Smart and Functional Materials for Microsystems in Space Applications

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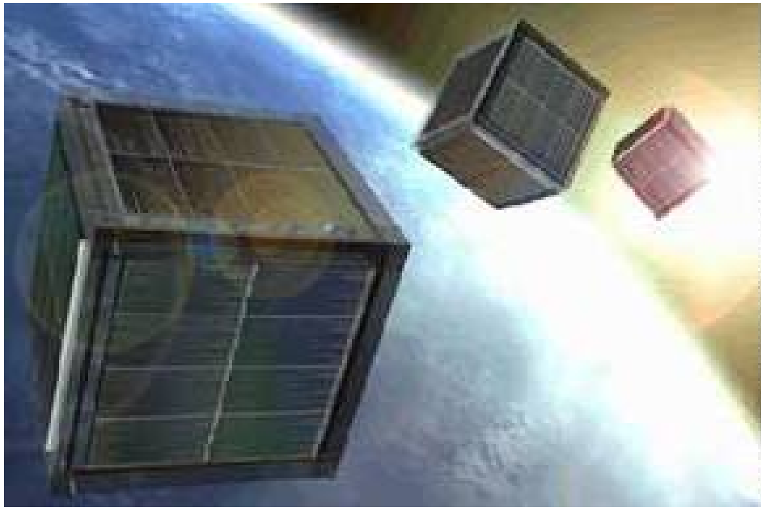
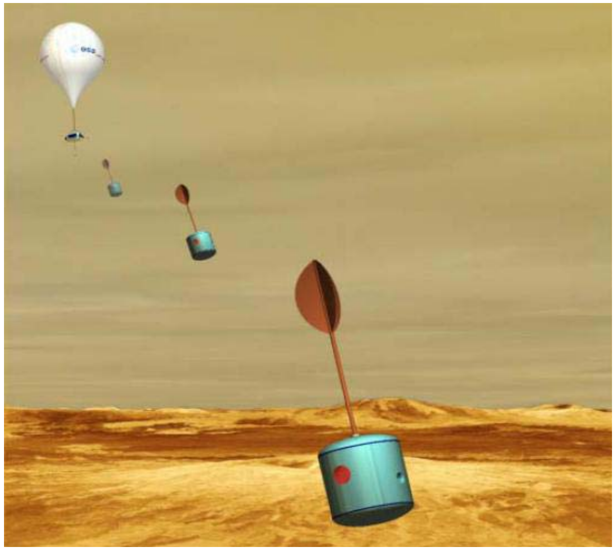
London, 24 April, 2008

Miniaturisation for Space

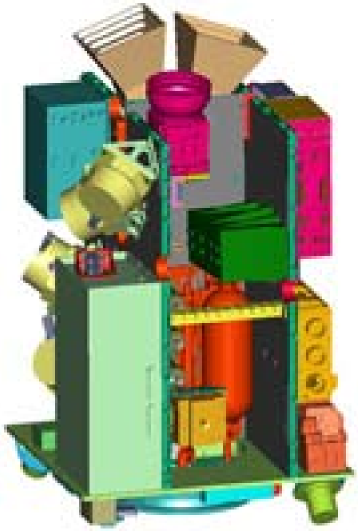




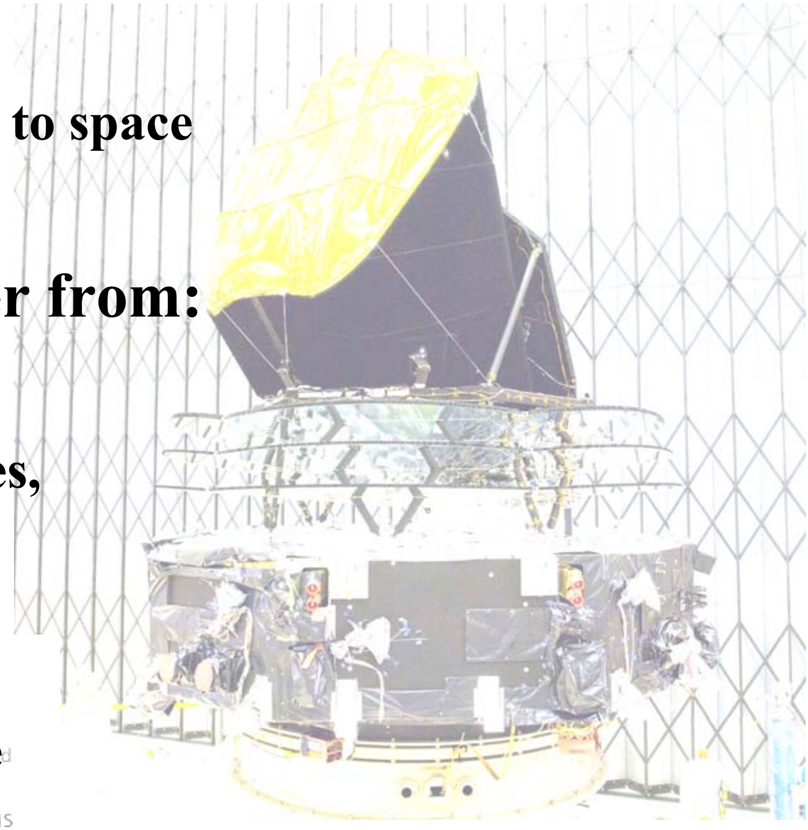
Microsystems in space today

- 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

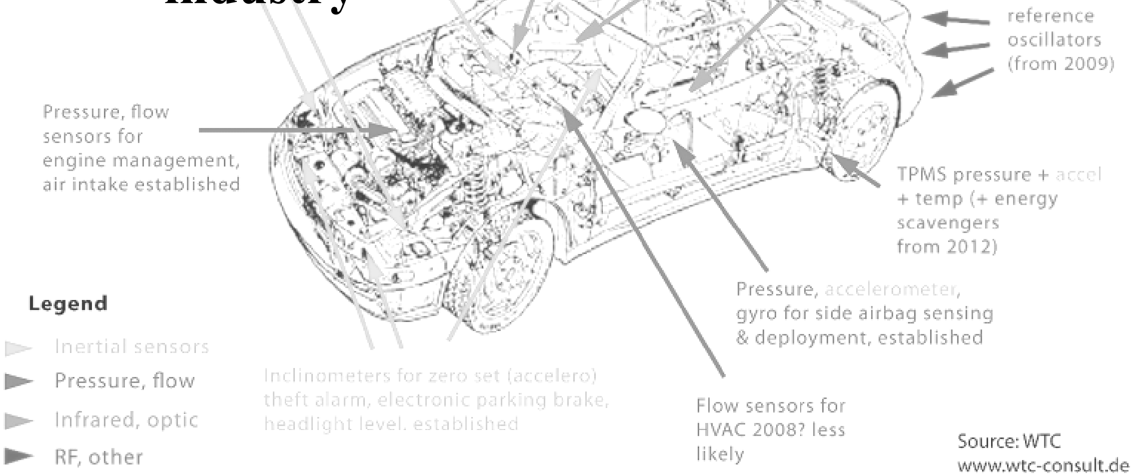


Challenges for bringing microsystems to space



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

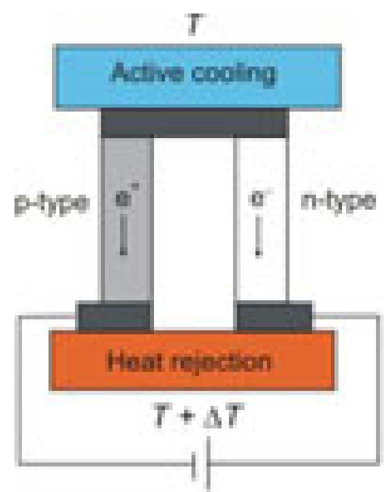
- A smart material provide both sensing and actuating capabilities, possibly also responding to the sensed input, with or without feedback loop.

  - Piezoelectrics with electromechanical coupling
  - shape-memory materials that remember their original shape
  - electrorheological fluids with adjustable viscosities
  - chemical sensors which mimic the human nose

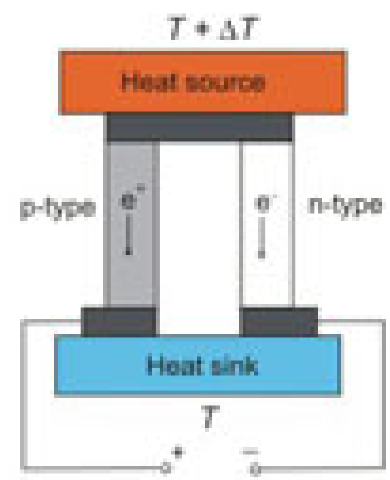
Functional Materials

- 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



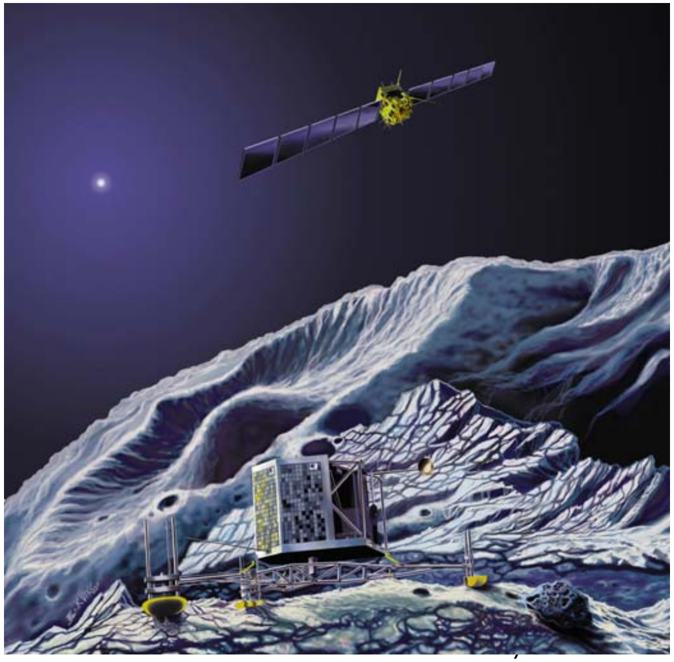
Cooling (Peltier effect)



Power generation (Seebeck effect)

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

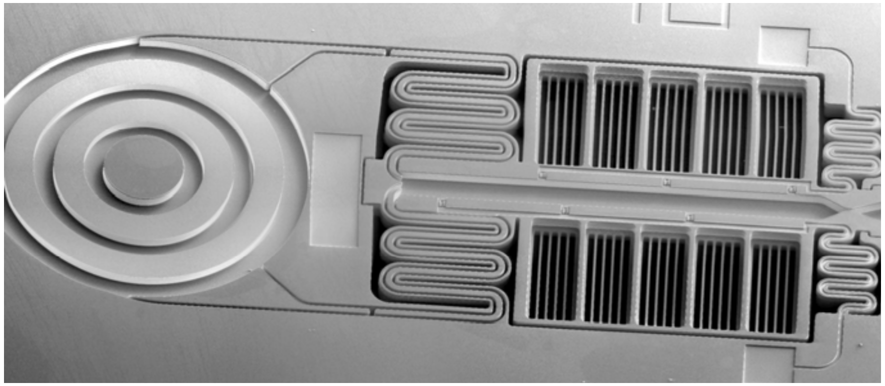
	Mecha-nical	thermal	electric	magnetic	radiation	Chemi-cal
mechanical	acoustics, fluidics	friction	piezo-electricity, piezo-resisitivity	piezo-magnetism	tribolumin-iscense	-
thermal	thermal expansion	-	pyro-electricity, Seebeckeff.	-	Radiation heat	reaction
electric	piezo-electricity Electro-striction	resistive heat, Peltier eff.	Langmuir probe	Electro-magnetism	electro-lumin-iscense	electro-lysis
magnetic	magneto-striction	thermo-magnetism	magneto-resistance	-	-	-
radiation	Radiation pressure	bolometry	photo-electricity	-	-	photo-reaction
chemical	Hygro-metry	calorimetry	Electro-galvanic cell	NMR	chemo-lumin-iscense	-

Microsystems Integration

- L0: Feature level
- L1: Device level
- L2: Device package
- L3: Mounting board
- L4: Chassis, box, harness
- L5: Entire system (S/C)

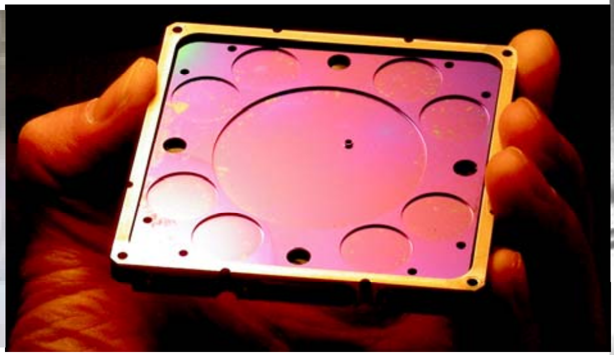
- Sensors
- Actuators
- Integrated Feedback

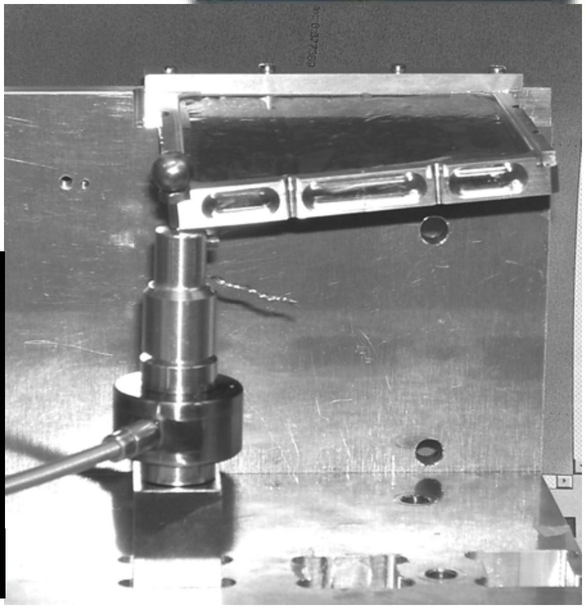
- → **Integration levels merging**



Multifunctional Microsystems example

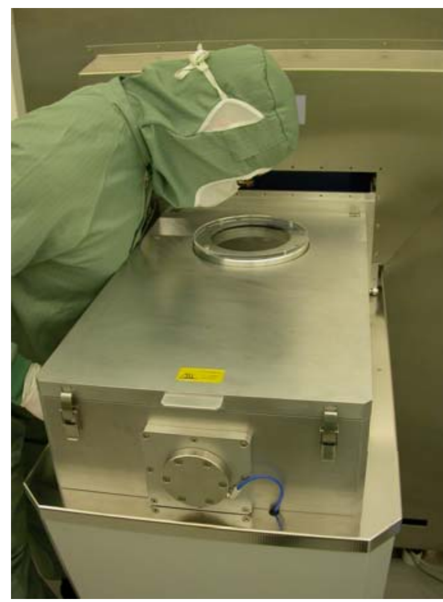
- Communication function
- Thermal management
- Structure
- Simultaneous triple usage of paraffin
  - Low loss antenna substrate
  - Thermal heat storage
  - Actuator for thermal conductance switch





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

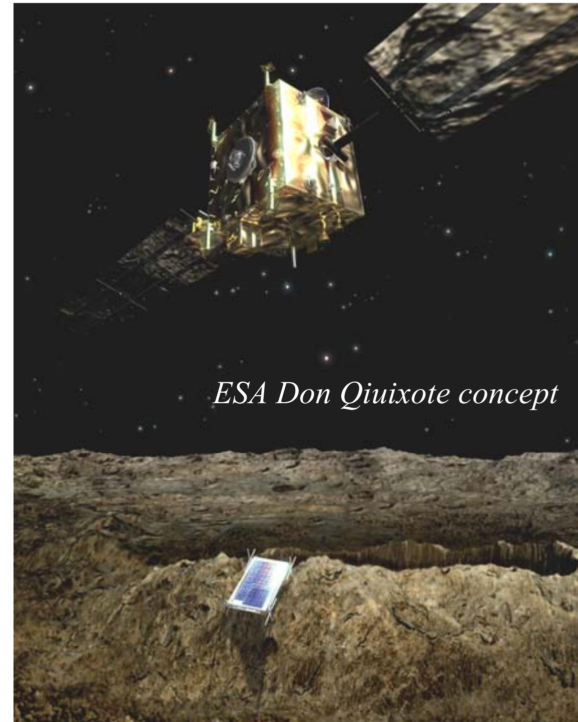
- Smart and functional materials can provide system-level functions to integrated microsystems and spacecraft systems

- 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

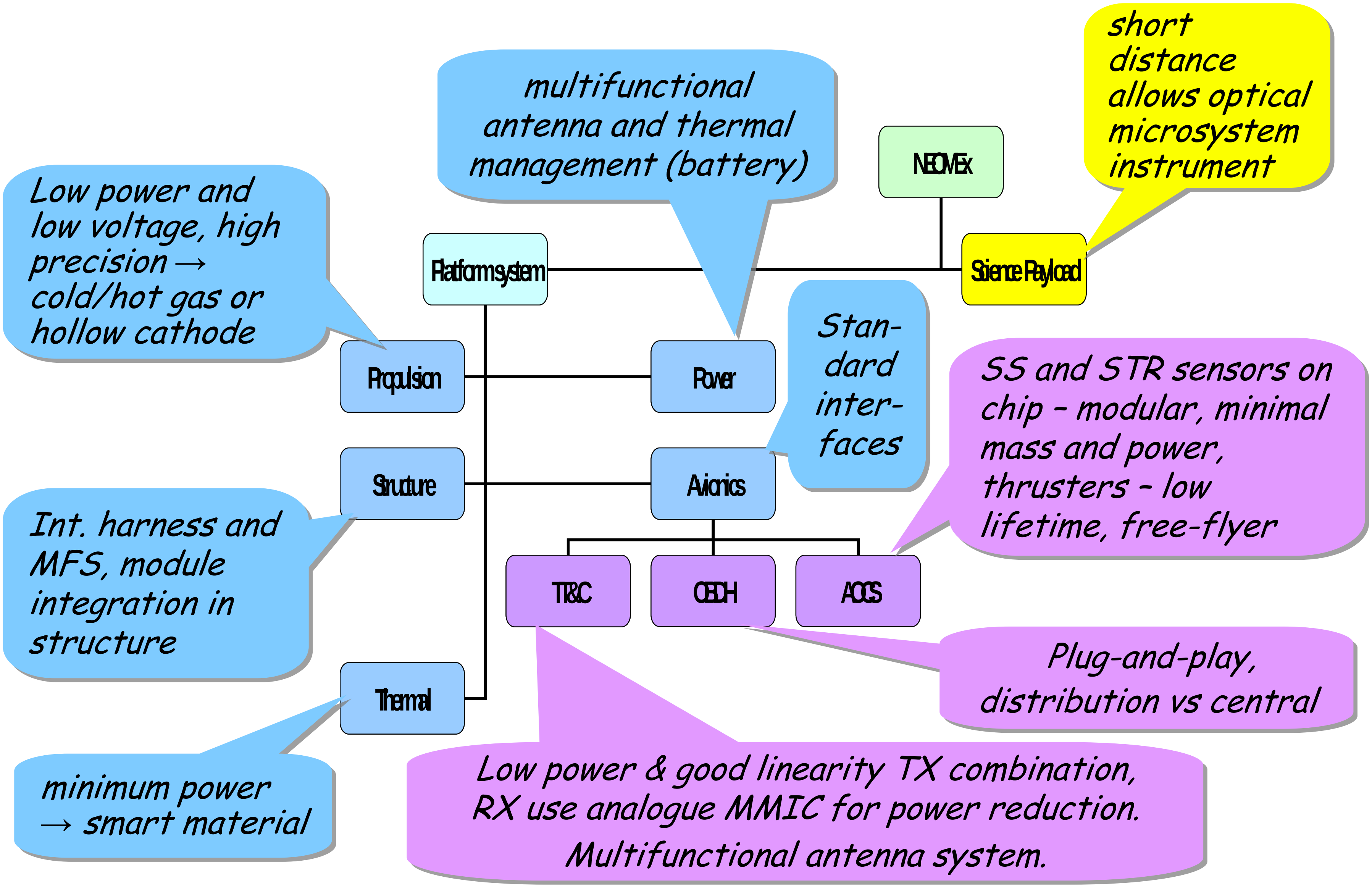
- NEOMEx: Near Earth Object Micro Explorer
- **Objective:** To perform close-up scientific investigations on several sites on a Near Earth Object.
- **Constraints:** Extreme mass-limitation, 5 kg platform, 2-4 kg payload of 10-15 W
- **Challenge:** use microsystems integrated in a system to gain performance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



ESA Don Qiuixote concept

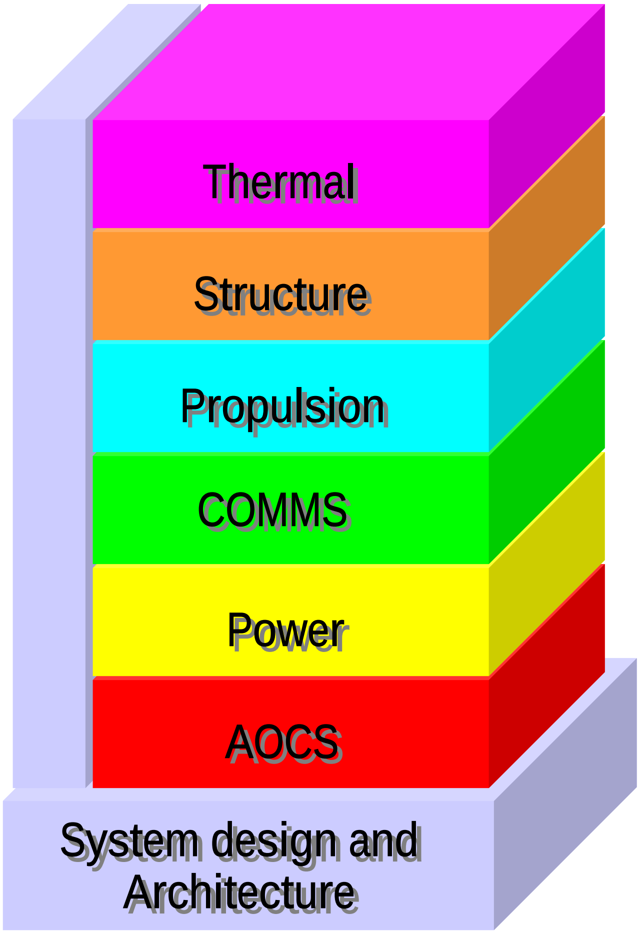
Courtesy of JAXA

Microsystem-based nanospacecraft



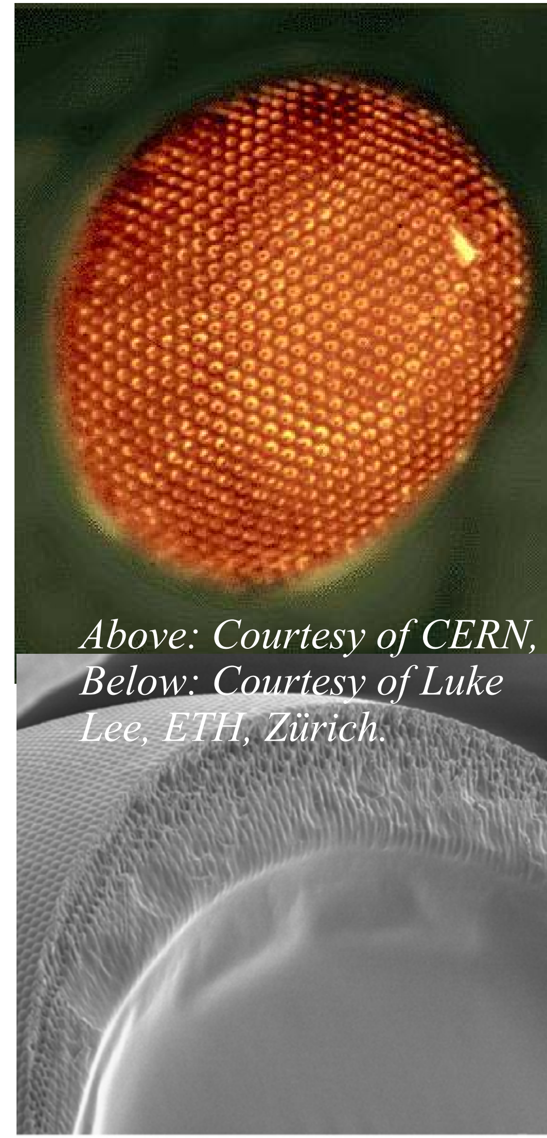
Modularity, reusability, integration

- 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



Above: Courtesy of CERN, Below: Courtesy of Luke Lee, ETH, Zürich.

Thank You for your attention!

… more questions?