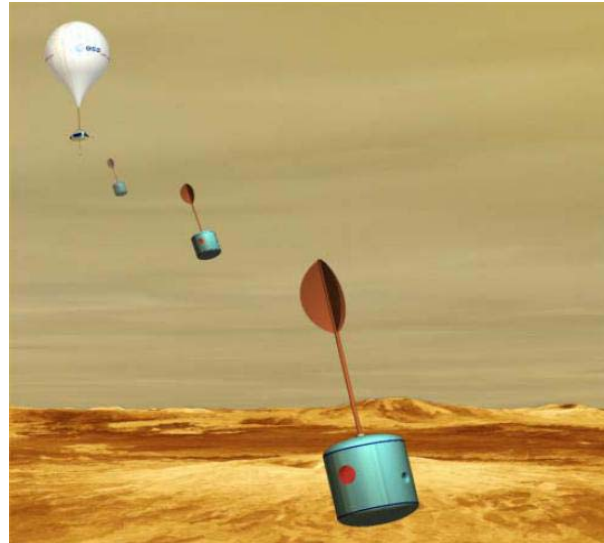
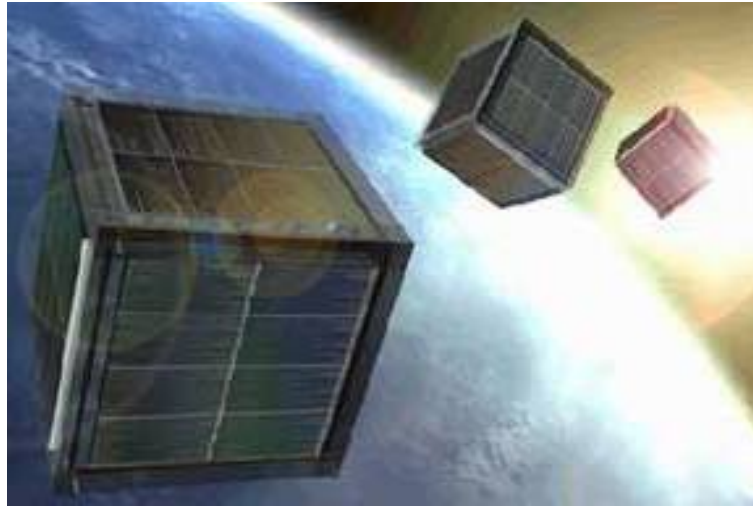


Smart and Functional Materials for Microsystems in Space Applications

Johan Köhler
European Space Agency

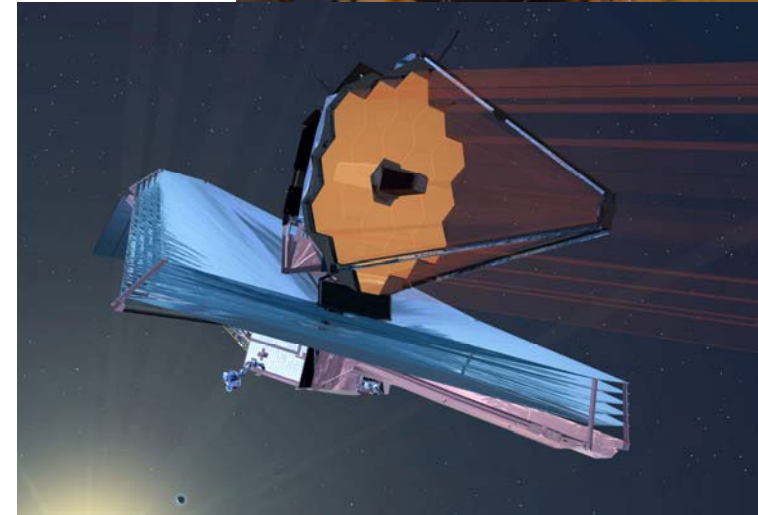
Miniaturisation for Space



London, 24 April, 2008

Microsystems in space today

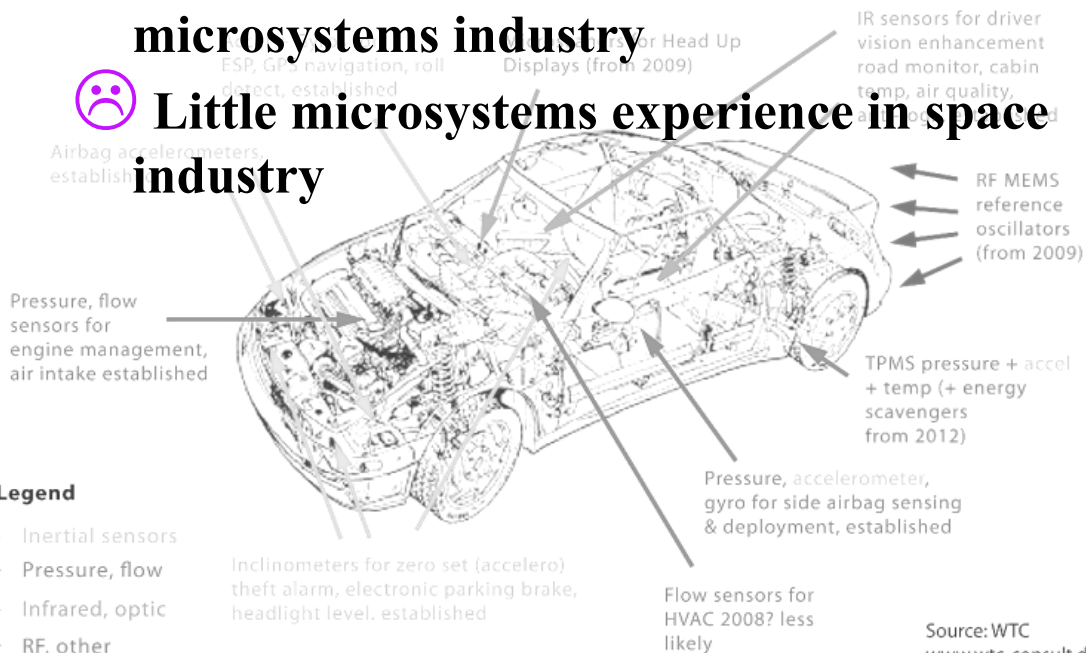
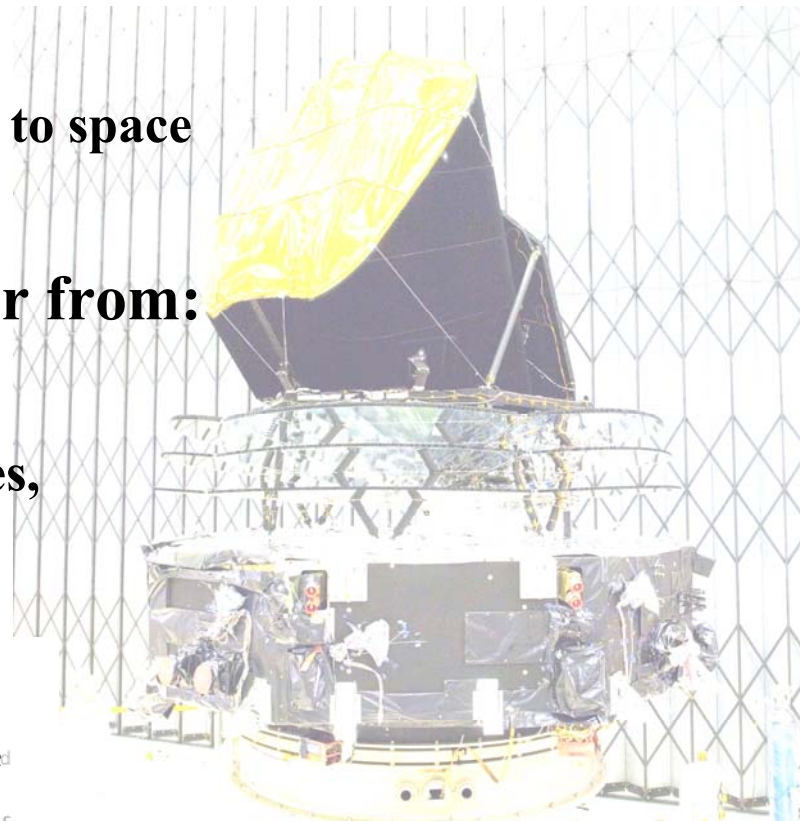
- Microdevices, mainly sensors, used in particular cases.
- Sensors and microdevices under development include:
 - MEMS rate sensor
 - Accelerometers
 - MEMS RF Switches
 - Life Marker Chip for ExoMars
 - Micro Shutter Arrays



Challenges for bringing microsystems to space

Microsystems for space today still suffer from:

- ☹️ **Poor heritage**
- ☹️ **Insufficient integration (bulky interfaces, packages, and harnesses)**
- ☹️ **Little space technology experience in microsystems industry**
- ☹️ **Little microsystems experience in space industry**



Smart materials

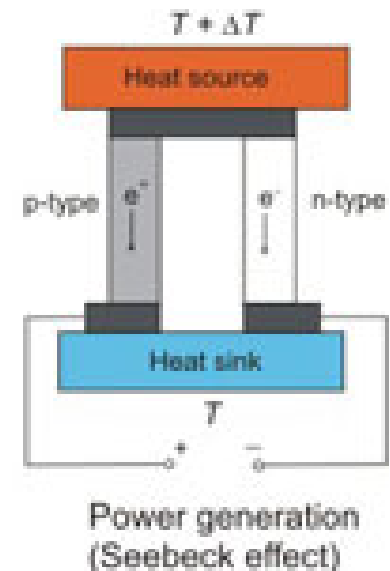
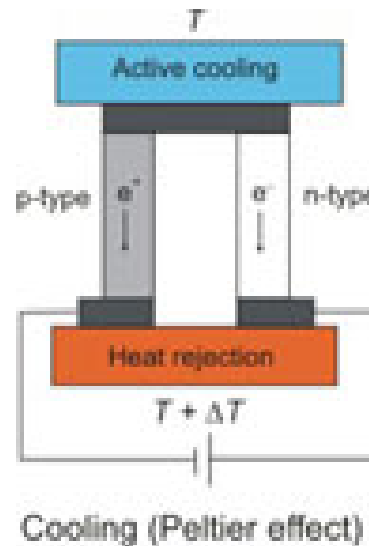
- A smart material provide both sensing and actuating capabilities, possibly also responding to the sensed input, with or without feedback loop.
 - Piezoelectrics with electromechanical coupling
 - shape-memory materials that remember their original shape
 - electrorheological fluids with adjustable viscosities
 - chemical sensors which mimic the human nose



Functional Materials

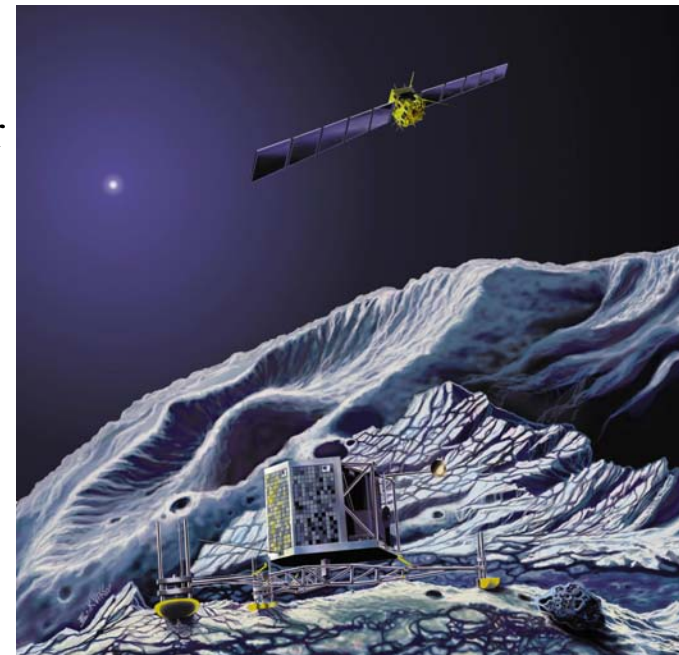
- The physical and chemical properties of functional materials are sensitive to a change in the environment (temperature, pressure, electric field, magnetic field, optical wavelength, adsorbed gas molecules, or pH value).
- Functional materials utilize their inherent properties and functions of their own to achieve an designed effect.

- Dielectrics
- Pyroelectrics
- piezoelectrics
- Ferroelectrics
- semiconductors
- ionic conductors
- superconductors
- electro-optics
- magnetic materials



Smart and Functional Materials for Microsystems in Space Applications

- Advanced sensor systems (e.g. integrated sensor fusion)
- Integrated power microsystems (PowerMEMS)
- Self-tuning or adaptive systems (e.g. optics, RF)
- Thermal management (micro-coolers, thermal coatings)
- Mechanical dampeners for extremely compliant structures (gossamer designs)
- Compact and power-efficient actuator materials for mechanisms, valves, etc.
- Rugged and accurate sensor materials for systems monitoring
- Space Science instrumentation
 - Sensors: electric nose, tongue, etc
 - Sample preparation and manipulation systems

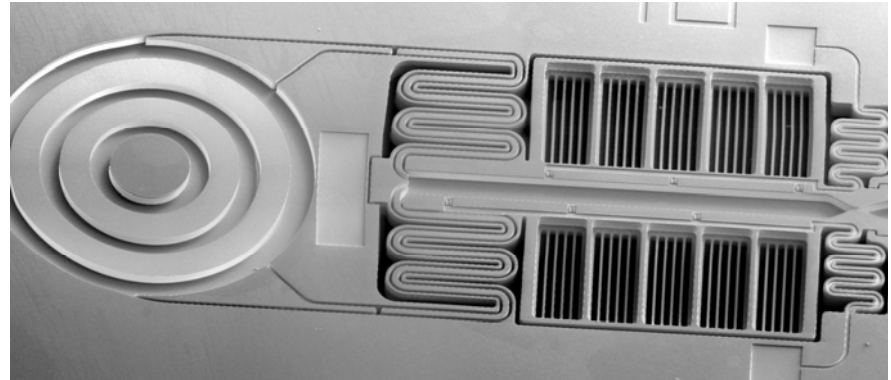


Domain interactions

	Mechanical	thermal	electric	magnetic	radiation	Chemical
mechanical	acoustics, fluidics	friction	piezo-electricity, piezo-resistivity	piezo-magnetism	triboluminescence	-
thermal	thermal expansion	-	pyro-electricity, Seebeckeff.	-	Radiation heat	reaction
electric	piezo-electricity Electrostriction	resistive heat, Peltier eff.	Langmuir probe	Electro-magnetism	electroluminescence	electrolysis
magnetic	magnetostriction	thermo-magnetism	magneto-resistance	-	-	-
radiation	Radiation pressure	bolometry	photo-electricity	-	-	photo-reaction
chemical	Hygrometry	calorimetry	Electro-galvanic cell	NMR	chemoluminescence	-

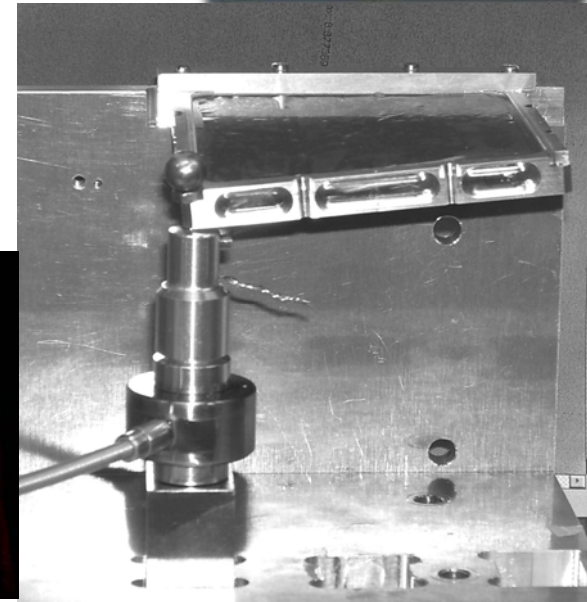
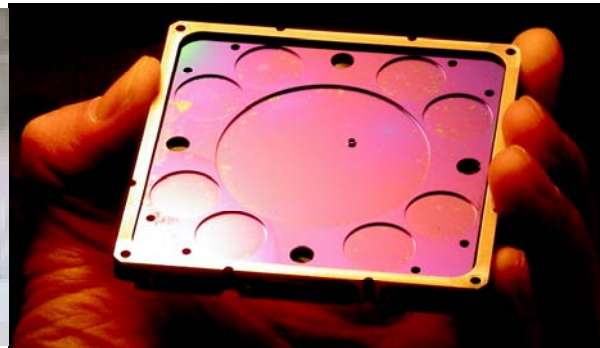
Microsystems Integration

- L0: Feature level
 - L1: Device level
 - L2: Device package
 - L3: Mounting board
 - L4: Chassis, box, harness
 - L5: Entire system (S/C)
-
- Sensors
 - Actuators
 - Integrated Feedback
-
- → **Integration levels merging**



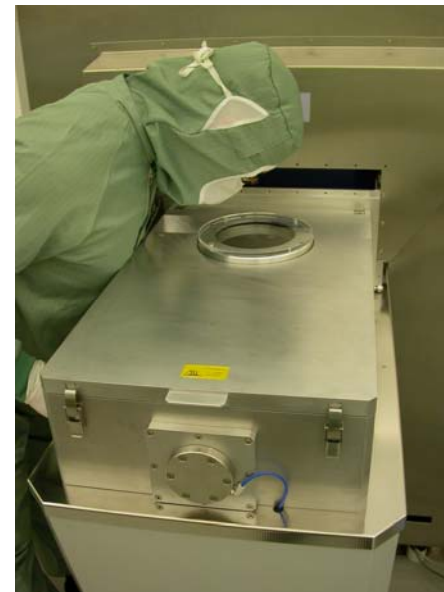
Multifunctional Microsystems example

- Communication function
- Thermal management
- Structure
- Simultaneous triple usage of paraffin
 - Low loss antenna substrate
 - Thermal heat storage
 - Actuator for thermal conductance switch



Pushing materials into microsystems

- Mainly silicon micromachining and thin-film deposition techniques
- Batch manufacturing is preferred to enable mass production
- Complex process sequences can ruin smart and functional materials
- How will the microsystem be packaged?
- How will the smart or functional material be addressed?



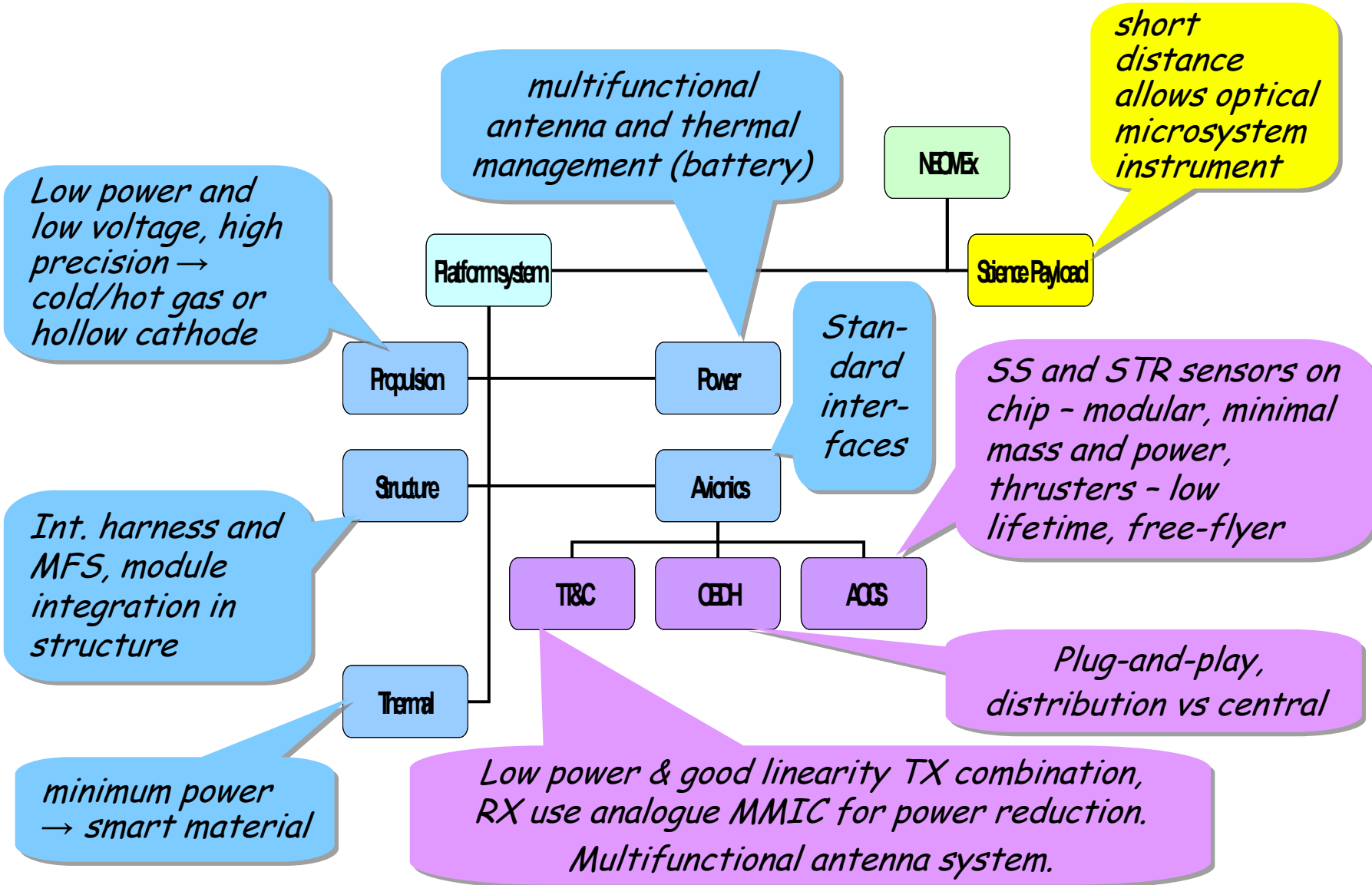
System-level Functions with Materials

- Smart and functional materials can provide system-level functions to integrated microsystems and spacecraft systems
- Smart and functional materials can improve significantly on the integration level of microsystems.
- Smart and functional materials are instrumental to future highly integrated complex microsystems for space.

The NEOMEx Case

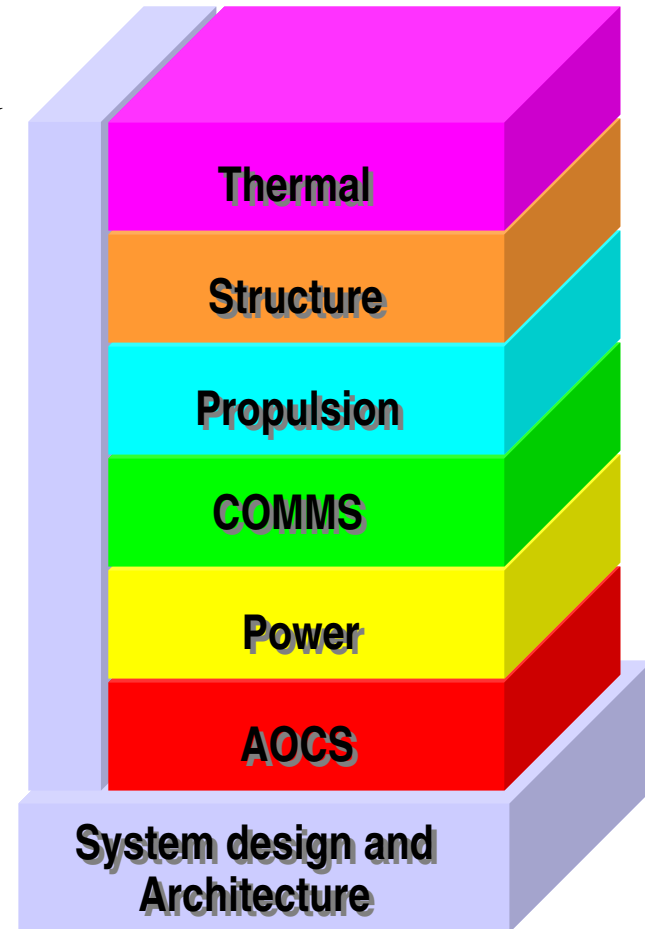
- NEOMEx: Near Earth Object Micro Explorer
- **Objective:** To perform close-up scientific investigations on several sites on a Near Earth Object.
- **Constraints:** Extreme mass-limitation, 5 kg platform, 2-4 kg payload of 10-15 W
- **Challenge:** use microsystems integrated in a system to gain performance with respect to mass.
- Explorer mission applications as first target.
 - *Possible mission enabler*
 - *Mass saver*





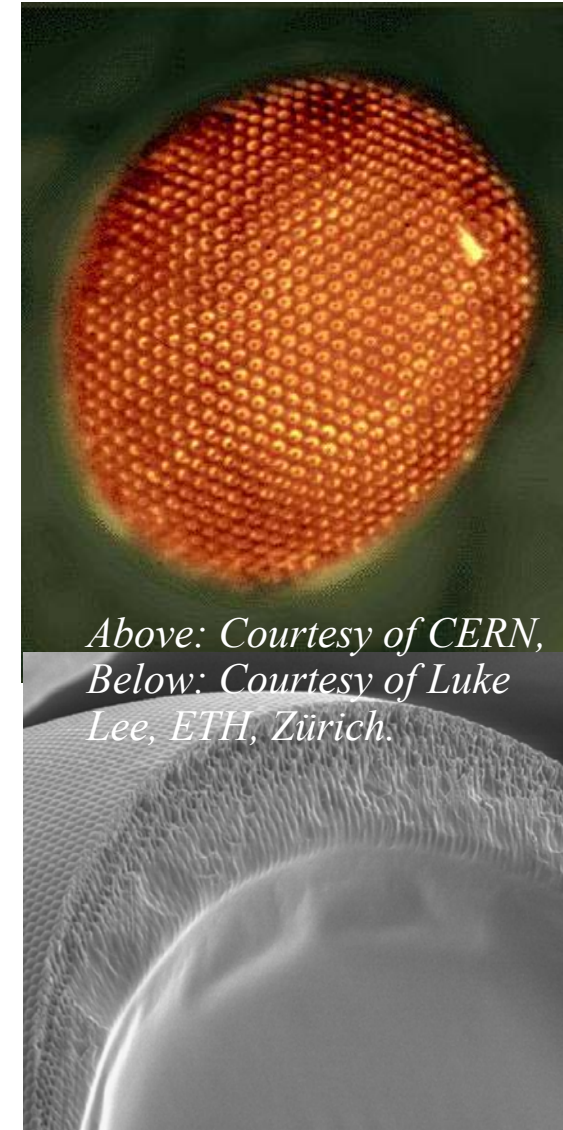
Modularity, reusability, integration

- General platform with mission-specific platform and payload modules
- Modularity and integration on system-of-microsystems level with allow maximum reusability
- Appropriate selection from a set of microsystem modules, according to the mission
- **Microdevices to microsystems, microsystems into systems-of-microsystems**
 - *without compromising the miniaturization or performance.*



Materials in NEOMEx

- Thermal domain
 - Smart thermal control coatings
 - Thermal management microsystems
- Power Domain
 - Batteries
 - Power management devices, micro-power converters
- Packaging and Integration
 - Multifunctional structures for microsystem integration
 - Connectors and interfaces



Thank You for your attention!

... more questions?

