

# Aware Systems on Chip

Axel Jantsch

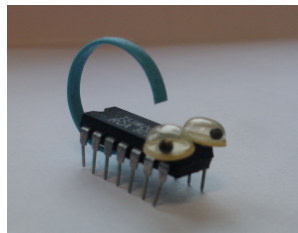
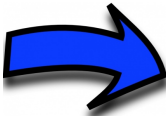
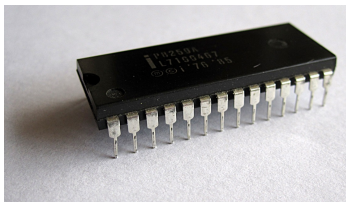
January 14, 2016



TECHNISCHE  
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Vienna University of Technology

# Making Chips Aware

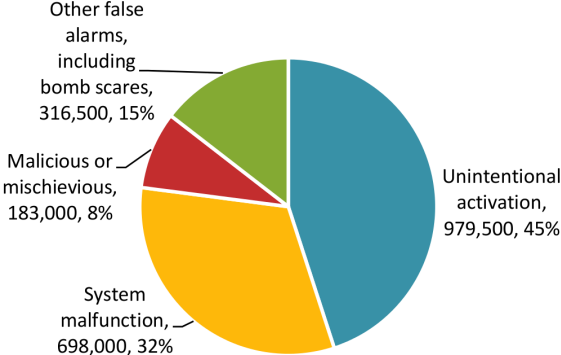


# False Alarms



# False Alarms

Fire Department Responses in 2009 to False Alarms, by Type of False Alarm





# Air France Flight 447 in 2009



## Air France Flight 447 in 2009

The BEA's final report from 2012 concluded that:

*“Temporary inconsistency between the measured airspeeds, likely following the obstruction of the Pitot probes by ice crystals”*

caused the autopilot to disconnect, after which the crew reacted incorrectly and ultimately led the aircraft to an aerodynamic stall from which they did not recover.





*Nature does nothing uselessly, Aristotle*

# What do we mean with Awareness?

Does a bridge know when it is weakening?

# What do we mean with Awareness?

Is a thermometer aware of the temperature?

# What do we mean with Awareness?

Does a robot recognize its own limbs?

# What do we mean with Awareness?

Does a surveillance system recognize its own camera?

# What do we mean with Awareness?

Is a human aware of her immune system?



# What do we mean with Awareness?

Is a human aware of her own arms?

# Which Ingredients Lead to Awareness ?



Johan Moreelse's "Der Alchemist", 1630

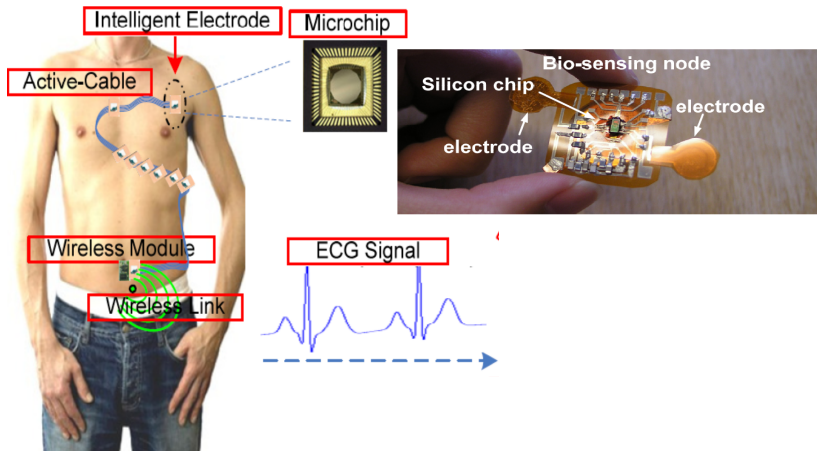
# Which Ingredients Lead to Awareness ?



- ▶ Data abstraction
- ▶ Disambiguation
- ▶ Desirability scale
- ▶ History
- ▶ Goals
- ▶ Learning
- ▶ Inspection

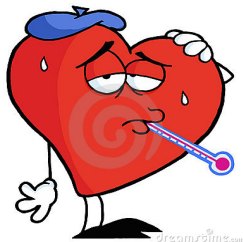
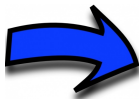
Johan Moreelses "Der Alchemist", 1630

# Awareness for Resource Constrained, Insect-like Gadgets

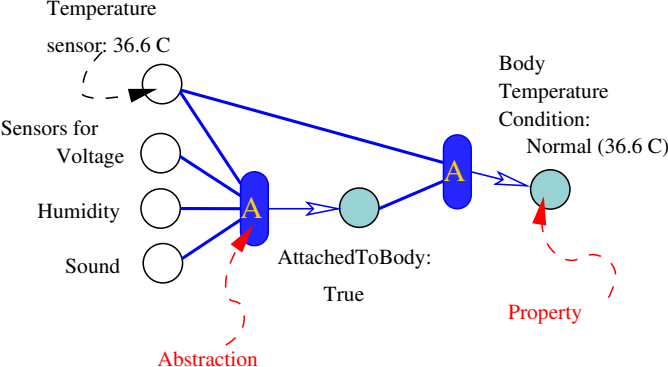


# Abstractions and Models

Abstraction: Mapping of Measurements  $\Rightarrow$  Properties

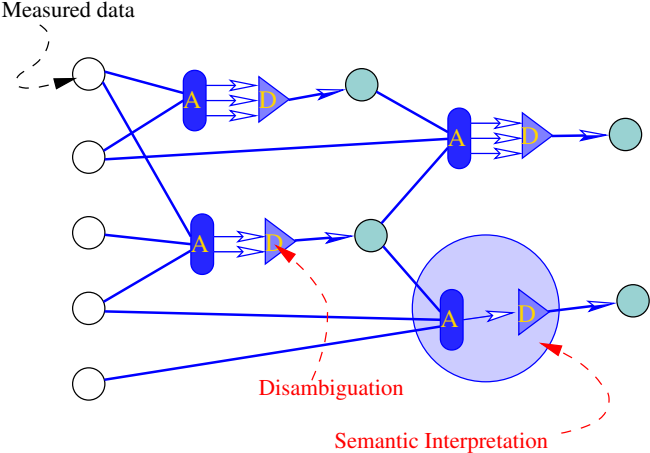


# Abstractions and Models



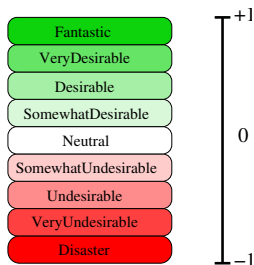
# Disambiguation

Selection among several interpretations



# Desirability Scale

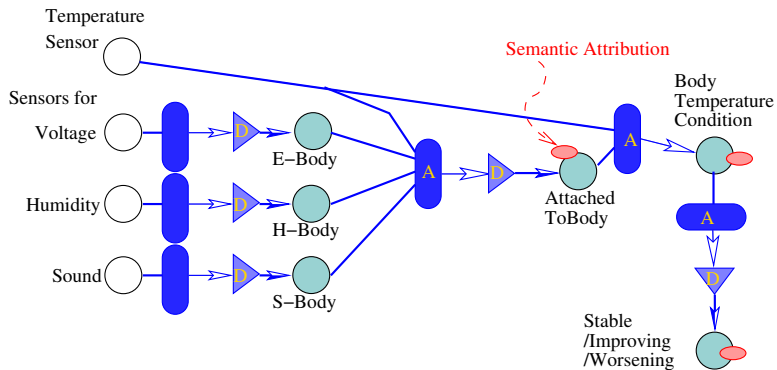
Desirability is the common, internal currency.



**Semantic Attribution** maps the values of a property to a point in the desirability scale.



# BioPatch with Semantic Attribution



# History

**History of a Property** The evolution of the values of a property.

**Abstracted History** The history stores abstracted values.

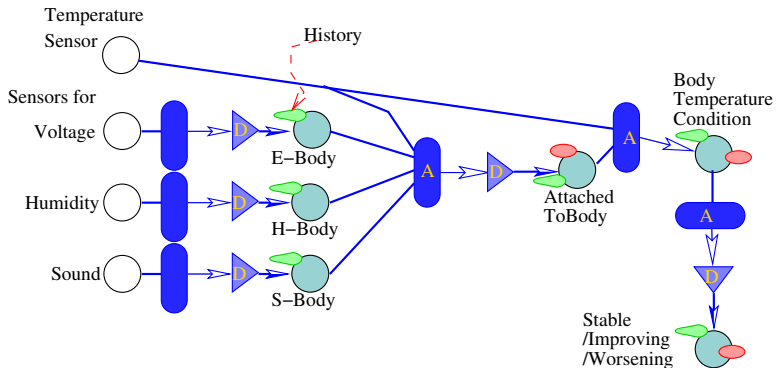
**Attributed History** The history is annotated with attributions.

**Fading History** If the property values are more abstracted the longer ago they have occurred.

**Consolidating History** Relevant memories are enforced, irrelevant memories are cleaned.

**Evolving History** Memories are adjusted to fit later observations.

# BioPatch with History

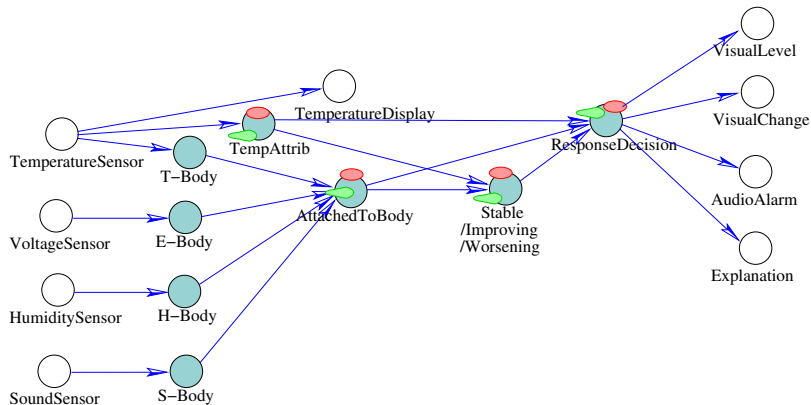


# Expectations and Goals

- ▶ Expectations on Environment
- ▶ Expectations on Subject
- ▶ Sub-Goals
- ▶ Goals
- ▶ Purpose



# Acting BioPatch

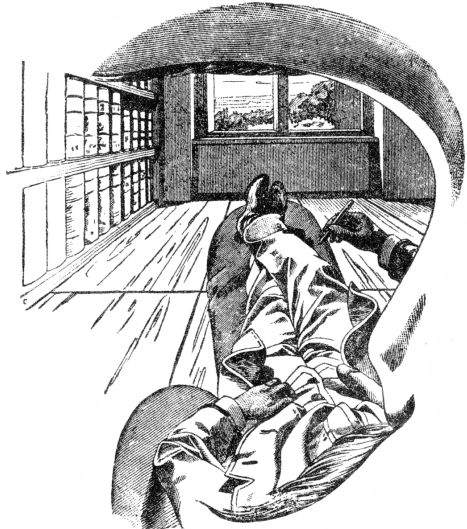


# Inspection and Simulation

Self Inspection Engine

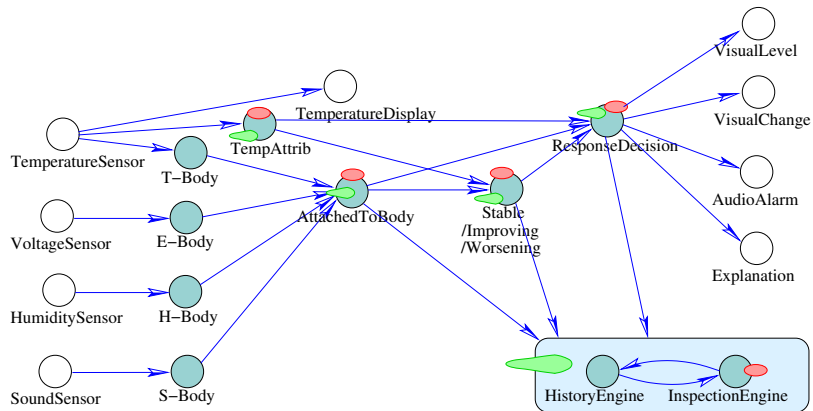
Model Transformation

Simulation

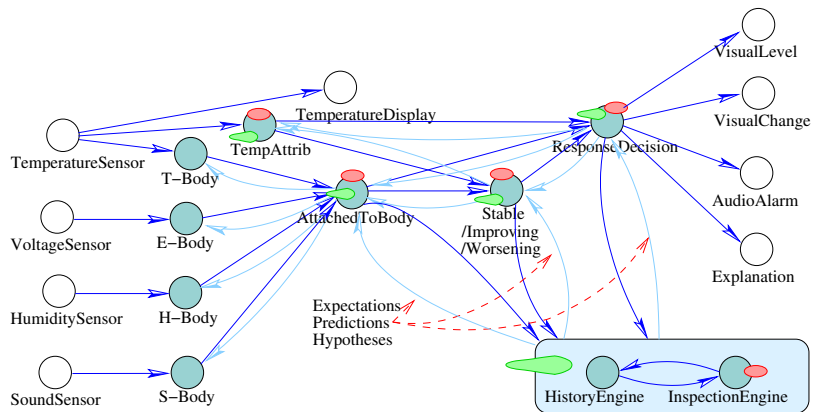


Ernst Mach "Innenperspektive", 1886

# Self-inspecting BioPatch

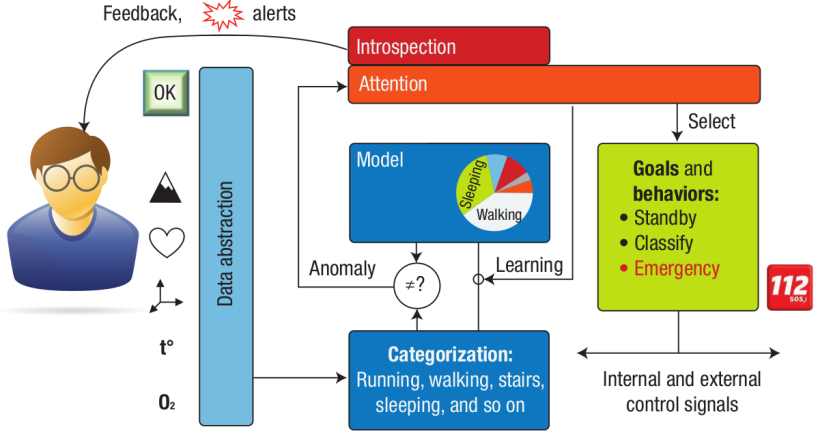


# BioPatch with Top-down Prediction

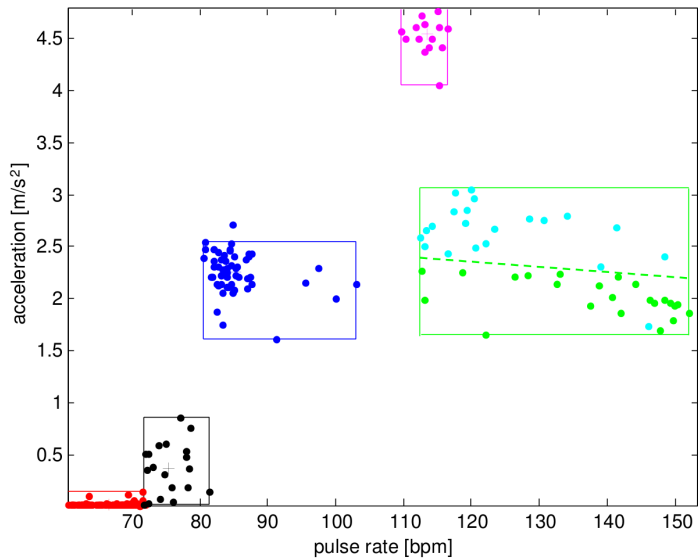




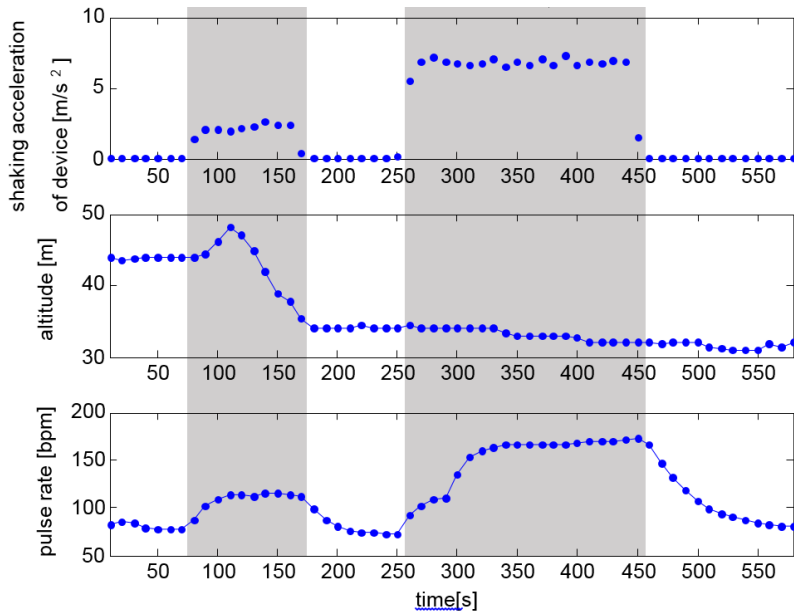
# Health Monitoring



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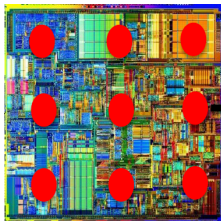


# Health Monitoring



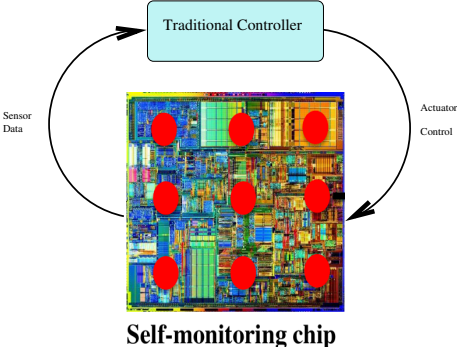
# Self-Aware SoC

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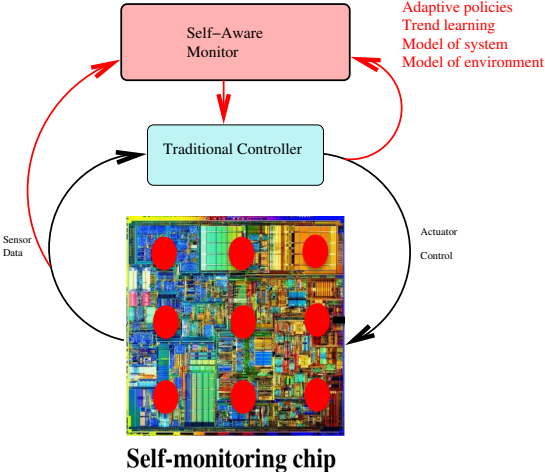


**Self-monitoring chip**

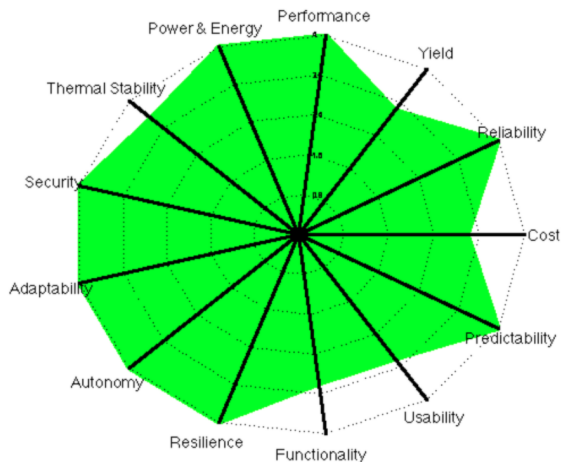
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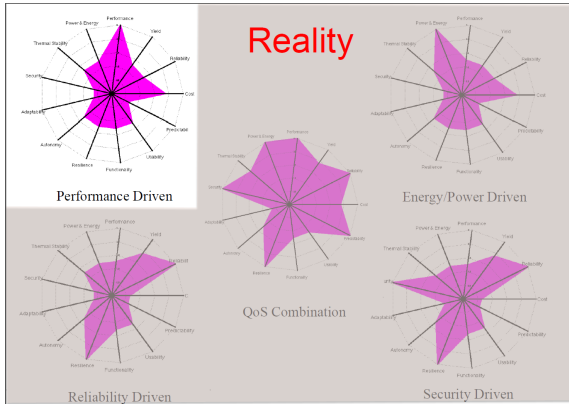


# The SoC Radar

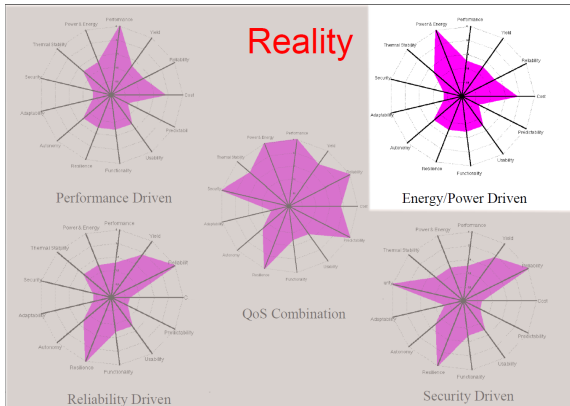




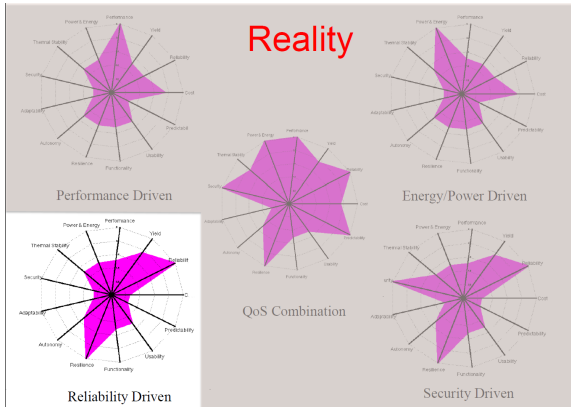
# The SoC Radar



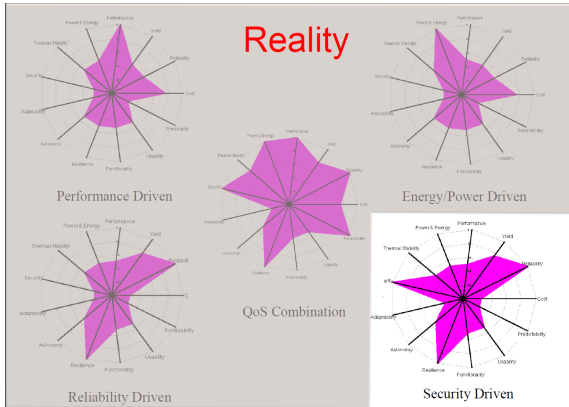
# The SoC Radar



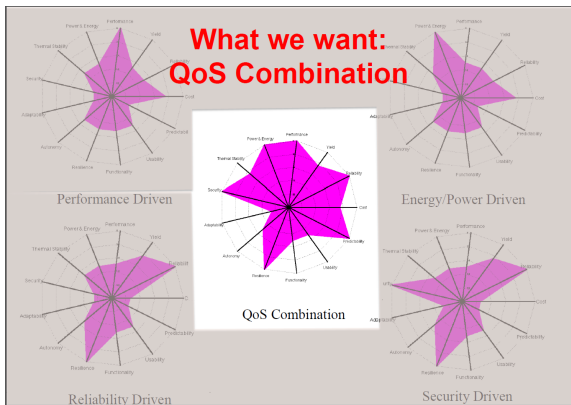
# The SoC Radar



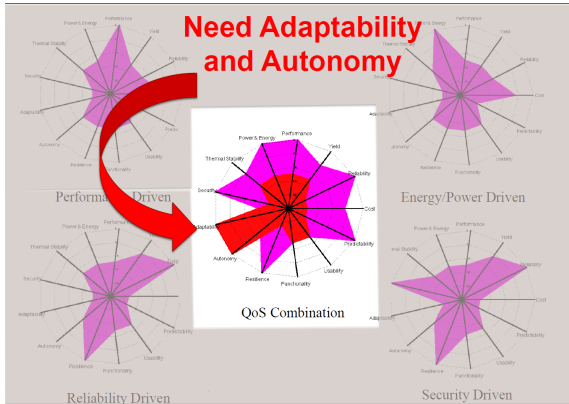
# The SoC Radar



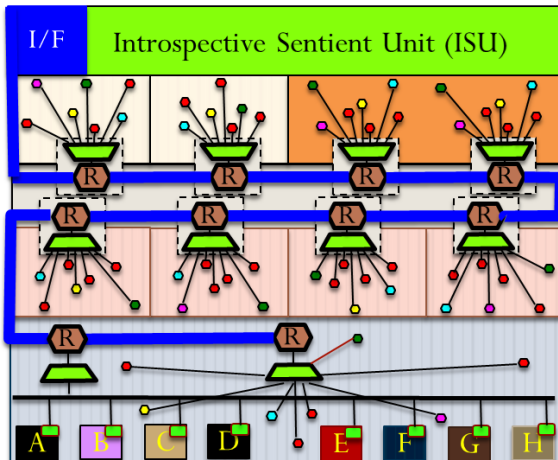
# The SoC Radar



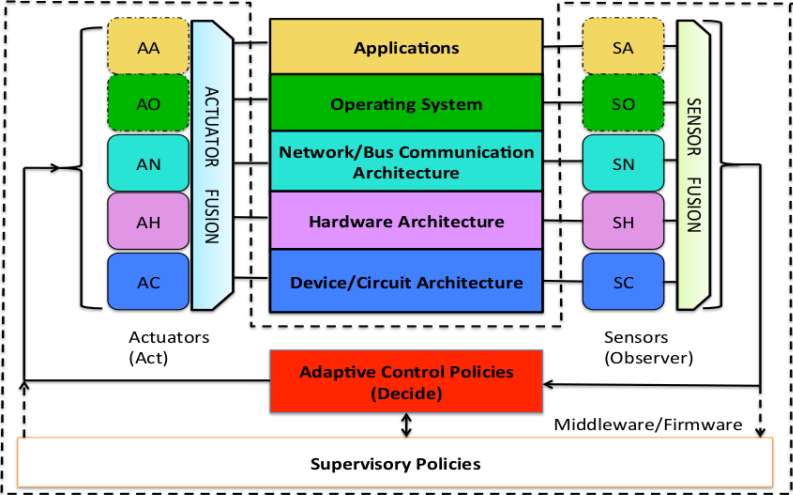
# The SoC Radar



# CPSoC - A Sensor Rich SoC Platform



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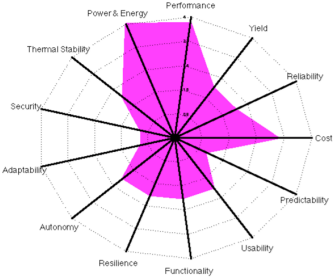
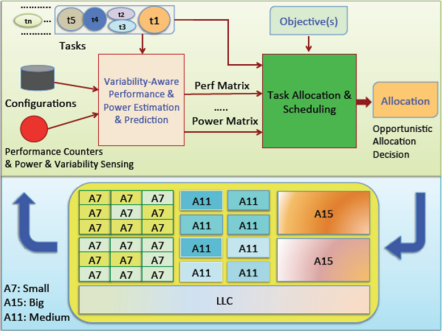




# Sensing and Actuating at All Layers

| Layers                | Virtual/Physical Sensors  | Virtual/Physical Actuators  |
|-----------------------|---|---|
| Application           | Workload, Power, Energy, Execution Time                             | Approximation, Algorithmic choice, Transformations                        |
| Operating System      | System utilization, Peripheral states                               | Task allocation, Partitioning, Scheduling, Migration, Duty cycle          |
| Network/Bus           | Bandwidth, Packet/flit status, Channel status, Congestion           | Adaptive routing, Dynamic BW allocation, Channel allocation, Flow control |
| Hardware Architecture | Cache miss rate, Access rate, IPC, Throughput, Resource utilization | Cache sizing, Issue width sizing, Reconfiguration, Resource provisioning  |
| Circuit/Device        | Circuit delay, Aging effects, Leakage, Temperature, Device faults   | DVFS, Clock gating, Power gating  |

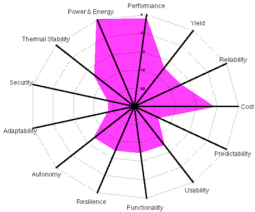
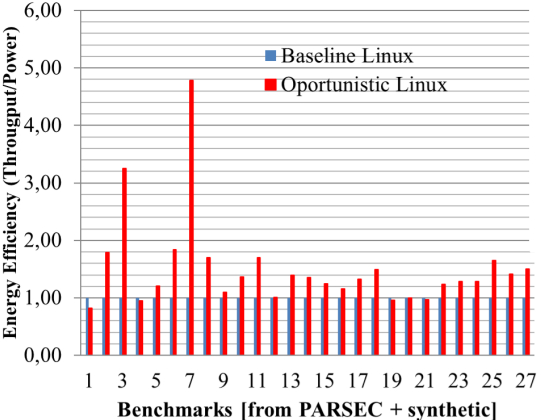
# Improvement of Energy Efficiency



**Goal:**

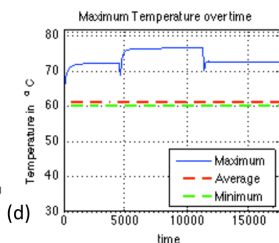
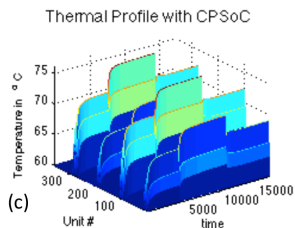
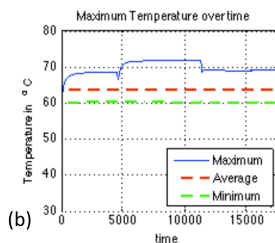
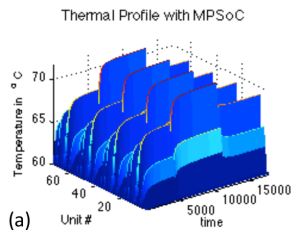
- Energy Efficiency

# Improvement of Energy Efficiency



**51% Average Improvement for Quad-core**

# Thermal-Aware Performance

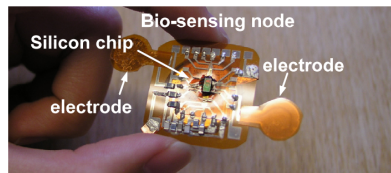


Throughput improvement by 70%-300% for same power and temperature.

Dutt Research Group 2014

# Awareness Properties

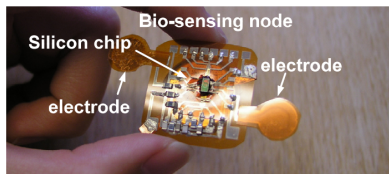
- ▶ Data abstraction
- ▶ Disambiguation
- ▶ Desirability mapping
- ▶ History maintenance
- ▶ Expectations and goals
- ▶ On-line learning
- ▶ Inspection



**Potential benefits by making the devices holistically aware of their situation and purpose.**

# Awareness Properties

- ▶ Data abstraction
- ▶ Disambiguation
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- ▶ Expectations and goals
- ▶ On-line learning
- ▶ Inspection



**Potential benefits by making the devices holistically aware of their situation and purpose.**

$$\leq 1 \text{ mW}$$

$$\leq 1 \text{ mm}^2$$

Questions ?

