Demand Compliant Design of Autonomous Robots

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"If every instrument could accomplish its own work, obeying or anticipating the will of others … if the shuttle could weave, and the pick touch the lyre, without a hand to guide them, chief workmen would not need servants."

Aristoteles, in "The Politics", 4th c. BC

Overview

- Motivation
- Complex system design methods
- Review of the DeCoDe method
- Autonomous robot design with DeCoDe
- Insights gained
- Conclusion

Motivation

- Build the robot we want on time and on budget (Ha ha…!)
- Research into the automation of cognitive processes
- Research into Quality by Design

Autonomous robots

- Prototypical for a wide class of autonomous systems (including living creatures).
- Their construction requires many disciplines.
- Will become the humankind's most complex artefact.
- Service and care robots require absolute safety and reliability

How to design such systems?

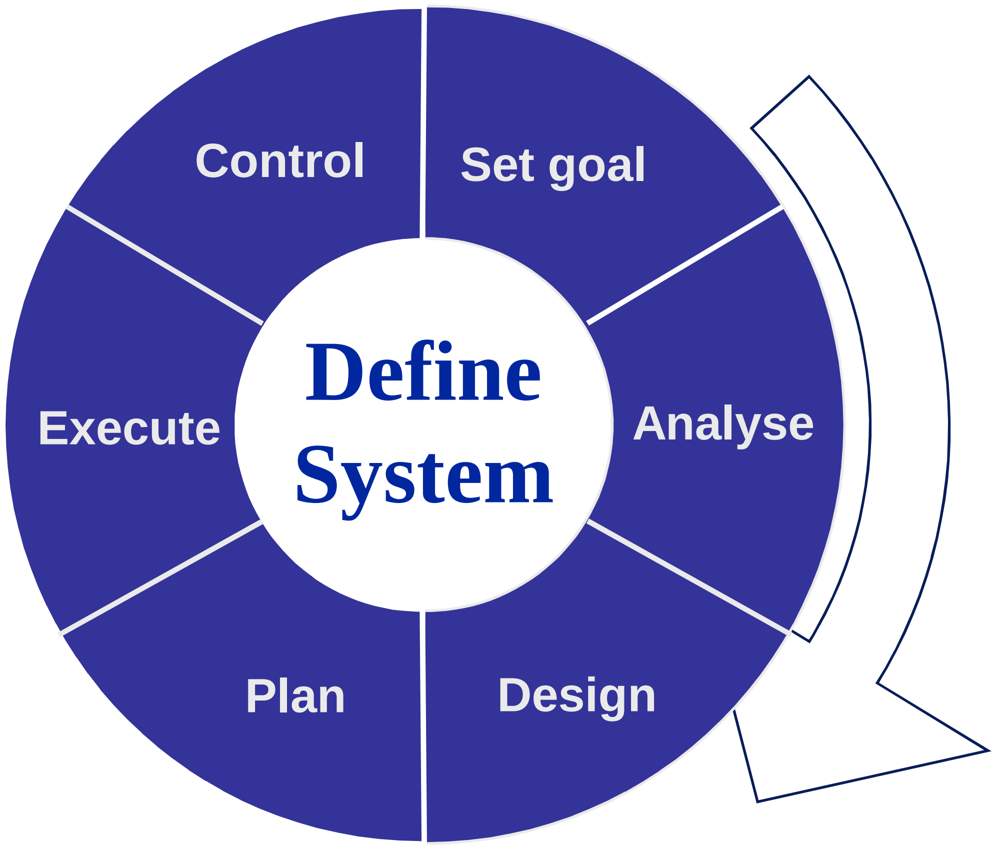
Hurdles found

- Hard to come to grips with the demands.
- Invisible barriers for knowledge transfer between the required disciplines.
- Multitude of isolated methods.
- Lack of tools for collecting, storing and communicating the design information.
- Lack of a start-to-finish, cross discipline framework for guiding the design process stages.

How to overcome the hurdles?

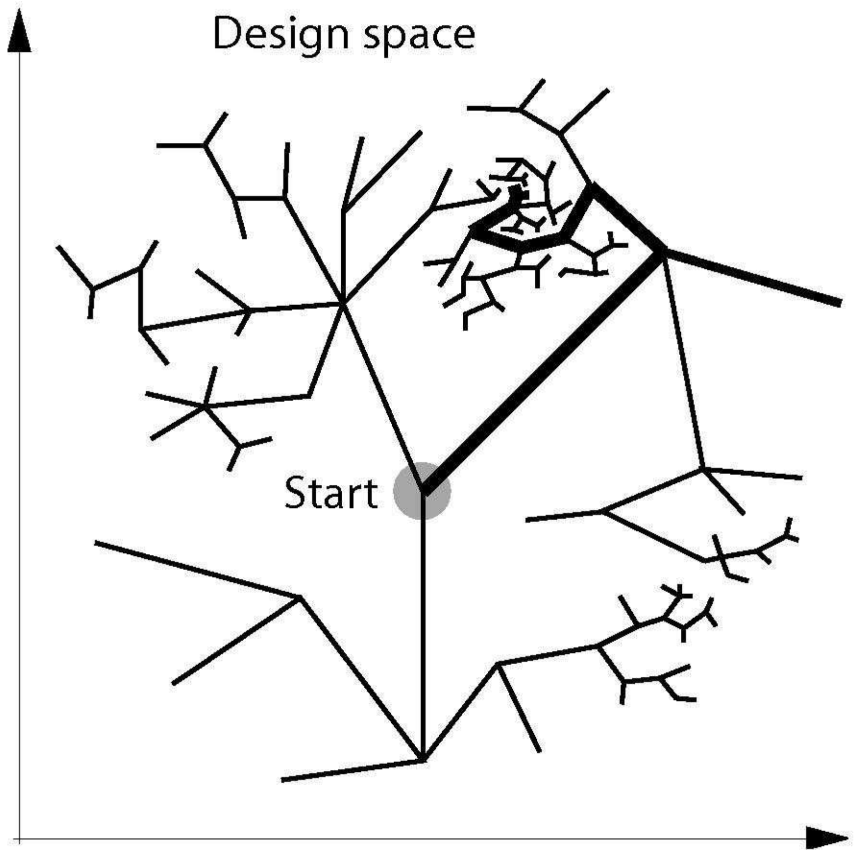
The nature of the task suggests a **Systems Engineering** approach

Generic Systems Engineering
(Winzer et al. 2004)



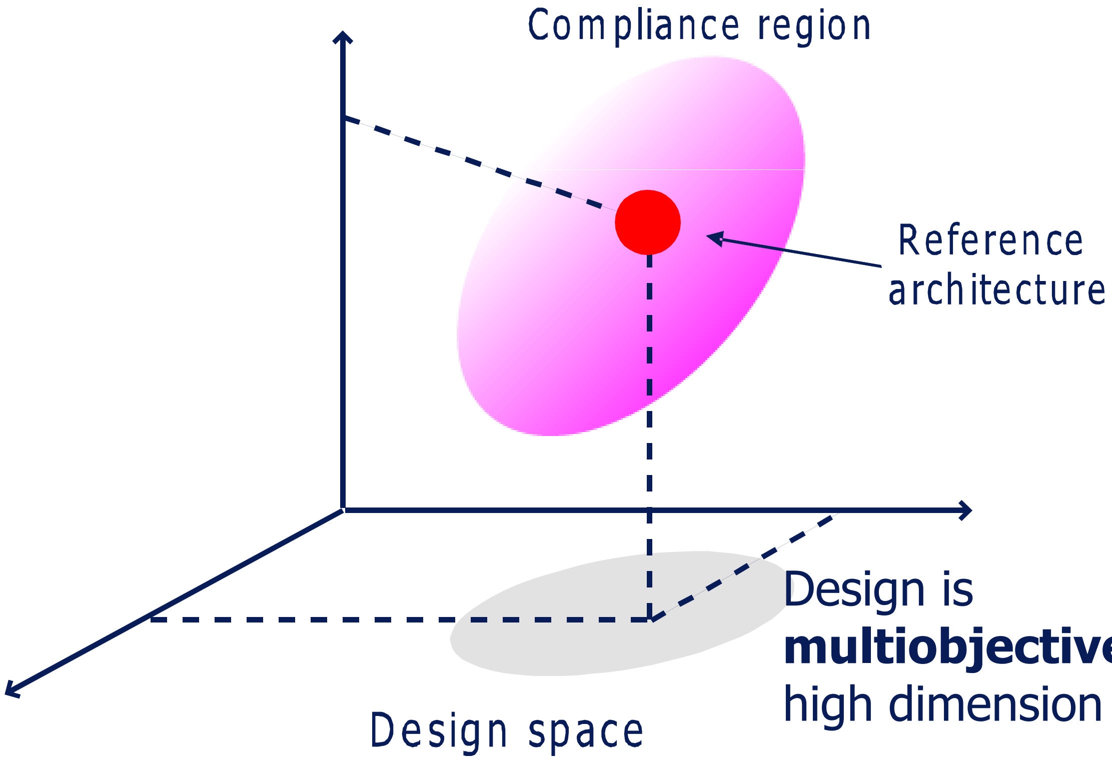
What is design?

Is it a directed search in design space?



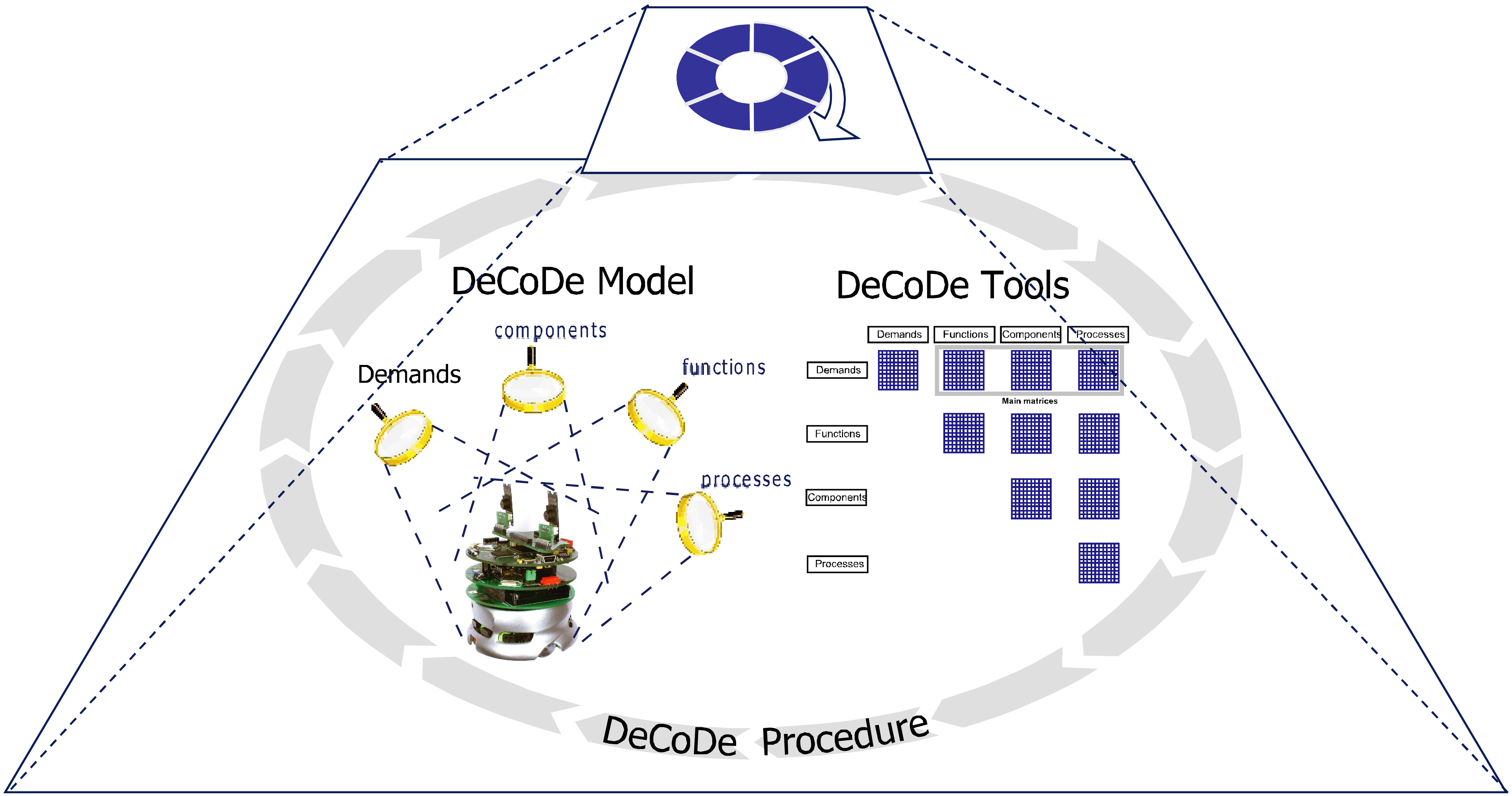
Design objective

If so, how do you we know when we have reached the goal?

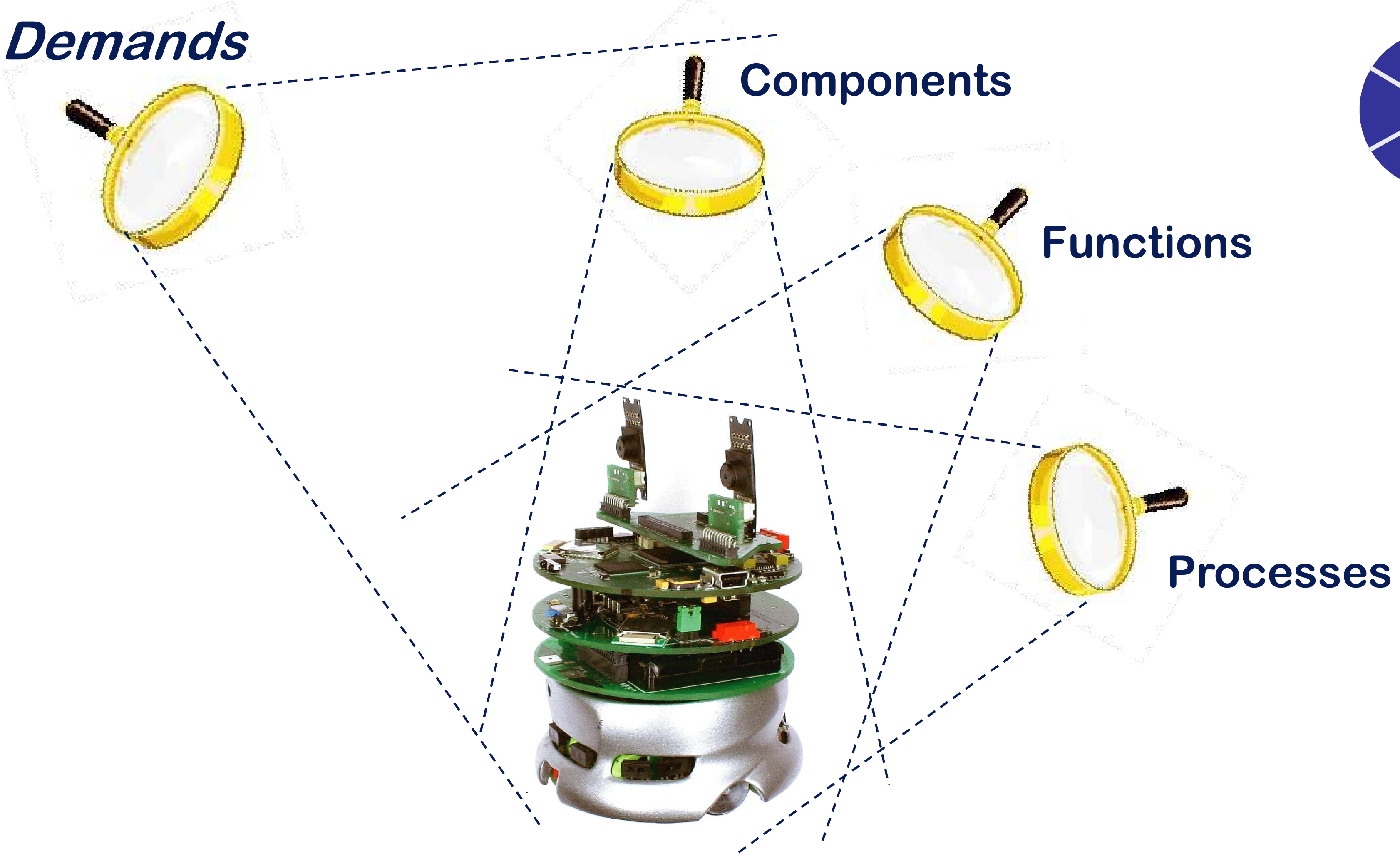


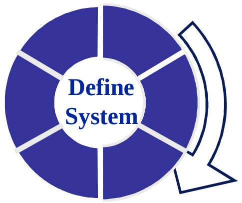
Design is **multiobjective optimisation** in a high dimension **design variable space**

DeCoDe philosophy

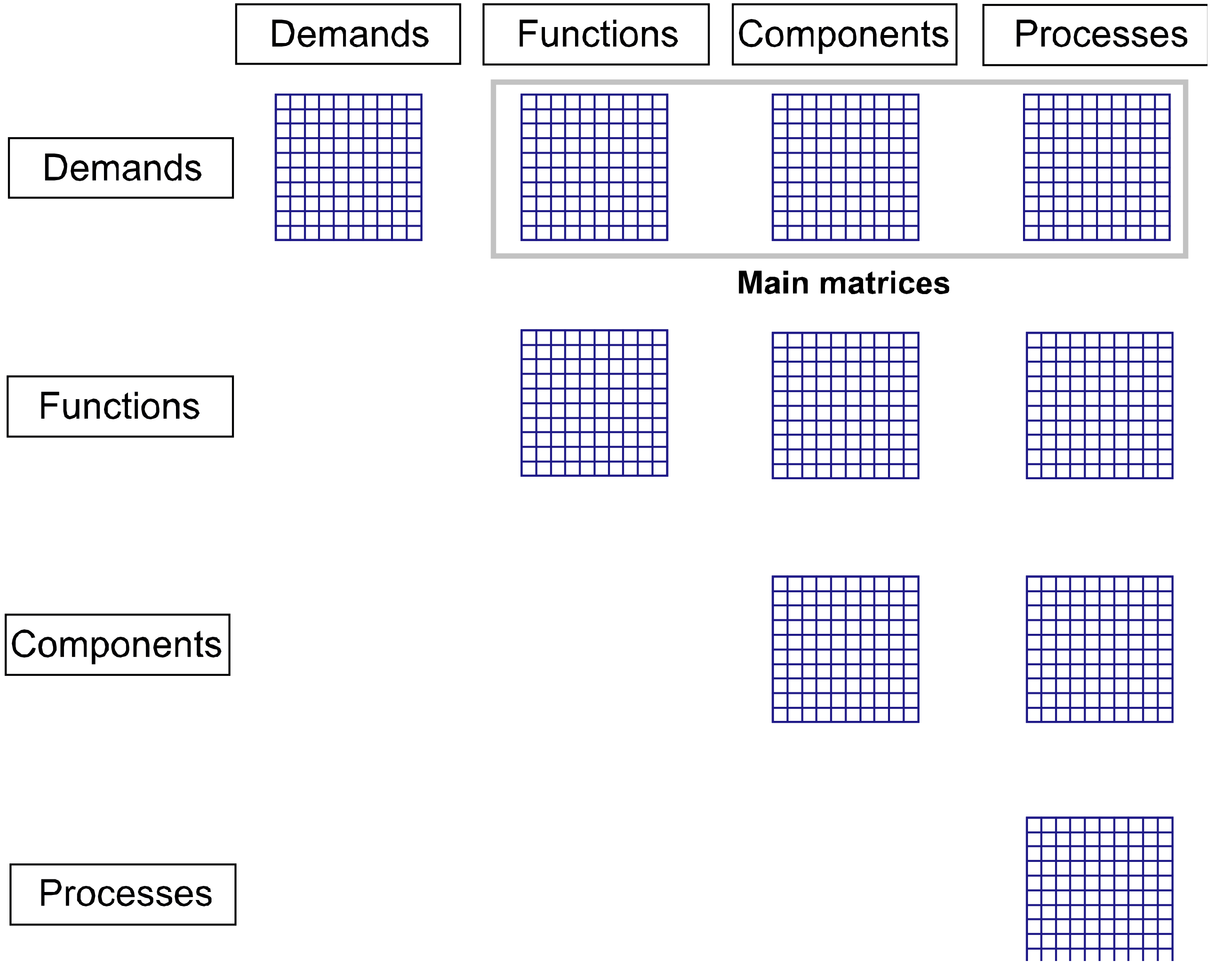


DeCoDe Views

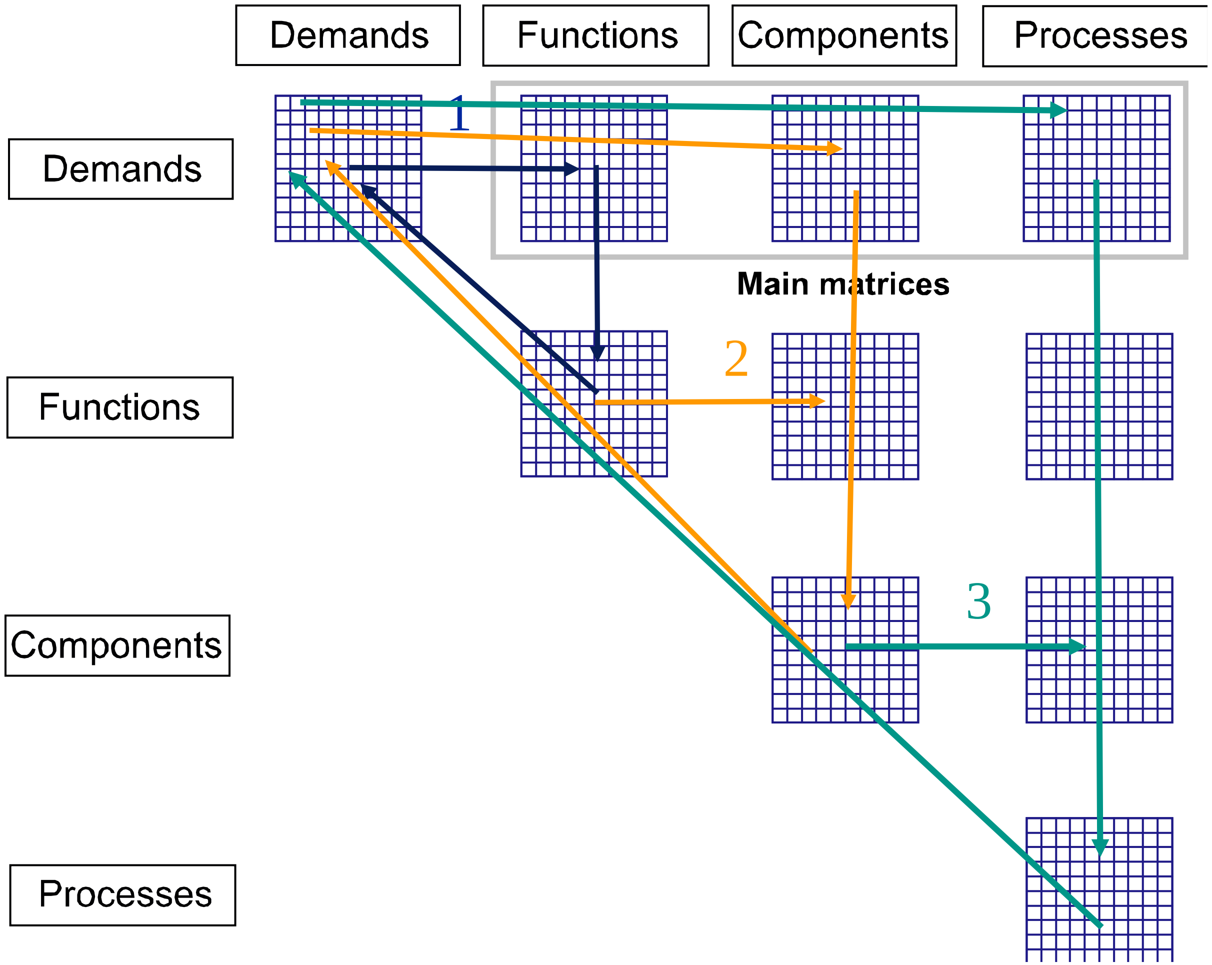




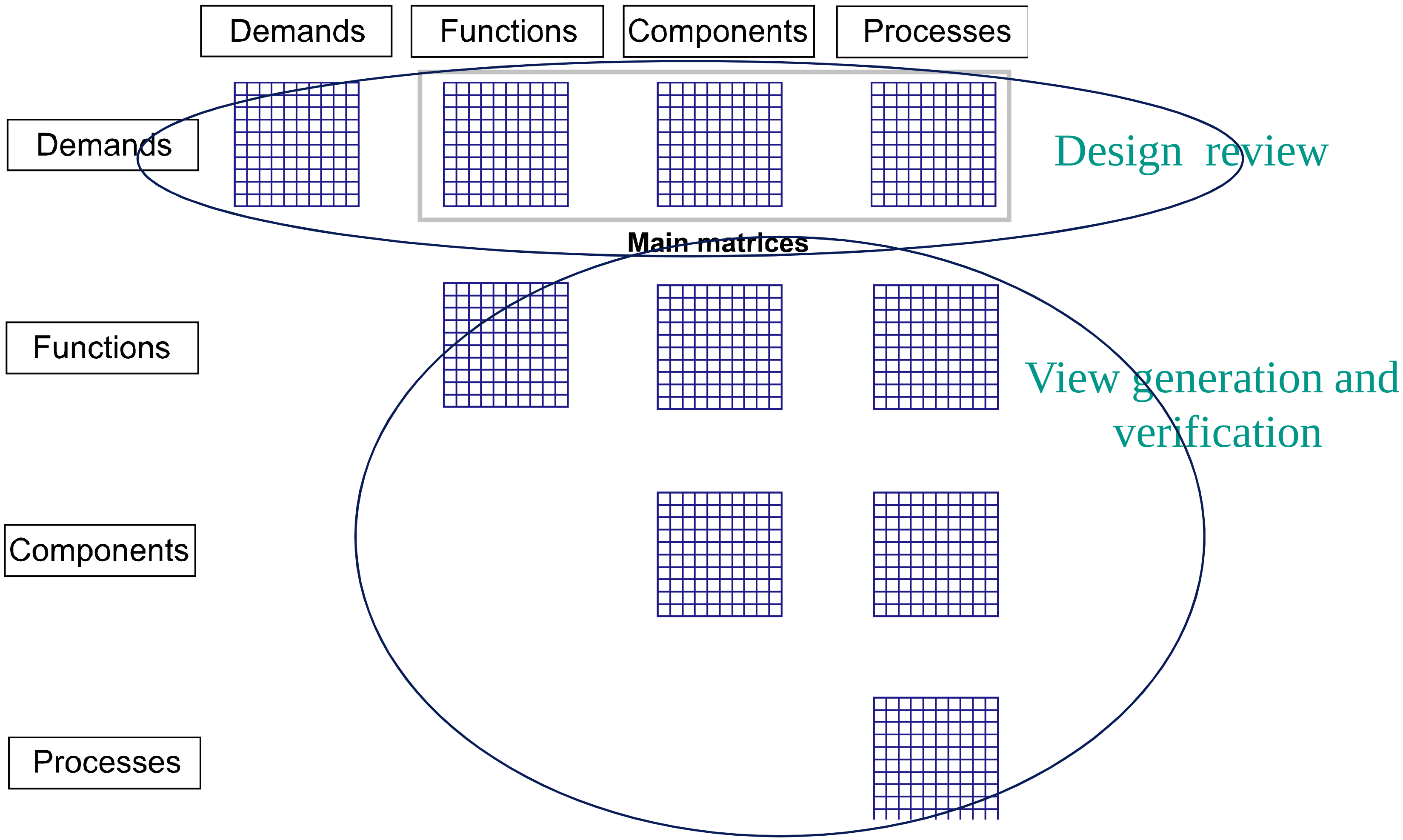
DeCoDe tools



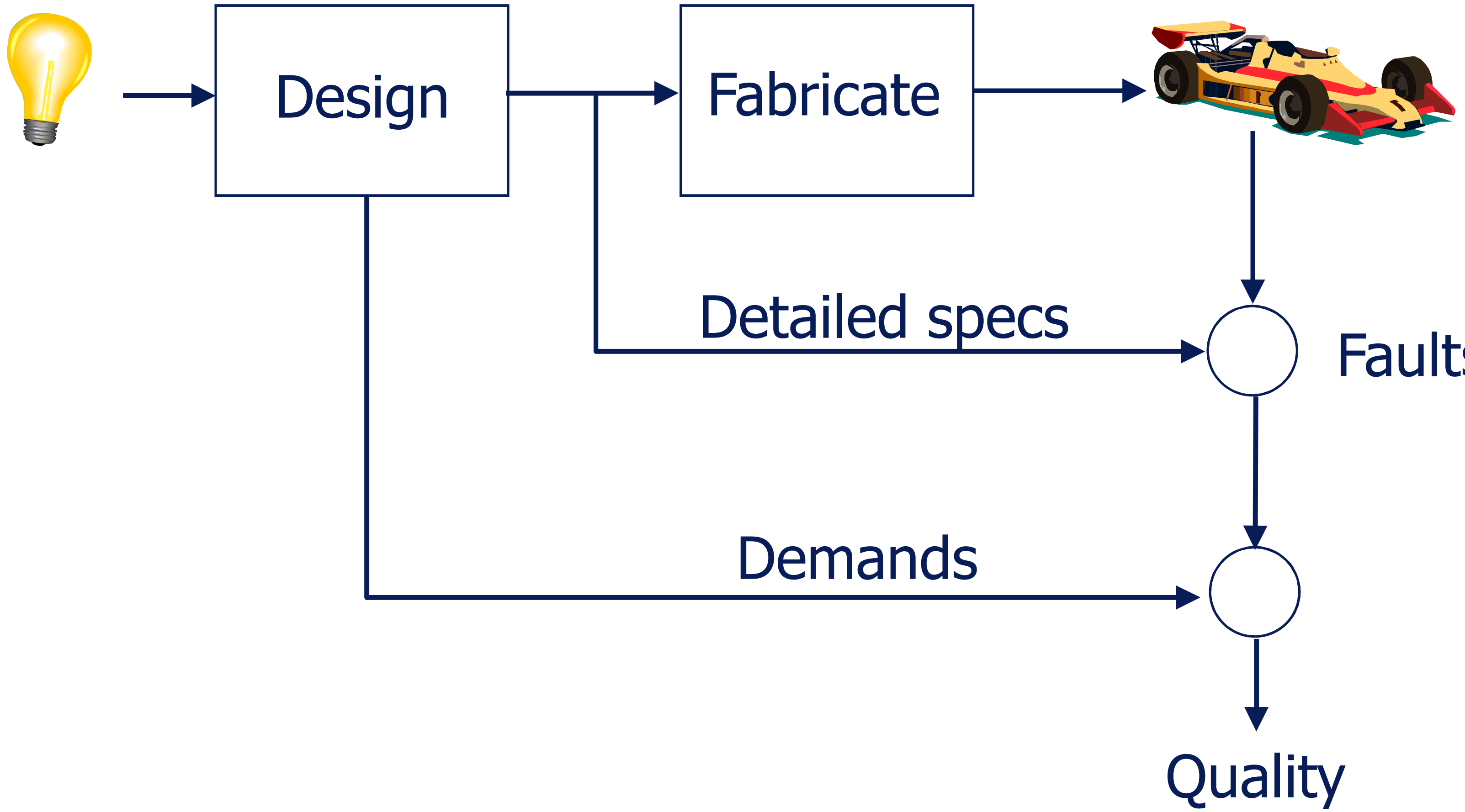
Principle design flow

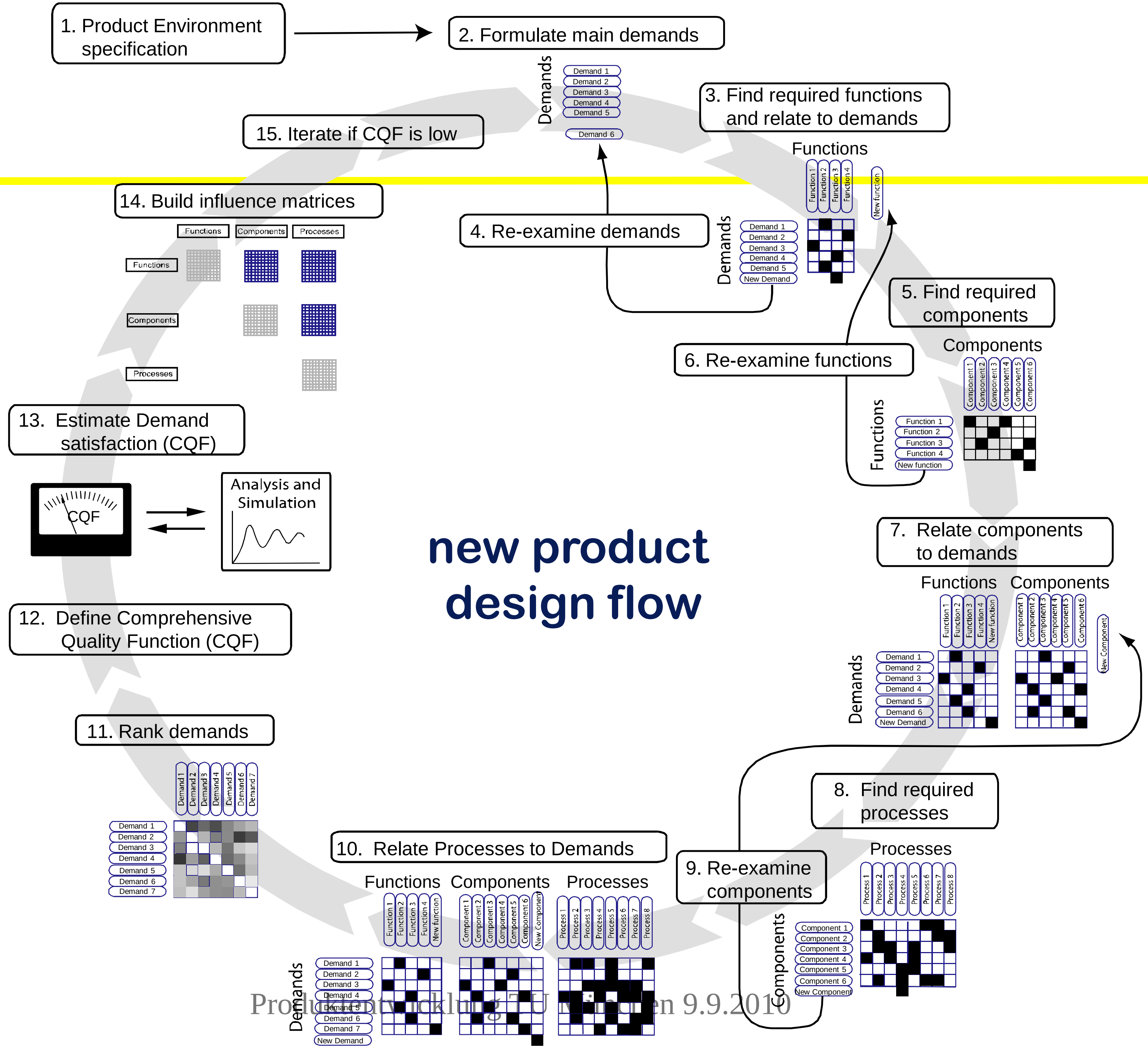


Usage of DeCoDe tools

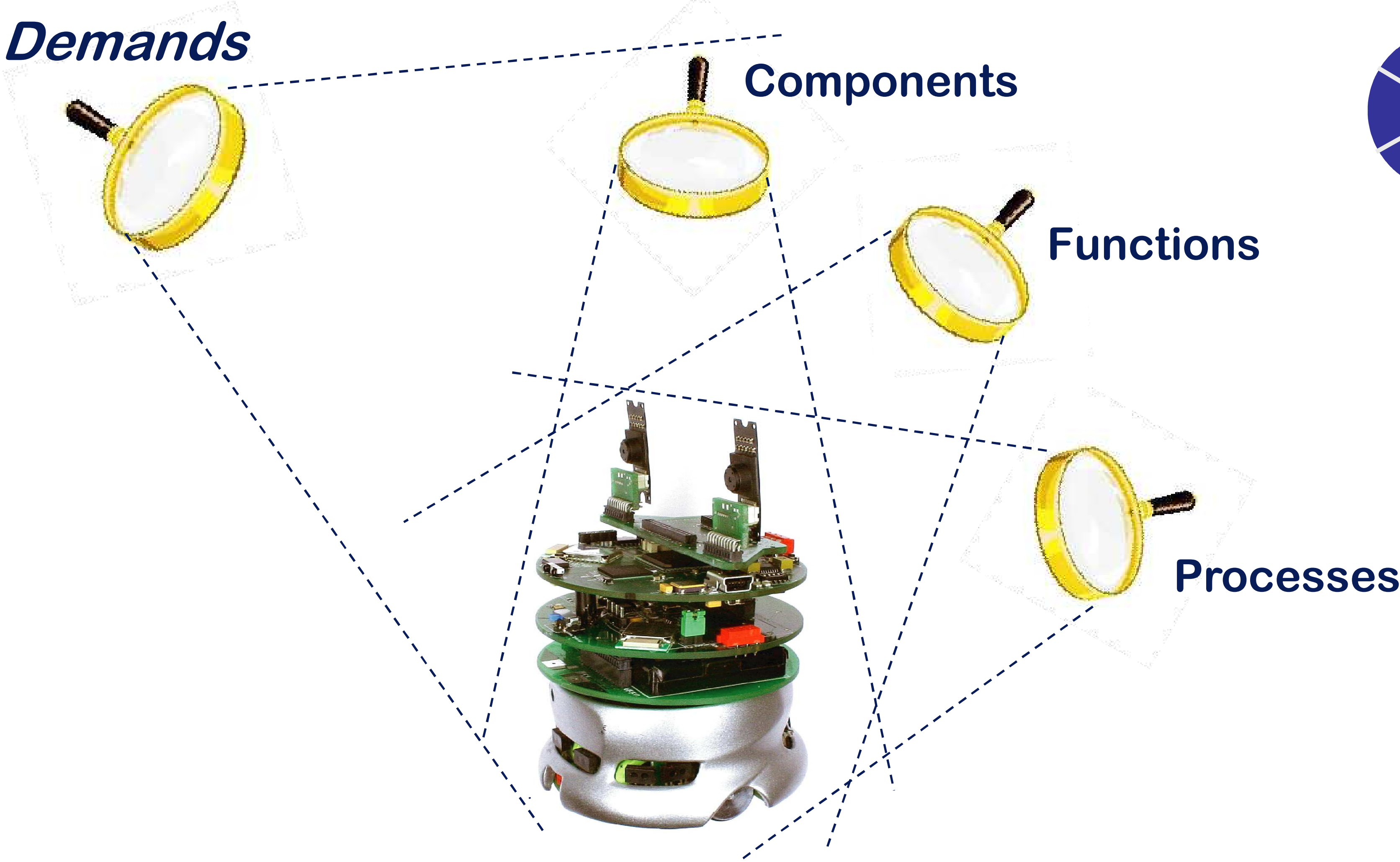


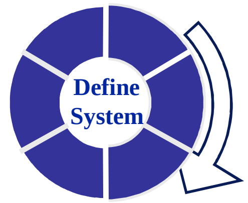
Product creation process




1. Product Environment specification
2. Formulate main demands
3. Find required functions and relate to demands
4. Re-examine demands
5. Find required components
6. Re-examine functions
7. Relate components to demands
8. Find required processes
9. Re-examine components
10. Relate Processes to Demands
11. Rank demands
12. Define Comprehensive Quality Function (CQF)
13. Estimate Demand satisfaction (CQF)
14. Build influence matrices
15. Iterate if CQF is low
Demands
Functions
Components
Processes
CQF
Analysis and Simulation
new product design flow

Autonomous soccer robot



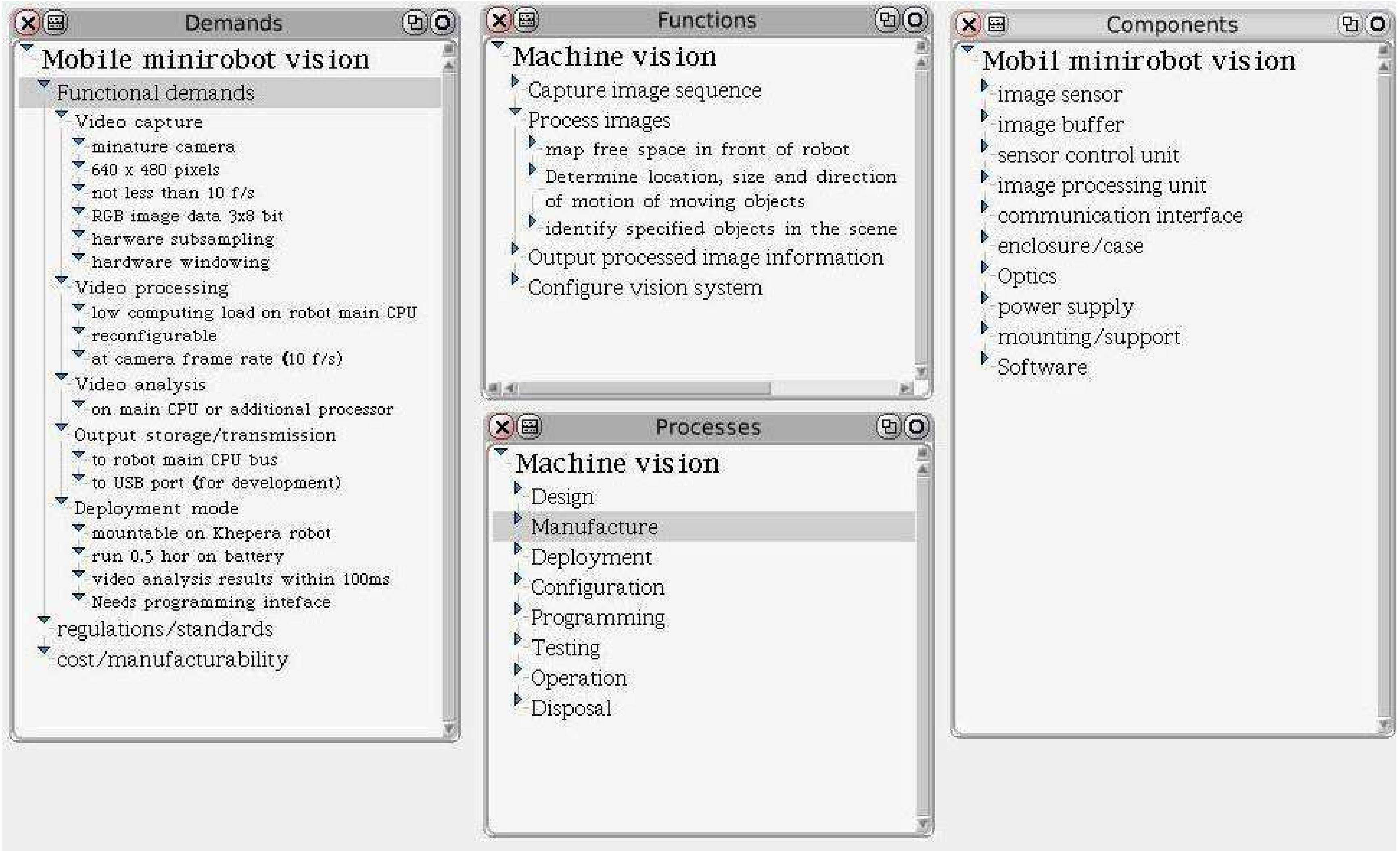


What?

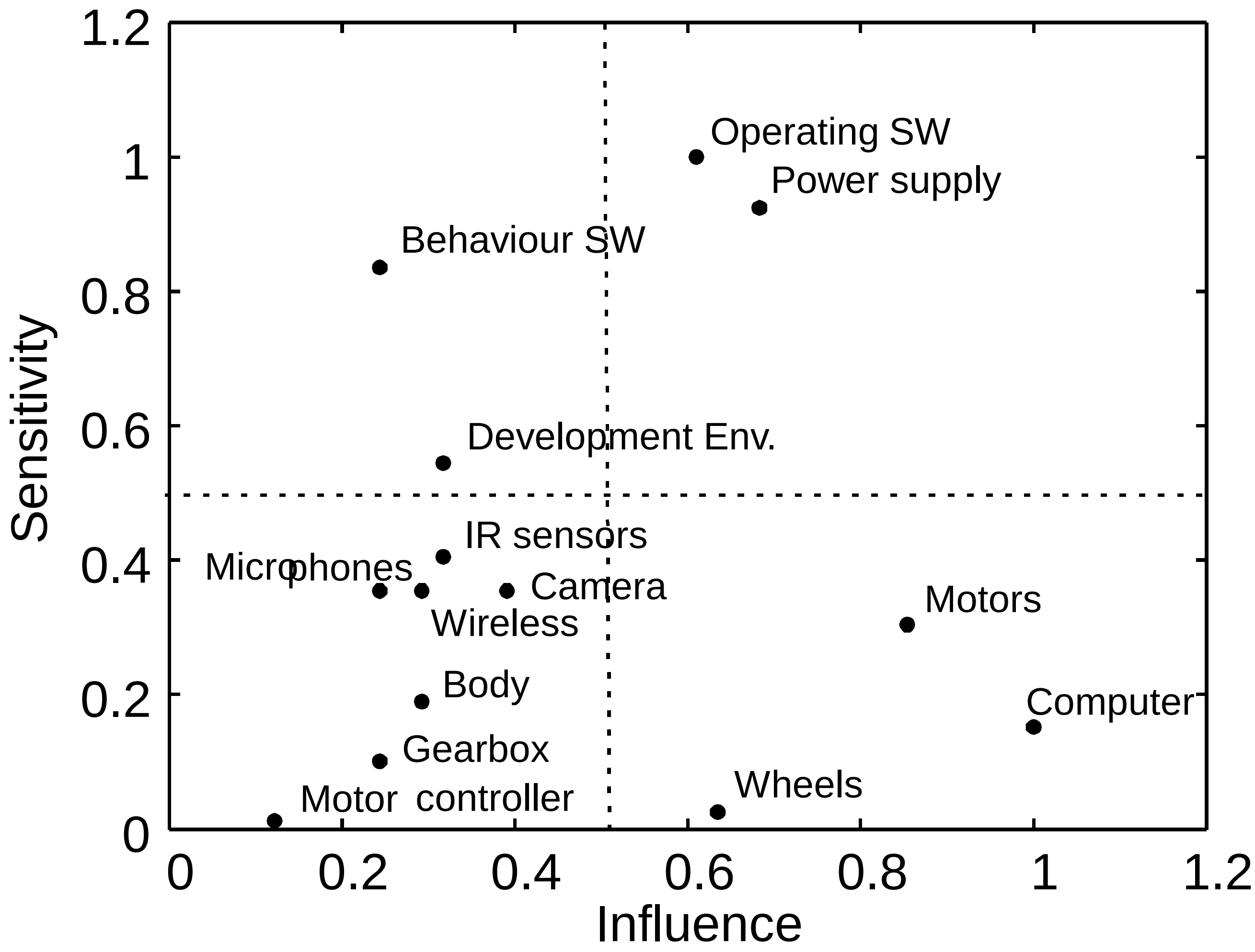
Zero-th order description (demand):

An inexpensive robot that can participate as a player in a team of one or more robots in a soccer style game as specified by the AMiRE 2008 rules.

DeCoDe catalogues



Influence-Sensitivity



Robot design – demand refinement

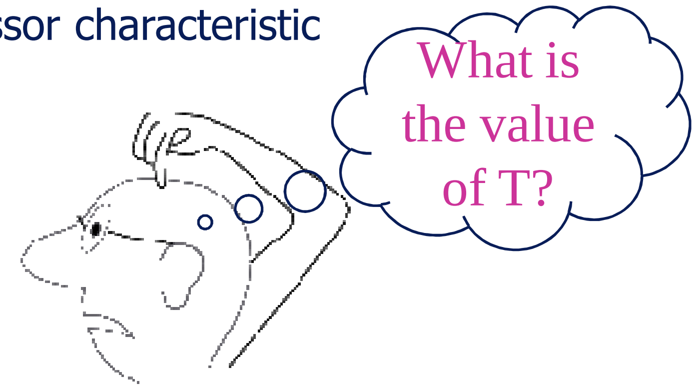
- Initial demand: must have sufficient computing power. this vague demand was quantified by simple modelling, still hard to evaluate though!
- By analysing the dependency of the body from motors, an implied function of the body was mad explicit (holding and protecting the parts) prompting the addition of new demands (All components must be within a single small volume).
- What does “easy to use” mean?

What is *sufficient* computing power?

Execution time of n machine instructions on a processor that takes on average i clock cycles per instruction and has a clock period c

Processor characteristic

$$T = nic$$



Is T the maximum reaction time of the robot?
Robot should not move more than 50 mm at maximum speed before it reacts.

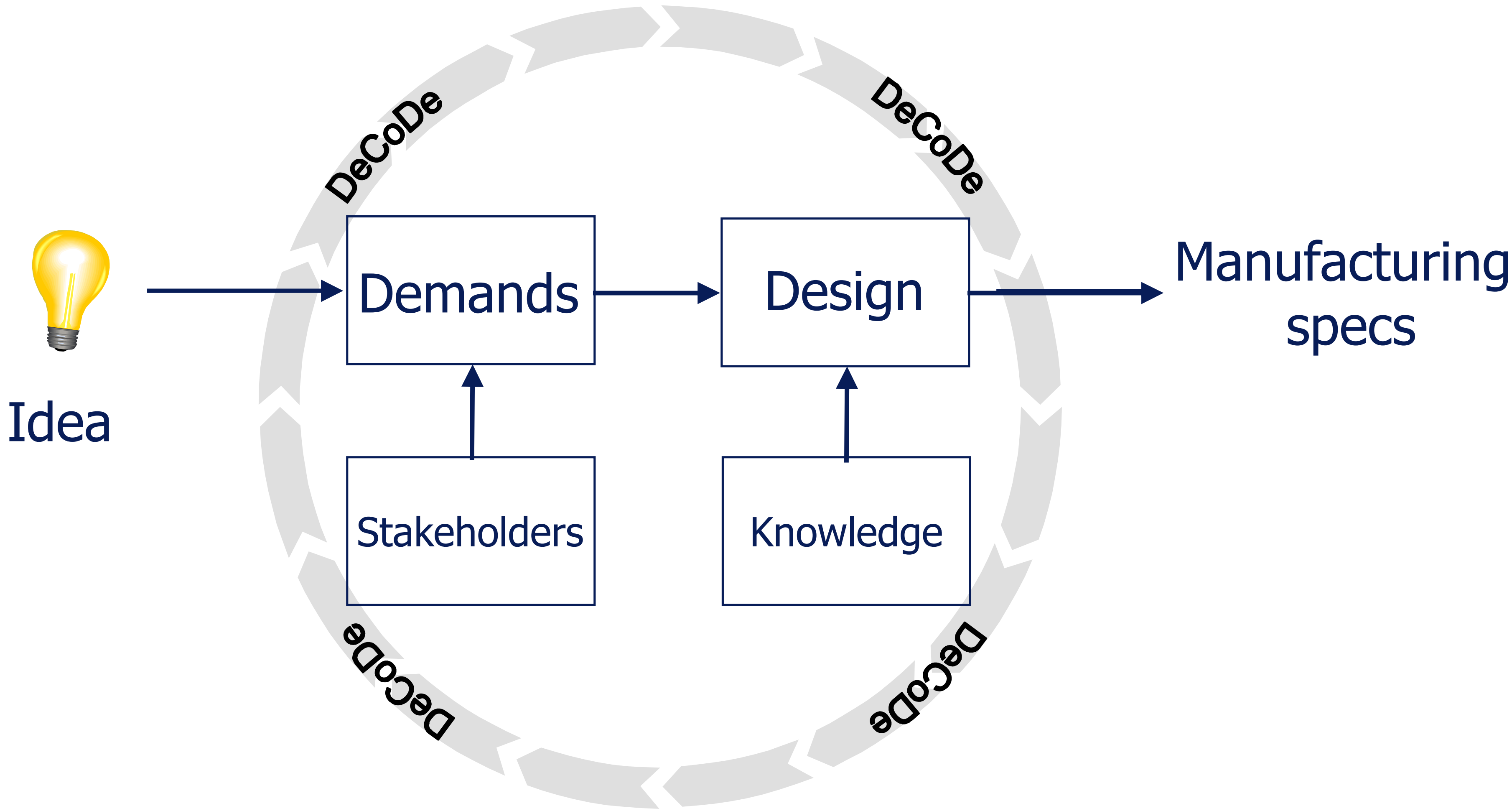
$$T = \frac{d}{v} = \frac{50\,mm\,s}{1000\,mm} = 50\,ms$$

OMAP3503 Cortex A8 i=2 c= 1/600 MHz

First design round highlights

* DeCoDe sets the agenda for the design process.
* Prioritise demands.
* Analyse interactions.
* Simple modelling helped to refine the demand on computational power.
* Implied demands became explicit, bringing neglected design issues into focus.

Design process



Conclusion

- The design process becomes structured.
- Demands are progressively made precise
- Demands and implementation clearly linked
- Design criteria are documented and traceable
- The initial DeCoDe cycles can be done with common software tools.
- Fully specifying a complex product with DeCoDe needs dedicated software tools.
- First steps in the long journey of DeCoDe development were taken.

?

Questions

You can also mail your questions to

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Robot design deficiencies

- Nowadays industry plays the "leading" role in robotics in the sense that it often defines the robotic capabilities available. Many times this results in more or less standard robots being introduced into the D&S (Defence & security) operations **without very thoroughly defined functional requirements**.
- This might be an appropriate approach for those cases where the users have no vision themselves on how to use robotic support in D&S operations. But many **users do have a view of their own** on their desired use of robotics. These views are **often characterised by short-term objectives and a limited understanding of technical issues**.
- **Research instead has usually no short-term objective** and often fails to provide practical applications. Ignoring scientific results, however, prevents interesting and innovative developments. Industry, especially medium-sized enterprises, should use research to fertilise their strategic development process.
- So, many times **there is a gap** between the industry's understanding of robots needed, the appliance of research results and the D&S users' understanding of robot technology as well as the technical feasibility of their requirements.

European Robotics home page http://www.european-robotics.eu/index2.html