Integrated Sensors and Actuators

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Fraunhofer ENAS

Outline

1. Internet of Things
   - Definition
   - What do we need to enable the Internet of Things?
     - Technologies
     - Social needs
2. General Trends in Automotive
3. Cluster of Excellence MERGE
4. Smart Systems Integration

Internet of Things – a new dimension

Until now the Internet was blind

…

the Internet only connects people at **anytime** and **anywhere**,

but the environment of these people could not be connected

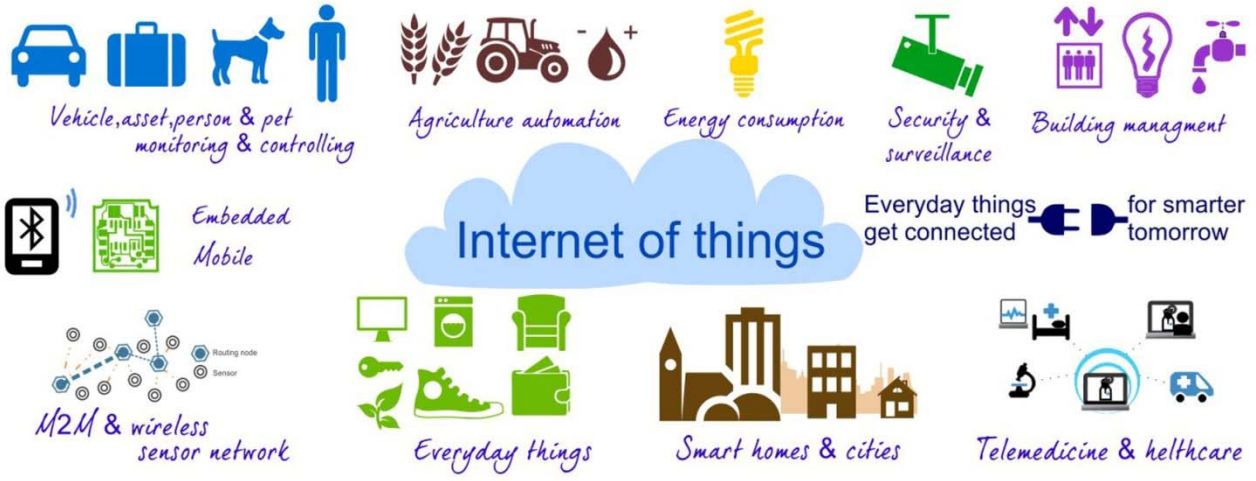
With **the Internet of Things** a new dimension could be connected:

ANYTHING

Source: Journal Internet of Things

Definition of IoT by EPoSS

„Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental and user context“

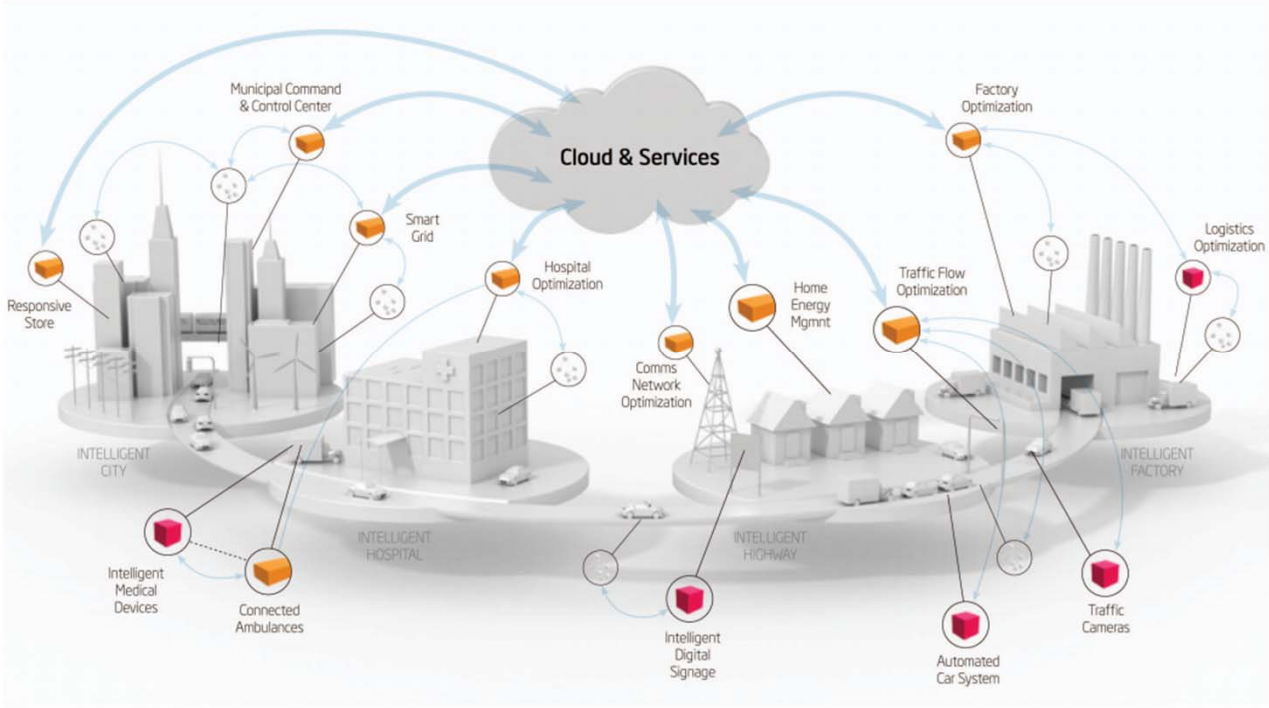


The Internet of Things is

> “a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols”

Internet of Things Definition according to Yole Développement

“Internet of Things devices is the aggregation of all sensing modules which are linked to the Cloud – either directly or through a gateway – and with which data is processed and valorized in any manner.“



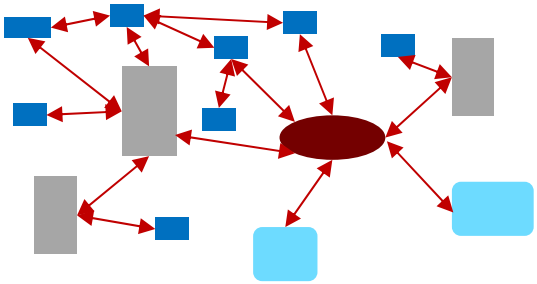
Sensors & Technologies for IoT, Yole Developpement 2014

Internet of Things – enabling Technologies

- Low power consuming devices (Electronics and sensors)
- Sensing devices: MEMS/NEMS
- NFC (Near Field Communication)
- RFID (Radio Frequency Identification)
- Smart Systems Integration
- New materials like polymers
- New technologies
- New radio standards for bandwidth and frequencies
- Consistent transmission protocols
  (or integration of different communication standards and protocols)
- Alternative energy sources, energy harvesting and low-power chipsets

Internet of Things – enabling Social Needs

- Create laws and control by an impartial governance authority
  (e.g. UN or an industrial consortium)
- Protection of privacy
- Regulation of the liability
- Protection of minorities
- Voluntary use of the smart things
- Creation of sensitive areas without networking
- Creation of the IoT by the general public (e.g. public forums, round tables)
- Education
  - At the school: to learn the critical use of the IoT
  - At the university: to analyze the effects of the IoT on the society



First Generation

- Sensing and actuation
- Signal conditioning and processing
- Wireless/wired communication
- Hybrid and monolithic integration, system on board, chip on board

Second Generation

- Multifunctional sensing, actuation and inference
- Predictive and adaptive
- Networking function
- Partially autonomous
- Partially 3D-integration

Third Generation

- Self-calibrating and self healing sensors and actuators
- Artifical intelligence
- Self-organized networks
- Energy autonomous
- Complete 3D-integration

1990 …. 2005 …. 2020

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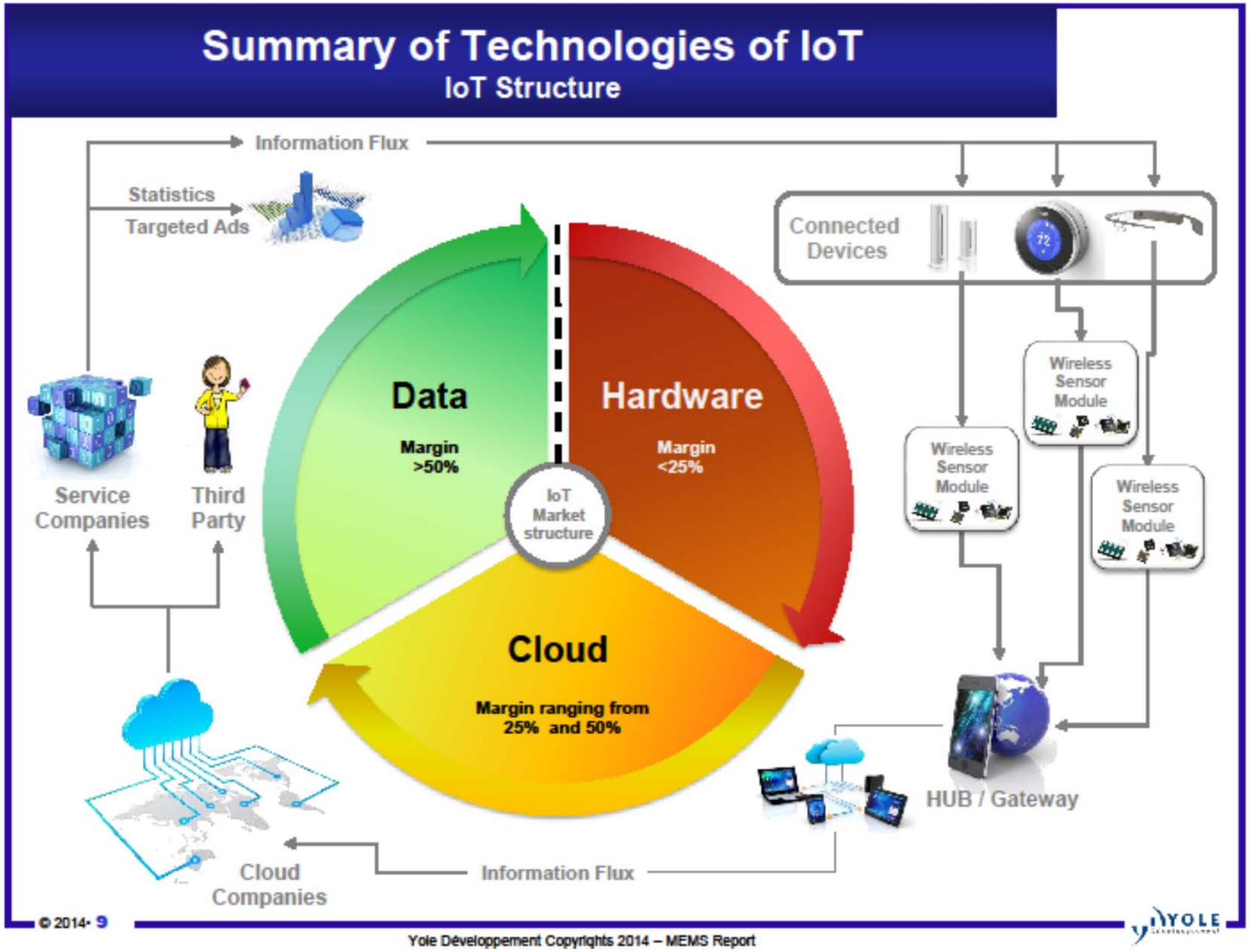
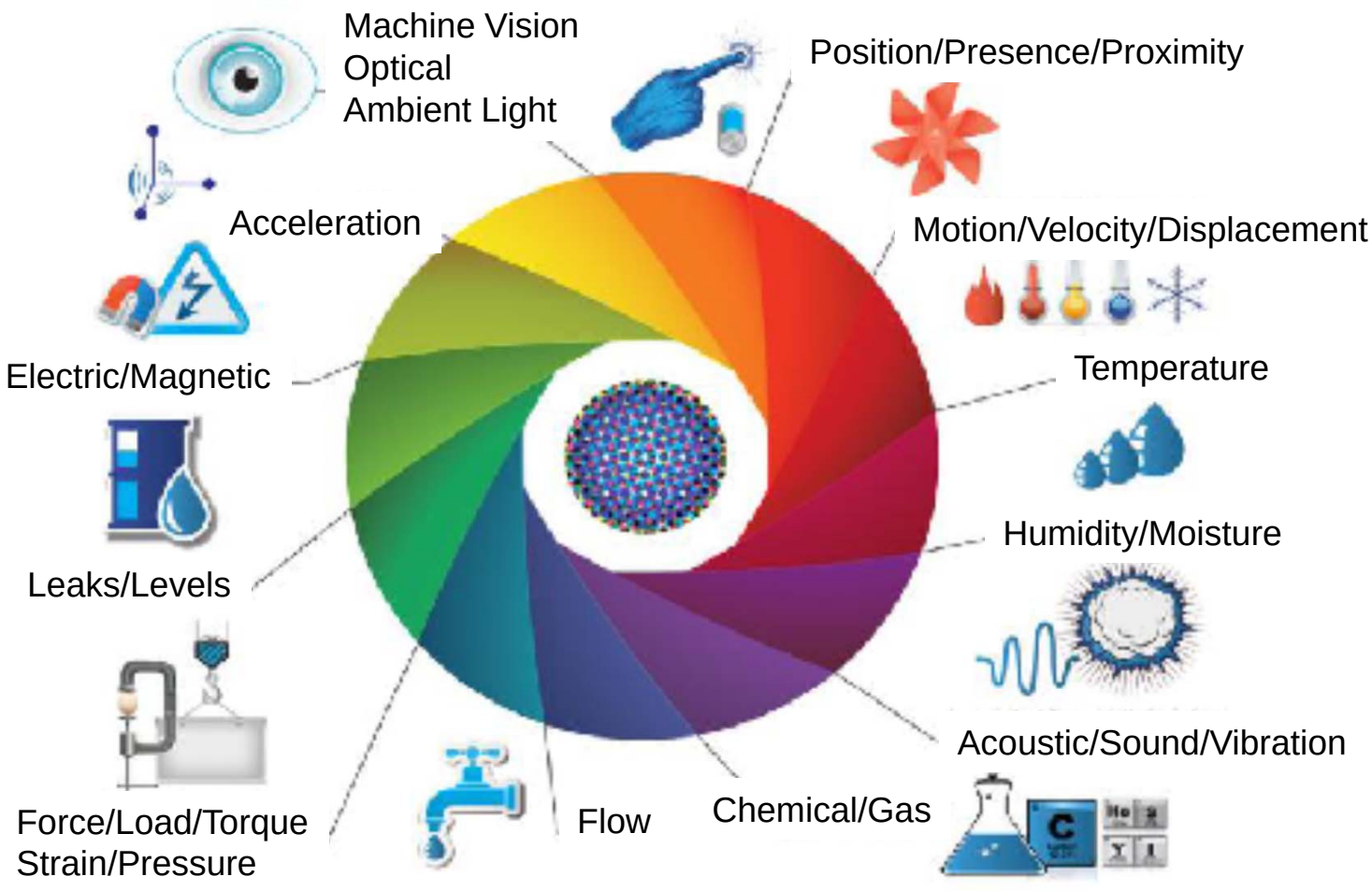
IoT Structure



Need for diversified sensors



Different types of sensors required by the Internet of Things. Source: Postscapes

IoT - General Trends in Automotive

- Navigation systems
- On board diagnostic systems
- Automatic parking assistant
- GPS based car lock down
- Automatic emergency communication

- Autonomous driving car
  - large number of sensors
  - historical data
  - resilient computing
- Traffic information exchange
- Route planning as swarm
- Traffic sign car intercommunication

Many issues are basically already solved (from hardware point of view), software is also not far behind.

So what is the point we are not there yet?

IoT - General Trends in Automotive

Issues

What happens in case:

- Wireless communication breaks down?
- The latest software upgrade of your computer is crashing?
- Your car catches a virus?
- A hacker has fun by making your car a full stop on the highway?
- An engineer leaks the code to make a car transmit the signature of emergency car?

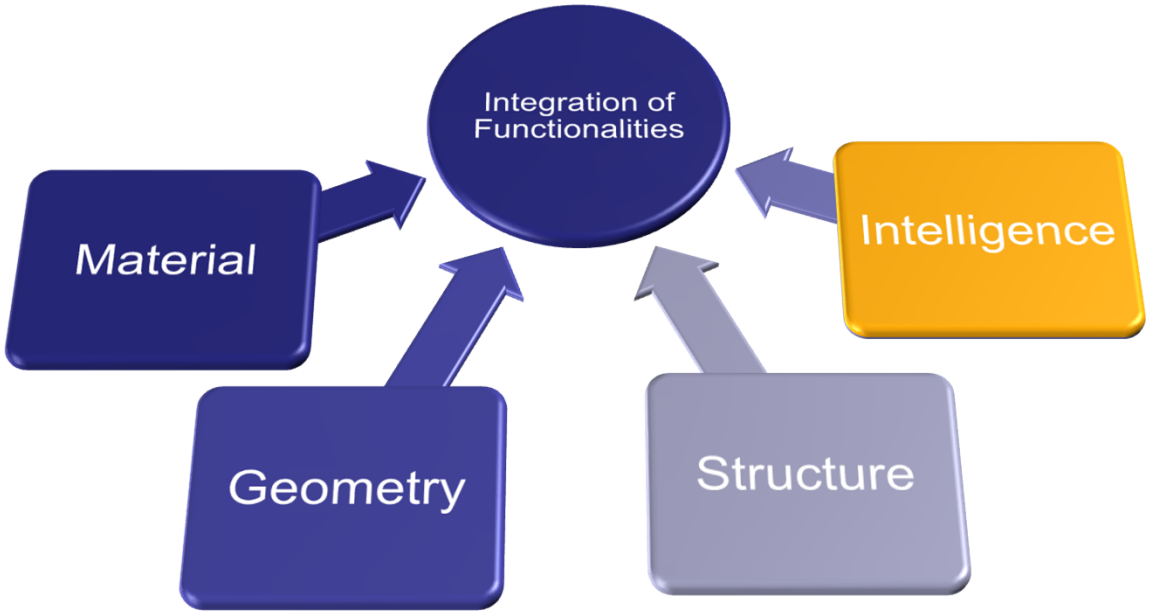
Such kind of challenges must be taken care of!
That is now more important than development of hardware!

Outline

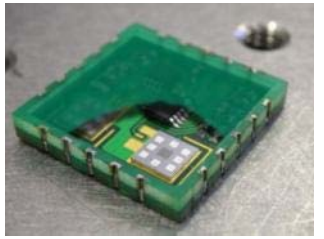
- Introduction
  - Integration of Functionalities
  - Smart Systems Integration
- Cluster of Excellence MERGE
- Smart Systems Integration
  - Incentive
  - Integration of fluidic actuators
  - Nanoparticle basied sensors
  - Metamaterialials
  - Integration of Silicon based sensors

Smart Structures

- Integration of Functionalities:
  Accommodate many functions in one part or preform
- Integration of Intelligence:
  Smart Systems Integration



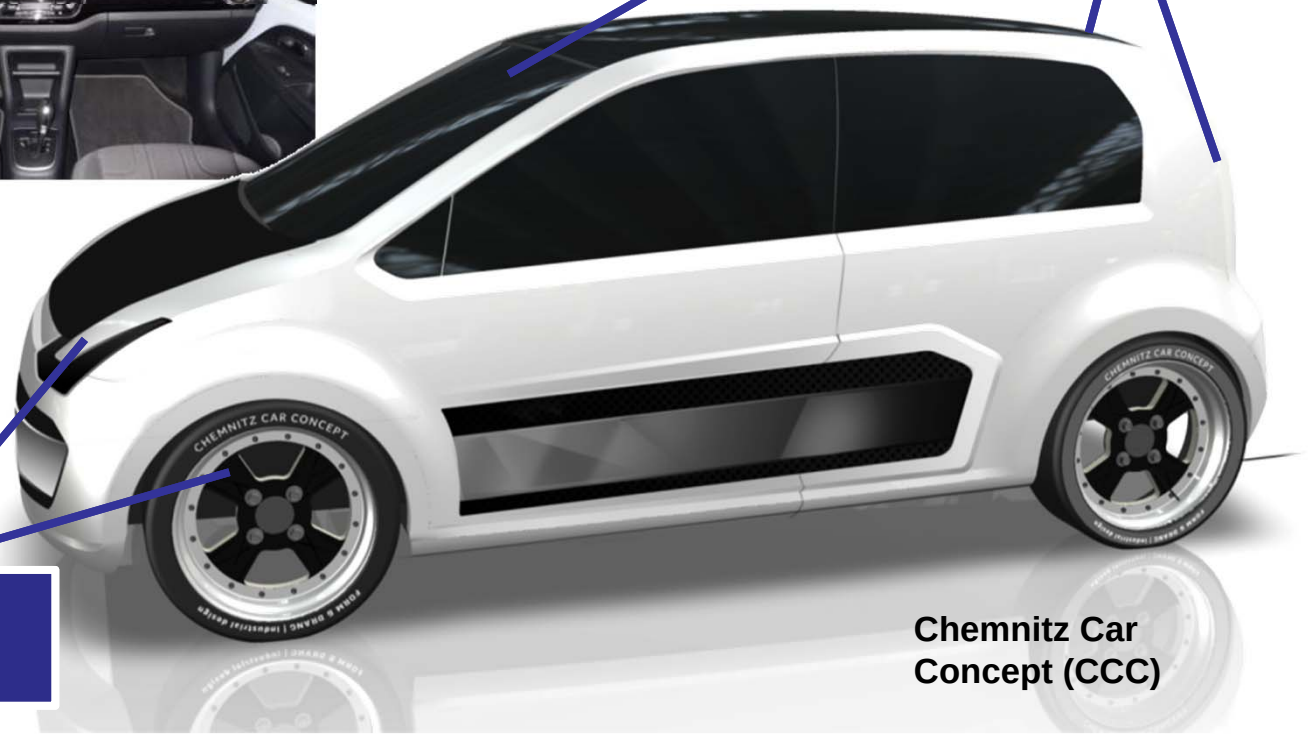
Embedded MEMS sensor module



MEMS in interposer structure

Smart Structures

Smart Structures in automotive applications:



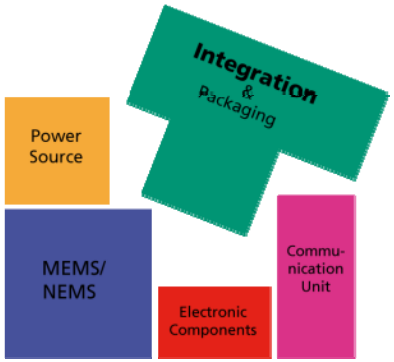
Sensors and Actuators

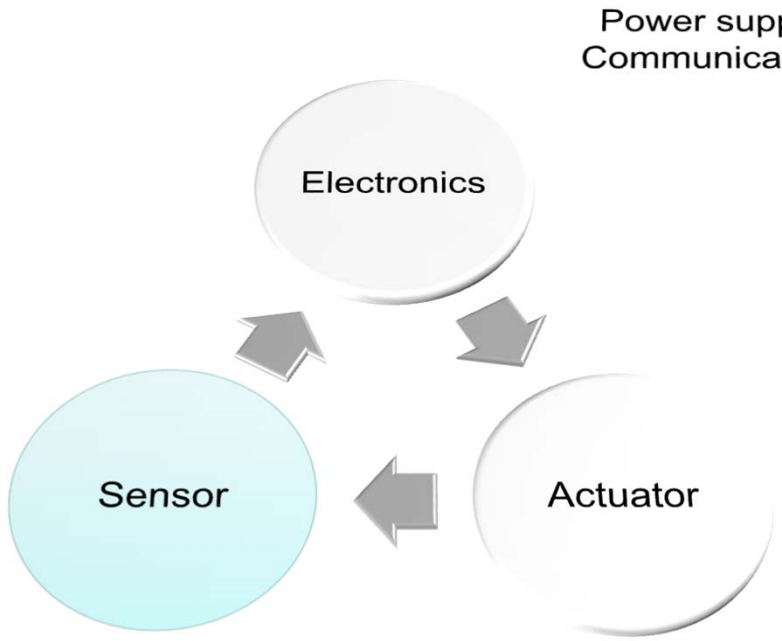
Smart Structures

Chemnitz Car Concept (CCC)

Smart Systems Integration

- Smart System Integration is more than just „Sensor-Integration“:



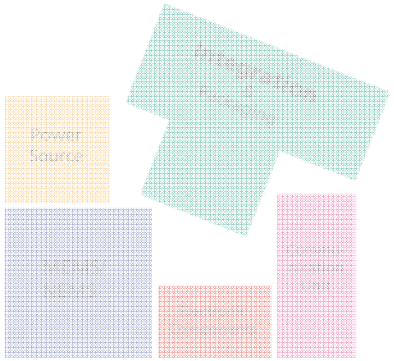


SHM, Stress and Strain
Vibration, Deformation
Humidity / Temperature

Optical: Illumination, Display
Thermal: active Deicing,
Heating / Cooling
Mechanical: Active damping,
Sonic transducers, Morphing

Smart Systems Integration

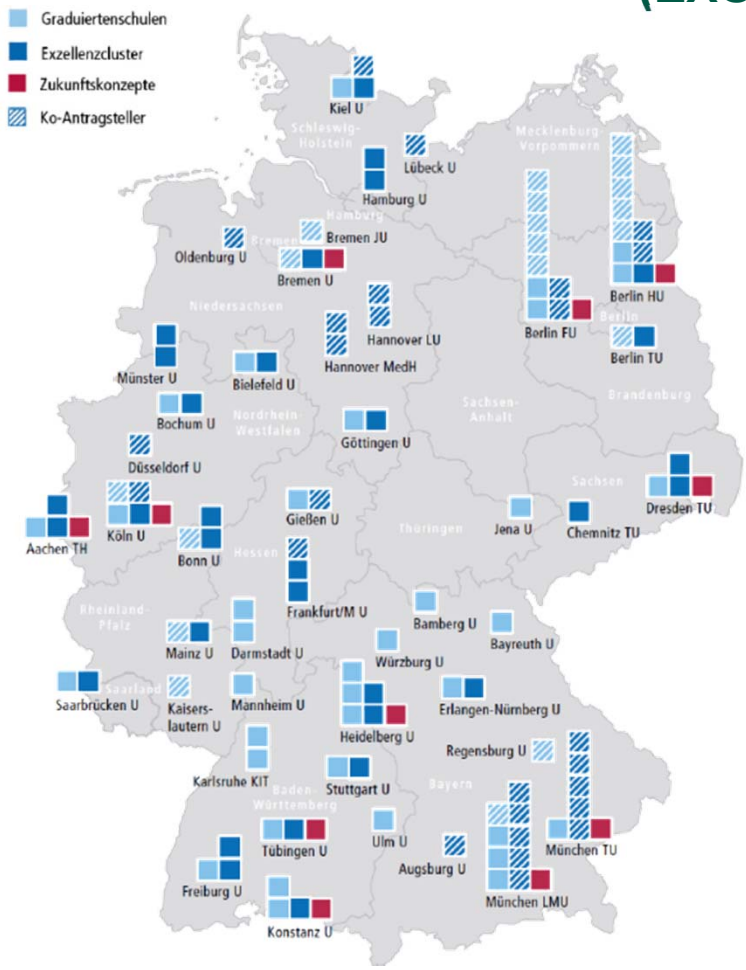
- Smart System Integration is more than just „Sensor-Integration“:



How to manufacture this in a mass producible way?

Cluster of Excellence MERGE

Merge Technologies for Multifunctional Lightweight Structures (EXC 1075)



- 01.11.2012-31.10.2017
- 34 Mio. EUR
- 100 researchers

TECHNISCHE UNIVERSITÄT CHEMNITZ

www.tu-chemnitz.de/MERGE

cetex

Fraunhofer ENAS

KVB KONSTRUKTION UND VERBUNDBAUWEISEN

Fraunhofer IWU

stfi

IFW Leibniz Institute for Solid State and Materials Research Dresden

TECHNISCHE UNIVERSITÄT DRESDEN

TECHNISCHE UNIVERSITÄT CHEMNITZ

Cluster of Excellence MERGE

MERGE Cluster of Excellence

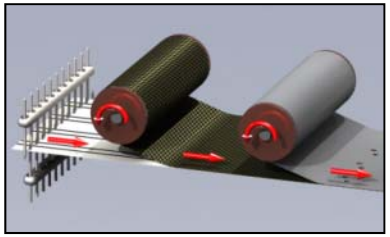
CLUSTER OF EXCELLENCE • Merge Technologies for Multifunctional Lightweight Structures

In-line process

IRD A

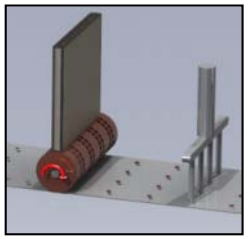
IRD D

IRD A/B



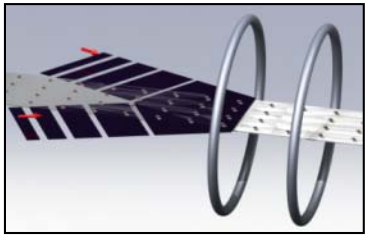
Fibre-foil-tape unit

IRD D



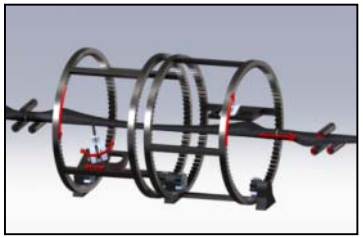
Sensor integration

IRD A/D



Fold winding

IRD A

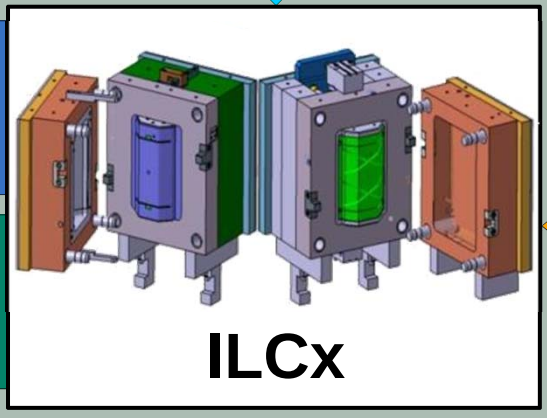


Contin. orbital wrapping

In-situ process

IRD B

IRD C



ILCx

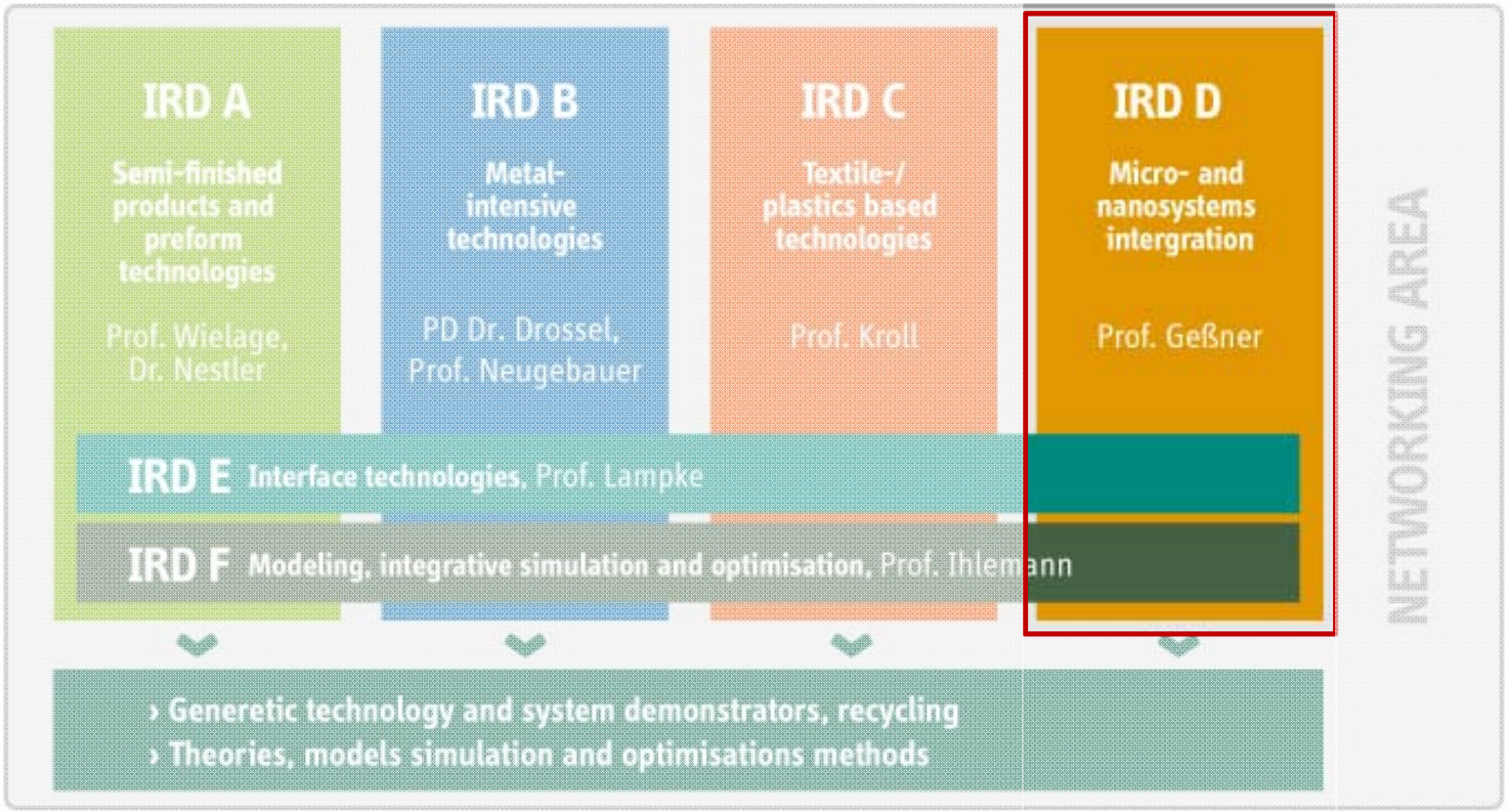
Master Unit with Plug & Produce Modules

Preform Wind Energy Rotor Blade (WERB)

Chemnitz Car Concept (CCC)

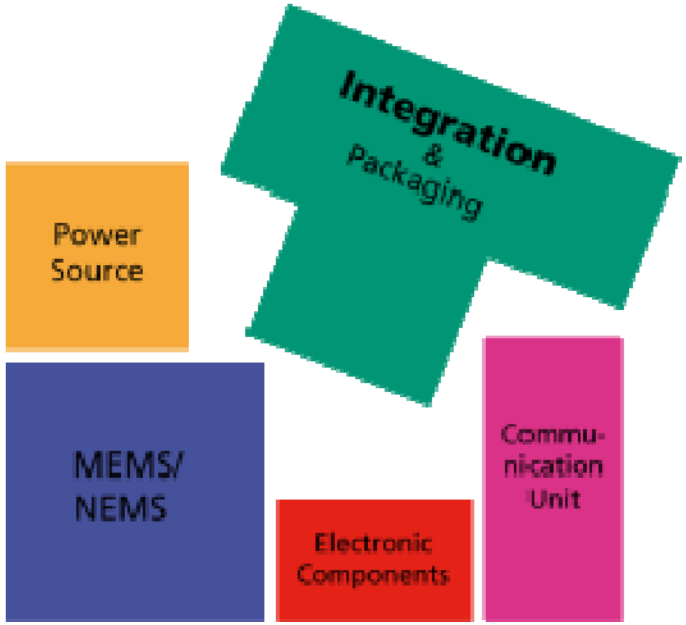
System Demonstrators

Cluster of Excellence MERGE



Smart System Integration

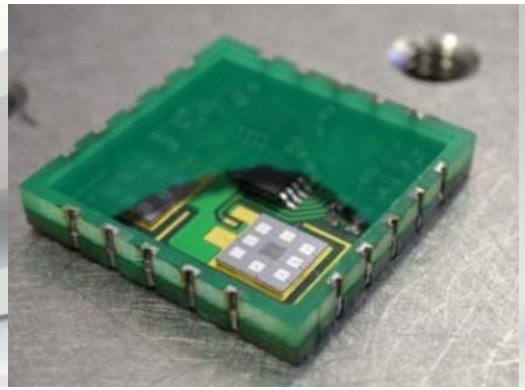
Integration of Sensors and actuators EXAMPLES



Overview

- Incentive of Smart Systems Integration in composite structures:
  - Integration of sensors and actuators in hybrid structures
  - Integration of electronics, power supply and communication
  - Increase of the performance and functional density
  - Development of innovative technologies for integration
  - Development of new sensor and communication concepts for functionalized structures

Fully integrated actuators for AFC



MEMS in interposer structure

Embedded MEMS sensor module

Integrated fluidic actuator engineering

Central objective:

- Integration of actuator structure and transducers Combination of functional layers and materials
- Integration in lightweight structures

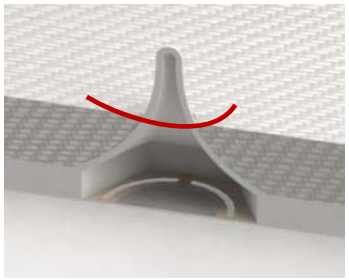
Actuator sections, SJA on the basis of MuCell® Technology

Use Case:

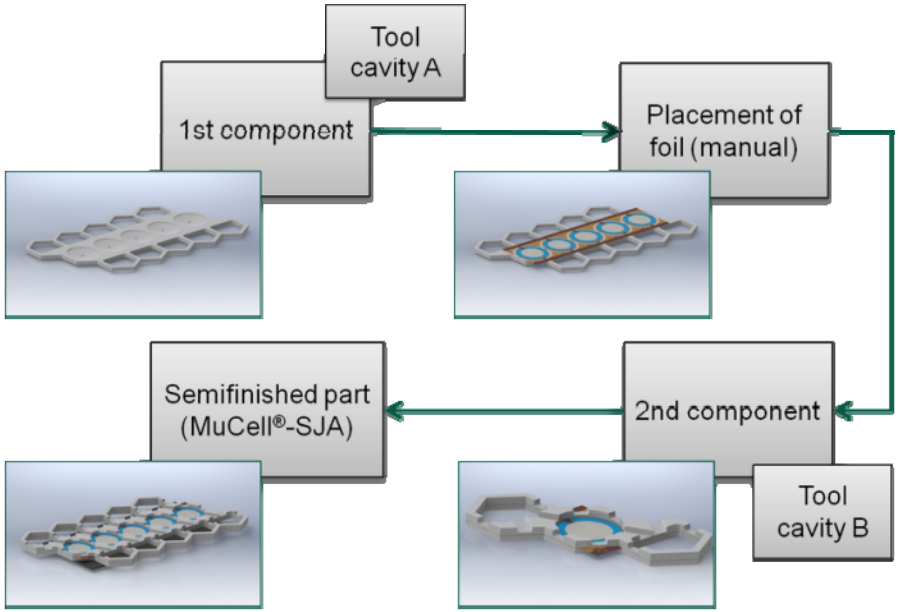
- Actuators for the active flow control for the reduction of flow resistance of cars

Integration in roof spoiler/ aerofoil sections: no modification of the structure is necessary.

Integrated fluidic actuator engineering



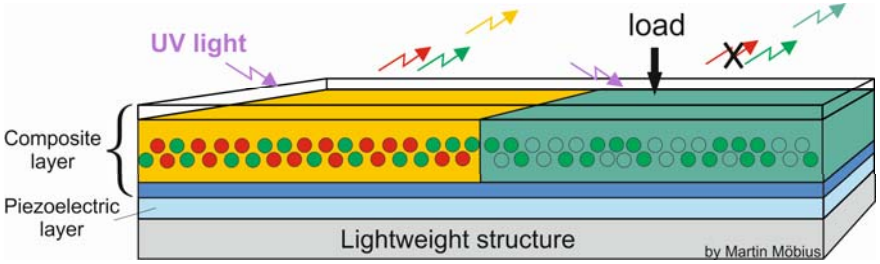
- Manufacturing
  - injection moulding of the first cavity
  - Insertion of transducers incl. contacting
  - injection moulding of the second cavity
  - Opening of the structure



Nano particle based sensors

Central objective:

- Pressure-sensitive film for sensors
- Color change under external force
- Integration in lightweight structure



Sensor layer and illustration of the function

Quantum Dots

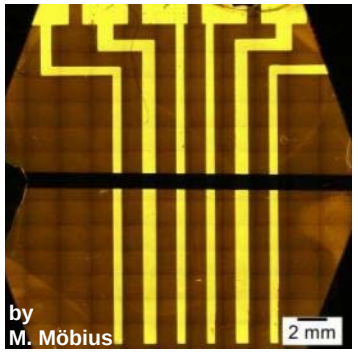
Use Case :

- Display of force effect (crash, damage) on vehicle parts

Volkswagen up!

Chemnitz Car Concept (CCC)

www.tu-chemnitz.de/MERGE/



Microscope image of a test structure
Source: Martin Möbius

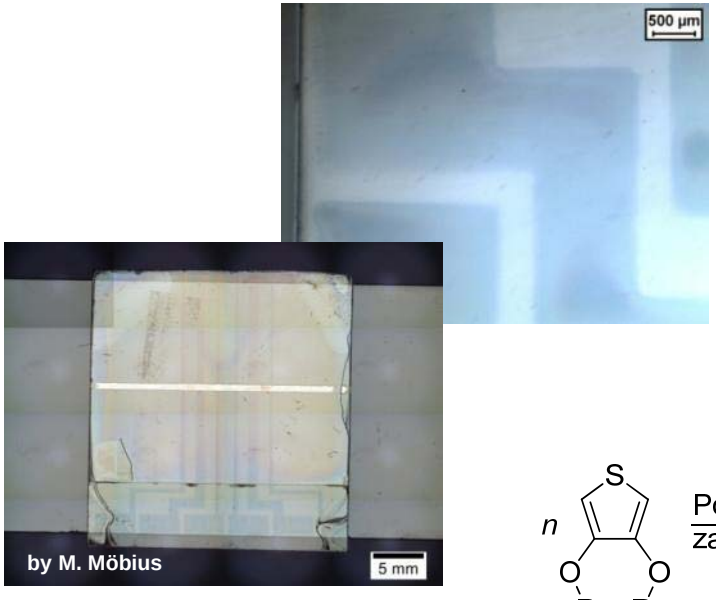
Production:

- Printing of metal and polymer layers
- Direct on devices or back injection
- Usage of new Particles and materials

Sheet fed inkjet printer DMP2831 *(Fujifilm Dimatix)*

25cm

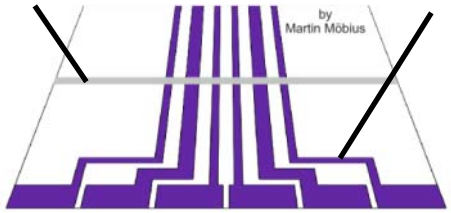
Dimatix FUJIFILM

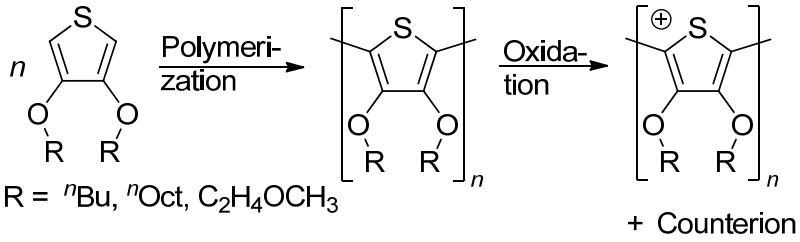


Layer stack with printed electrodes

Printed metal particles

Printed polymer





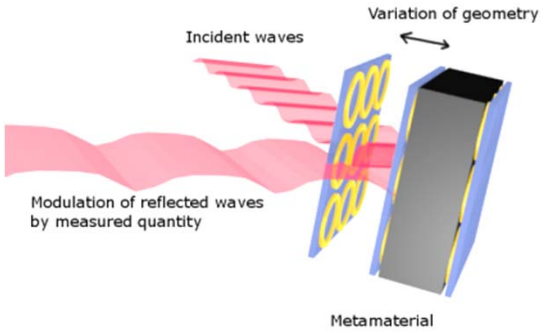
R = ^{n}Bu, ^{n}Oct, $C_2H_4OCH_3$

by E.A. Poppitz

Metamaterials

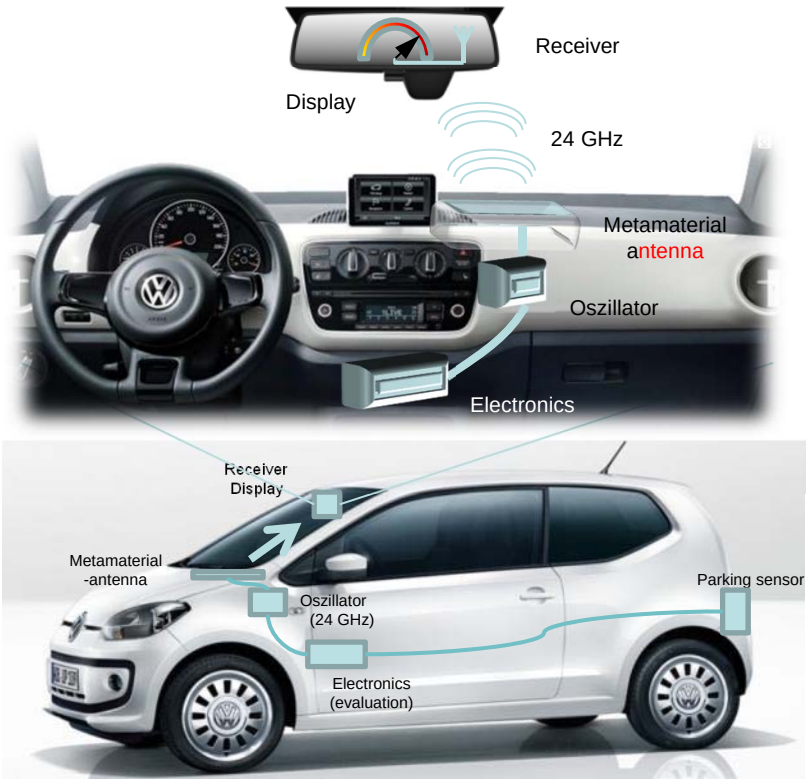
Central objective:

- Patch Antenna for energy & information transfer at 24/60 GHz
- Metamaterial for improved antenna effect and immediate sensor functionality
- Integration through printing technology



Use Case:

- Wireless display at rear-view mirror

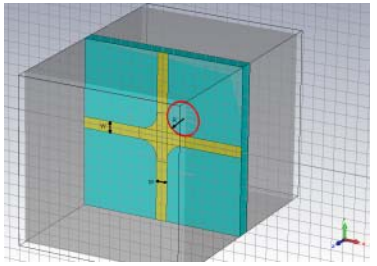


complete(!) wireless display at rear-view mirror

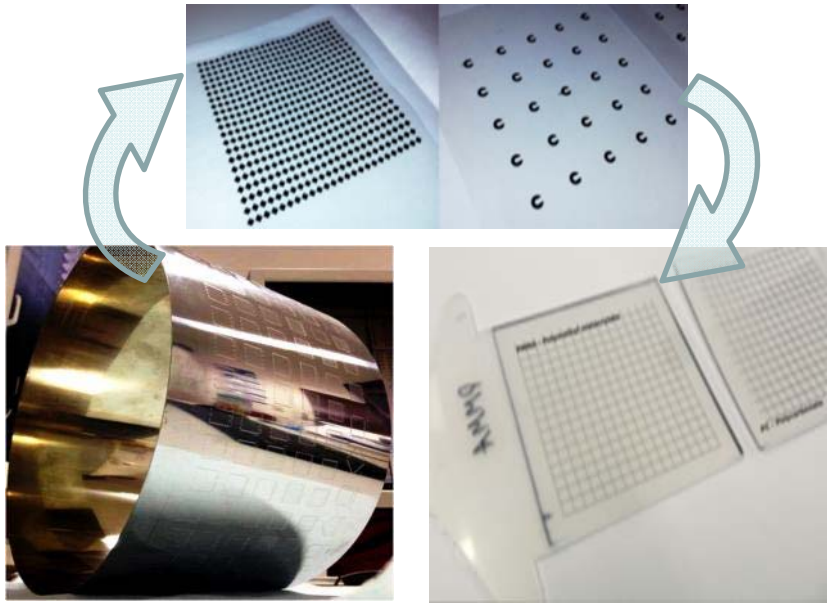
Metamaterials

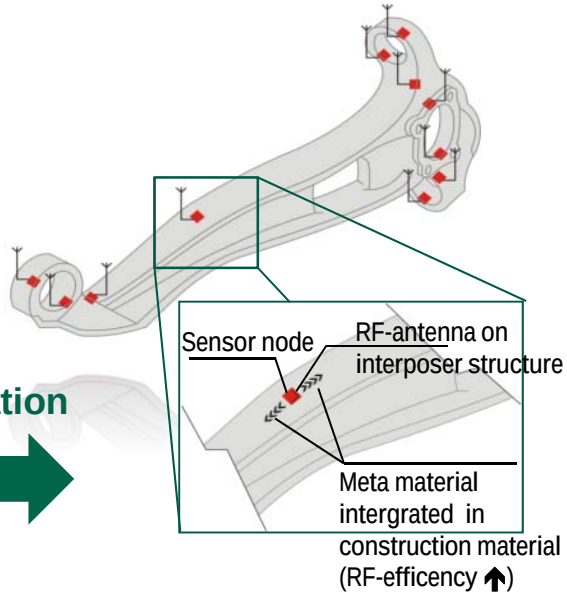
Manufacturing:

- Computer-aided design and simulation
- Production of cells on PET-foil with conductive ink
- Back injection moulding of printed structures



Modellierung: 3D-Zelle





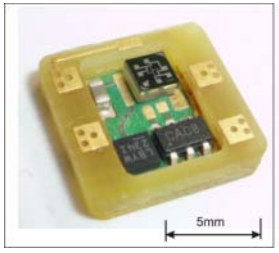
Integration

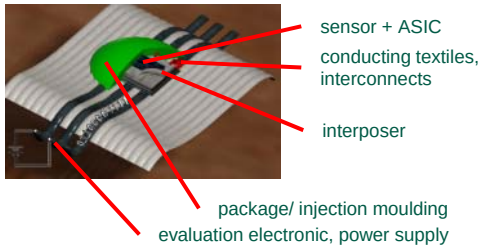
Metamaterial-based antenna in lightweight structures

Integration of Silicon-based sensors

Central objective:

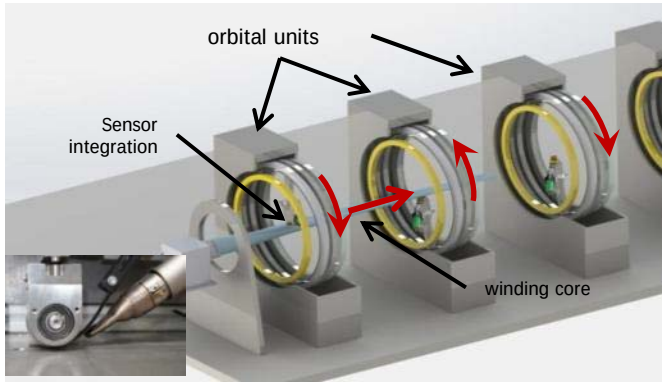
- Miniaturized modules for material integrated sensors
- Integration of si-sensors
- Suitable for R2R-manufacture





Examples of use:

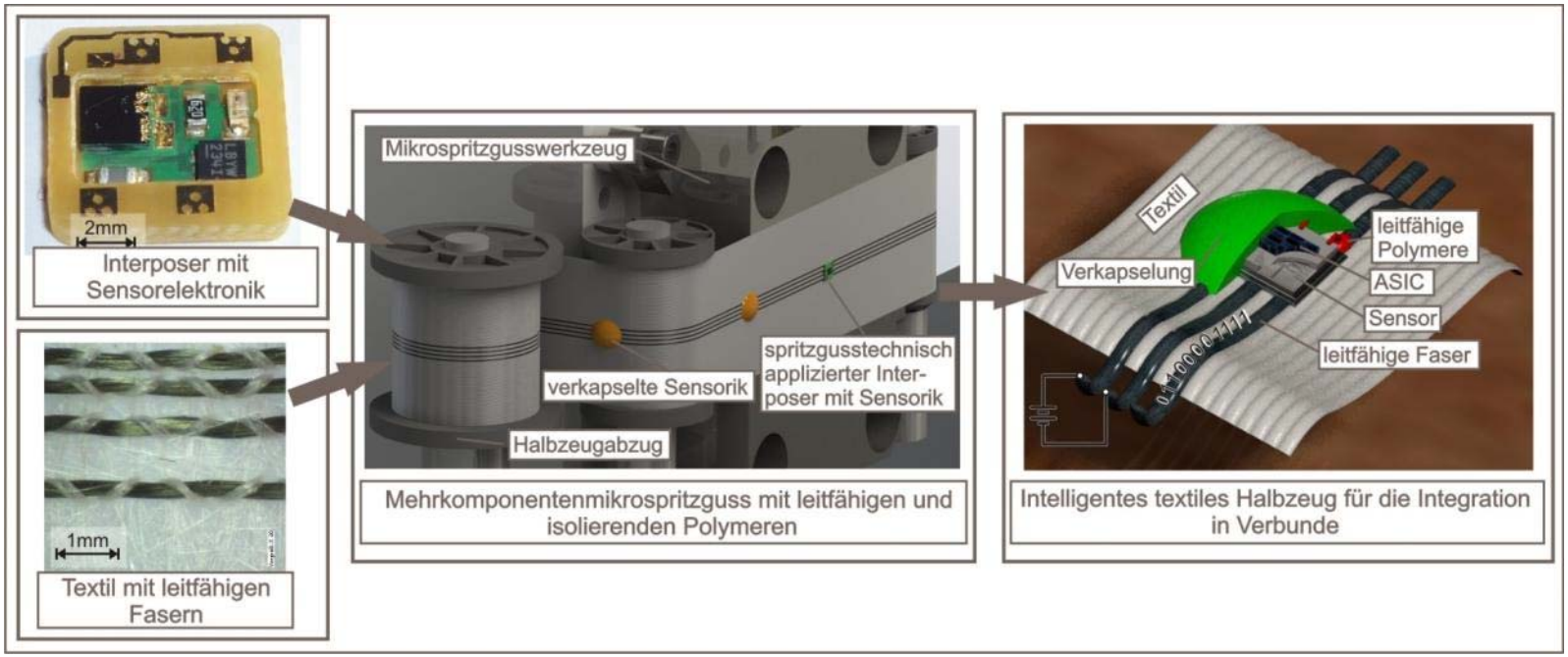
- Sensors for wind turbine rotors



- Sensors at interior

Integration of Silicon-based sensors

- Manufacturing of an „intelligent“ textile preform



Process chain for the mass production of an intelligent textile preforms

Function-integration

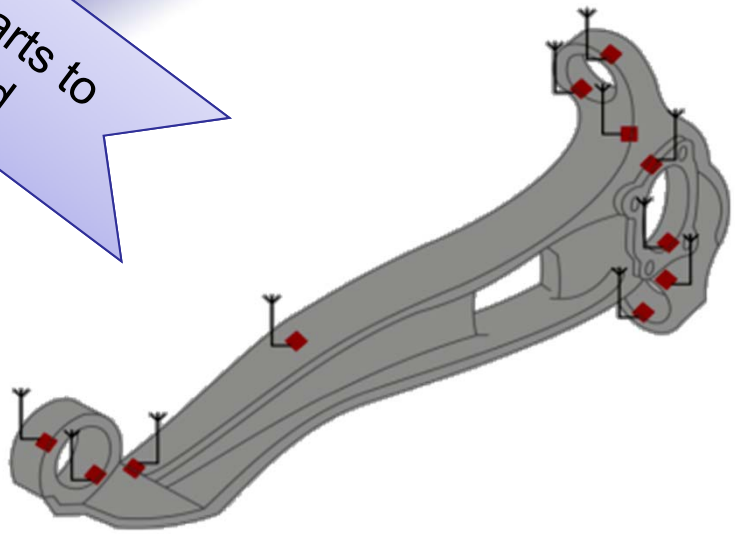
Smart Cities

Smart Technology

Smart Infrastructure

Smart Mobility

From smart parts to a smart world



Thank you for your attention!

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