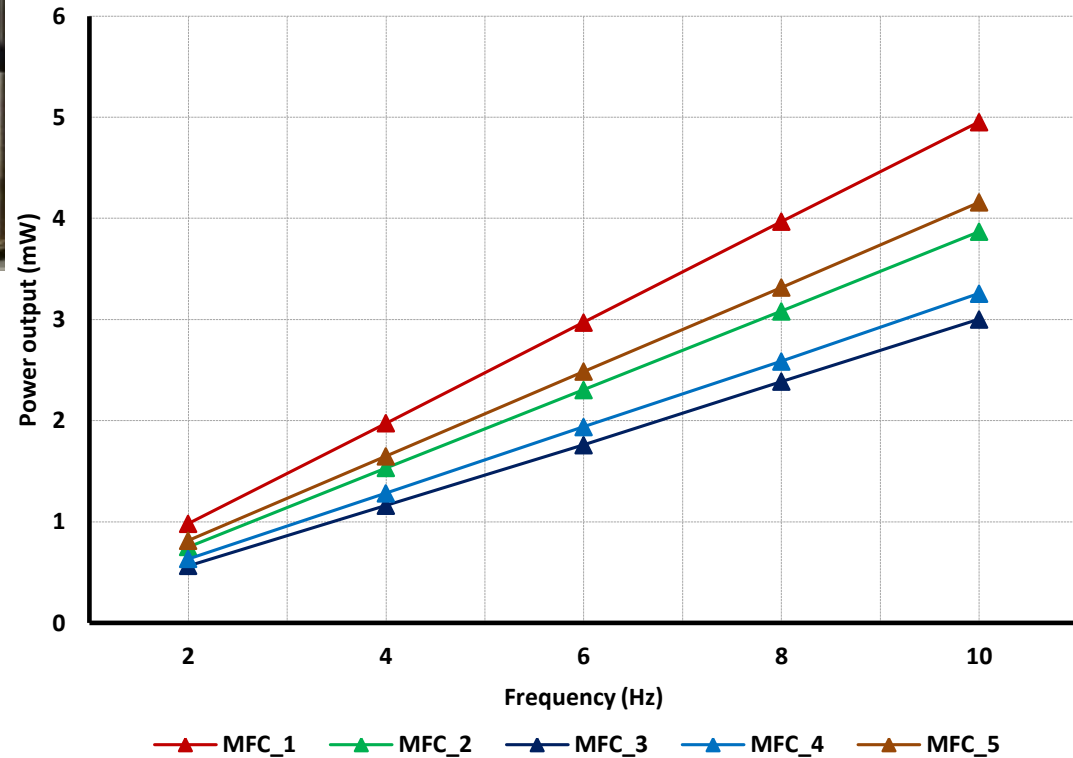
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WP2 MULTIFUNCTIONAL DEVICE WP5 DEMONSTRATOR

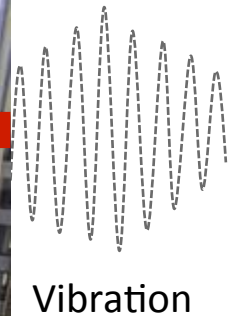
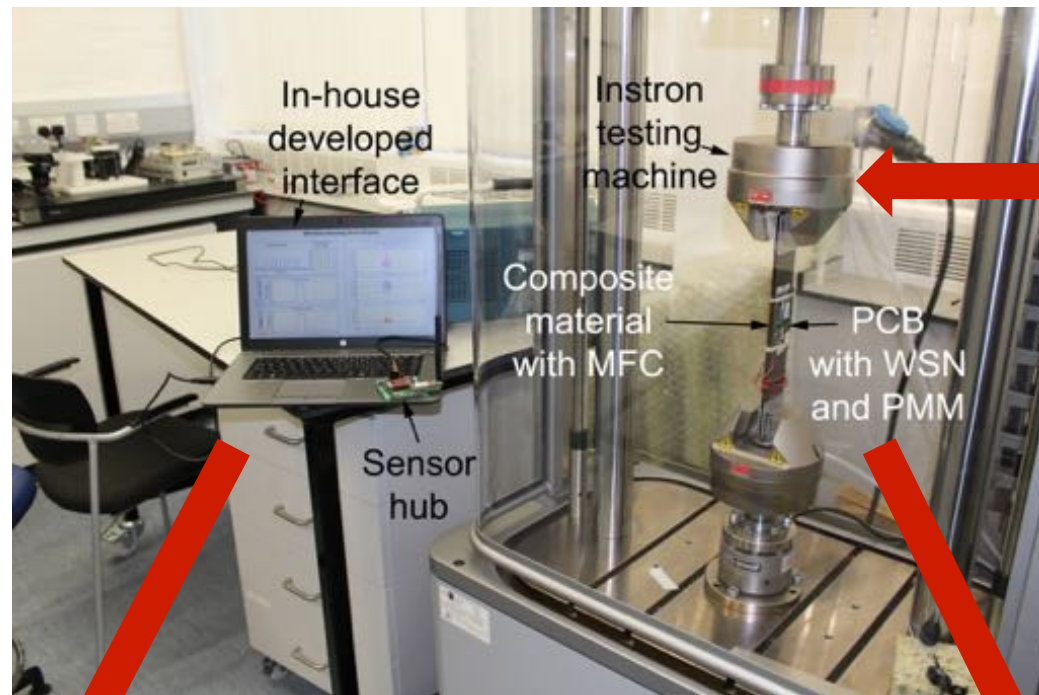


Bonding of the harvester

Up to 5 mW @10Hz



Sample	Bonding Method & Curing Conditions
MFC_1	MB, 70°C for 3 hours
MFC_2	VBOA, 60°C, 14.7 psi, 2 hours
MFC_3	VBIA, 70°C, 30 psi, 3 hours
MFC_4	VBIA, 70°C, 60 psi, 3 hours
MFC_5	VBCA, 125°C, 90 psi, 3 hours



Receiver board with wireless microcontroller

Base station

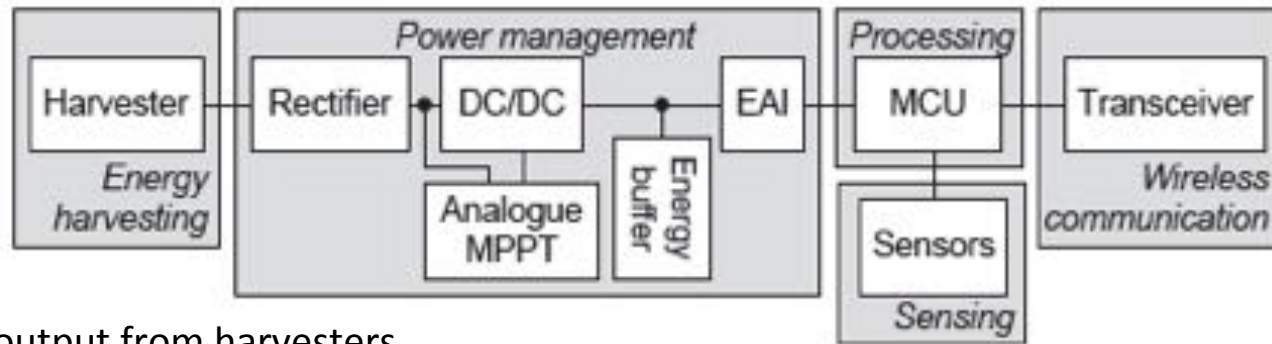


Data transmitted

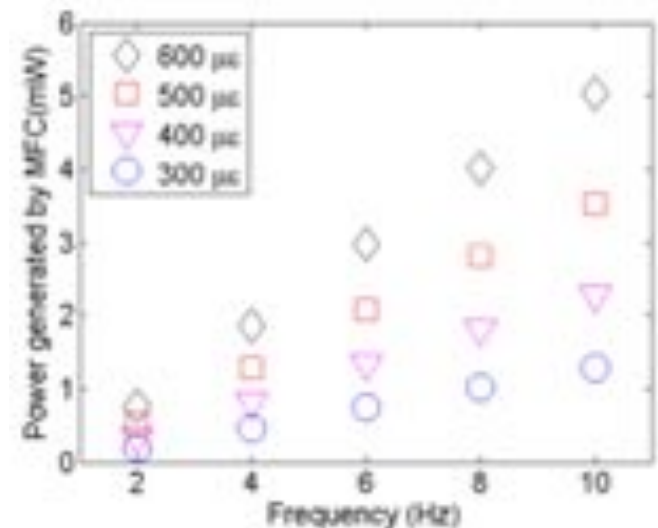
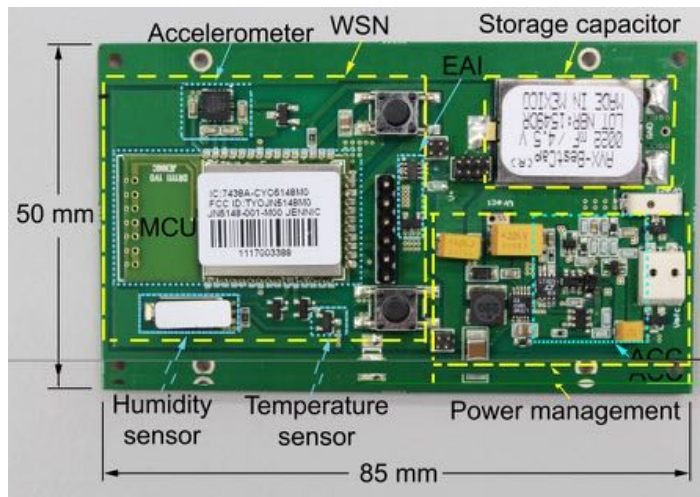


Vibration powered WSN

Demonstration of a full energy harvesting powered wireless sensor node using MFC energy harvester



- MPP output from harvesters
- Adaptive to variations of vibration and electric loads
- **Harvested Energy:**
 - 0.075 - 0.188mW/cm²** @ 4-10Hz & 600μs
 - 0.07 - 1.07mW/cm²** @ 2-10Hz & 800 -1400μs
- Peak $\eta_{\text{overall}} \rightarrow 74.25\%$
- Sleep current $\rightarrow 1.26\mu\text{A}$



WP4 INTEGRATION

smarter **Heterogeneous integration on flexible substrate**



chist-era

- Flexible substrate choice : Kapton, for its very good RF properties
- RF characterization of Kapton using ring resonator; choice of the best thickness for our application: 127 um thickness
- Set-up of the technological process in our clean room

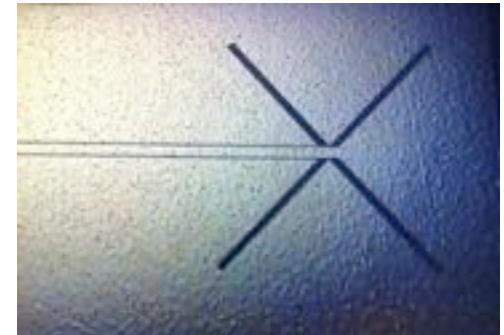
Ring resonator



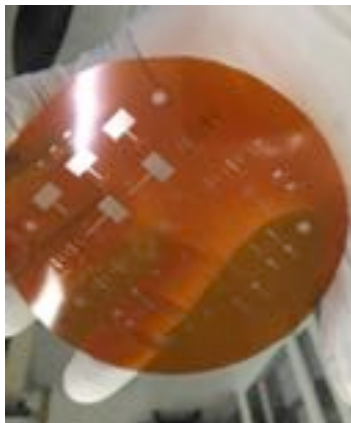
Patch antenna



Dipole antenna



Kapton wafer

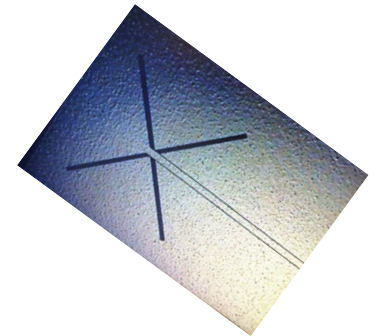
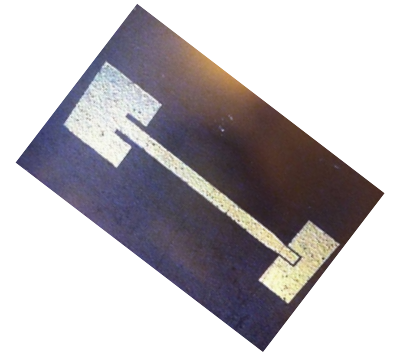


Dummy circuit & LNA on Kapton

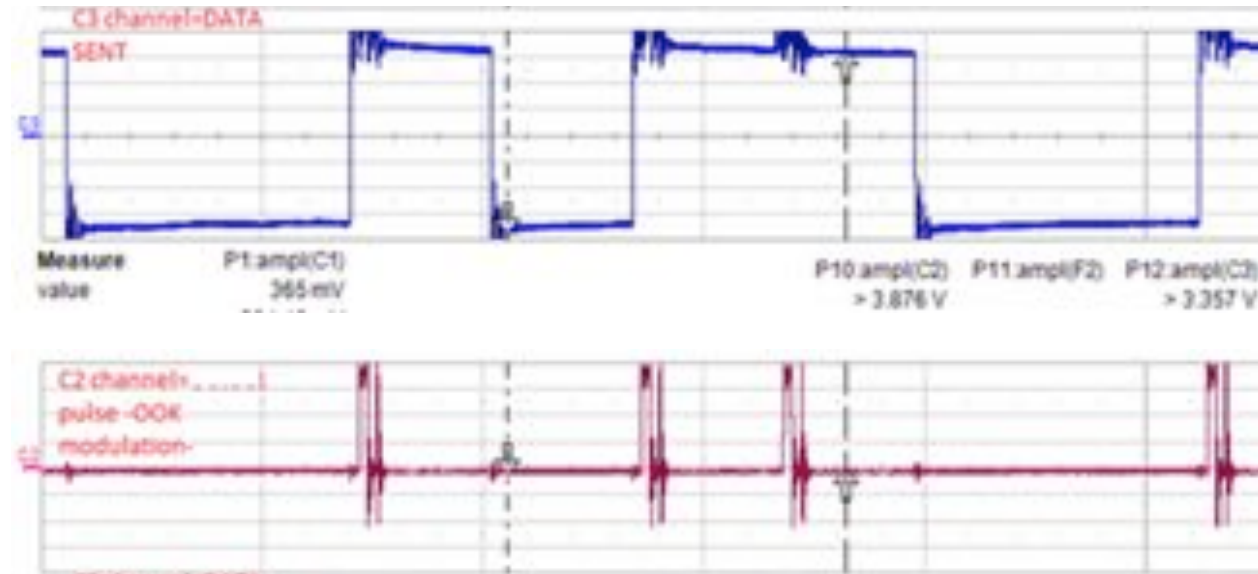


Heterogeneous integration on flexible substrate

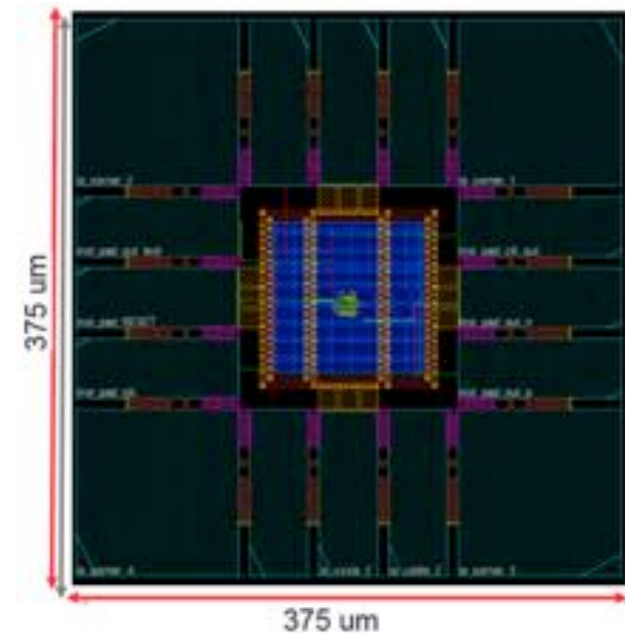
- *Antenna design*
- *Patch antenna – easy design*
 - *Bandwidth measured @60 GHz = 1.5 GHz*
 - *Gain ~ 4dB*
- *Cross slot dipole antenna*
 - *Bandwidth measured @ 60 GHz = 10 GHz*
 - *Gain ~ 2 dB*
- *Future work*
 - *Design and realisation of cross dipole antenna array – ultra wide band and high gain – optimal for our application*
 - *Flip-chip process set-up*



**OOK modulation + clock
gating: 46% power
consumption saving**

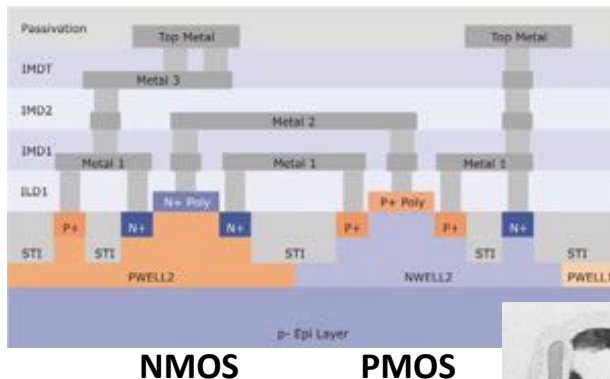


OOK IR-UWB Transceiver layout
using CMOS65nm technology



Technology

- XT018 – Smart Power SOC Platform
 - CMOS 1.8/5V
 - NVM Module
 - DMOS+HVMOS Modules
 - DEPL Module + Analog Devices



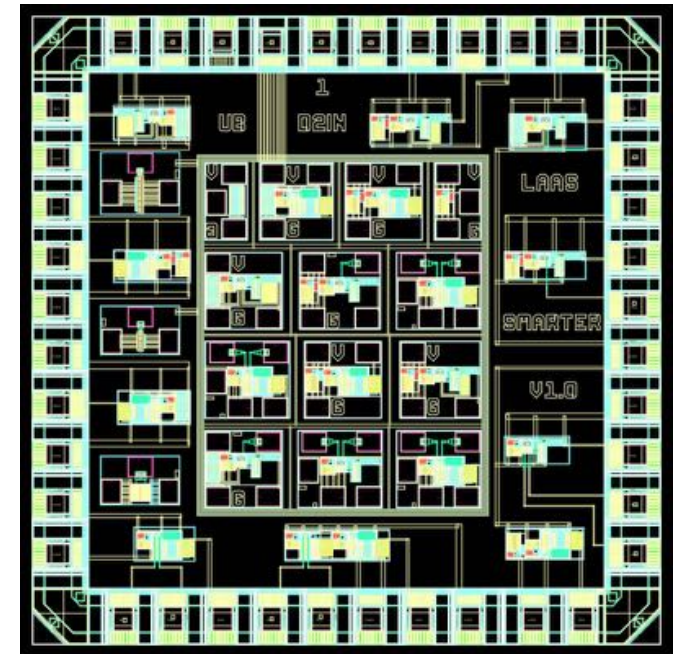
Dos campus d'excel·lència internacional

B:KC
Barcelona Knowledge Campus

HUB
Health University of Barcelona Campus

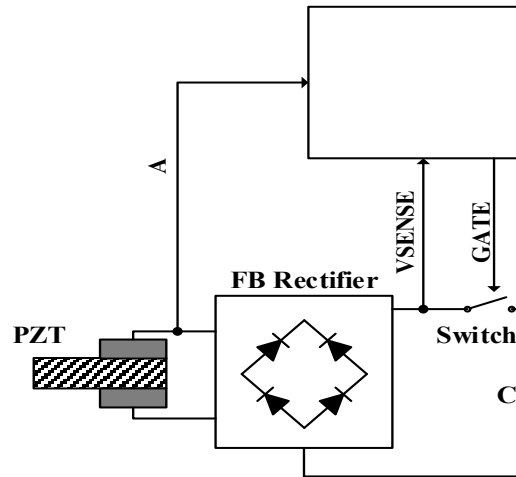


Low-power blocks: BandGaps ($\leq 100\text{nW}$), LDOs, OPAMPs, Temperature Sensors, ...

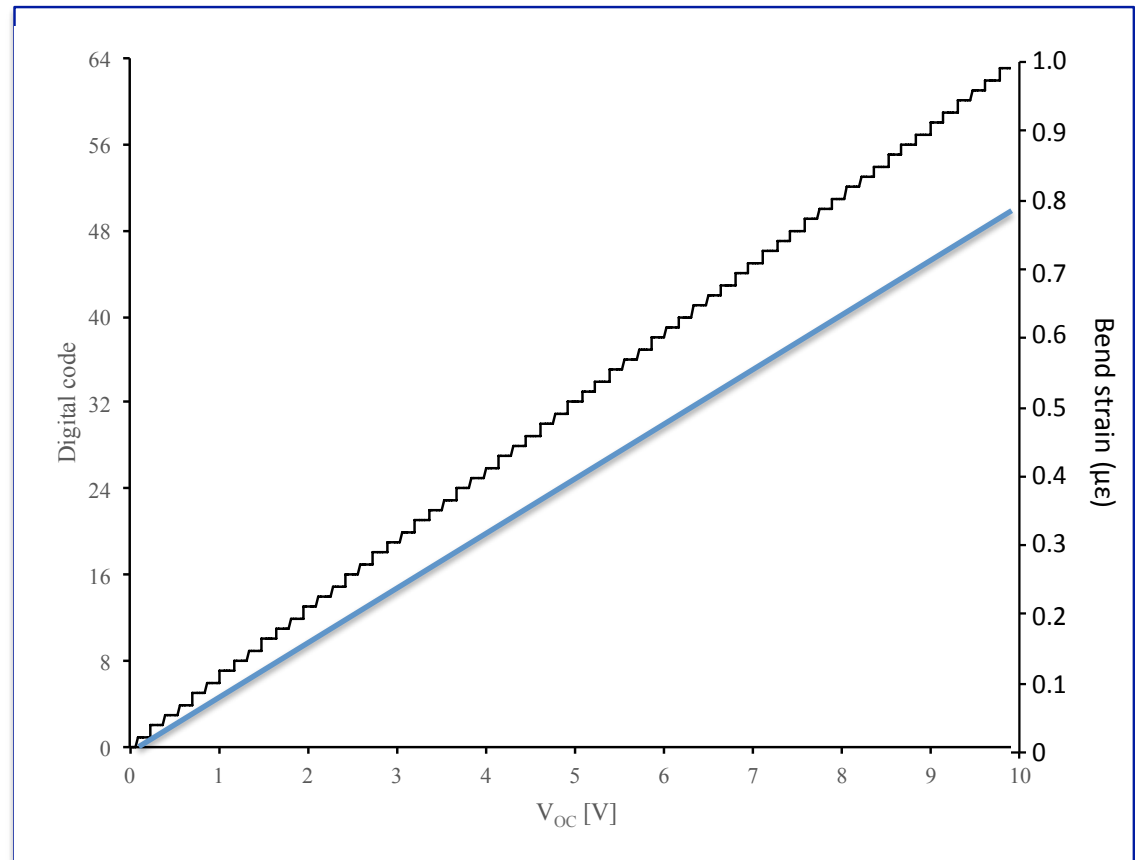


**Problems with the foundry
(not the design)**

Design of the standalone multifunctional energy harvester & sensing control circuit



Open-circuit voltage response to a bend strain



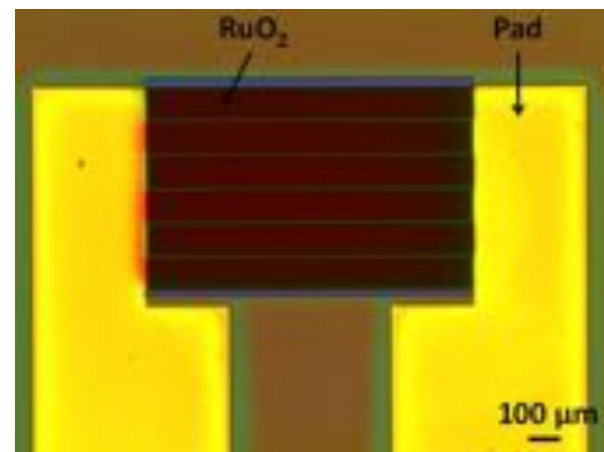
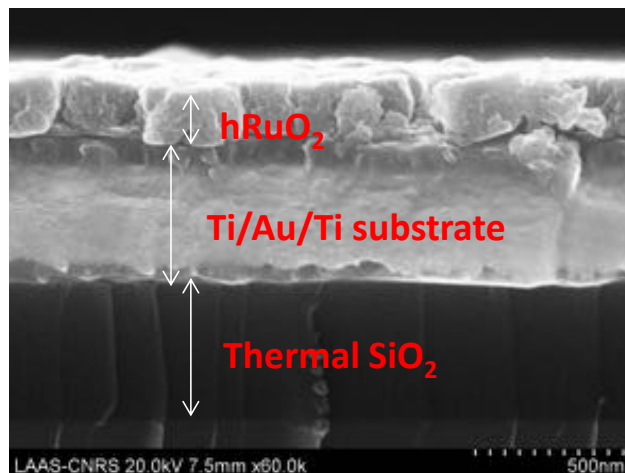
WP3 SMART ADAPTIVE STORAGE MICRO-SUPERCAPACITOR TECHNOLOGY

Micro-supercapacitor Technology Challenges

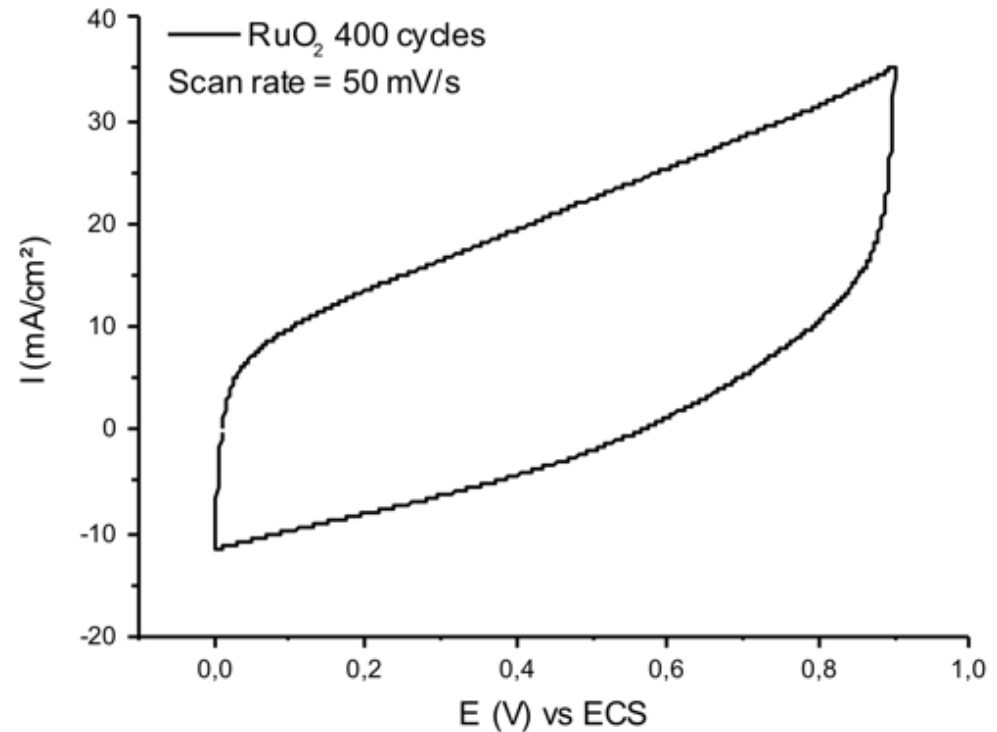
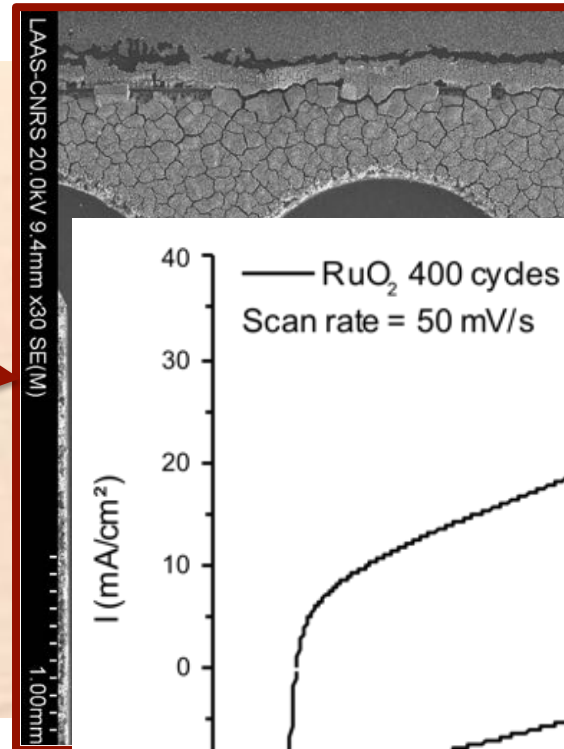
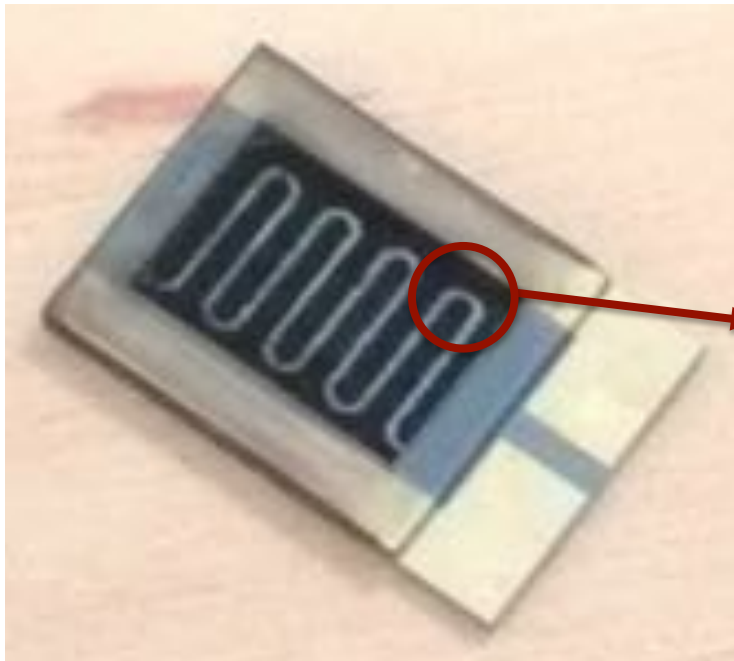
- Silicon integration:
 - *Co-integration with control circuitry for adaptive storage*
 - *Expected improved performance regarding self-discharge*
- Targeted specific energy: **1J/cm²**
- **Electrode material** is key
- Need for innovative **solid** electrolyte
- Need for wafer-level **airtight sealing**

Micro-supercapacitor Technology

Electrode	Electrolyte (liquid / solid)	Potential Window	Capacitance	Specific Energy	Further developments
<u>hRuO₂</u>	Liquid or solid	0.9 V	5 mF/cm ² (cell)	2 <u>mJ</u> /cm ² (cell)	Encapsulation
Activated Carbon	Liquid	2.3 V	2 mF/cm ² (cell)	5 <u>mJ</u> /cm ² (cell)	Encapsulation
<u>hRuO₂</u> /Porous Gold	Liquid (H ₂ SO ₄) or solid (PVA-	0.9 V	> 3000 mF/cm ²	>1J/cm ² (electrode)	- Stack configuration



Porous gold/RuO₂ electrodes
460mF/cm²

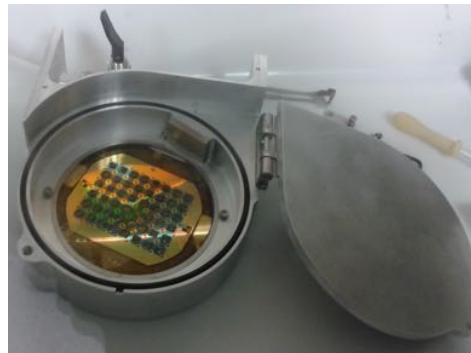


Microsupercapacitor encapsulation

- Constraints in fabrication: use of sensitive electrolytes < 1 ppm H₂O required
- ***Parylene encapsulation chosen for the final realization***
- Deposition system (Comelec) acquisition under process



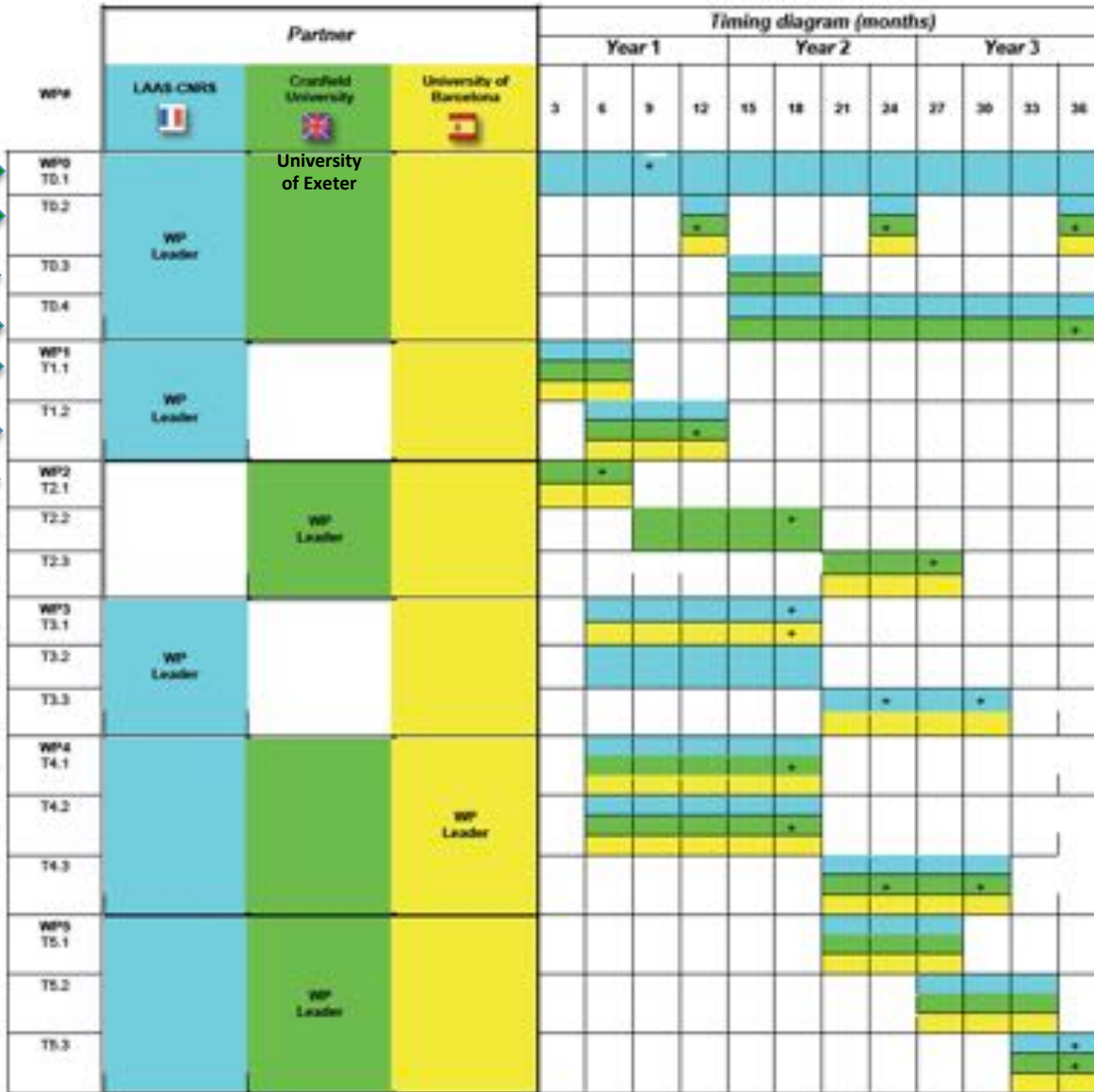
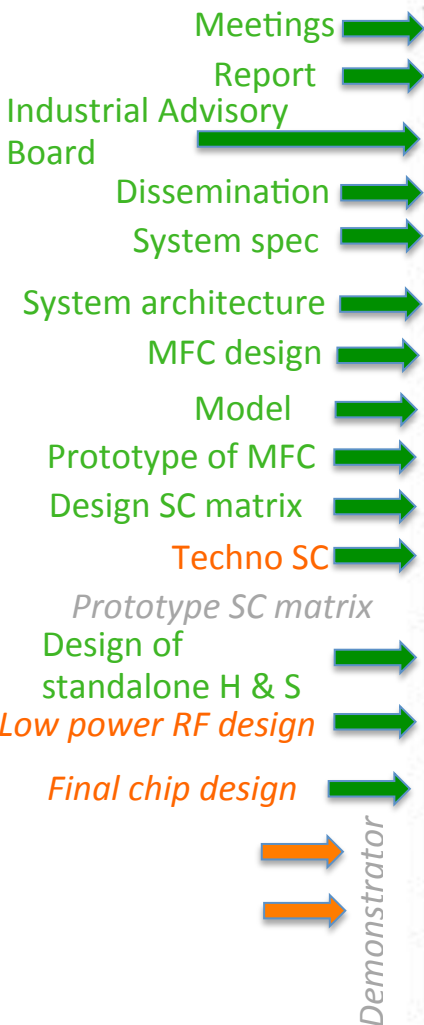
Transportable glove box



smarter



chist-era



Deliverables →	1	1	2	5	3	2	4
Milestones →	1	1	2	4	1	2	1
go/no-go							
Progress report / Expenses							
Consortium agreement / Final report							

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- *Dissemination (7 journals, 6 conferences, from Jan. 2015)*

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- ***Future achievements***

Remaining challenges:

- *flip chip on flexible substrates, microsupercapacitor encapsulation and co-integration*

Final achievements:

- *fully integrated prototype on flexible substrate (3 chips)*
- *alternative: commercial supercapacitors, PCB to build up a prototype (single transducer, low power RF transceiver, adaptive storage, adaptive power management...)*
- *final experiment on Exeter equipment*

Thank you