Mobile Robot Design

Prof. Francesco Mondada
IBI - STI - EPFL

Introduction to Mobile Robot Design

for Research / Education
from a mechatronic/interdisciplinary perspective

Goal: give you

- Some basic concepts and methodologies
- Some hints
- Some examples

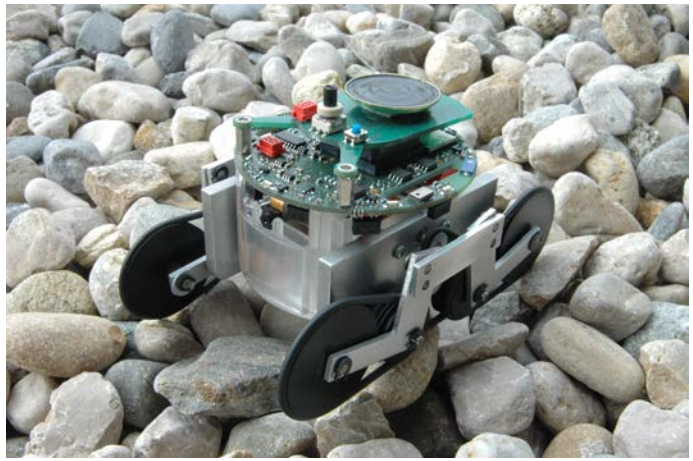
…hoping all this make sense to you
and will be useful in your PhD work.

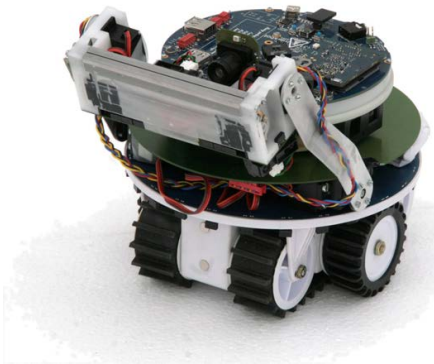
✓ Start with a short self-intro from everybody
✓ End with some feedback (moodle or directly to me)

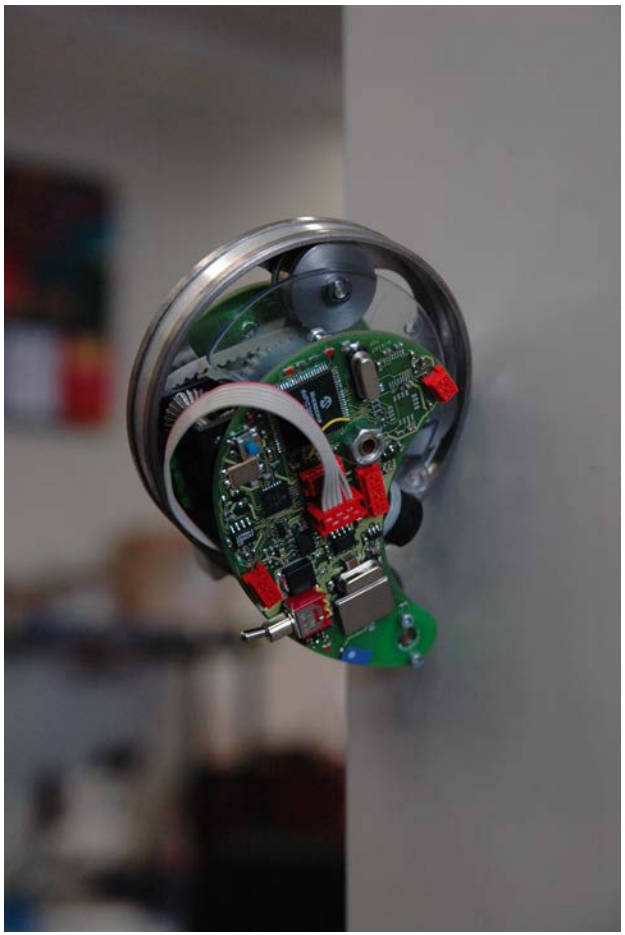
Structure:

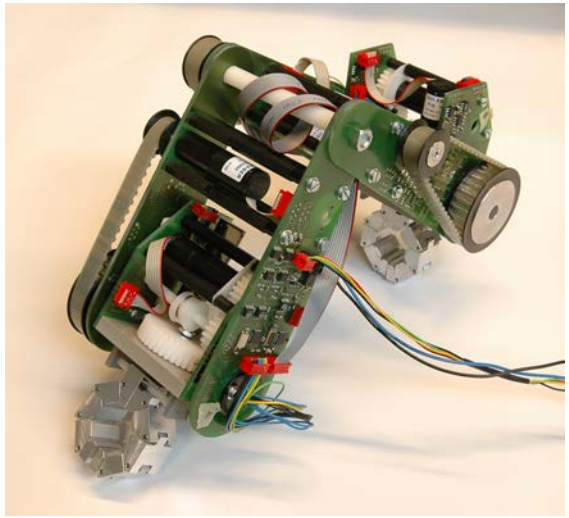
- Introduction
- Existing Mobile robot products
- How to develop a new robot
  - Standard product design
  - Mobile robot design in interdisciplinary research
- Case studies:
  - Khepera: Mechatronics >< Market (+flops)
  - e-puck & Thymio: Mechatronics >< Education
  - Leurre: Mechatronics >< Biology, methodology
  - S-bot & marXbot: Mechatronics >< Computer Science
  - Robotic glasses & ranger: Mechatronics >< user interaction
- Conclusion / assignements

Several of us are asked to design/control strange robots for research

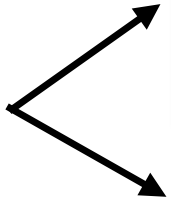








We have a choice between:



to buy a product

cheap but usually very closed and unflexible

to develop a new product

expensive, long but allowing a wide range of solutions

Structure:

- Introduction
- Existing Mobile robot products
- How to develop a new robot
  - Standard product design
  - Mobile robot design in interdisciplinary research
- Case studies:
  - Khepera: Mechatronics >< Market (+flops)
  - e-puck & Thymio: Mechatronics >< Education
  - Leurre: Mechatronics >< Biology, methodology
  - S-bot & marXbot: Mechatronics >< Computer Science
  - Robotic glasses & ranger: Mechatronics >< user interaction
- Conclusion / assignements

Existing products on the market

- Small historical background
- Existing products and features

Small historical background: IS Robotics, genghis

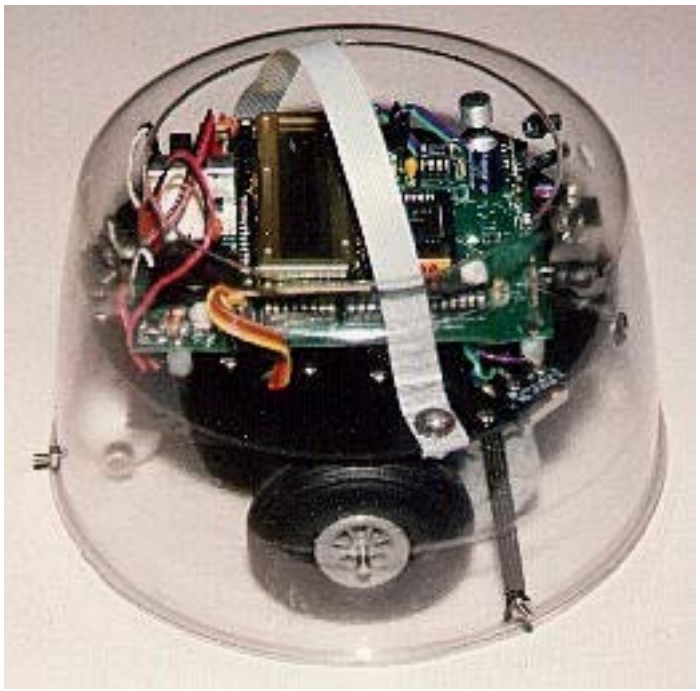
Small historical background:
Nomadic, nomad / RWI, B14

Small historical background: K-Team, Khepera

Small historical background:

ActivMedia (support from RWI), Pioneer

Small historical background: Rug Warrior



Mobile Robots: Inspiration to Implementation, Joseph L. Jones, Anita M. Flynn, A.K.Peters, 1993

Existing products and features:

Few old companies:

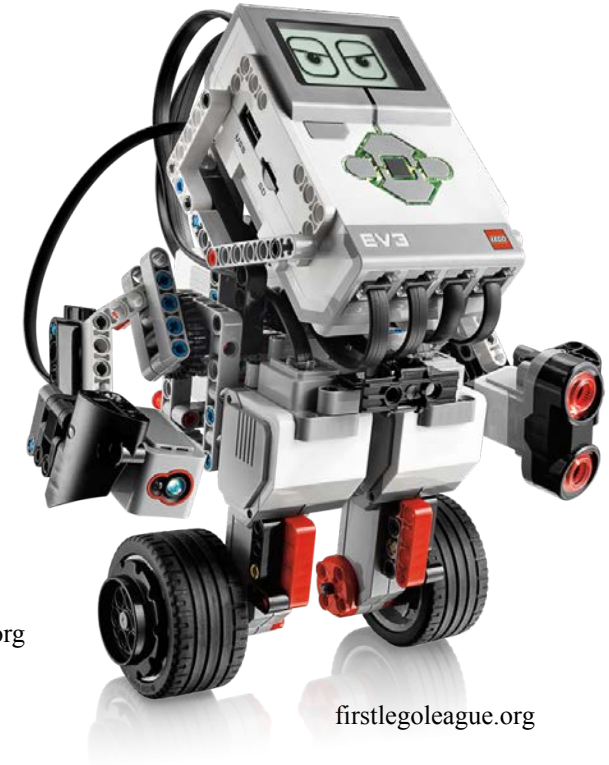
I-robot (IS-Robotics, RWI)
K-Team
Adept mobilerobots
(<- MobileRobots Inc <- ActivMedia)
no Nomadic anymore

many new ones

LEGO Mindstorm RCX / NXT / EV3

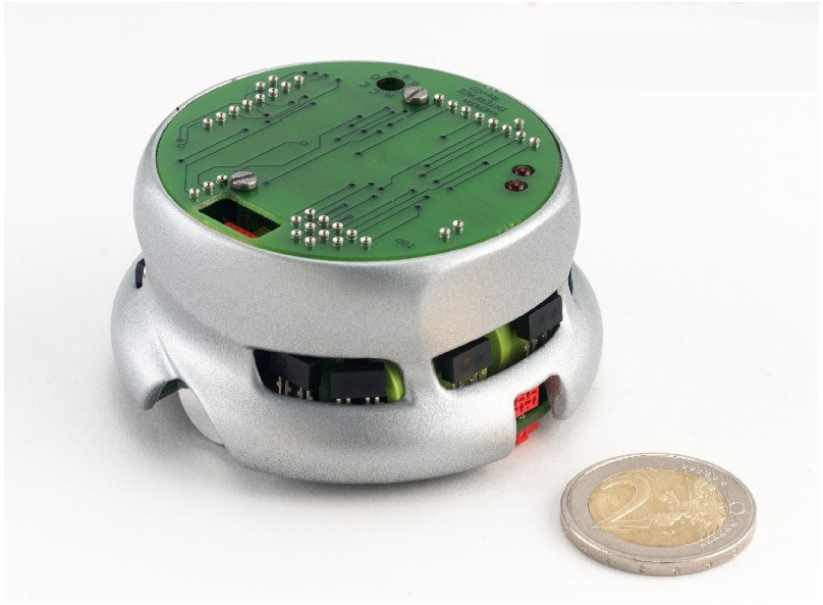
http://www.amiga-magazin.de

http://nxtasy.org

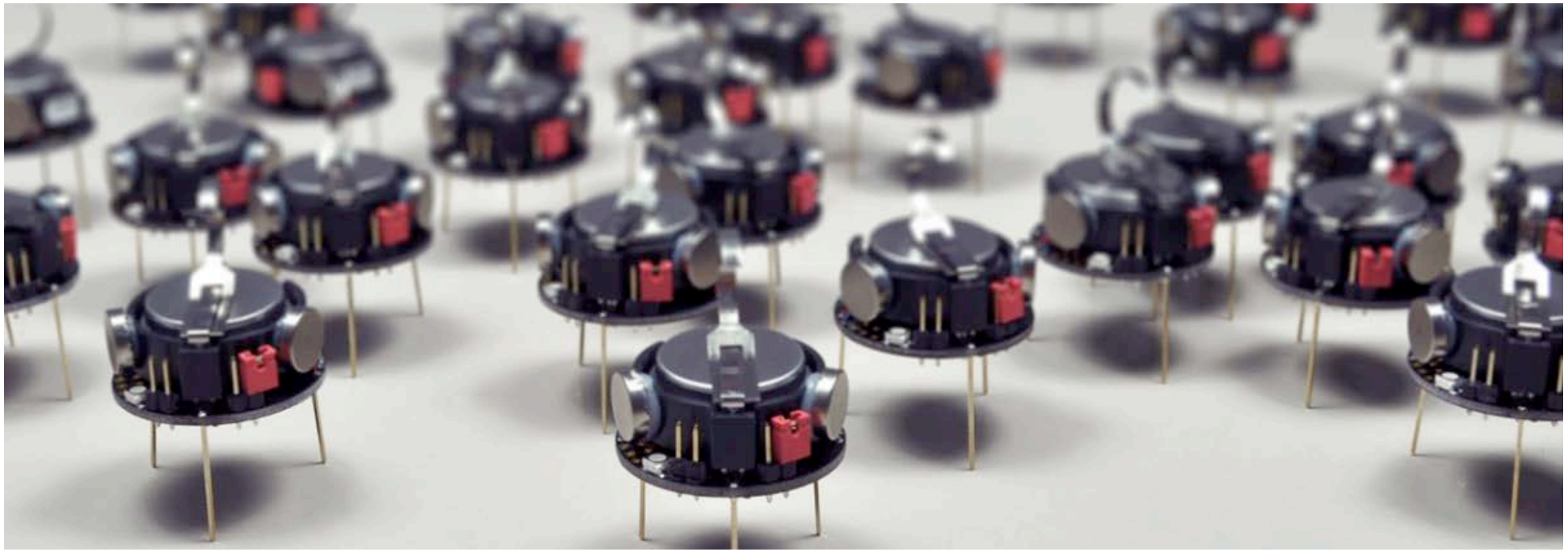


firstlegoleague.org

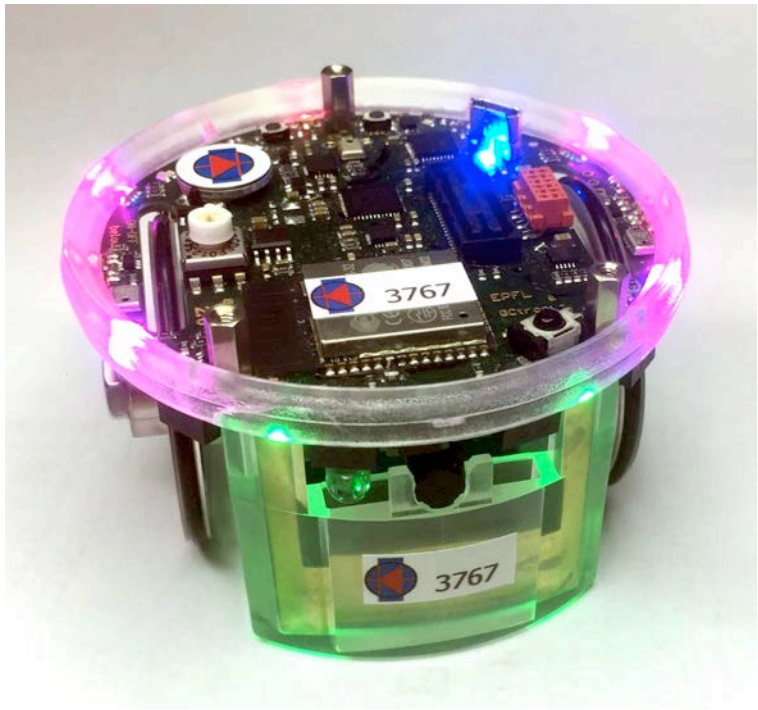
Khepera robot family



Kilobot



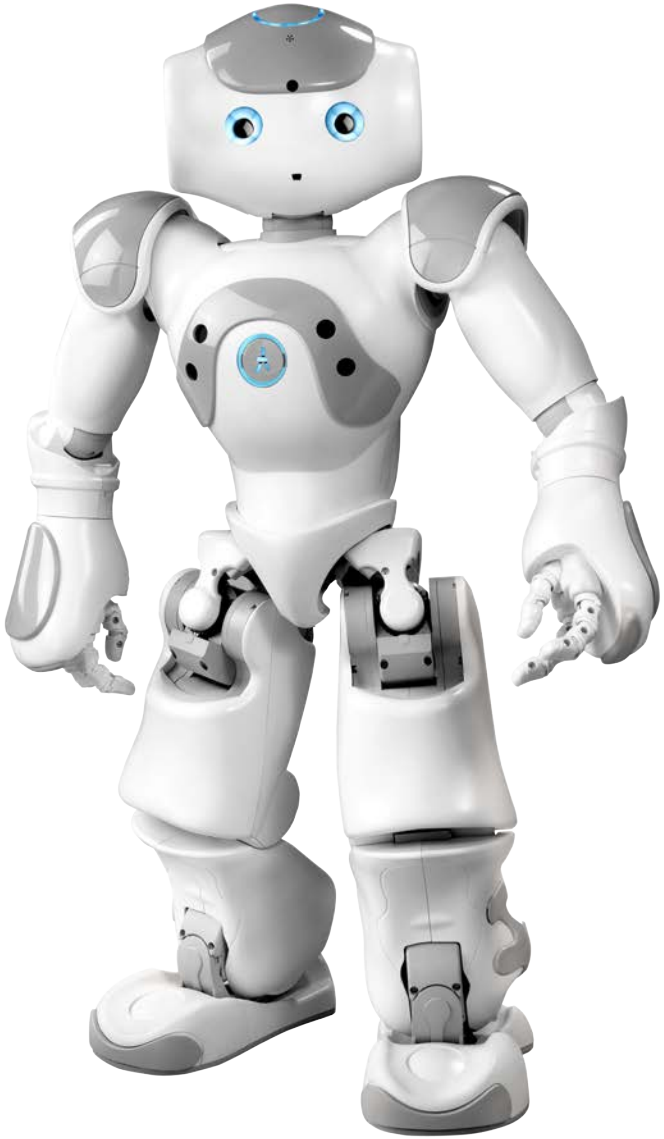
E-puck



iRobot Create® 2

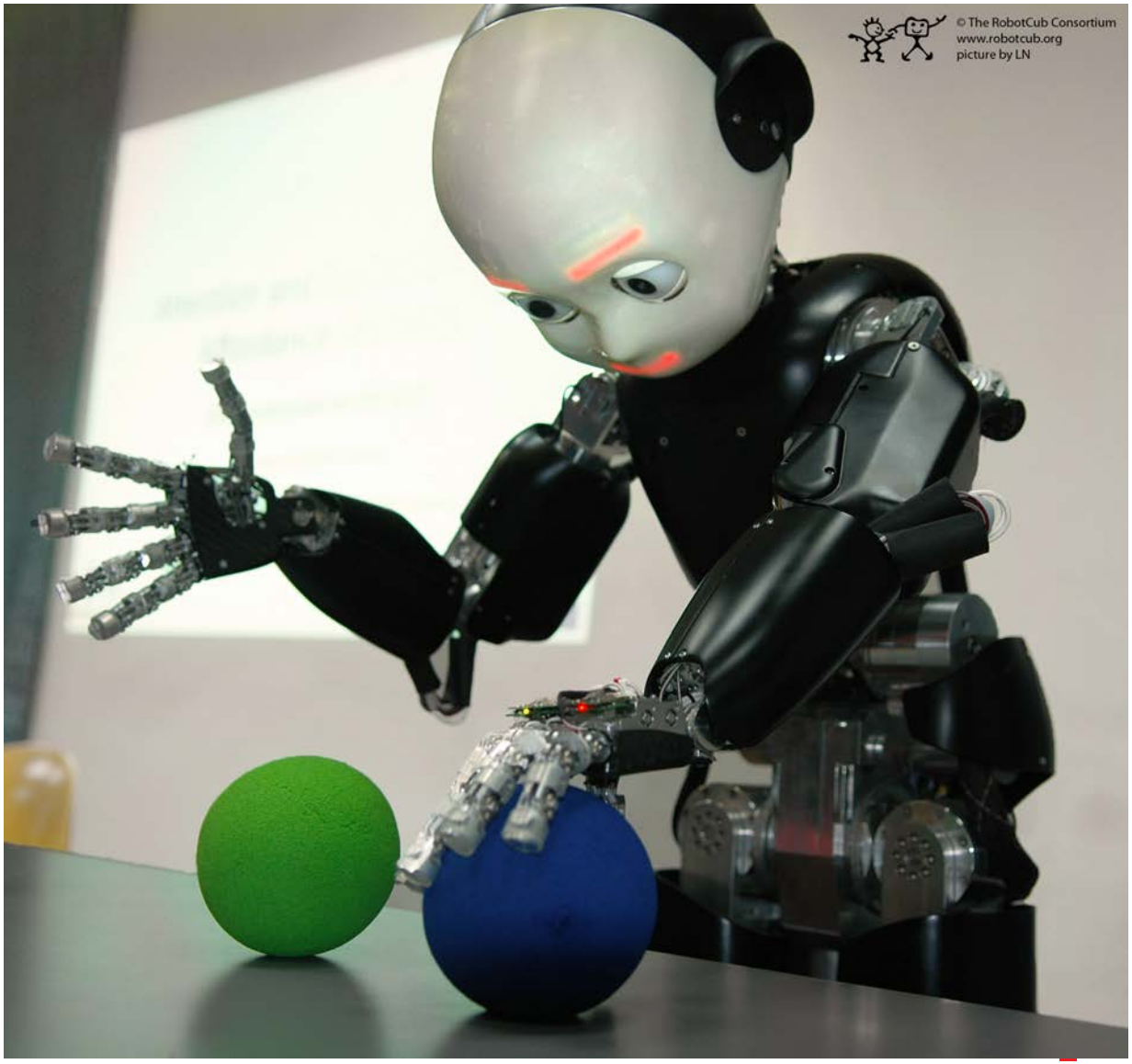
FESTO Robotino

Nao

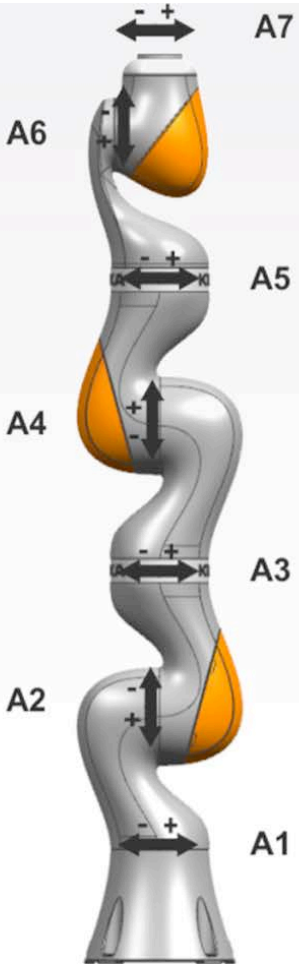


Willow Garage PR2

iCub



Arms

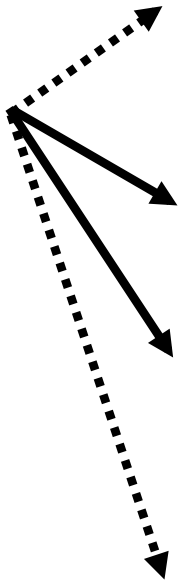


Flying robots

microdrone

eBee X

A choice between:



to buy a product

cheap but usually very closed and unflexible

to collaborate with another lab or company

to contribute or make a branch of an open product

to develop a new product

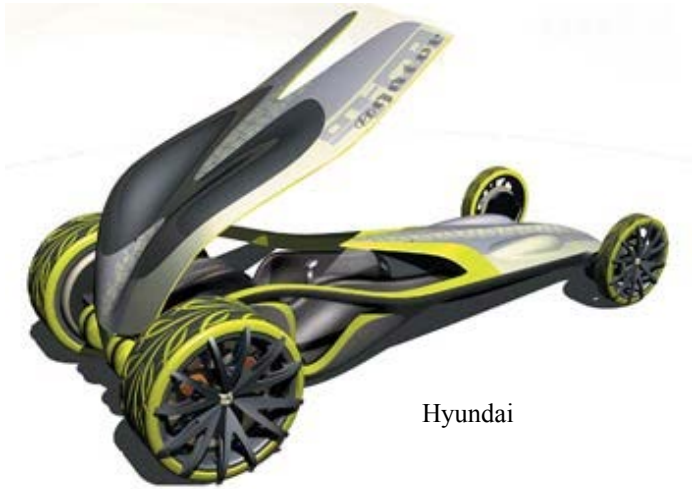
expensive but allowing a wide range of solutions

Structure:

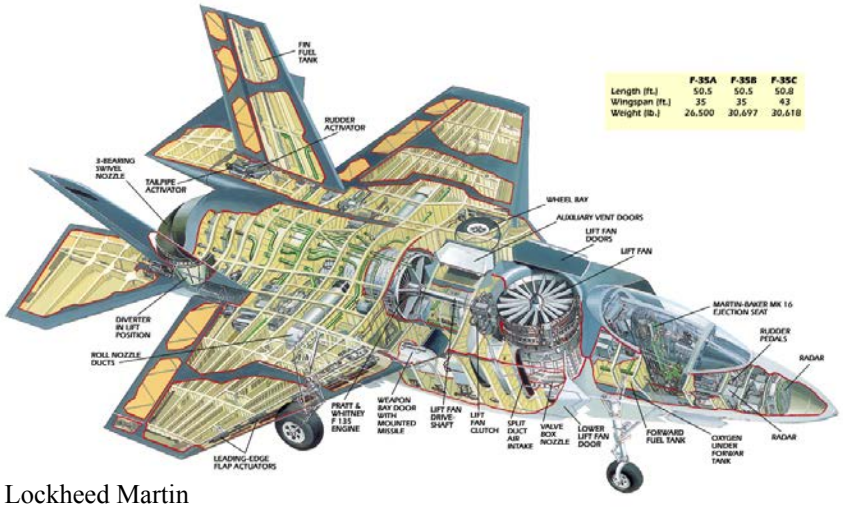
- Introduction
- Existing Mobile robot products
- How to develop a new robot
  - Standard product design
  - Mobile robot design in interdisciplinary research
- Case studies:
  - Khepera: Mechatronics >< Market (+flops)
  - e-puck & Thymio: Mechatronics >< Education
  - Leurre: Mechatronics >< Biology, methodology
  - S-bot & marXbot: Mechatronics >< Computer Science
  - Robotic glasses & ranger: Mechatronics >< user interaction
- Conclusion / assignements

There are some methods to design innovative products

Thomas Owen

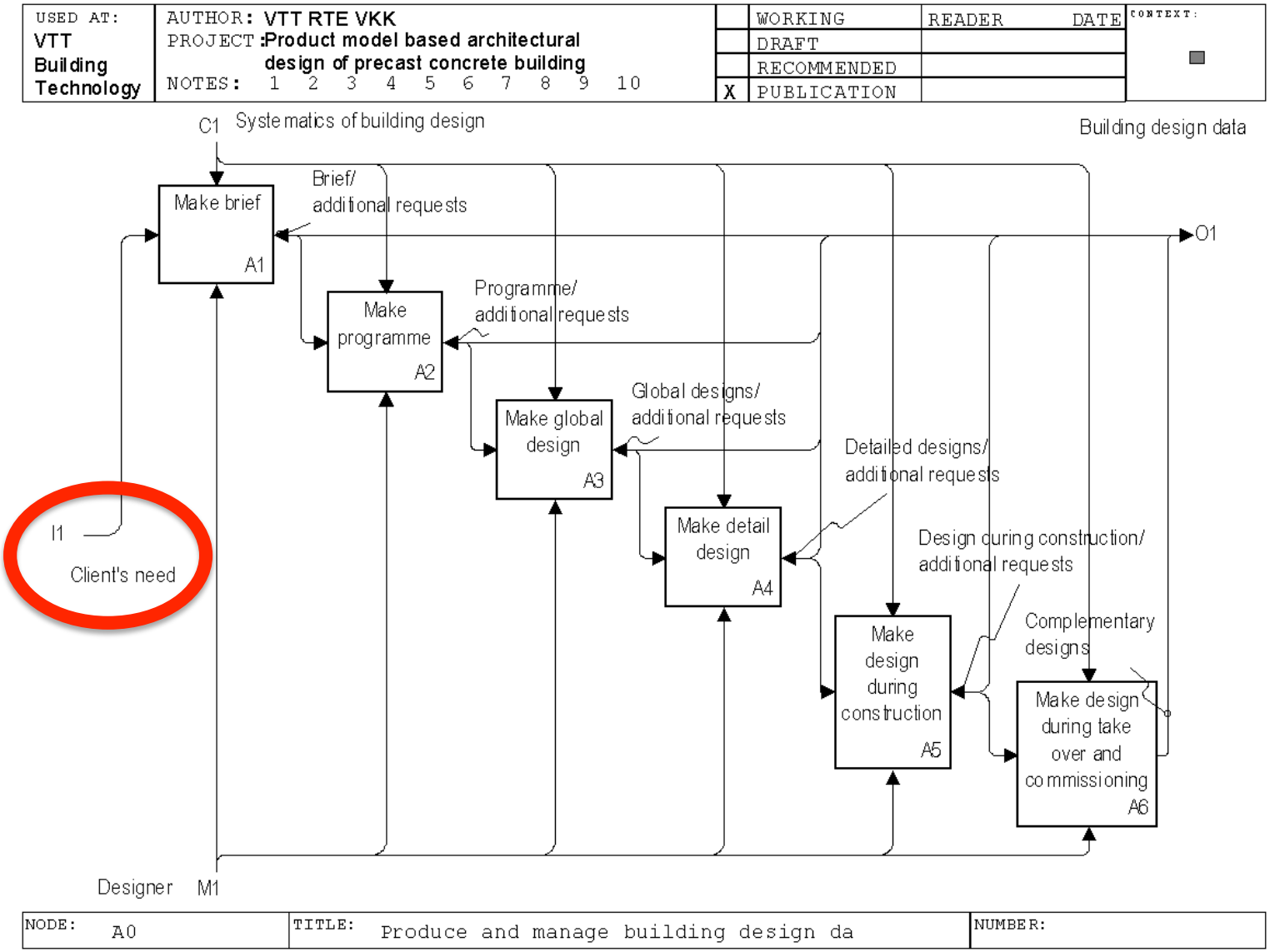


Hyundai



Lockheed Martin

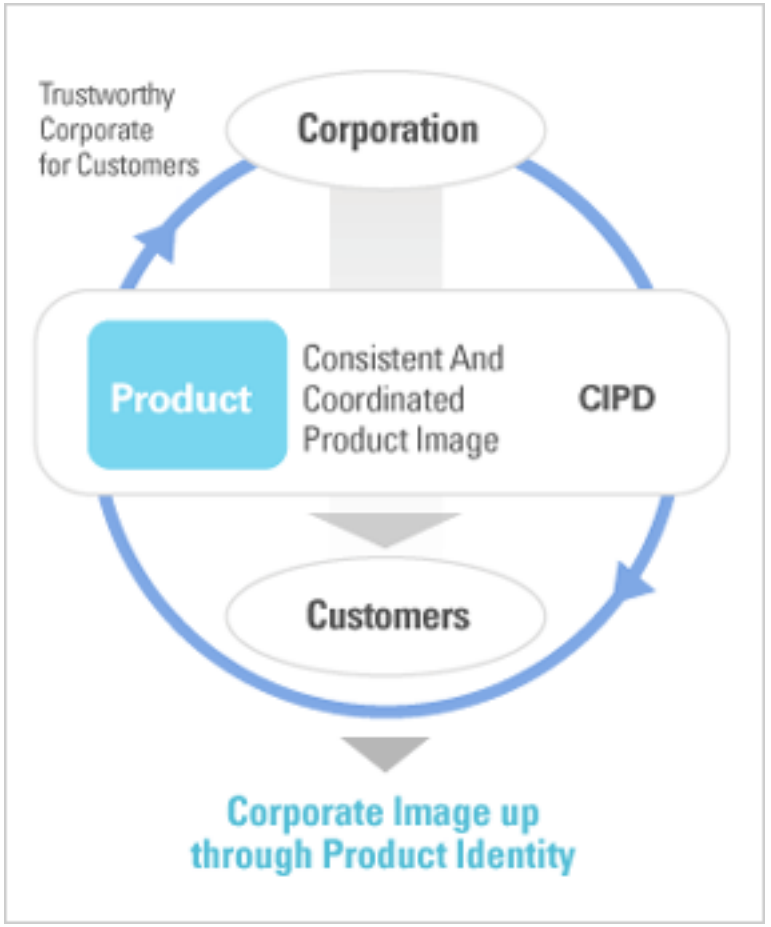
Oregon Scientific, ATC2K



Product Model Based Design of Precast Facades, Vesa Karhu,
VTT Building Technology, Technical Research Centre, Espoo, Finland
www.itcon.org/1997/1/paper.htm

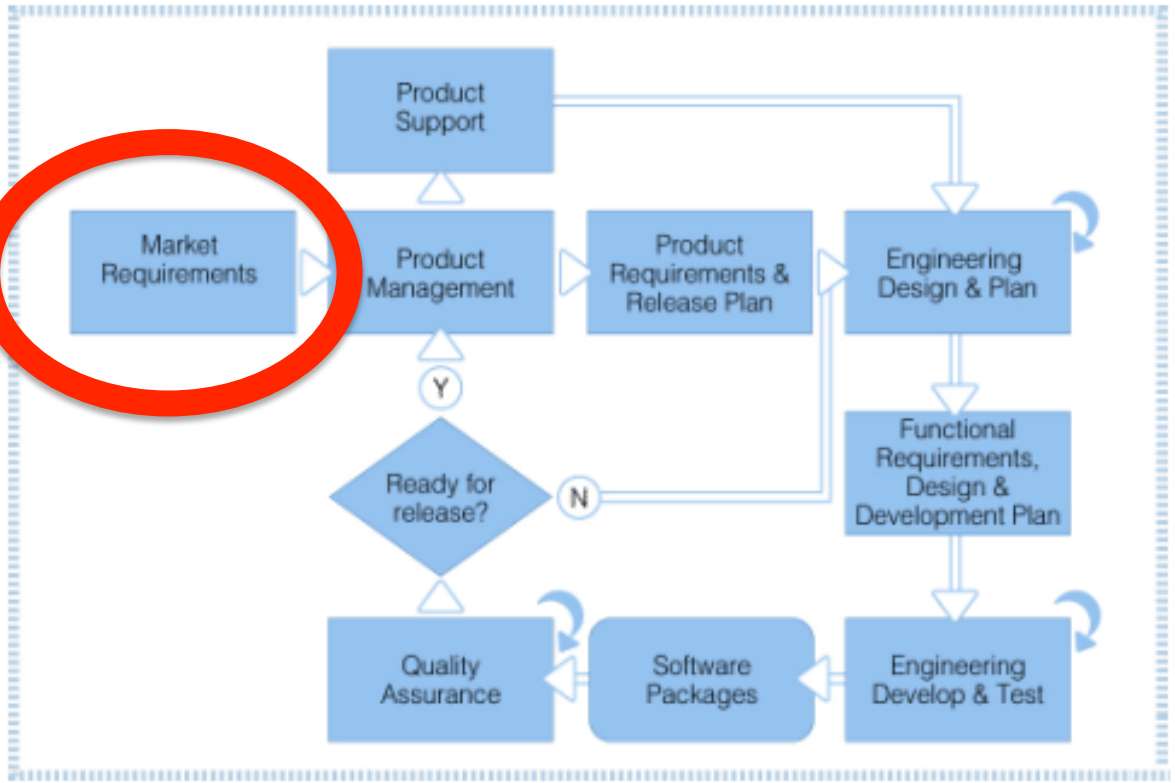
The customer / the market

KYOCERA

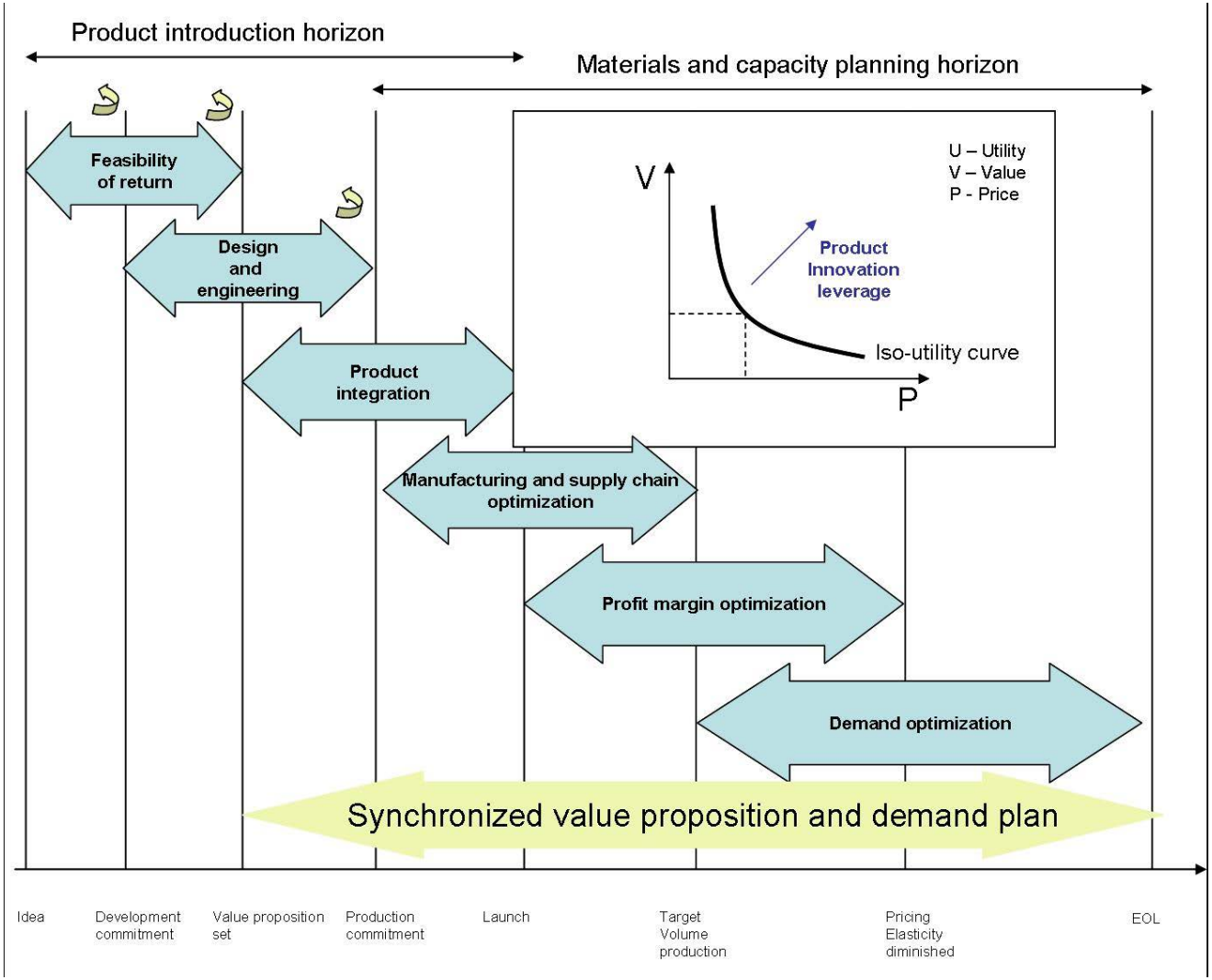


LG Electronics

Standard methodologies for product design

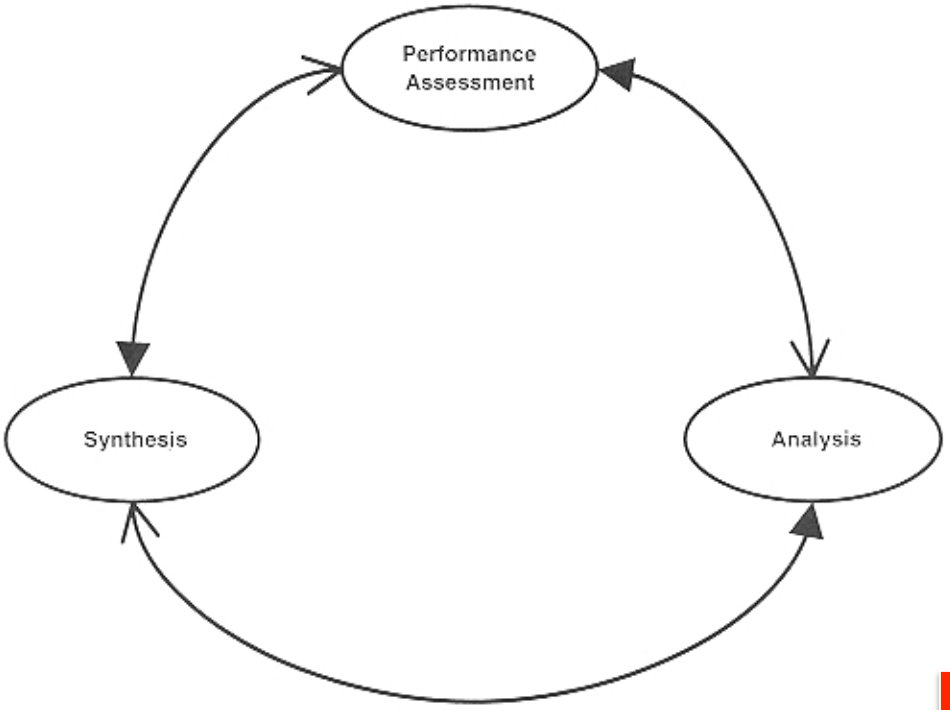


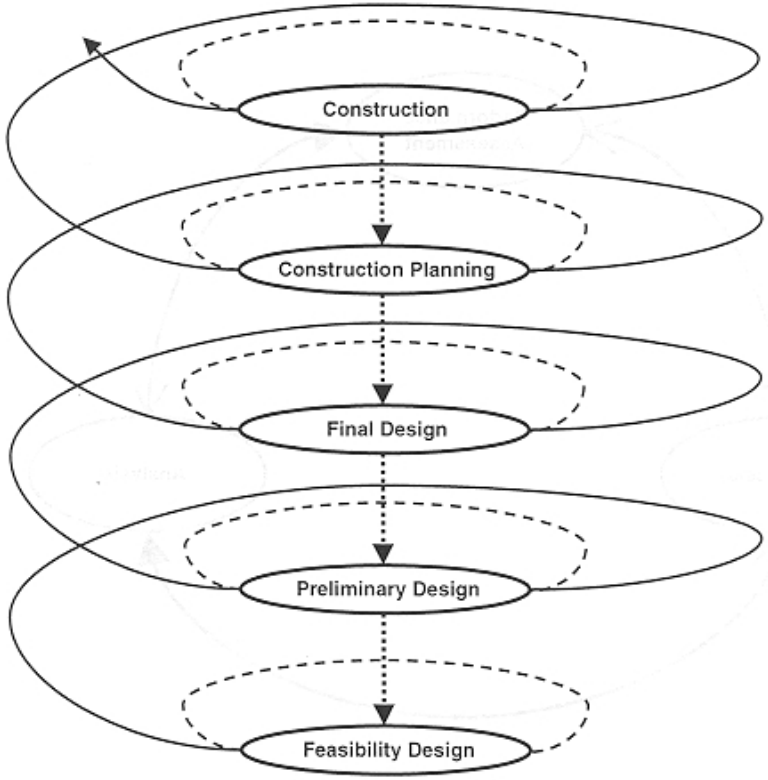
Linear?

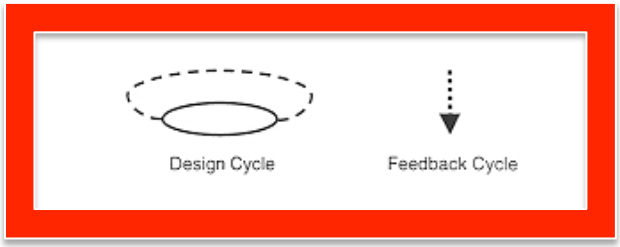


http://cpd-associates.com

Iterative!

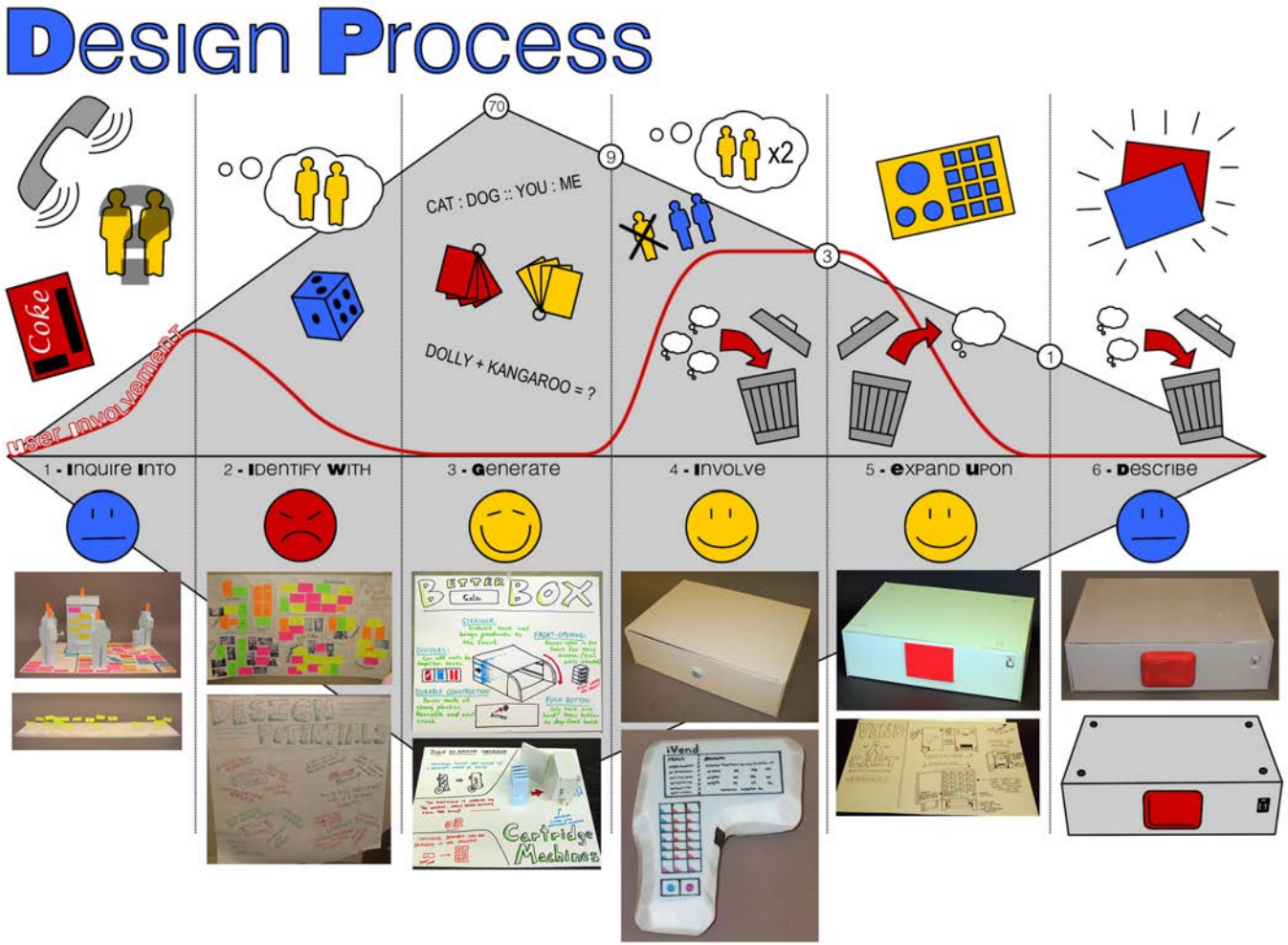






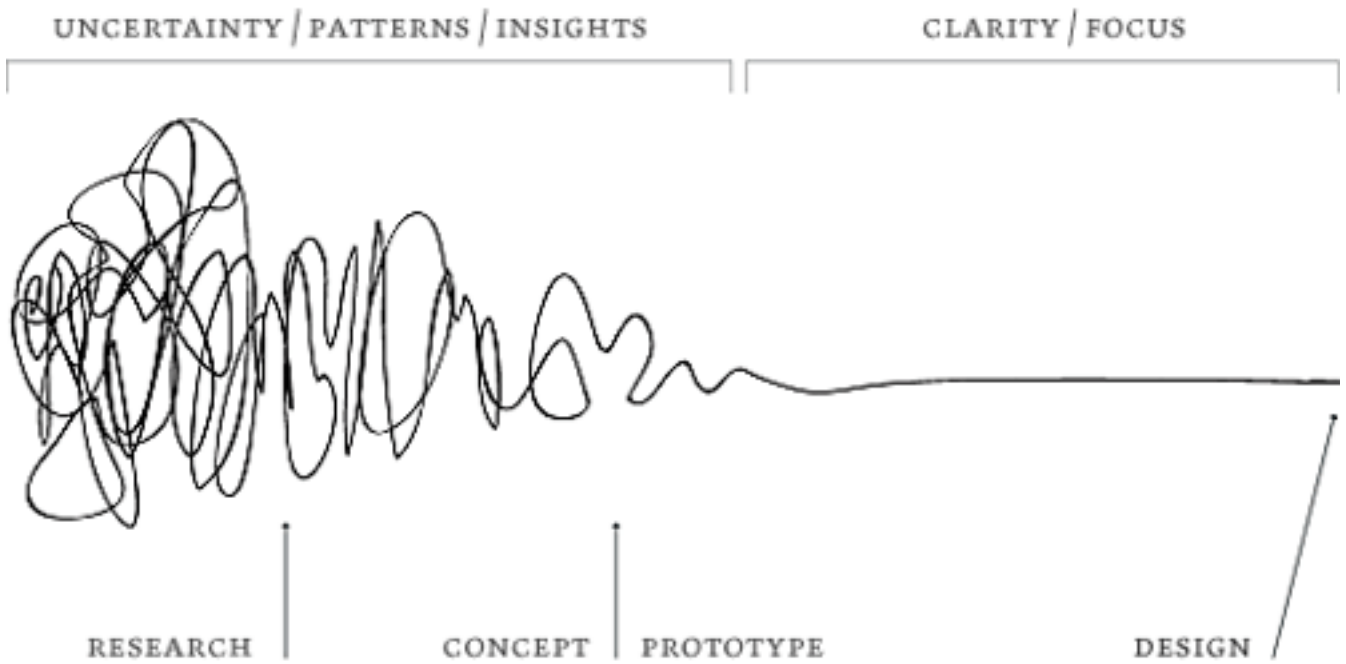
ocw.mit.edu/

Creativity / design phases:



seanmcb.com/portfolio/uocd-better-box

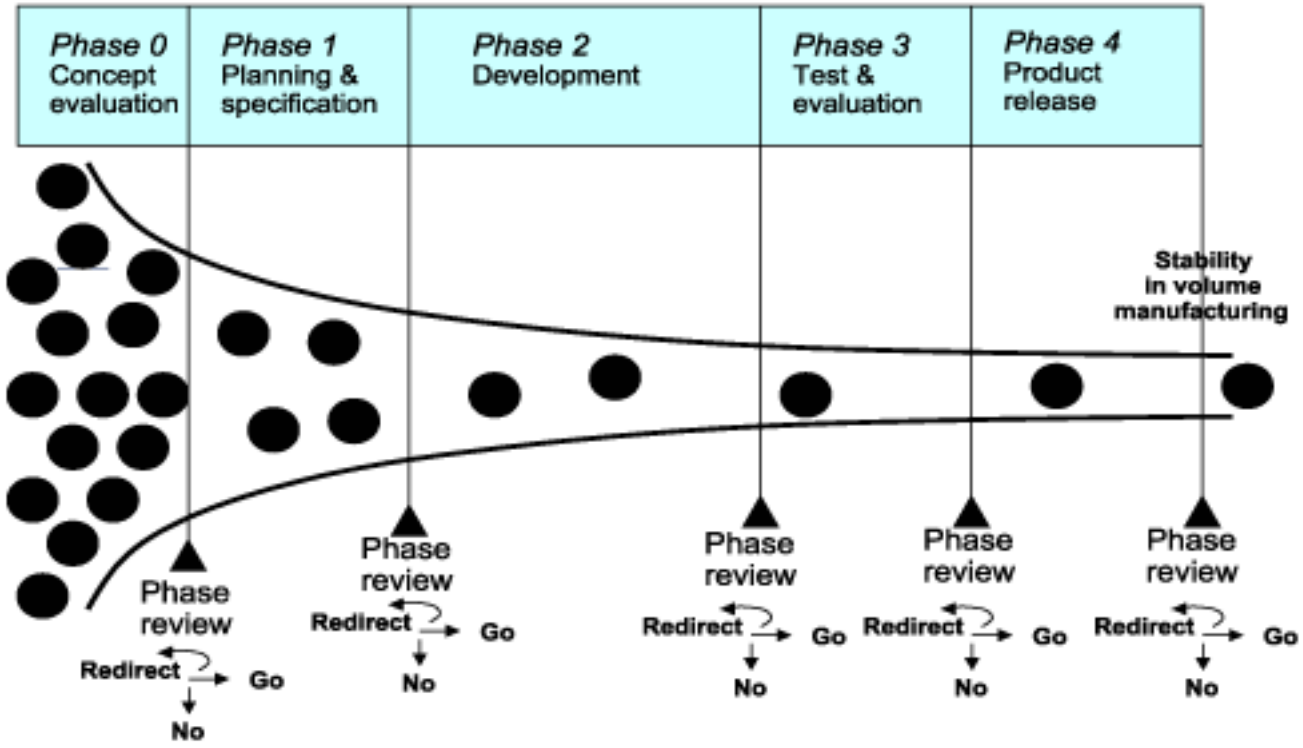
Creativity / design phases:



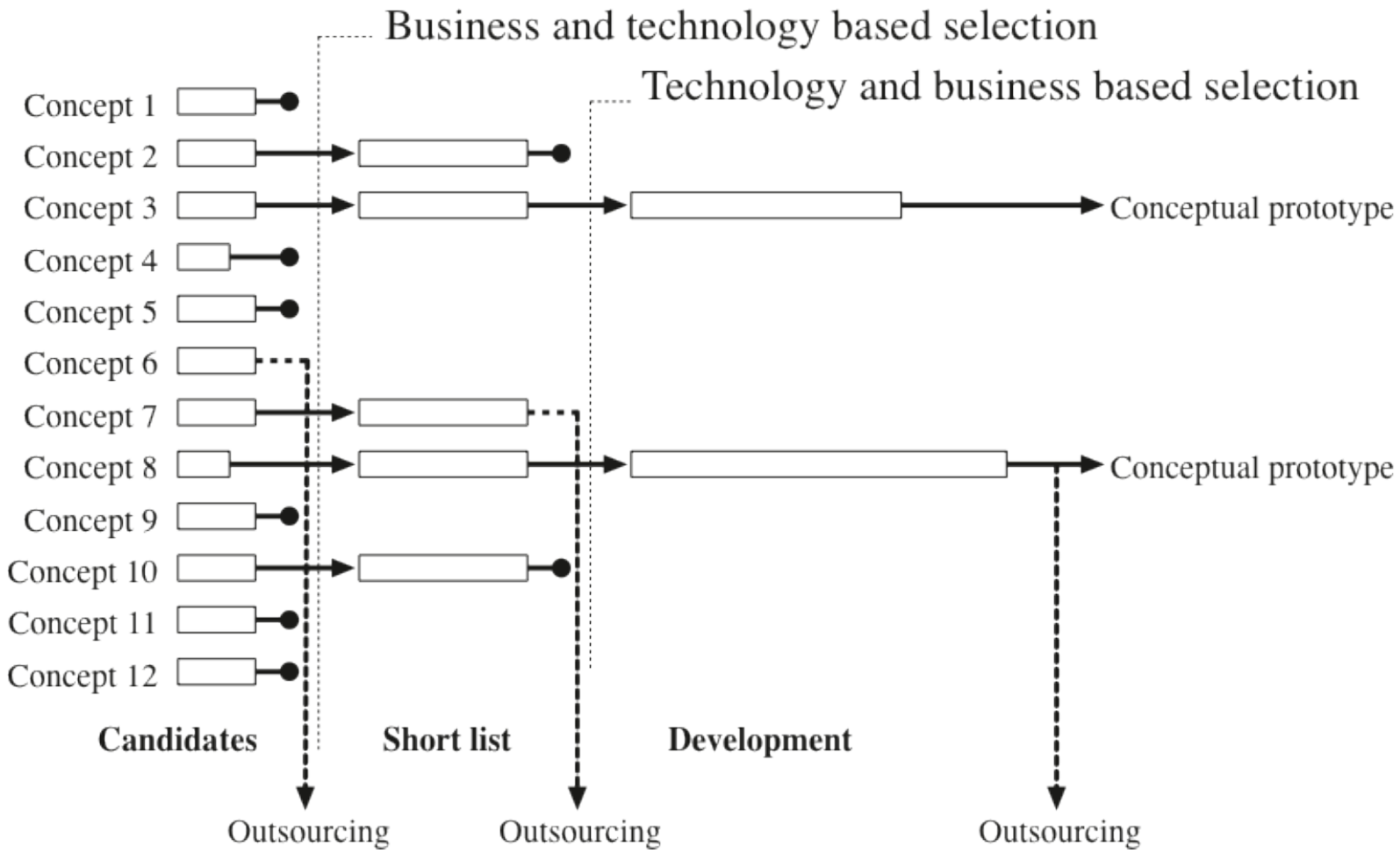
www.leadershipnow.com

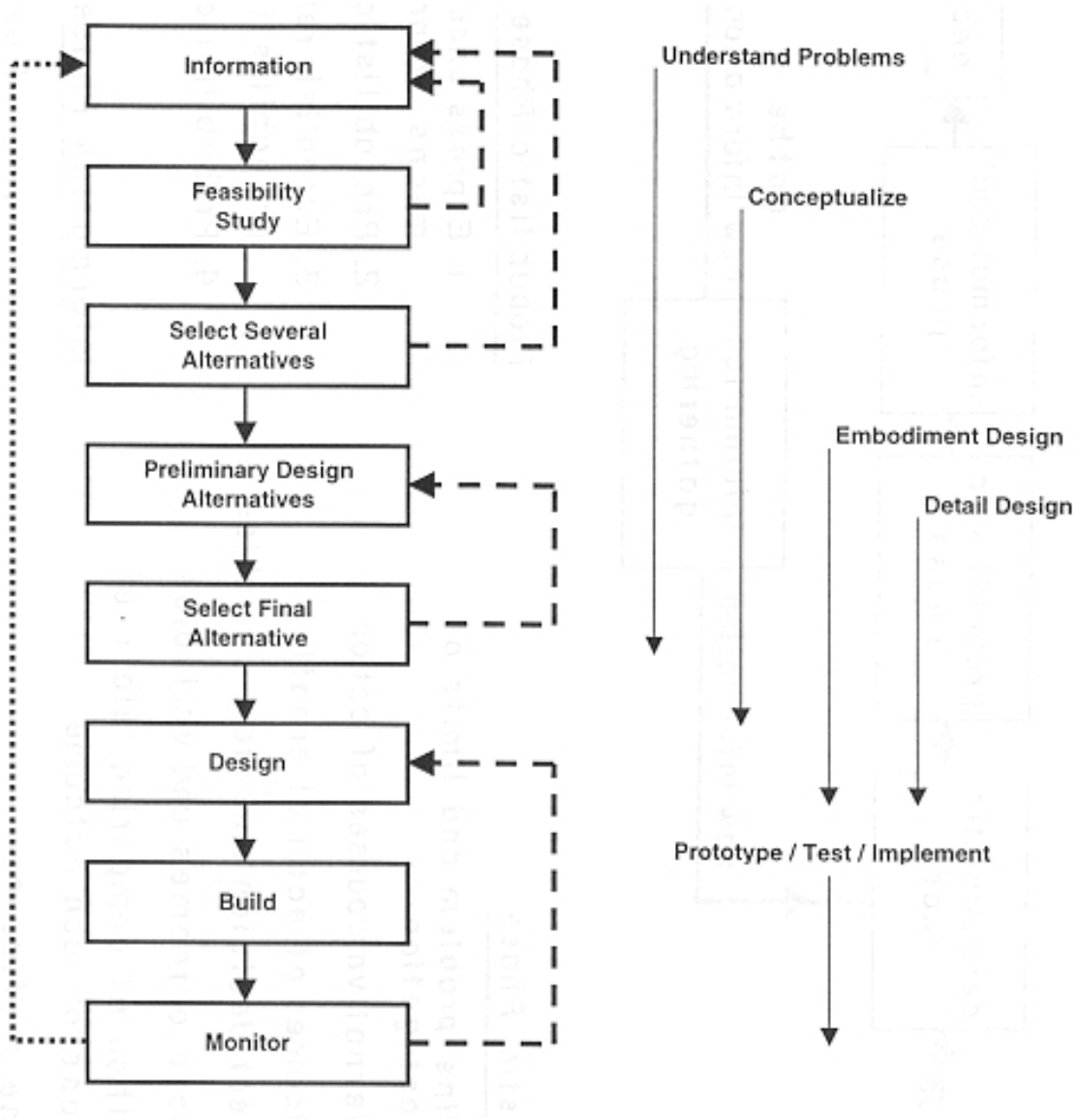
How to steer creativity?

Design process / milestones

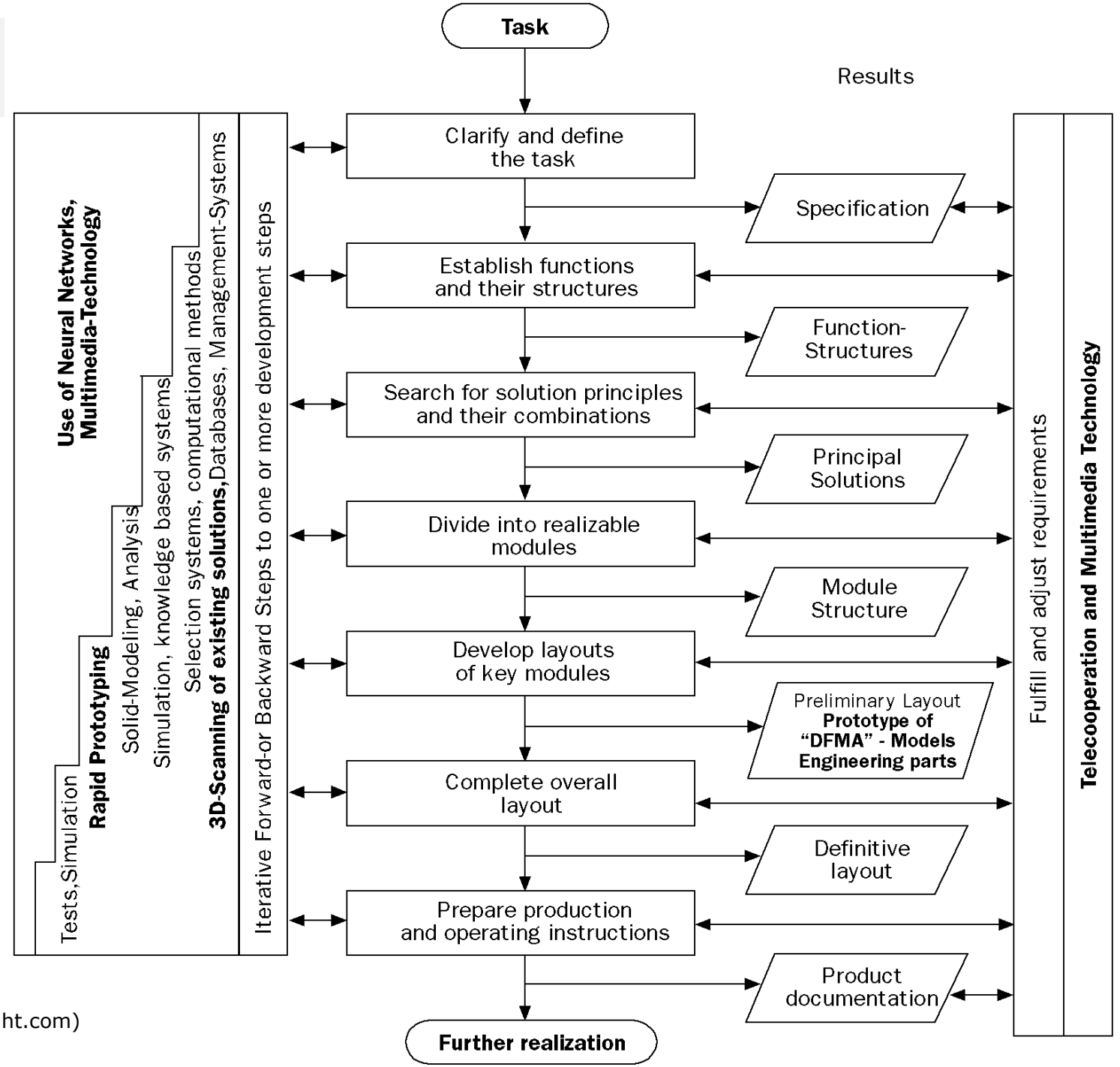


herkules.oulu.fi/isbn9514264509/html/c635.html


Business and technology based selection
Technology and business based selection
Concept 1
Concept 2
Concept 3
Concept 4
Concept 5
Concept 6
Concept 7
Concept 8
Concept 9
Concept 10
Concept 11
Concept 12
Conceptual prototype
Conceptual prototype
Candidates
Short list
Development
Outsourcing
Outsourcing
Outsourcing

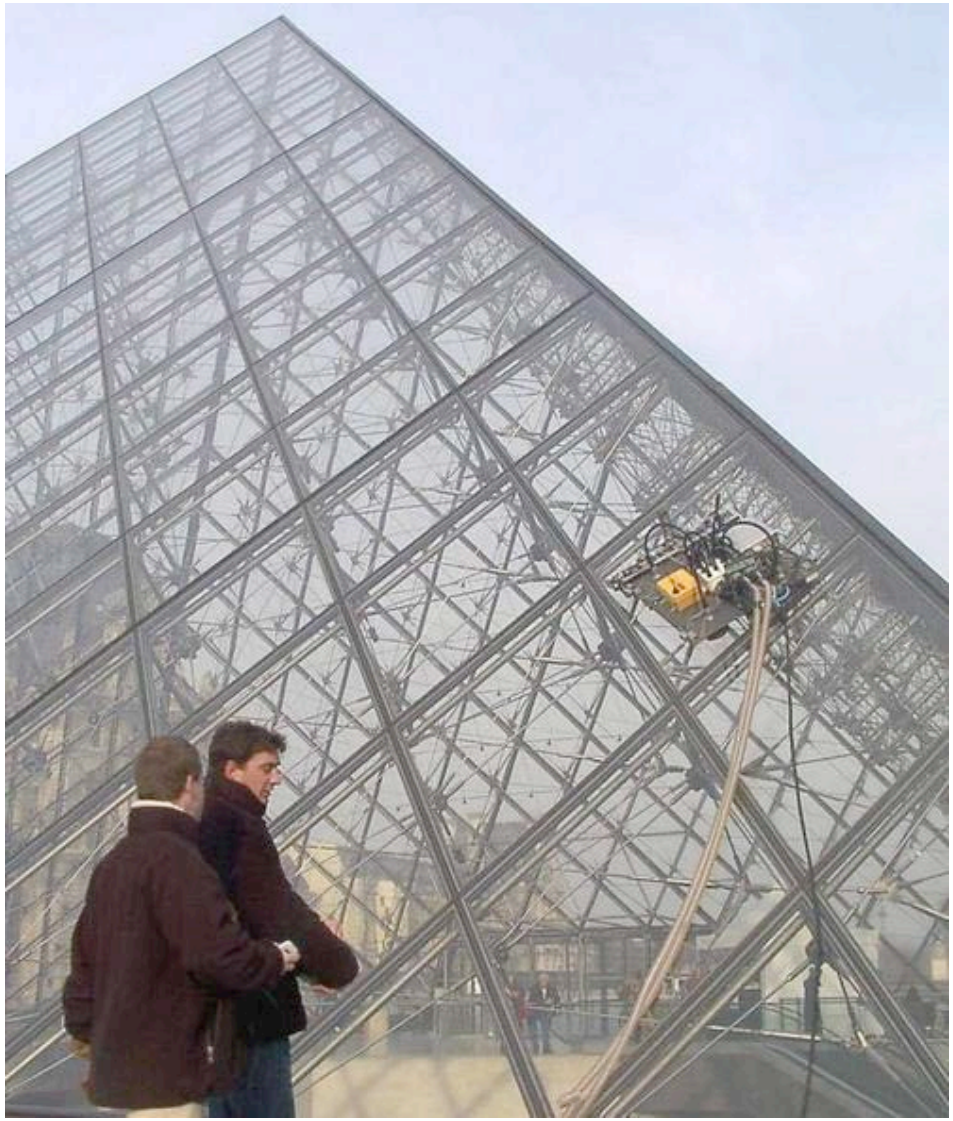

Information
Feasibility Study
Select Several Alternatives
Preliminary Design Alternatives
Select Final Alternative
Design
Build
Monitor
Understand Problems
Conceptualize
Embodiment Design
Detail Design
Prototype / Test / Implement

ocw.mit.edu



norm: VDI2221
(http://www.emeraldinsight.com)

Example: window cleaning robot



euron.org

Suction pads

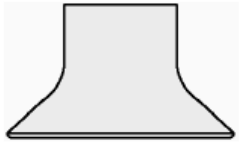
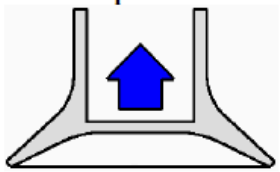
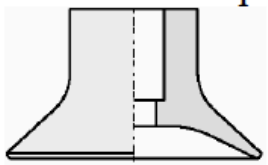
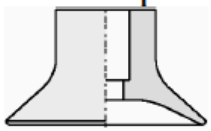
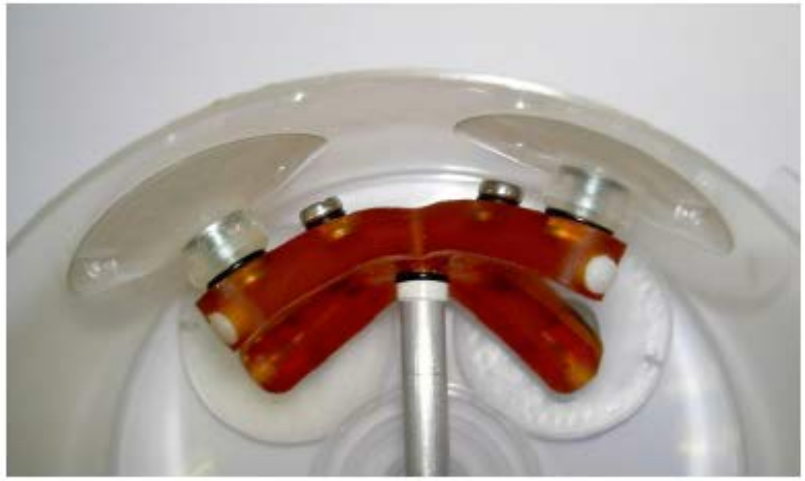
Concept	Characteristic	Constraints/Disadvantages
Passive suction pad 	The pad is pushed and pulled against a wall to crate and remove the fixation.	Smooth wall. We need a strong bi-directional controlled force to create and remove the fixation. [Cleanbot]
Deformable suction pad 	The pad is able to augment the internal volume (reducing the pressure) trough an active device. This can make the fixation stronger and the detachment easier.	Smooth wall. Activation-deactivation mechanism.
Vacuum suction pad 	The inner part of the pad is connected to a miniature electric vacuum pump (piston or diaphragm) that can be switched on or off.	Smooth wall. Miniature vacuum pump. [Darpa, Biggalo, Mrwallspect3, Ninja]
Sliding vacuum suction pad  Little μ_d	The pad is a vacuum type and has, on the wall, a little dynamical friction coefficient. The pad could alternatively be fixed or could slide in function of the level of the vacuum.	Very smooth wall (window) Miniature vacuum pump. [Clim@tron]

Table 4: Holding mechanisms based on suction pads

Michele Leidi, "Design and prototyping of a climbing robot "



Michele Leidi, "Design and prototyping of a climbing robot "

Combination of concepts:

- adhesion
- lifting
- energy harvesting

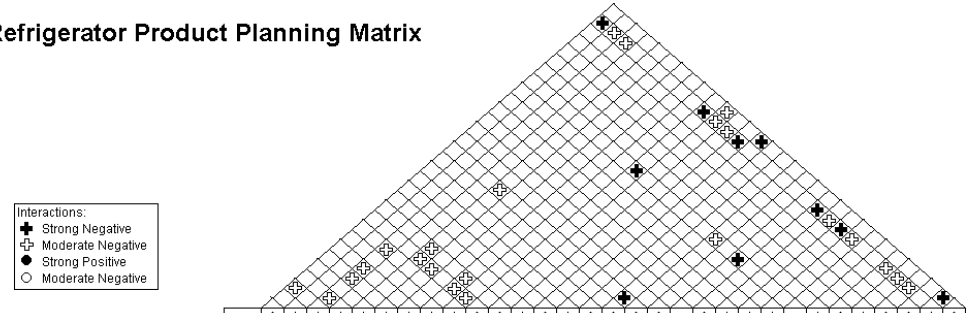
Some other well known design methods (to be combined…):

- Functions subdivision by “axiomatic design”
- “TRIZ” to be used to find solution for functions.
- Optimization of product: “QFD”

EPFL

QFD

Refrigerator Product Planning Matrix



	Customer Needs	Priority	Compressor energy efficiency rating	Insulation efficiency	Noise measurement-front	Refrig. temp. range (on/off cycle)	Refrig. temperature variation	Refrig. cooling speed (from 30°C to 5°C)	Freezer temp. range (on/off cycle)	Freezer temperature variation	Freezer cooling speed (30°C to -15°C)	Volume efficiency (total/usable)	% Shelf & tray area adjustable	Drawer/shelf pull force	# of visibility features	Dis-assy & re-assy time for cleaning	% of features rated easy to clean	Freezer width	Refrigerator shelf depth & width	Freezer shelf height	Door tray depth	Warranty period (years)	Water filter replacement time & cost	10 year service contract cost	Time to disassb & reassb door	Refrigerator depth	Stainless & trim panel option prices	Focus group rating - appearance	Water temperature	Water filter indicator & life	Ice produced daily	Manufacturing cost	No. of adjustable temp. drawers	Competitive Evaluation (1-Low, 5-High)	Sales Points	Improvement Goal	Improvement Factor	Relative Development Effort
	Goal		↑	↓	↓	↓	↓	↓	↓	↓	↓	↑	↑	↓	↑	↓	↑	↑	↑	↑	O	↑	↓	↓	O	↓	↑	↓	↑	↑	↓	↑	1 3 5				
Operation	Low energy consumption	4	5	5																												U MGF A W	1.0	3	1.1	1
	Quiet	1			5																											MFA WG U	1.0	5	1.0	0
	Maintains temperature	3		1		3	3	3	3	3	3																					FA MWG U	1.0	5	1.0	0
	Preserves food & freshness	3		1		5	5	5	5	5	5																				5	MFA WG U	1.2	5	1.0	0
Storage	Maximize storage space	5		3								5						3	3	3												U MG FA W	1.1	5	1.4	5
	Flexibility for changing storage needs	3										3	5	1		3															3	A U WGF M	1.0	3	1.1	1
	Easy access & visibility	4											1	5	5	3		1	1	1												U FA WG M	1.0	3	1.2	1
	Easy to clean	2														5	5															MWGFA U	1.0	5	1.0	0
	Handles large containers & items	4										3	3					5	5	5	5											U WGA MF	1.0	3	1.2	1
Reliat	Reliable, doesn't break	5																				5										M WGA F U	1.0	5	1.0	0
	Easy & low cost to service	3																				5	5	5	1							U MA WG F	1.0	4	1.3	1
Kitchen	Easy to deliver & install	1																							5	3						MWGFA U	1.0	5	1.0	0
	Fits in kitchen space	5		3								5														5						UMF A WG	1.1	5	1.4	5
	Coordinates with kitchen décor	4																							3	5	5						U MFA WG	1.0	3	1.1	1
Disp	Dispenses purified water	3				1																3						5	5			UMFA W G	1.0	3	1.0	0
	Provides & dispenses purified ice	3							1													3						5	5	5		UMFA G W	1.0	3	1.0	0
$	Low price	3																													5	M UWG FA	1.2	5	1.2	5
Technical Evaluation (Italicized numbers represent subjective ratings)	U	5.3	160	160	30	2.0	2.0	220	4.0	2.0	110	53%	2	3	2	3	4	300	450x478	4	3	1	5	29	2	4	5	2kg	486	3 drw					
	M	5.5	150	150	34	4.0	3.0	228	6.0	4.0	121	56%	5	4	4	5	2	316	464x478	3	5	4	2	28	1	4	5	5kg	513	3 drw					
	W	5.5	150	150	34	2.0	2.0	235	4.0	2.0	121	55%	4	4	5	4	2	320	422x413	5	5	5	2	28	4	4	5	2.3kg	471	3 drw					
	G	5.5	150	150	34	3.0	2.0	230	5.0	3.0	121	58%	3	4	4	5	3	320	440x460	3	5	5	2	28	5	4	5	2.3kg	487	3 drw					
	F	5.5	150	150	34	3.0	3.0	230	5.0	3.0	121	55%	4	3	4	3	3	310	418x446	3	5	5	2	28	3	4	4	2.3kg	511	3 drw					
	A	5.5	150	150	34	3.0	3.0	230	5.0	3.0	121	56%	3	3	4	2	4	310	430x466	2	5	5	2	29	3	4	4	2.3kg	511	3 drw					
Target Value		5.8	150 Kcal/mh°C (equiv. to R-141b)	30 decibels	2°C	2°C	160 minutes	3°C	2°C	100 minutes	60%	x%	< 2 Kg	Equal to Whirlpool	X minutes	X%	320mm	450mm wide x 420mm deep	X mm	180 mm	5yr Compressor / 2yr Parts	<3 minutes & $15	< $99	< X minutes	24 inches	$60 Stainless & $40 Trim Pkg	70% rating	X°C	Yes / 6 months	2.5 kg/day	$502	4 drawers					
Technical Difficulty (1-Low, 5-High)		4	5	2	1	2	1	2	2	1	5	4	2	3	2	2	3	4	1	1	3	2	1	1	5	3	3	1	3	3	5	5					
Importance Rating		22	75	5	30	27	27	30	27	27	101	36	27	24	34	10	52	52	52	24	45	38	20	9	55	22	22	30	30	15	22	28					

U - Us
M - Maytag
W - Whirlpool
G - GE
F - Frigidaire
A - Amana

www.npd-solutions.com/qfd.html

Structure:

- Introduction
- Existing Mobile robot products
- How to develop a new robot
  - Standard product design
  - Mobile robot design in interdisciplinary research
- Case studies:
  - Khepera: Mechatronics >< Market (+flops)
  - e-puck & Thymio: Mechatronics >< Education
  - Leurre: Mechatronics >< Biology, methodology
  - S-bot & marXbot: Mechatronics >< Computer Science
  - Robotic glasses & ranger: Mechatronics >< user interaction
- Conclusion / assignements

How should we design our research robots ?

Do they are standard products?
Can we apply standard product design methods?
Do our robot fit to products profiles?
How? If not, why, where?

The customer? Which market?

Who defines the needs?

- Your colleague doing behavioral studies
- The reviewers / stakeholders
- Your thesis director?
- The funding agency
- Those who will read your articles

how “customers” should steer innovation?

- difference between technical and functional requirements. Technical requirements will hardly be innovative!
- Experience versus being naïve
- Difference in background
- Quantity of thinking
- Methodology

Specifications: where are they?

Very important to clarify the specs.
No marketing department…. You do the job.
-Ask (yourself) for the real need and not
the expected solution.
- Make them stable, written.
- Translate need into technical specifications.

Methodology: flexibility required…

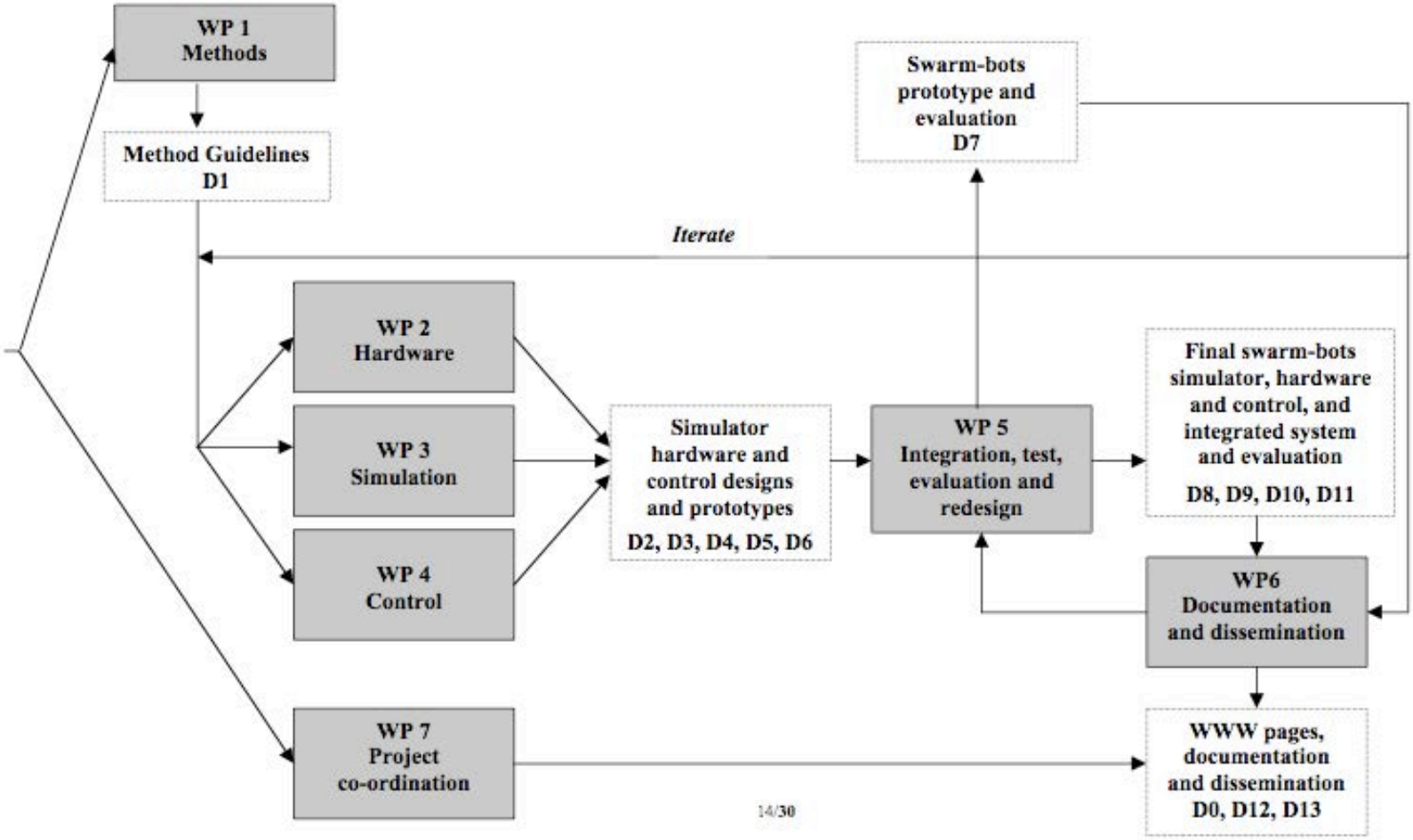
Keep the global design approach, adapt for your specific case

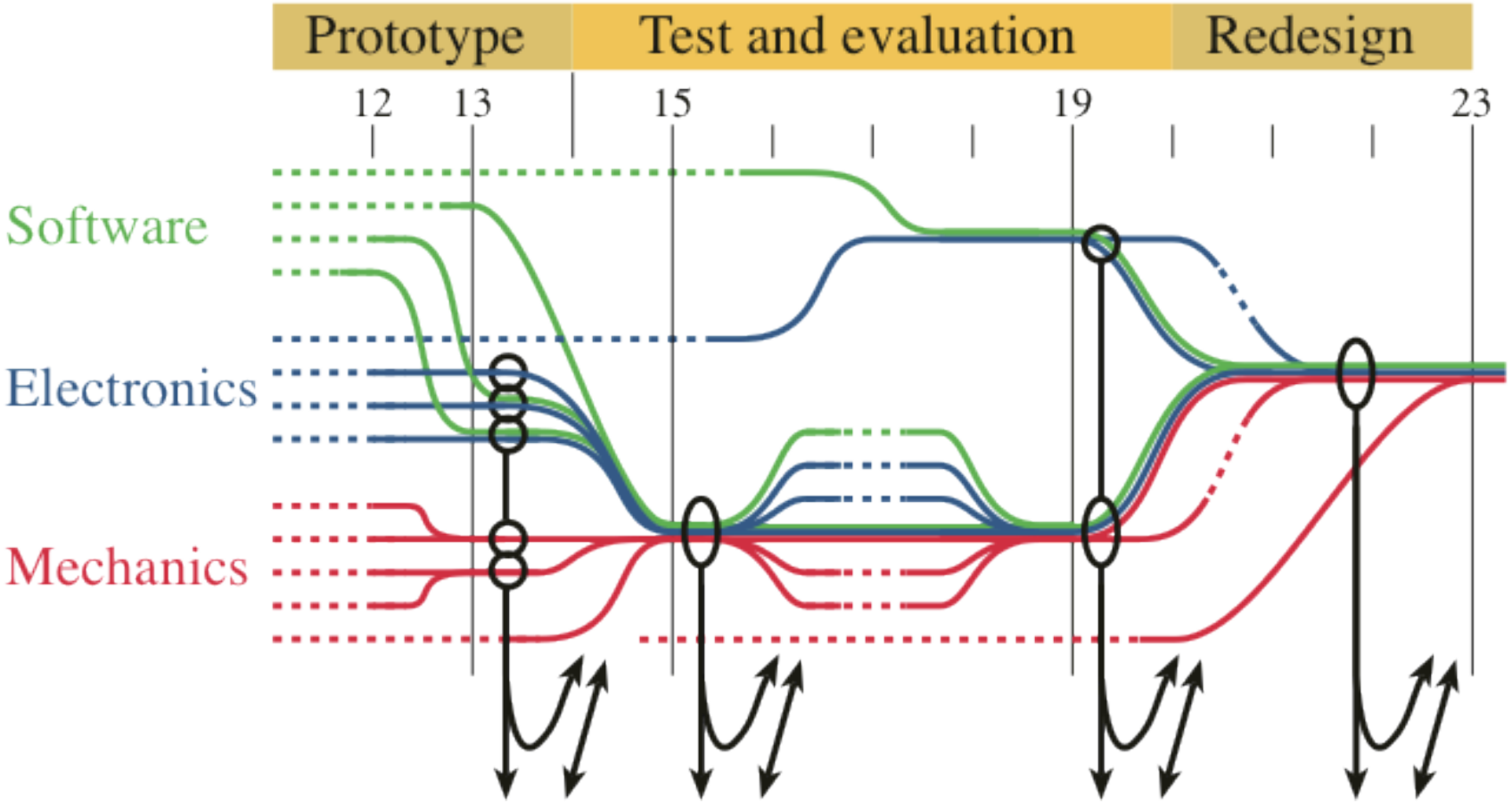
Bring core competences,
take advise on other fields

Often a methodology is defined in the project

B6.3 Project Structure (Pert diagram)

Graphical presentation of the project s components, showing their interdependencies (Pert diagram)

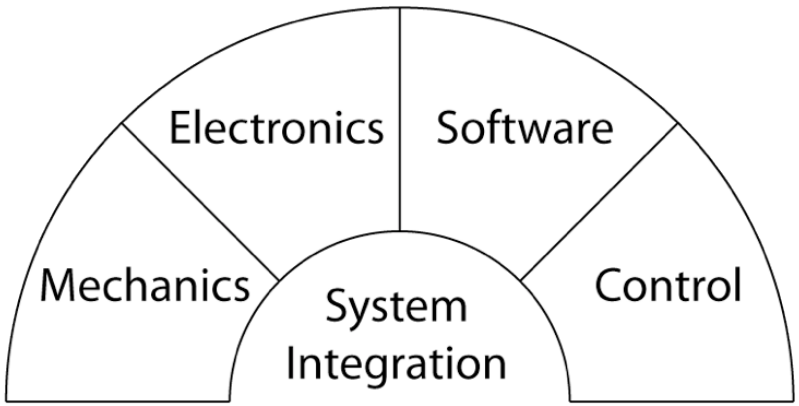



Prototype
Test and evaluation
Redesign
12
13
15
19
23
Software
Electronics
Mechanics

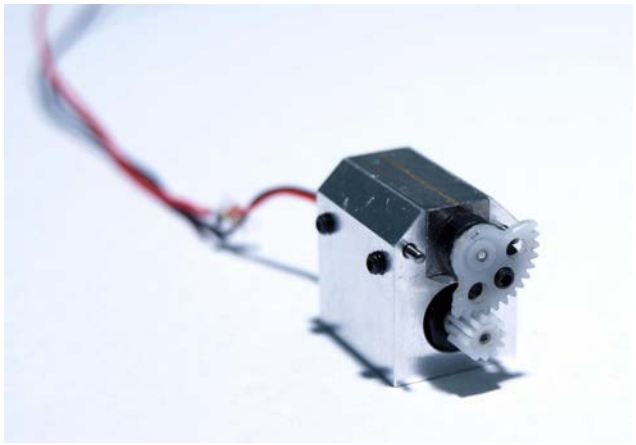
Swarm-bots

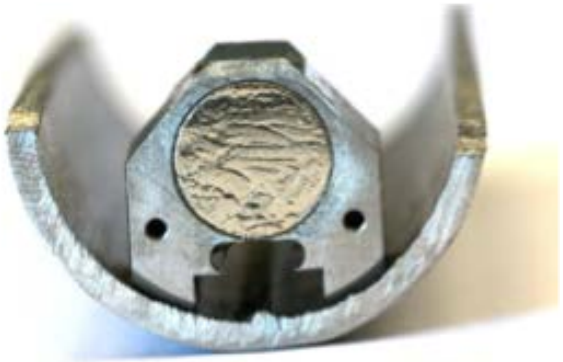
Products are increasingly multidisciplinary…

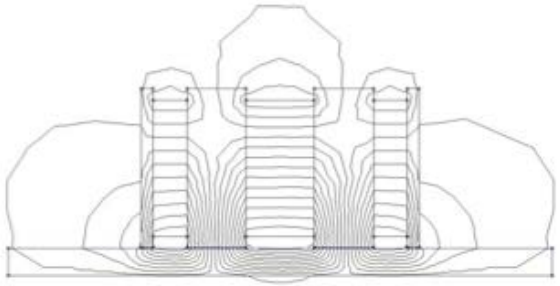
Core competences:



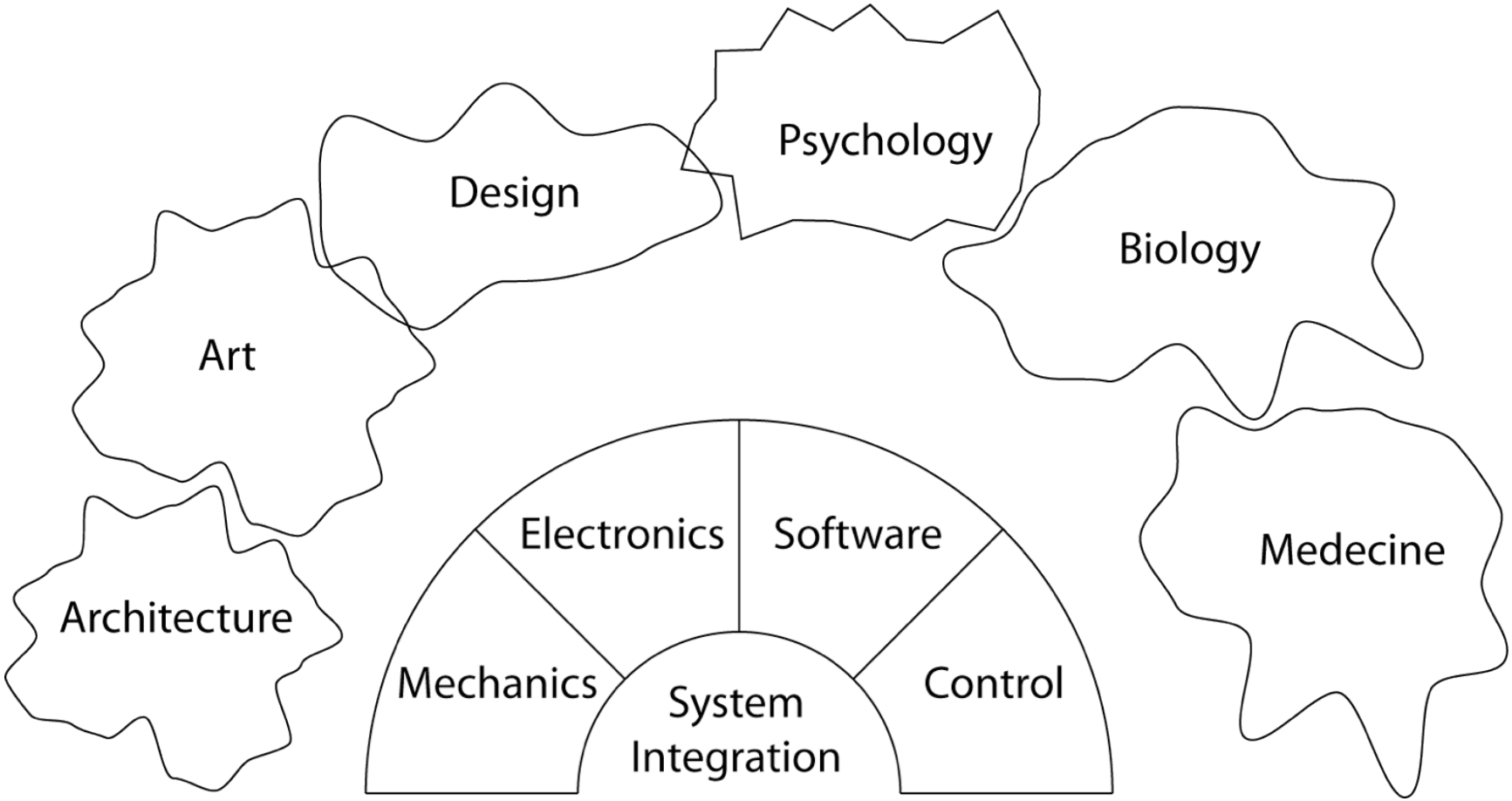
Core competences:

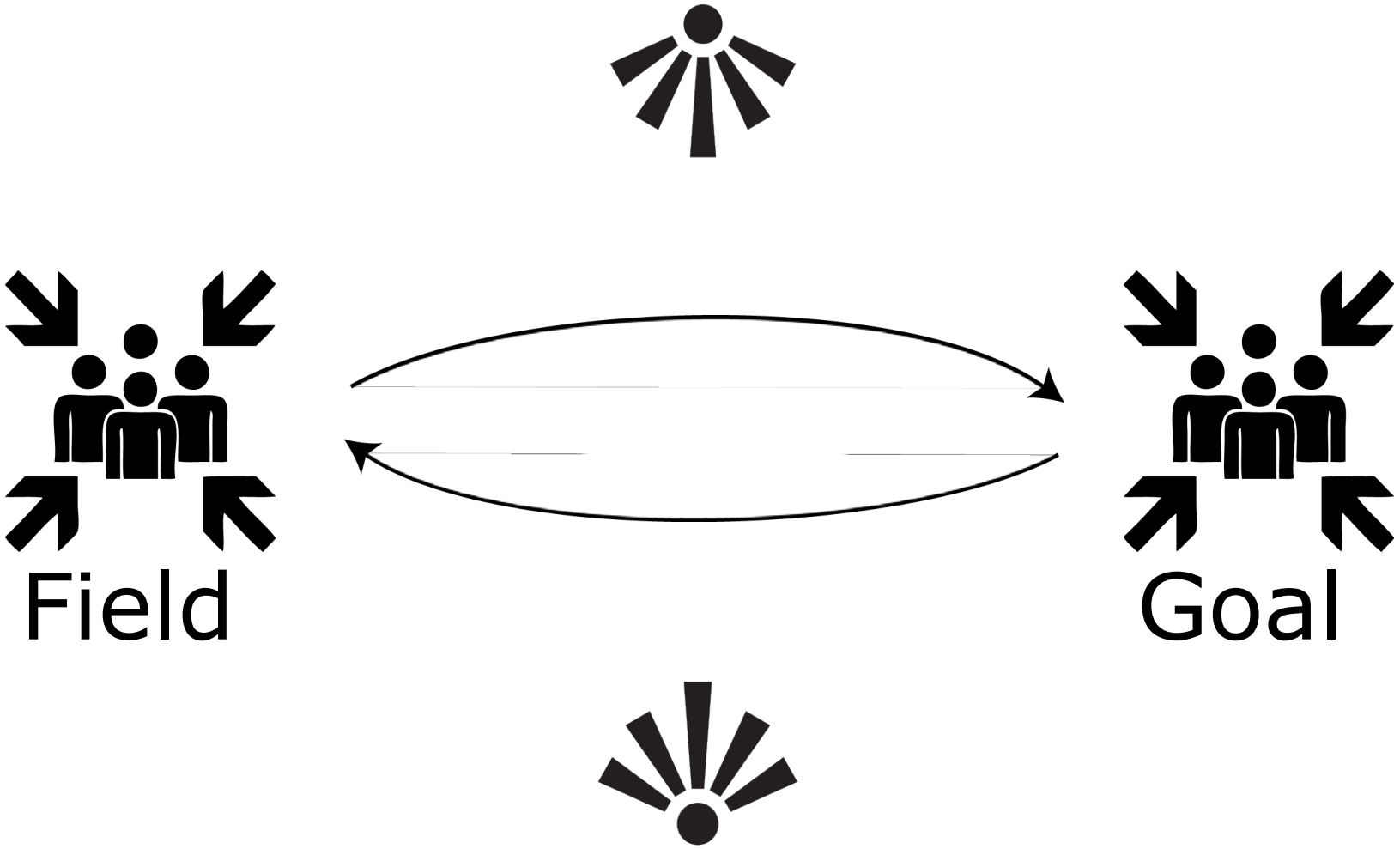


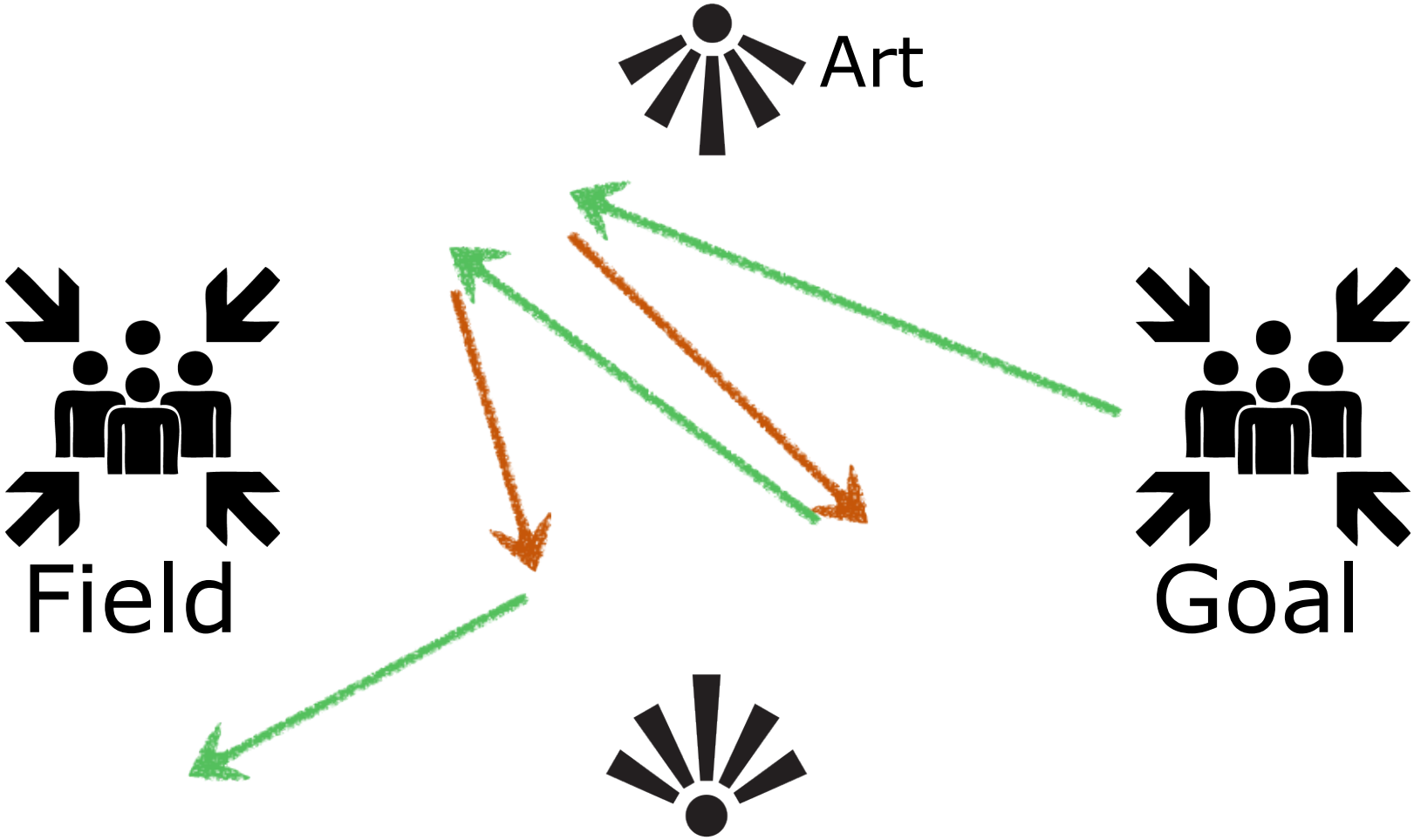


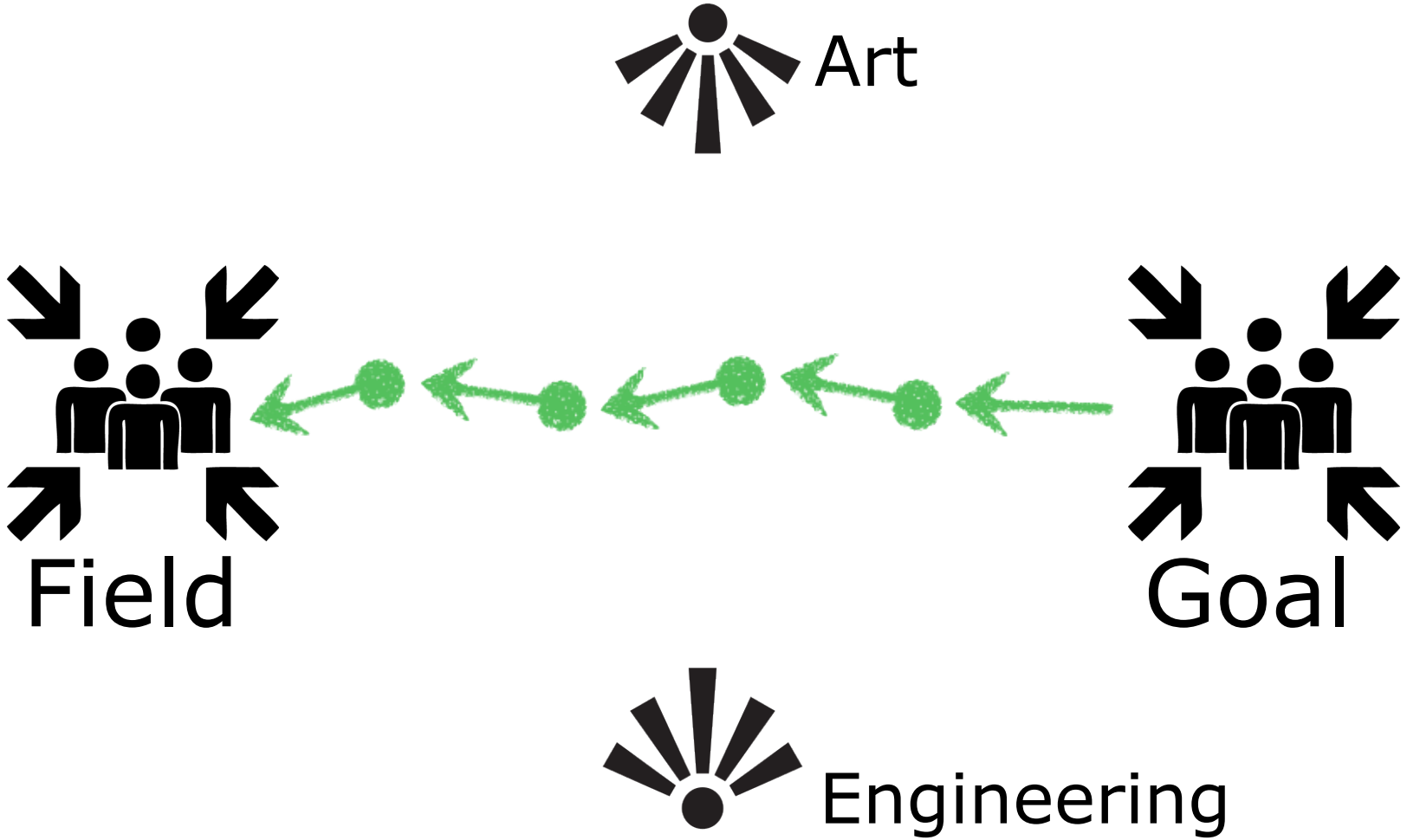


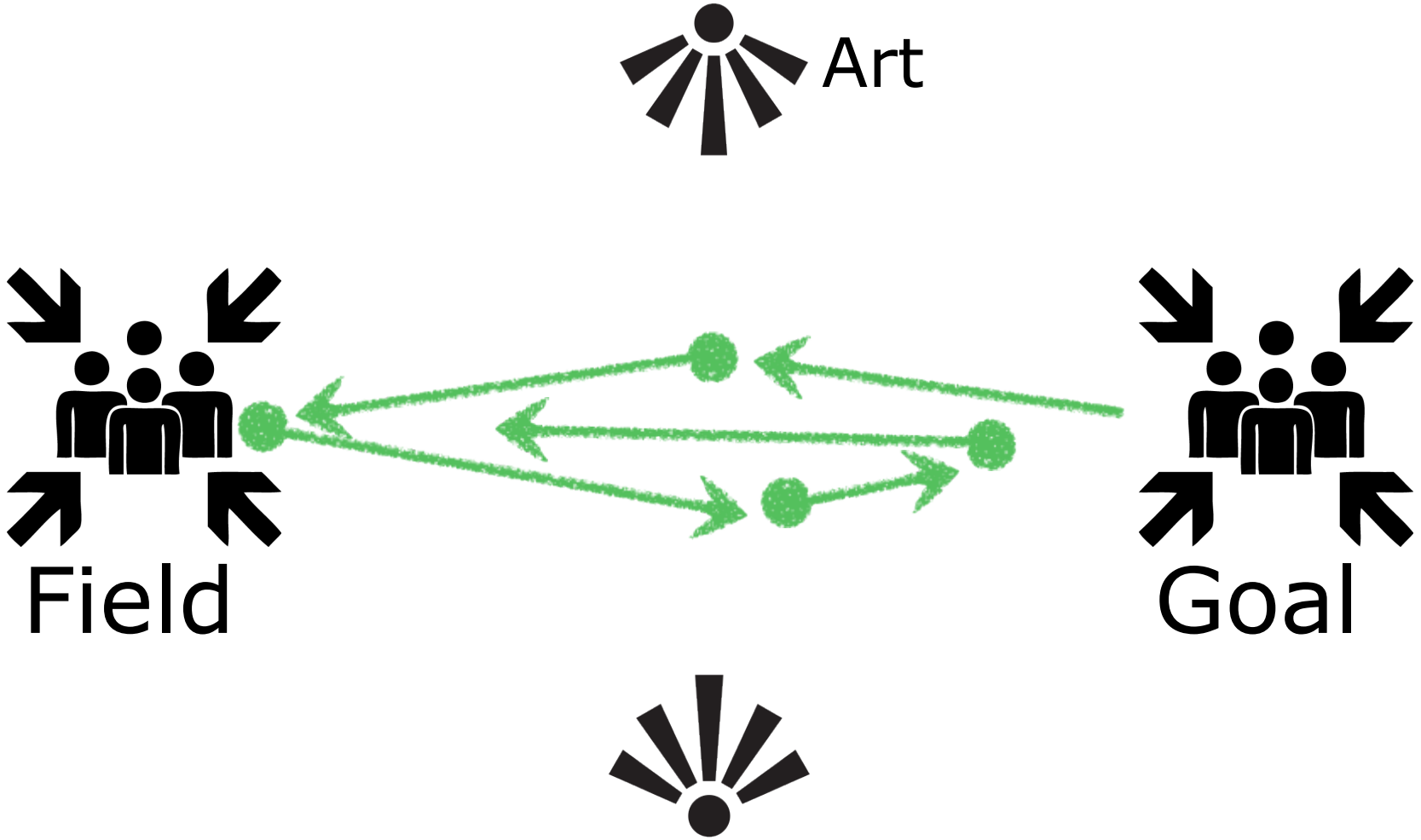
Interdisciplinary work



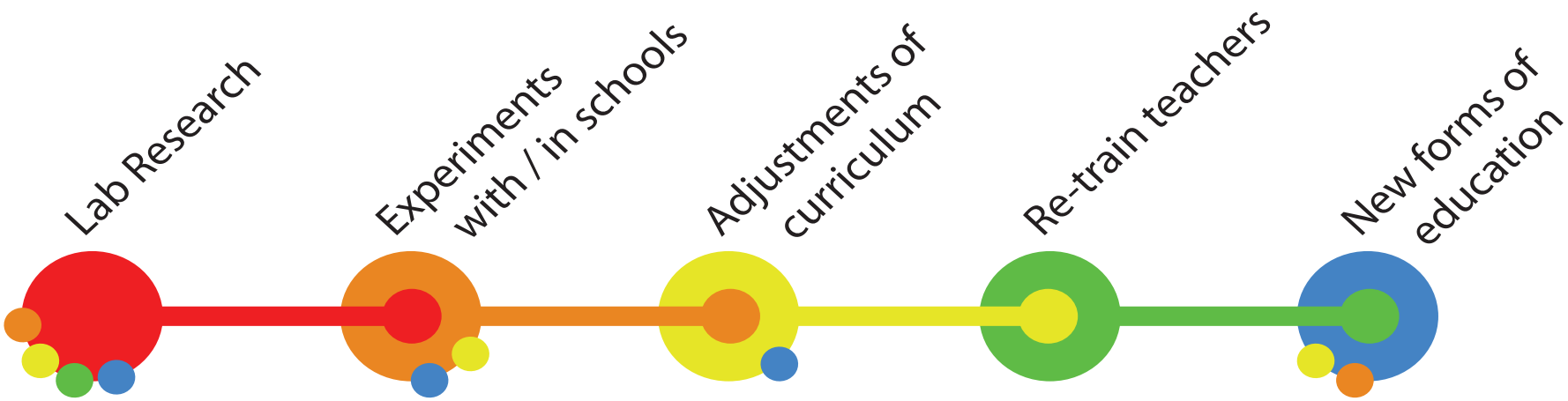

Field
Goal


Art
Field
Goal


Art
Field
Goal
Engineering


Art
Field
Goal

Being aware of the real problems: translational!



Design process / milestones

- Milestones / Deliverables are classical steps
- Often presented to experts
- Form depends on field and of the experts

Selling the idea

Common in engineering (eng. to eng.)

Can become more complex when selling to:

- Your collegue doing behavioral studies
- The reviewers / stakeholders
- The funding agency
- Those who will read your articles

Open / proprietary IP

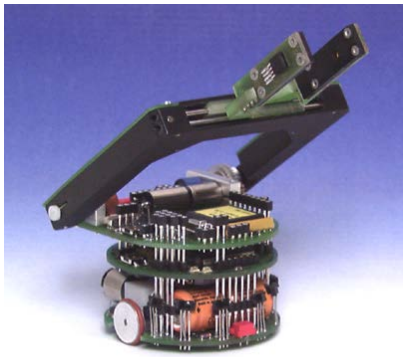
OPEN:

- not mix open data with open IP
- very common in the academic world
- welcome by funding agencies
- not compatible with industrial applications

Structure:

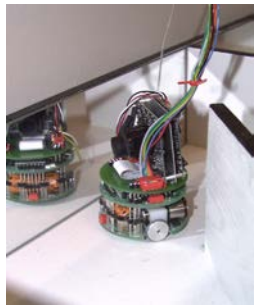
- Introduction
- Existing Mobile robot products
- How to develop a new robot
  - Standard product design
  - Mobile robot design in interdisciplinary research
- Case studies:
  - Khepera: Mechatronics >< Market (+flops)
  - e-puck & Thymio: Mechatronics >< Education
  - Leurre: Mechatronics >< Biology, methodology
  - S-bot & marXbot: Mechatronics >< Computer Science
  - Robotic glasses & ranger: Mechatronics >< user interaction
- Conclusion / assignements

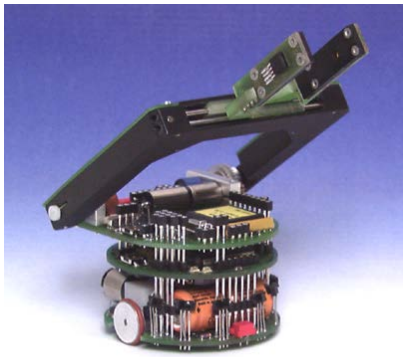
Khepera miniature mobile robot



Scientific impact:

- Worldwide switch from simulation to Khepera
- ~1000 laboratories acquired Khepera
- Khepera in >6000 publications (on Google scholar)
- Khepera methodology is a standard in AI research
- 2 edited books (proceedings), 4 book chapters,
  4 journal papers, 13 conferences
- Core paper with 676 citations
- Created one conference (AMiRE, 6 editions)
- Cover of most scientific journals (Nature in 2000)



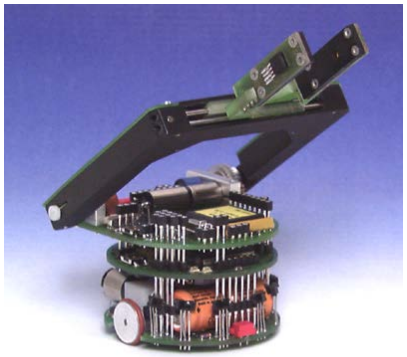


Khepera miniature mobile robot

The customer?

- Us as researchers in a given project
- Our boss
- Colleagues in Biology ans CS (neural networks research)
- More and more universities

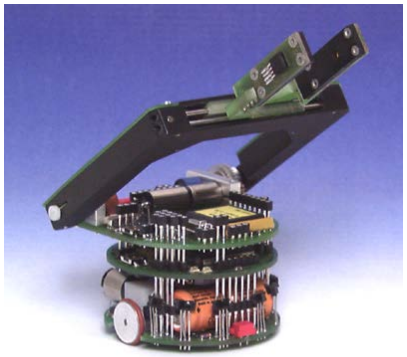
Khepera miniature mobile robot



Specifications: where are they?

- Based on some good and innovative ideas
- Defined during the project
- Based on our own needs
- Based on our design experience
- Based on our vision of “nice design”

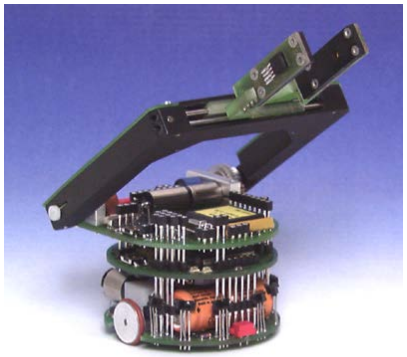
Khepera miniature mobile robot



Methodology
Design process / milestones

- Classical engineering process based on
  - Research of solutions
  - Comparison of several solutions
  - Choice and integration
- Design by iterations, few time pressure

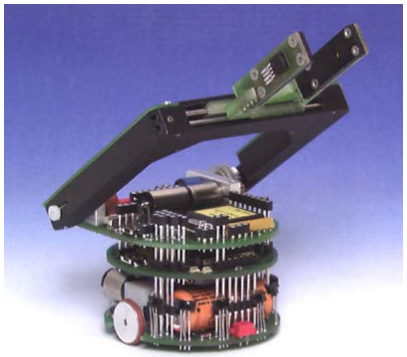
Khepera miniature mobile robot



Open / proprietary IP

- Proprietary (EPFL)
  schematics, implementation and code
- Agreement with K-Team company
- Royalties from K-Team company

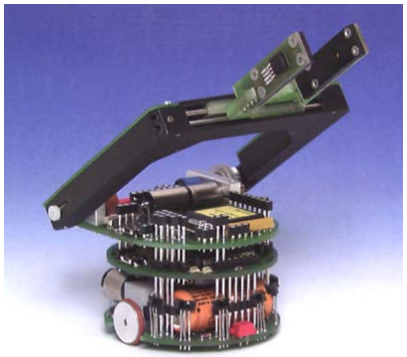
Khepera miniature mobile robot



Selling the idea:

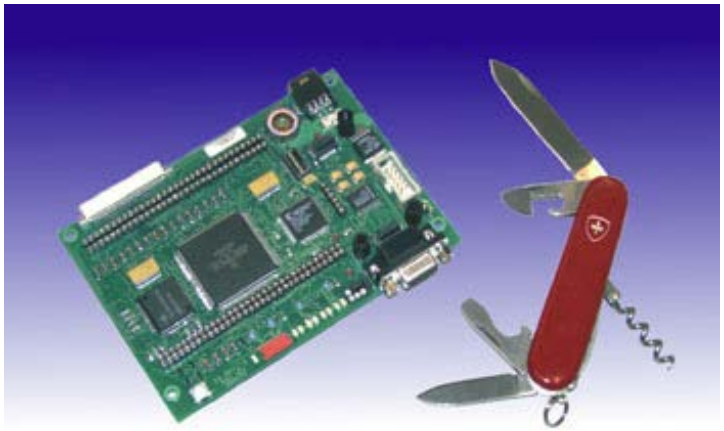
- based on scientific results
- answering to strong needs
- corresponding to a trend (Alife - robotics)
- becoming the tool of a community

Khepera miniature mobile robot



A good example?

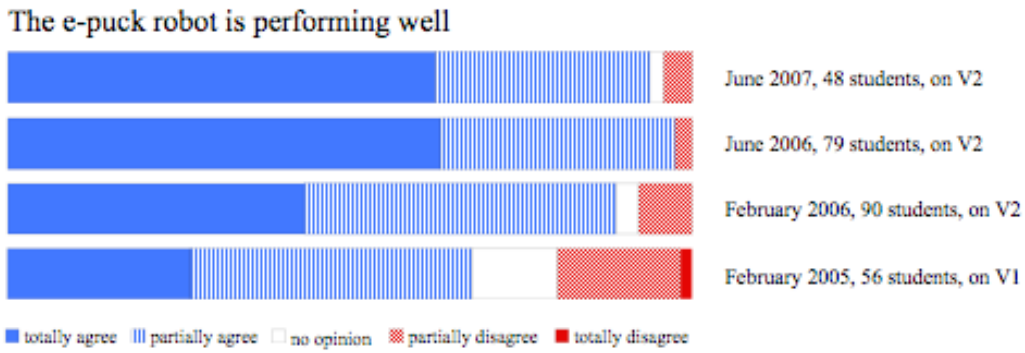
Perhaps, but has not been repeated in K-Team
2nd - 3rd … attempts failed:



e-puck education robot

Achievements:

- Open robot platform for a large number of EPFL courses
- Excellent feedback from students:



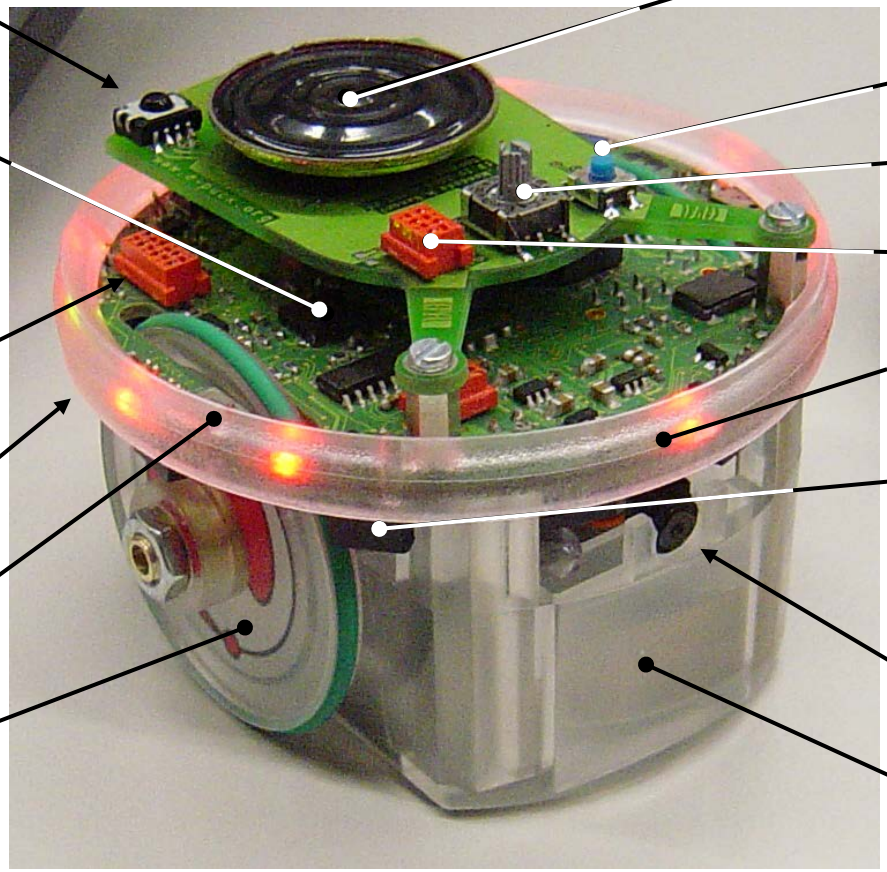
- ~100 laboratories using it
- Two companies producing it, many resellers

e-puck: clear goals

- Develop a modern and cheap desktop mobile mobile robot that can be used in university-level education as motivation tool and system example.
- Have an uniform robotic platform in education at EPFL and abroad.
- Introduce robots as education tools earlier in the curriculum.

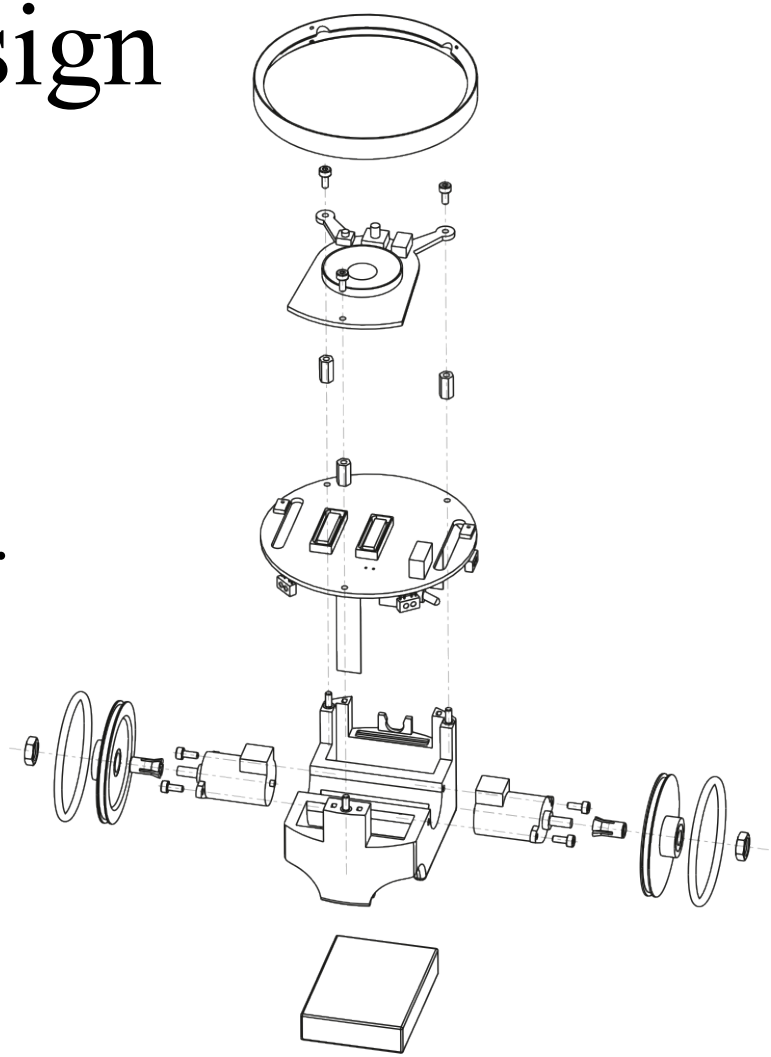
(was clear after discussing with lot of people)

Overview

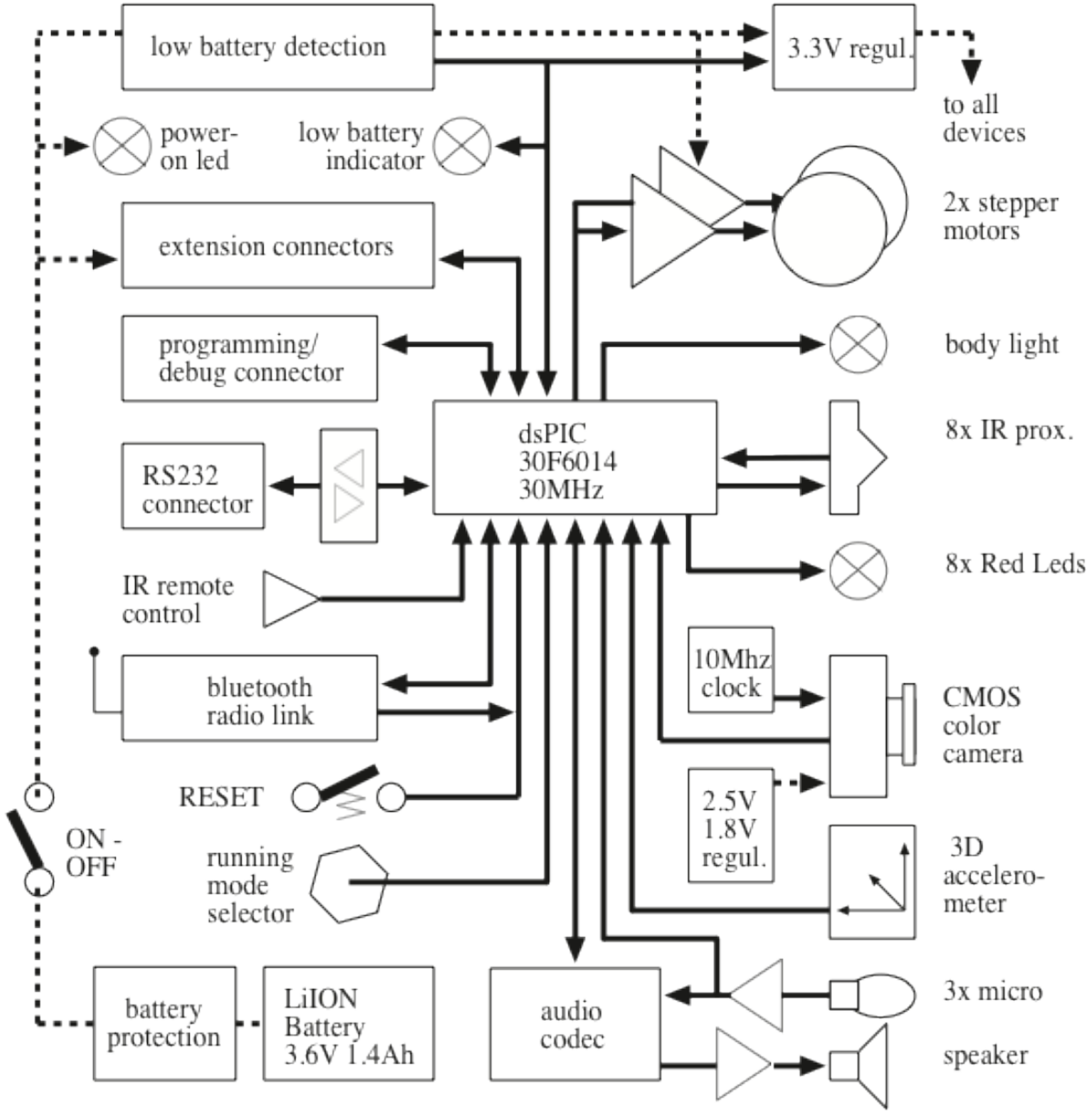

IR receiver
(remote control)
Accelerometer
Programming and
debug connector
(ICD2)
ON-OFF
microphones
Wheels with
stepper motor
Speaker
Reset
Mode selector
RS232
Ring of LEDs
IR proximity
sensors
CMOS camera
Li-Ion accumulator

Robot design

- Clean mechanical structure.
- Modern electronics, processor and software.
- Flexible to teach many fields.
- User friendly.
- Good robustness and simple maintenance.
- Cheap. (<500 euro)



Electronics



Methodology, milestones

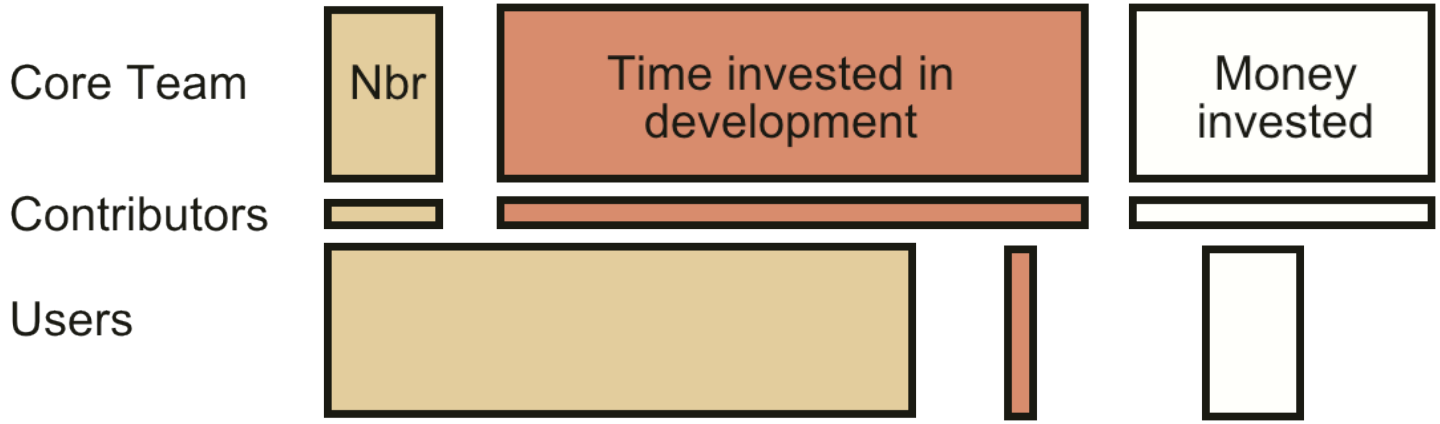
- Interative process implemented in an EPFL project
- “Classical” design methodology with a strong interaction with potential users, both teachers and classes
- Milestones in term of validation into classes

Dissemination and visibility

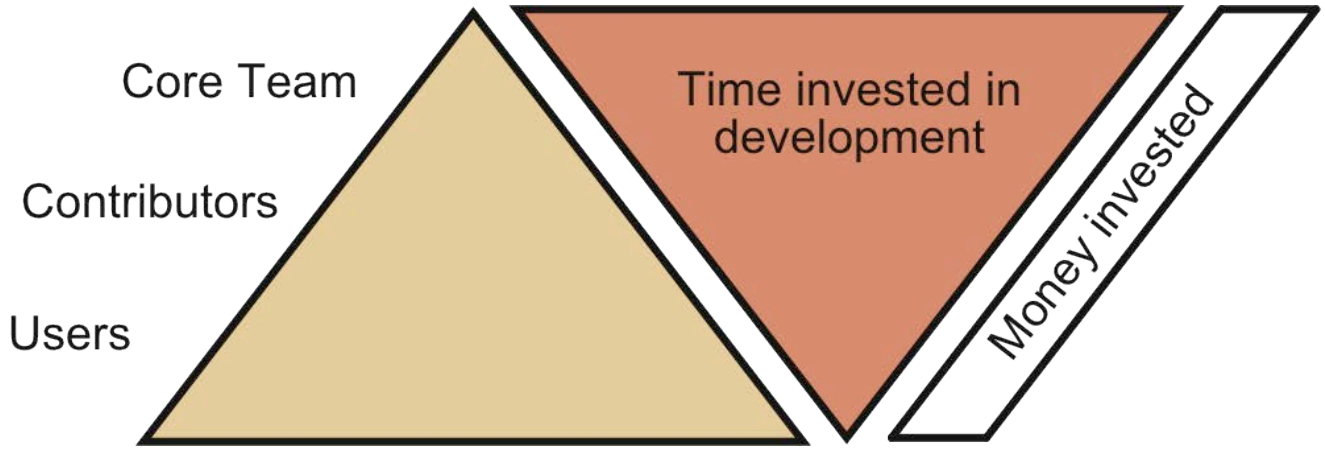
- Collaboration with existing company?
  - Khepera: failed
  - E-puck: success
- New spin-off?
  - Khepera: success
  - Thymio: success
- Open product?
  - E-puck: success in visibility, ~development
  - Thymio: success in visibility, less in development

Software

Proprietary



Open

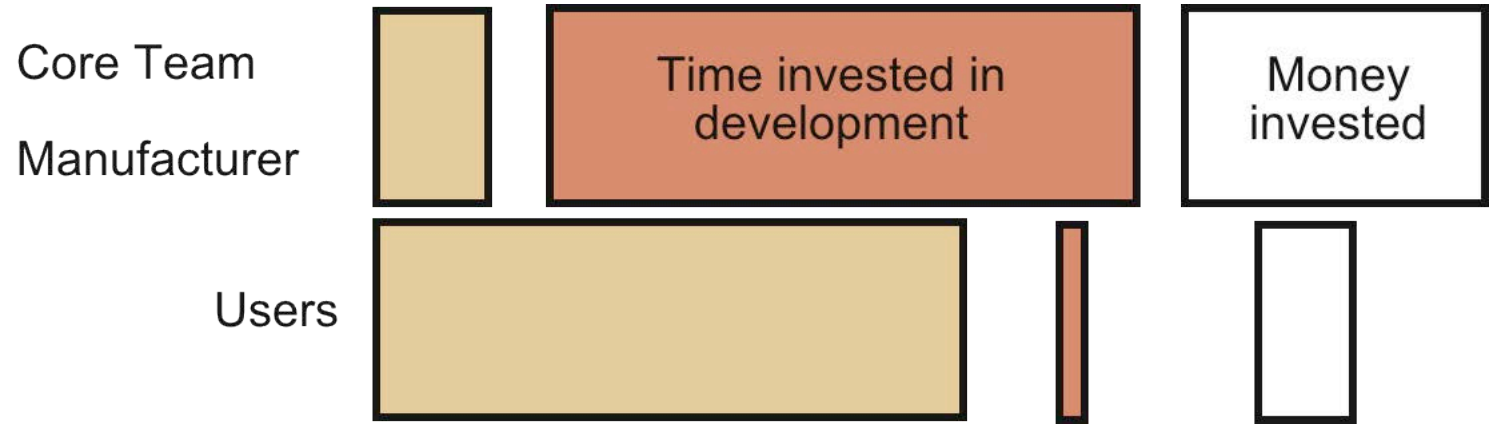


Proprietary to Open Software

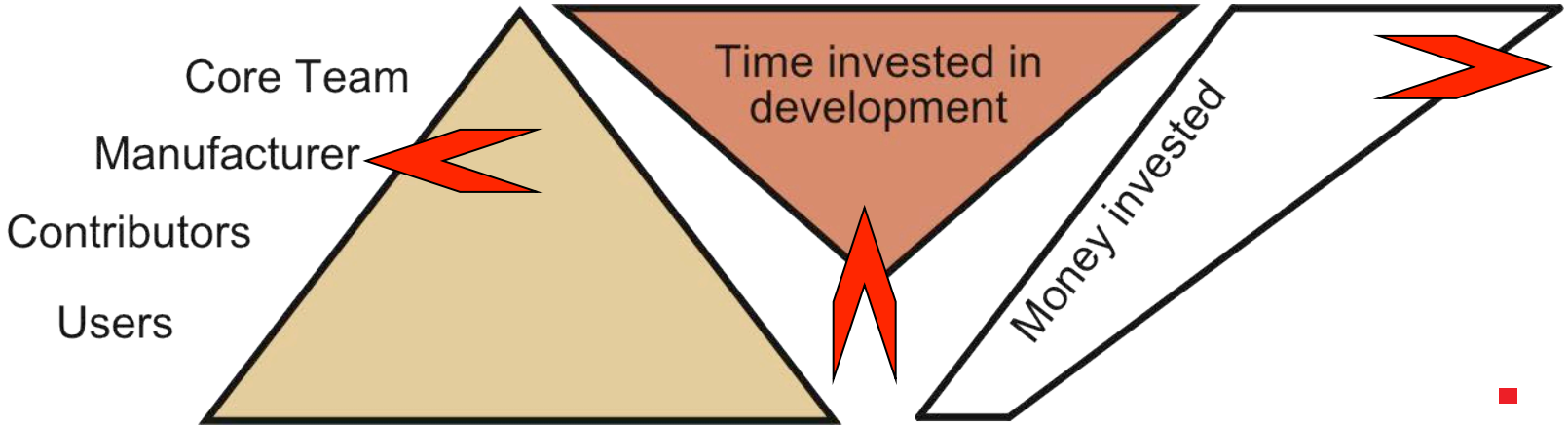
- Toward a real community working on the software in a cooperative way (dev. tools)
- Participation of the user to the development (no gap user-developers). Large contributors middle class
- Development time spread among all layers
- Lower cash investment at all layers (time ≠ money)
- Still often based on proprietary hardware

Hardware

Proprietary



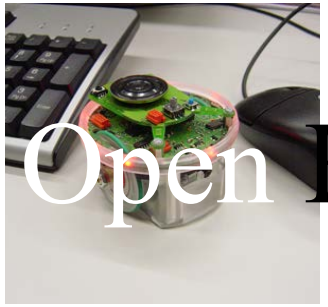
Open



Open Software to Open Hardware

- Introduction of development costs and equipment
- Introduction of a manufacturer in the community
- Less possibilities for participation to the developments
- Still based on components constrains

Proprietary to Open Hardware



- Toward a real community working on the hardware in a cooperative way for a common need
- Adaptive community of developers
- Participation of the user to the development (no gap user-developers)
- Development time spread among all layers
- Same cash investments at all layers (time ≠ money)
- New role of the manufacturer and coordinator

e-puck as Open Hardware

Advantages:

- Drive hardware developers into “open” dynamics
- Community providing quality and energy
- Perfect spreading in academic environment
- Fully transparent for education
- Lower support costs
- Manufacturers: competition on service quality, reduction of vendor locking

Challenges:

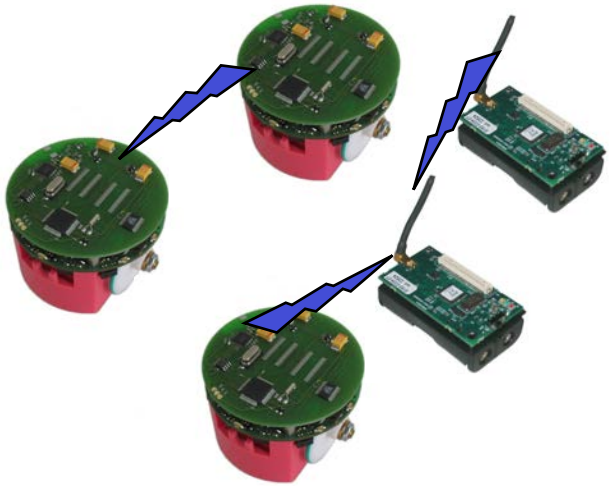
- Invest to spread, not common reflex
- Finding right manufacturer, business model
- Coordinate the community

Problems found

- Open hardware does not mean “everybody can manufacture it”
- Open documentation, open production files, open access to manufacturer, open …?
- Control or not control your community? Sort or not sort your manufacturers?
- Few real feedback, people use and do not contribute => importance of contributive tools
- How to maintain the community on the long term?

Contributions in hardware

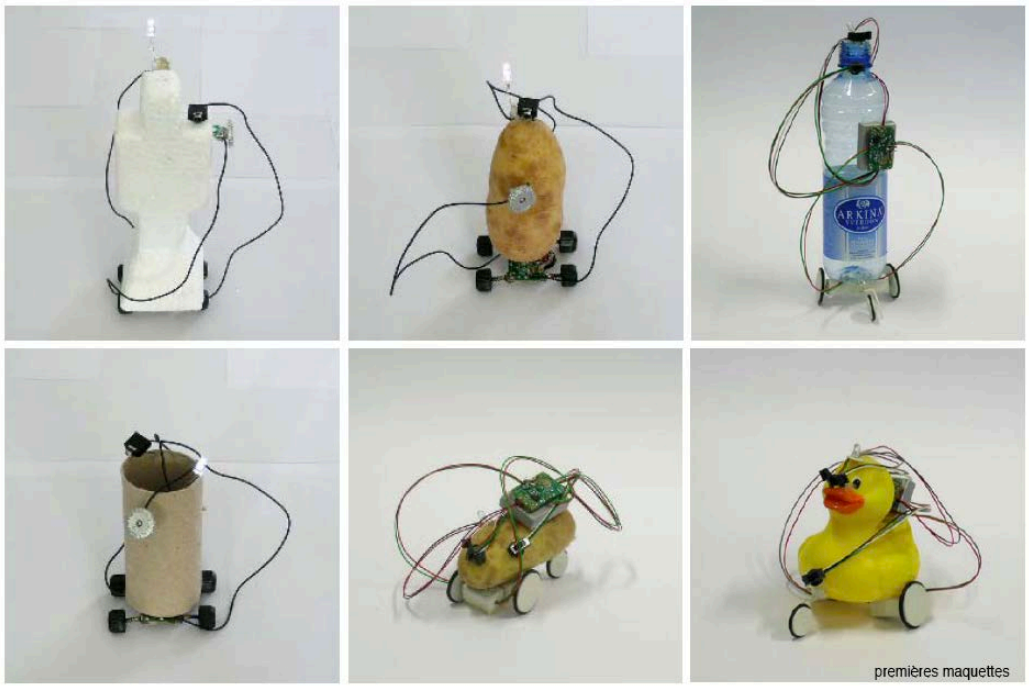
Extension turrets:



Contributions in software

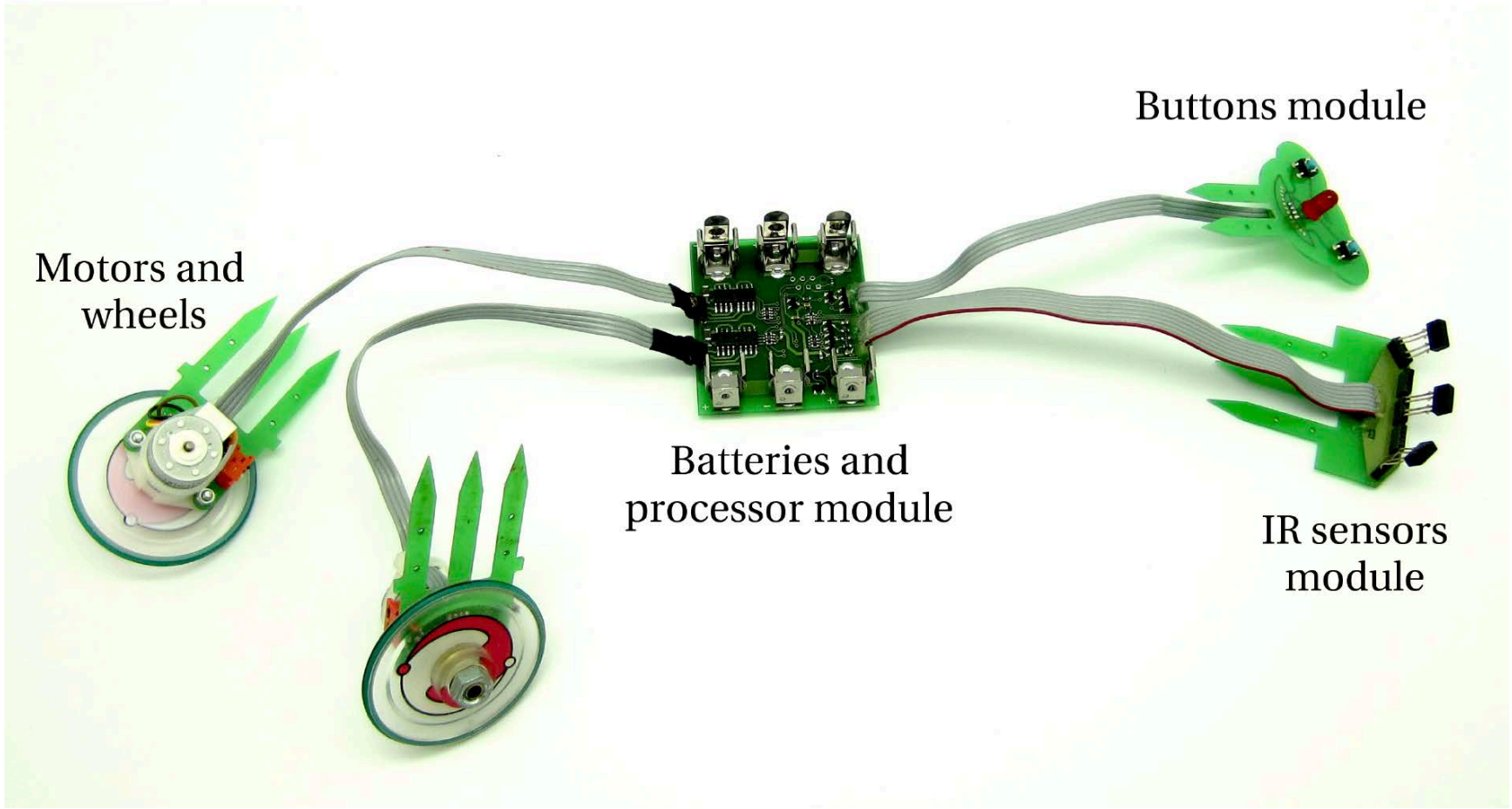
- Developing environments
- Low level libraries
- Demos

Thymio II robot



Julien Ayer & Nicolas Le Moigne, ECAL

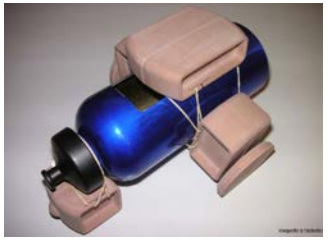
Thymio 0 robot

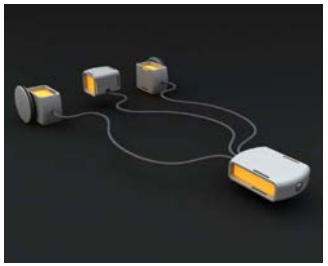


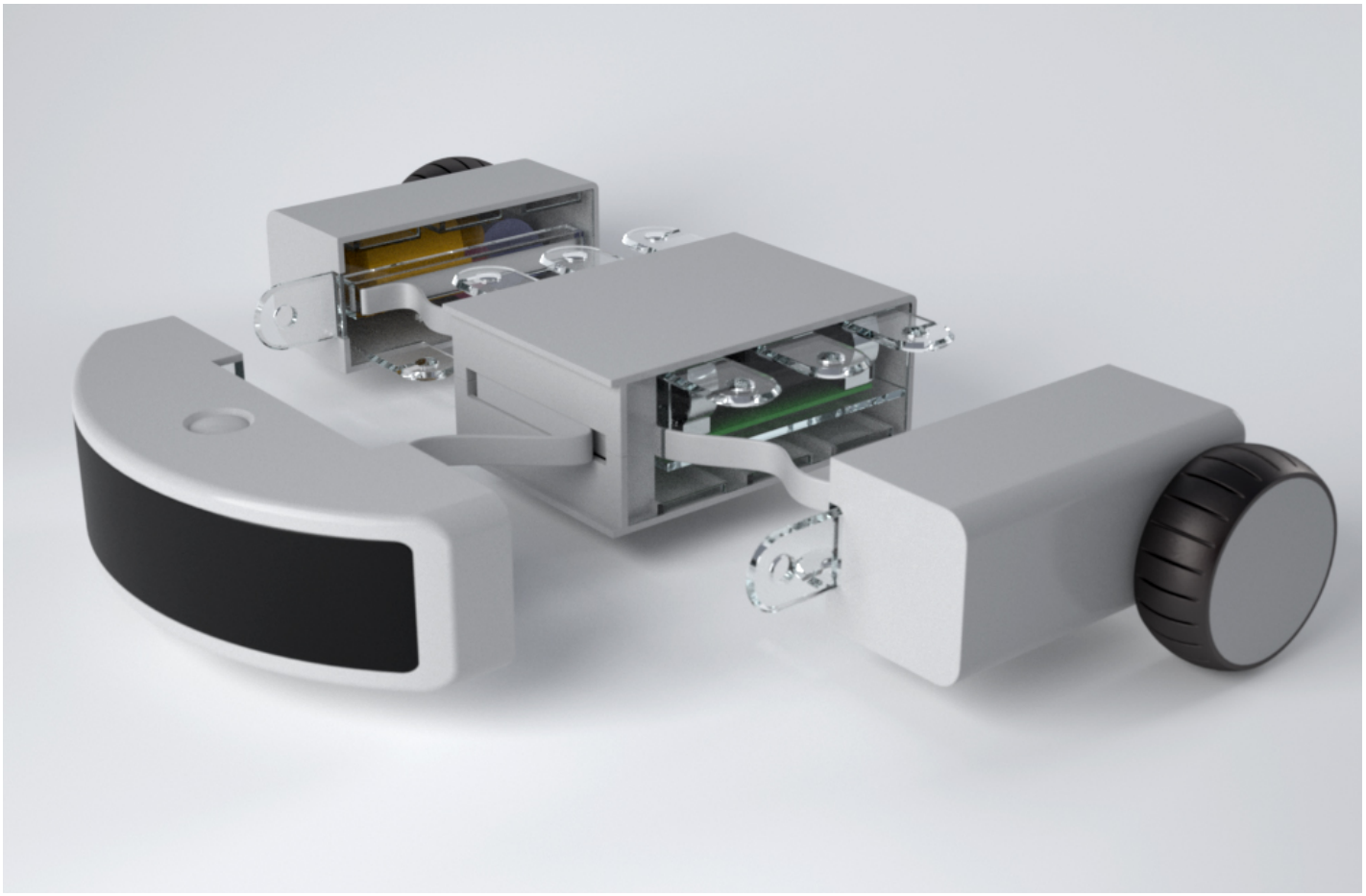
Fanny Riedo, "Thymio: a holistic approach to designing accessible educational robots", PhD thesis 6557, EPFL, (2015)

Thymio 0 robot

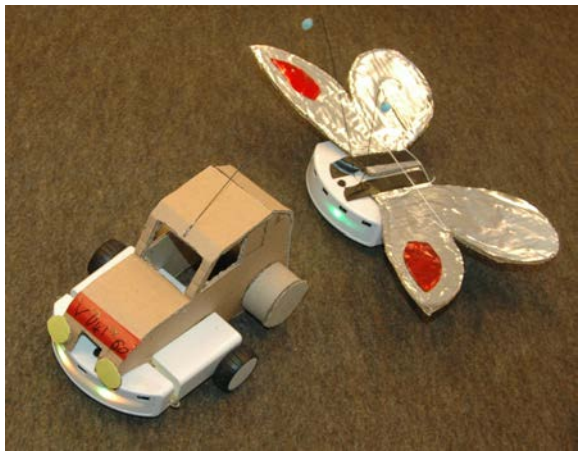
Thymio II robot





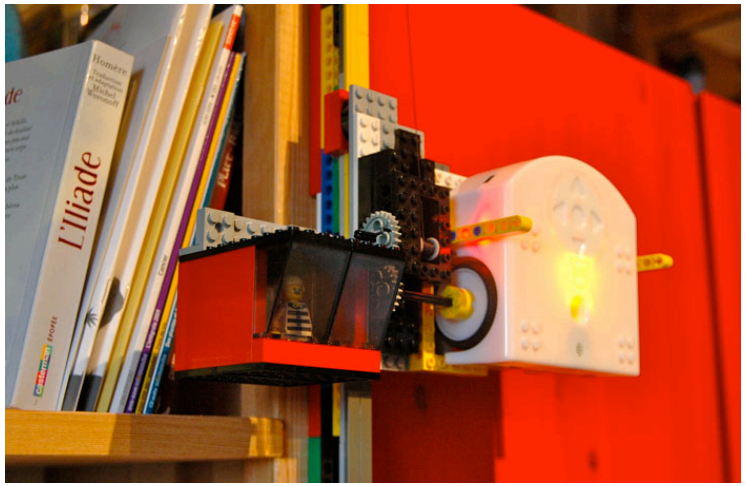


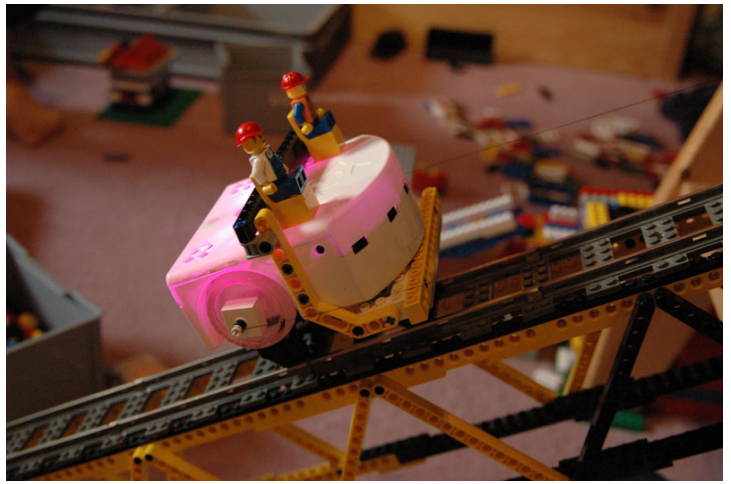
Thymio II robot

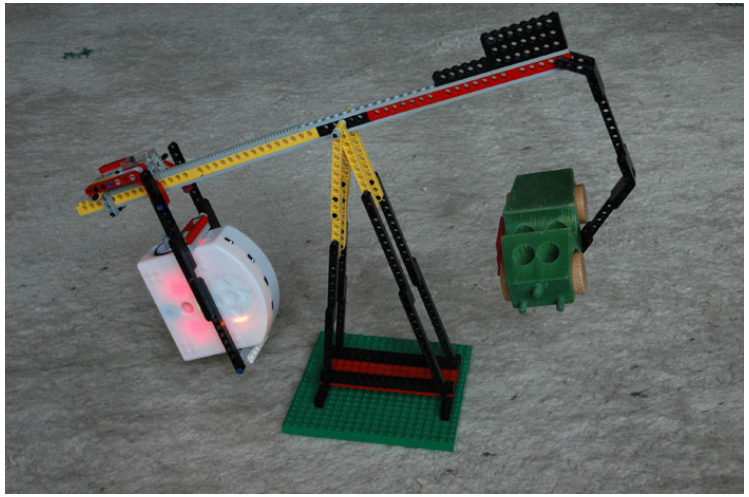


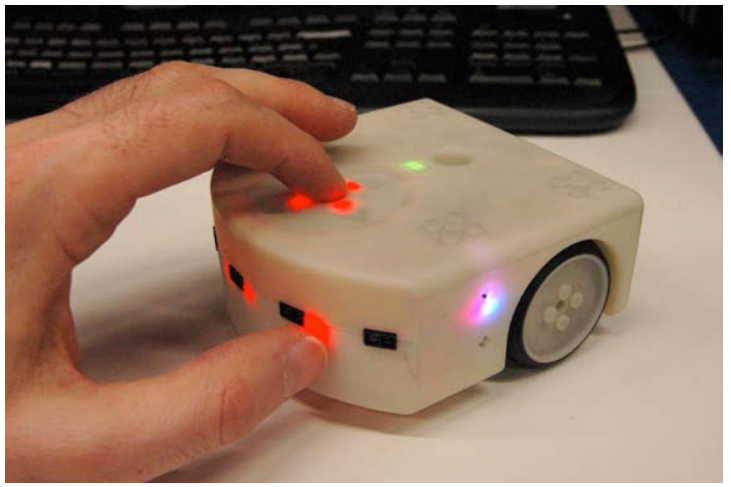
Thymio II robot

Thymio II robot









Thymio II robot

Impact:

- Sold 50’000 units mainly to schools
- Convinced teachers, institutions
- New interaction features
- Innovative programming concept and environment
- Excellent base for user studies

Thymio II robot

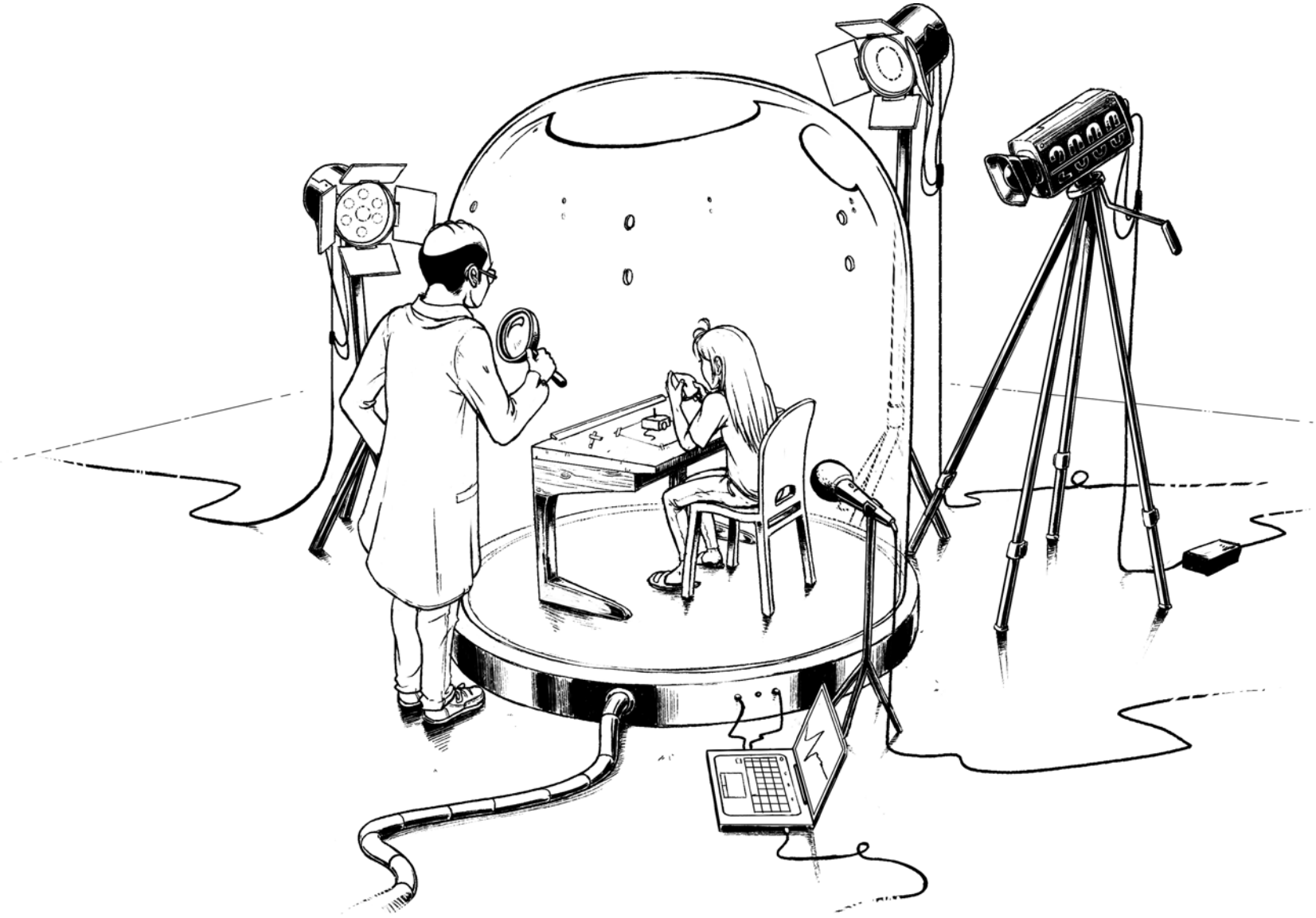
The customer?

- Us for promotion of technology
- Our boss
- Colleagues in promotion of science
- More and more schools and teachers

Thymio II robot

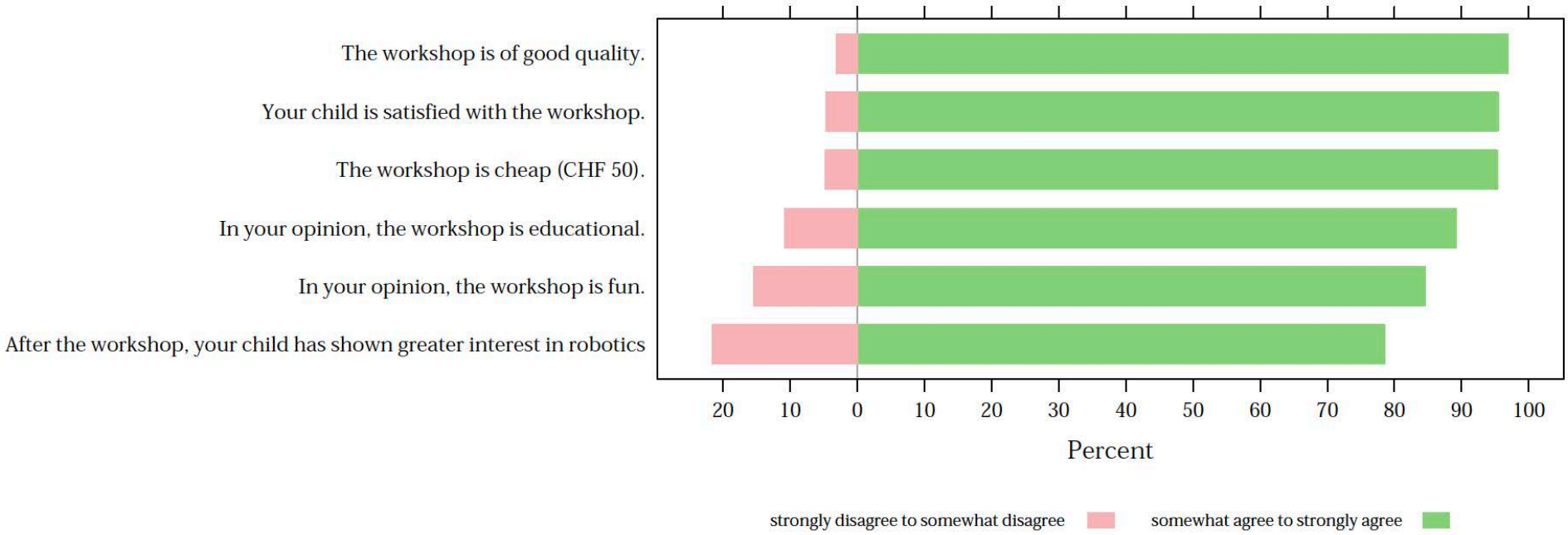
Specifications: where are they?

- Based on a lot of feedback combined with some innovative ideas
- Defined during three years of project
- Based on our own needs
- Based on our design experience
- Fitting mass-production needs



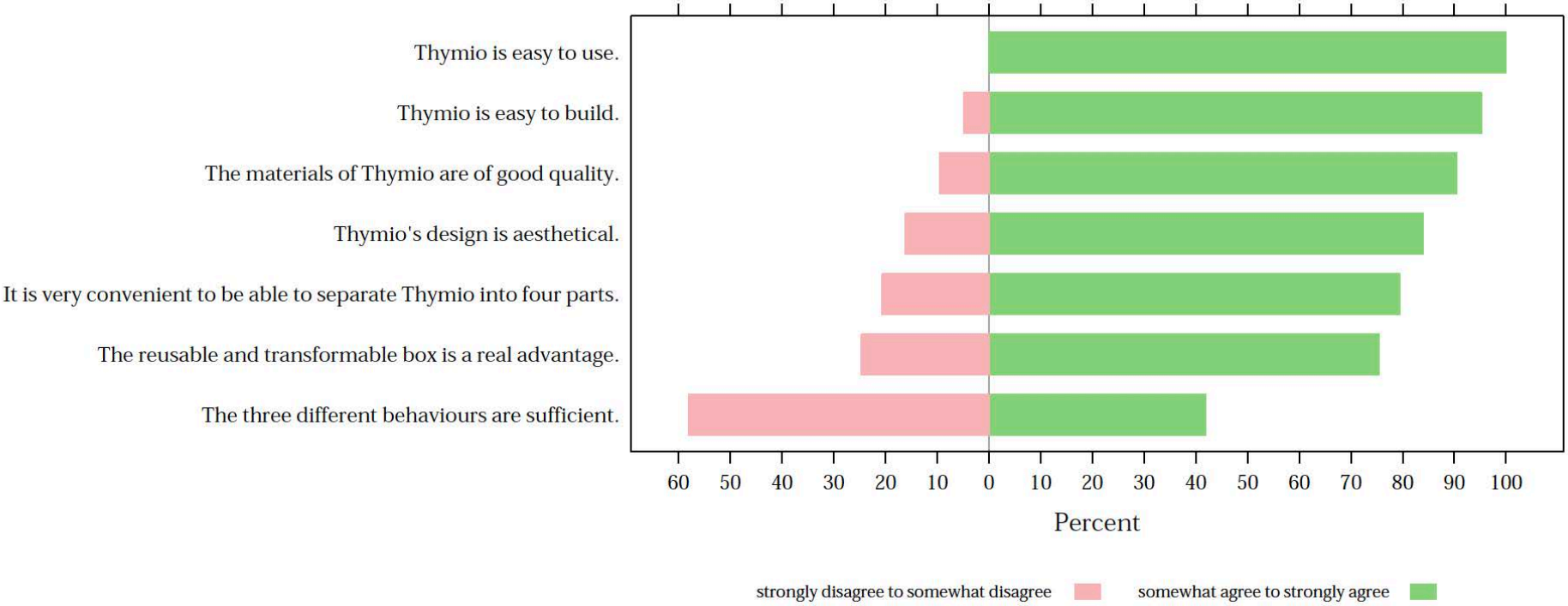

?
!!
TAP TAP
TAP TAP
Toc! Toc!
Poc
HE!HO!
TUP

Market Study with HEIG-VD
Parents feedback on Thymio I, n=65



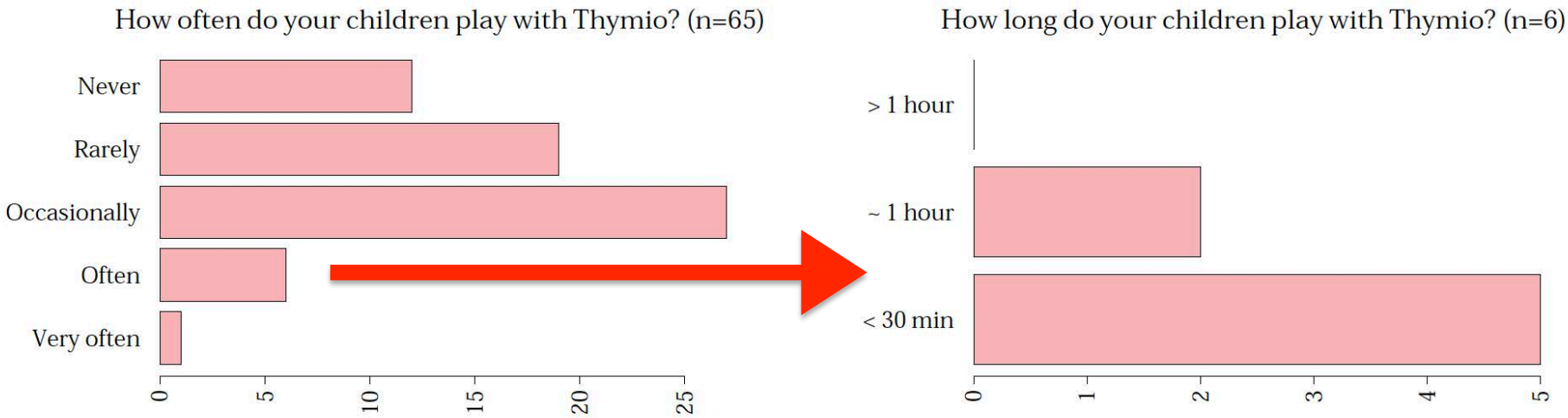
Fanny Riedo, "Thymio: a holistic approach to designing accessible educational robots", PhD thesis 6557, EPFL, (2015)

Parents feedback on Thymio I, n=65

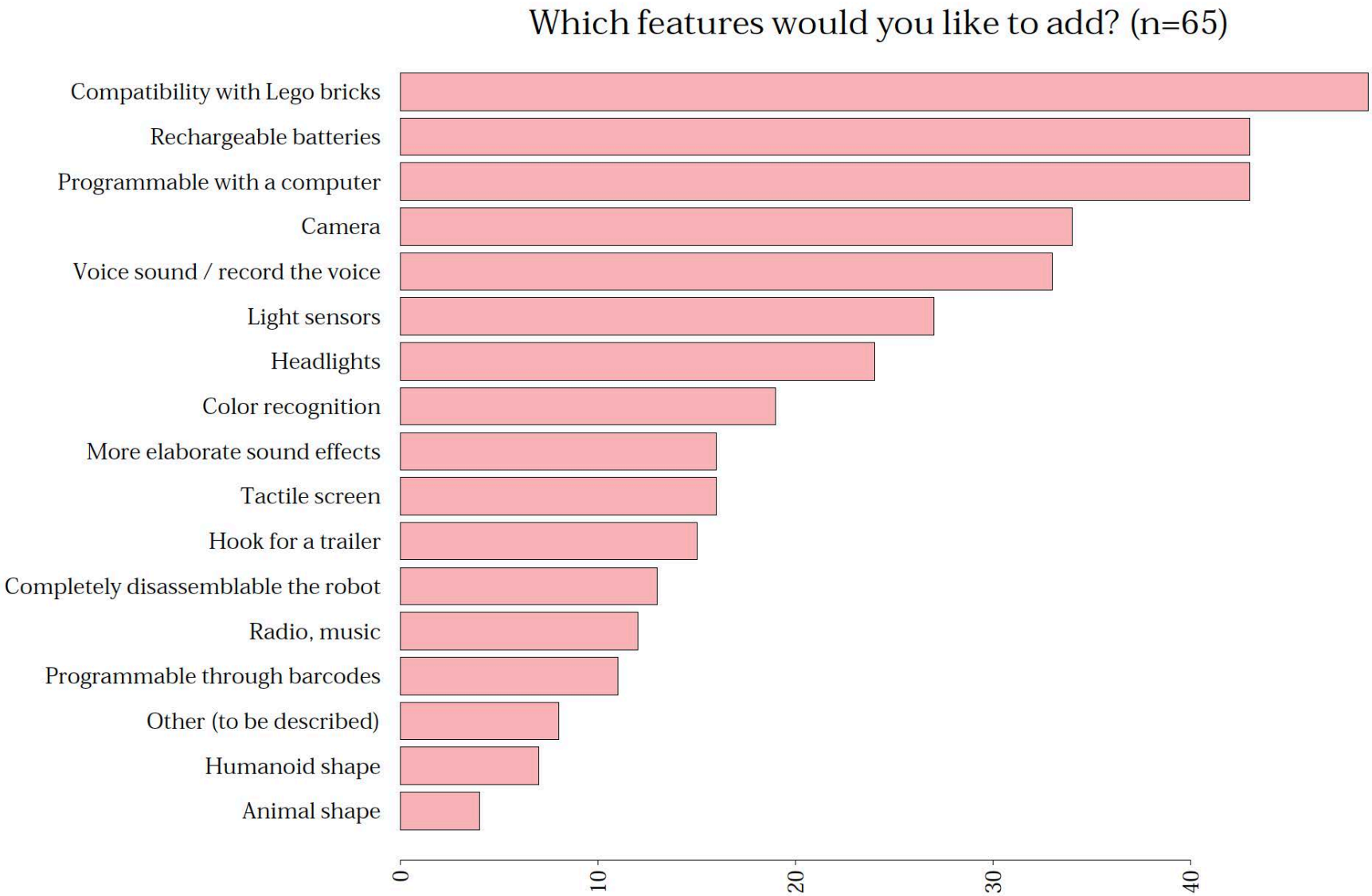


Fanny Riedo, "Thymio: a holistic approach to designing accessible educational robots", PhD thesis 6557, EPFL, (2015)

Parents feedback on Thymio I, n=65



Fanny Riedo, "Thymio: a holistic approach to designing accessible educational robots", PhD thesis 6557, EPFL, (2015)



Fanny Riedo, "Thymio: a holistic approach to designing accessible educational robots", PhD thesis 6557, EPFL, (2015)

Thymio II robot in the school curriculum: teachers

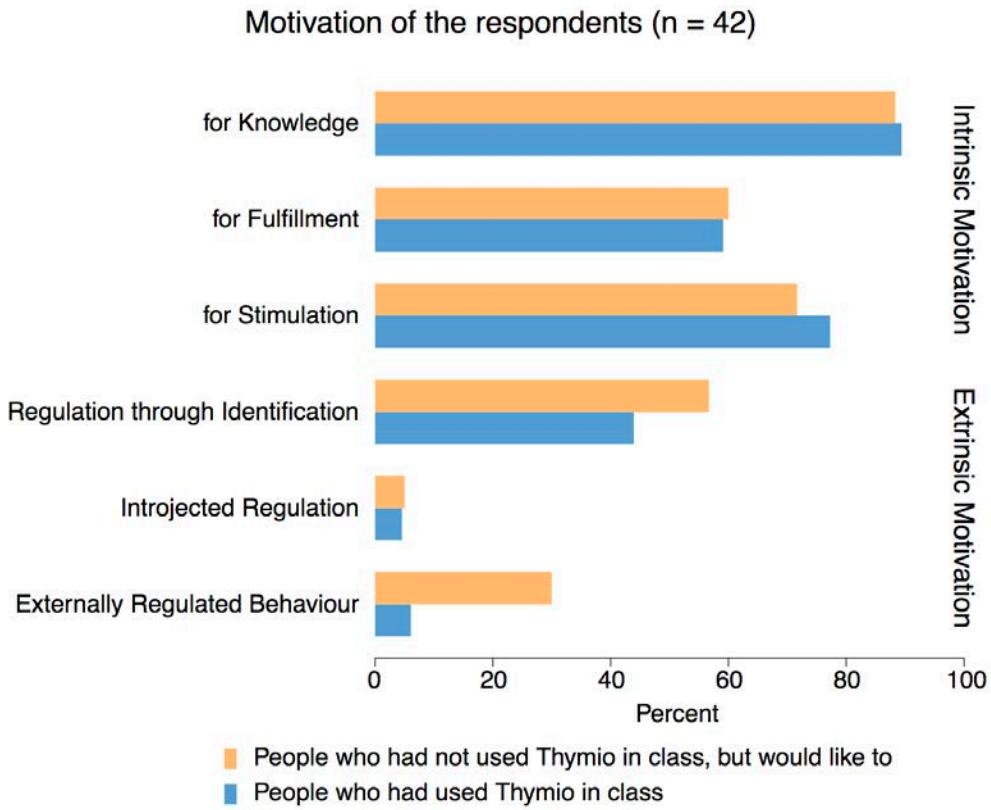
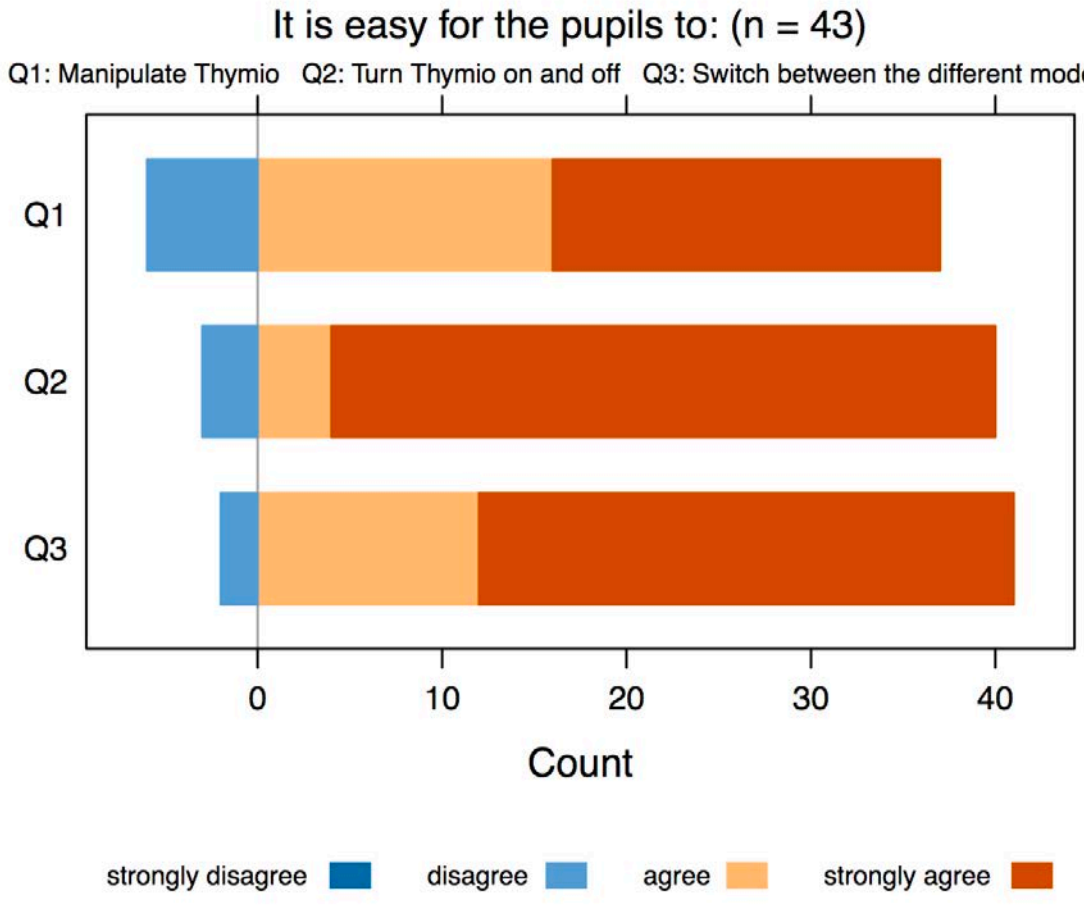


Fig. 5: Motivation of teachers: each type of motivation was measured by three different questions. Amotivation is not considered because this study covers only teachers who had decided to act, by attending at least one training session.

Chevalier, Morgane, Fanny Riedo, and Francesco Mondada. "Pedagogical Uses of Thymio II: How Do Teachers Perceive Educational Robots in Formal Education?." *IEEE Robotics & Automation Magazine* 23, no. 2 (2016): 16-23.

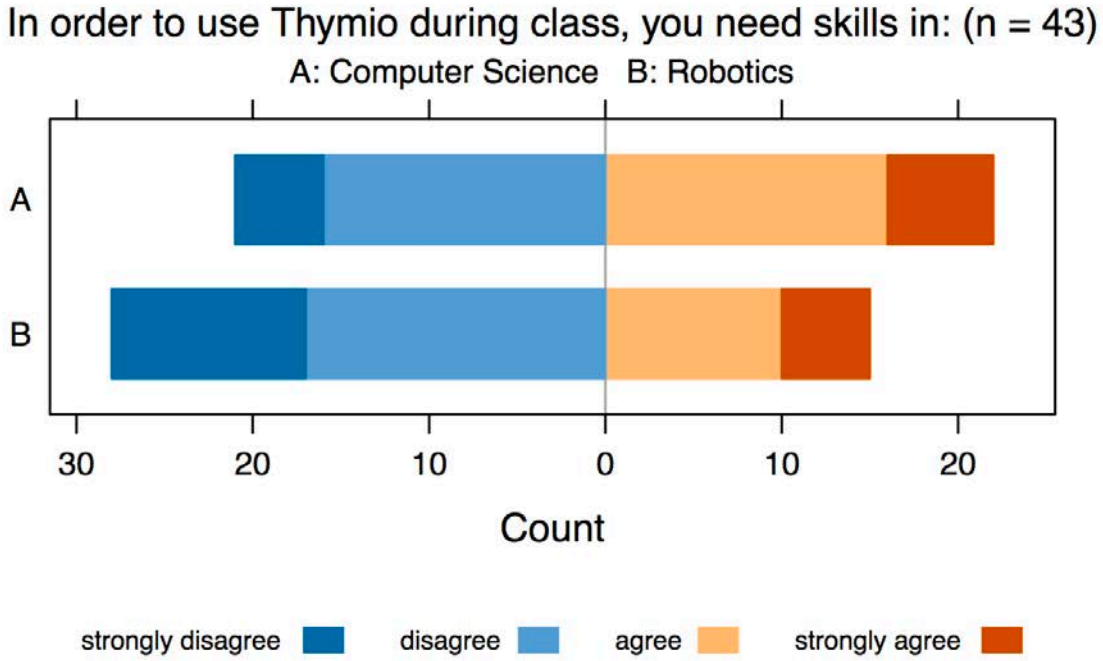
Thymio II robot in the school curriculum: teachers



(b) Teachers' opinions on Thymio's usability by pupils.

Chevalier, Morgane, Fanny Riedo, and Francesco Mondada. "Pedagogical Uses of Thymio II: How Do Teachers Perceive Educational Robots in Formal Education?." *IEEE Robotics & Automation Magazine* 23, no. 2 (2016): 16-23.

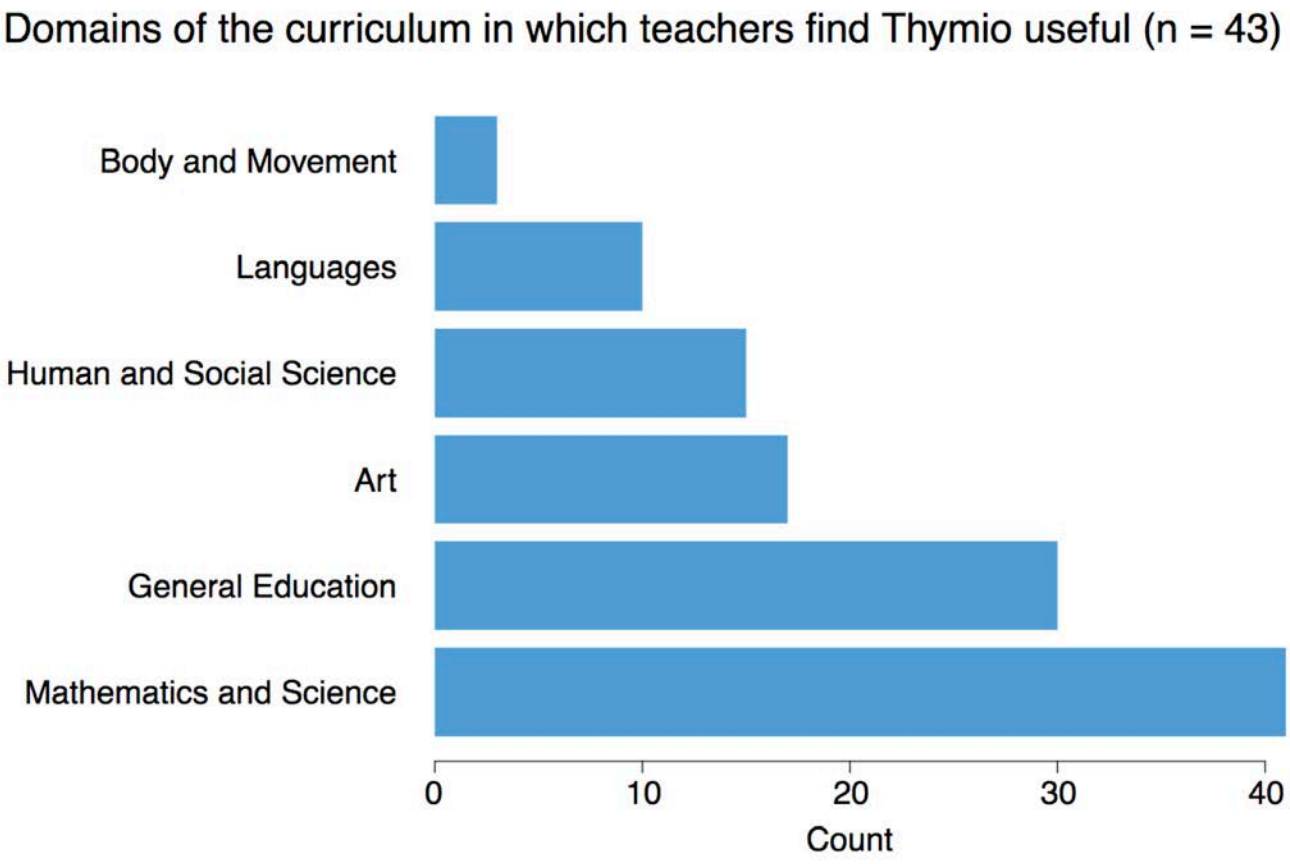
Thymio II robot in the school curriculum: teachers



(a) Professional skills teachers consider necessary in order to use Thymio with their class.

Chevalier, Morgane, Fanny Riedo, and Francesco Mondada. "Pedagogical Uses of Thymio II: How Do Teachers Perceive Educational Robots in Formal Education?." *IEEE Robotics & Automation Magazine* 23, no. 2 (2016): 16-23.

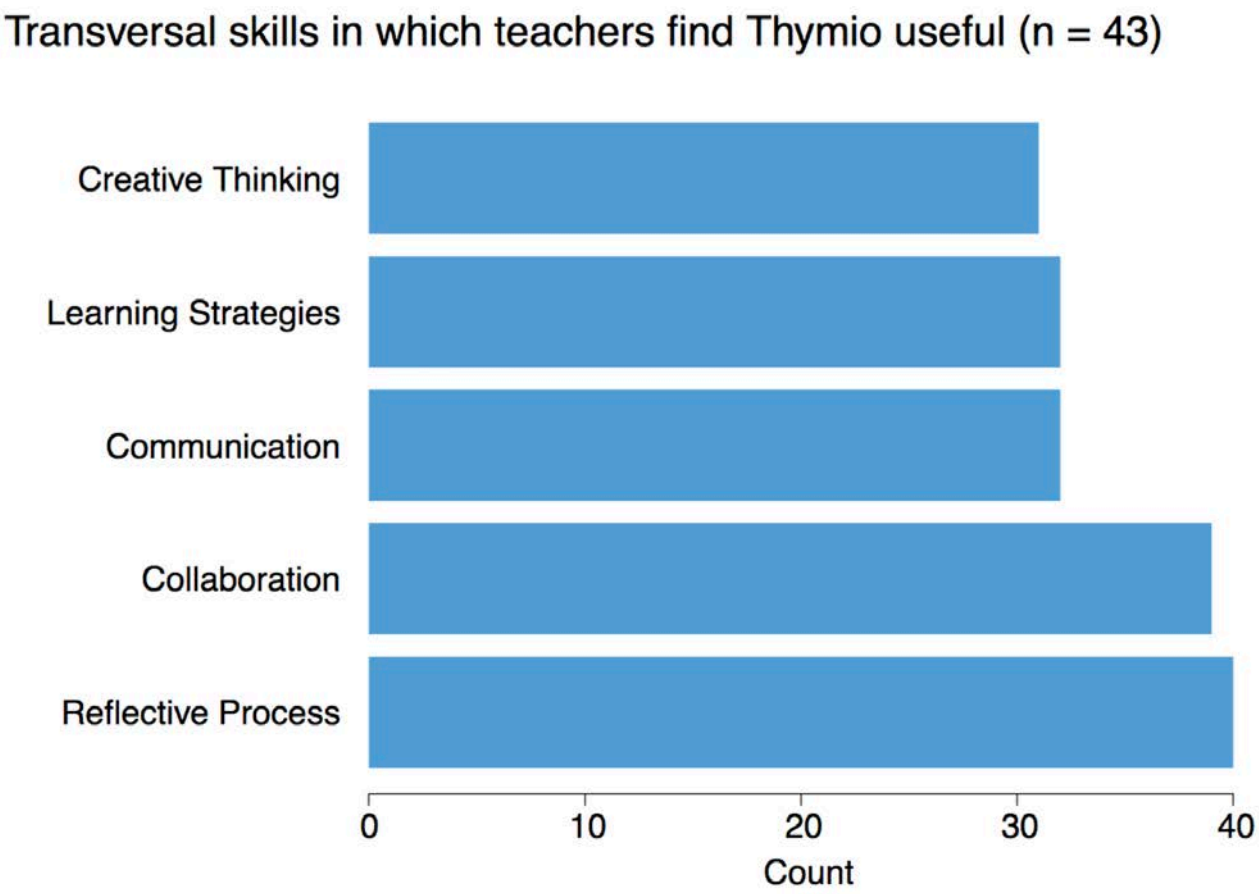
Thymio II robot in the school curriculum



(a) Domains of the Swiss curriculum (PER)

Chevalier, Morgane, Fanny Riedo, and Francesco Mondada. "Pedagogical Uses of Thymio II: How Do Teachers Perceive Educational Robots in Formal Education?." *IEEE Robotics & Automation Magazine* 23, no. 2 (2016): 16-23.

Thymio II robot in the school curriculum



(b) Transversal objectives of the Swiss curriculum (PER)

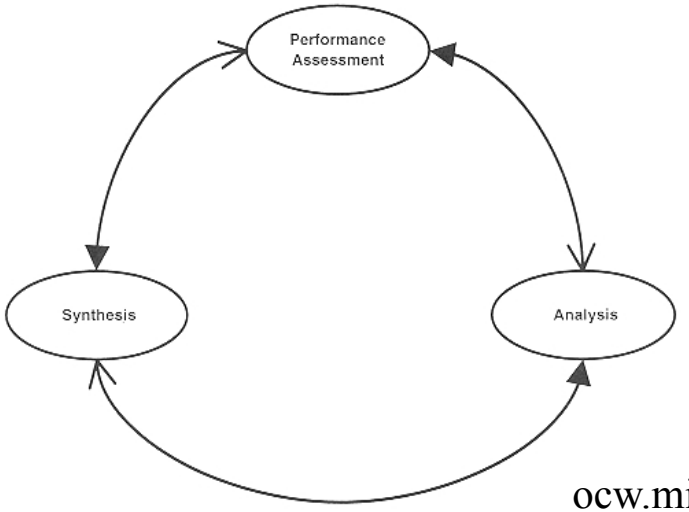
Chevalier, Morgane, Fanny Riedo, and Francesco Mondada. "Pedagogical Uses of Thymio II: How Do Teachers Perceive Educational Robots in Formal Education?." *IEEE Robotics & Automation Magazine* 23, no. 2 (2016): 16-23.

Thymio II robot

Methodology

Design process / milestones

- Classical approach, lot of constraints for low price
- Design by iterations, no real time pressure



ocw.mit.edu/

Thymio II robot

Open / proprietary IP

- Open
  schematics, implementation and code
- Manufacturing by a non-profit association
- Main result: image,
  not participation!

Thymio II robot

Selling the idea:

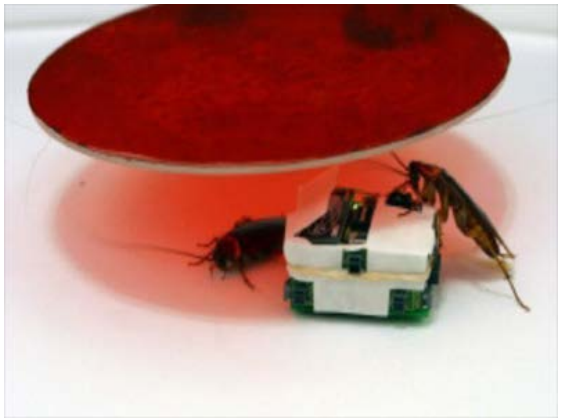
- based on the robotic festival, and contacts
- answering to strong needs
- corresponding to a trend (digitalization)
- low cost

Thymio II robot

Research topics:

- Robot mechatronics for education
- Interaction for education
- User studies (eye-tracking)
- Acceptance in school
- Biological studies

Leurre project



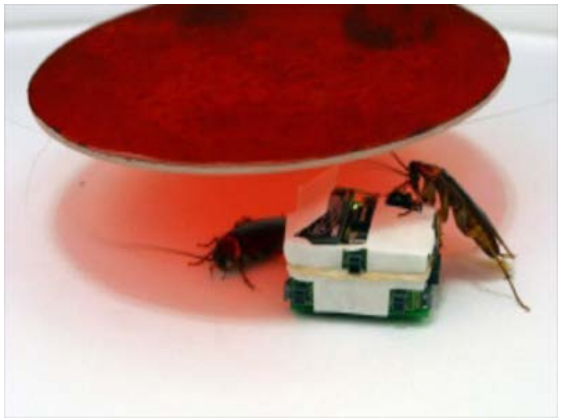
Achievements

- First creation of a mixed society (insects and robots well integrated)
- New knowledge on insects societies rules
- Methodology to influence animal collective decisions by artificial creatures
- Results on animal society decisions influenced by robots

Scientific impact

- Publication on SCIENCE in November 2007
- Continuation with SNF and FP7 on vertebrates
- Large H2020 continuation on bees

Leurre project



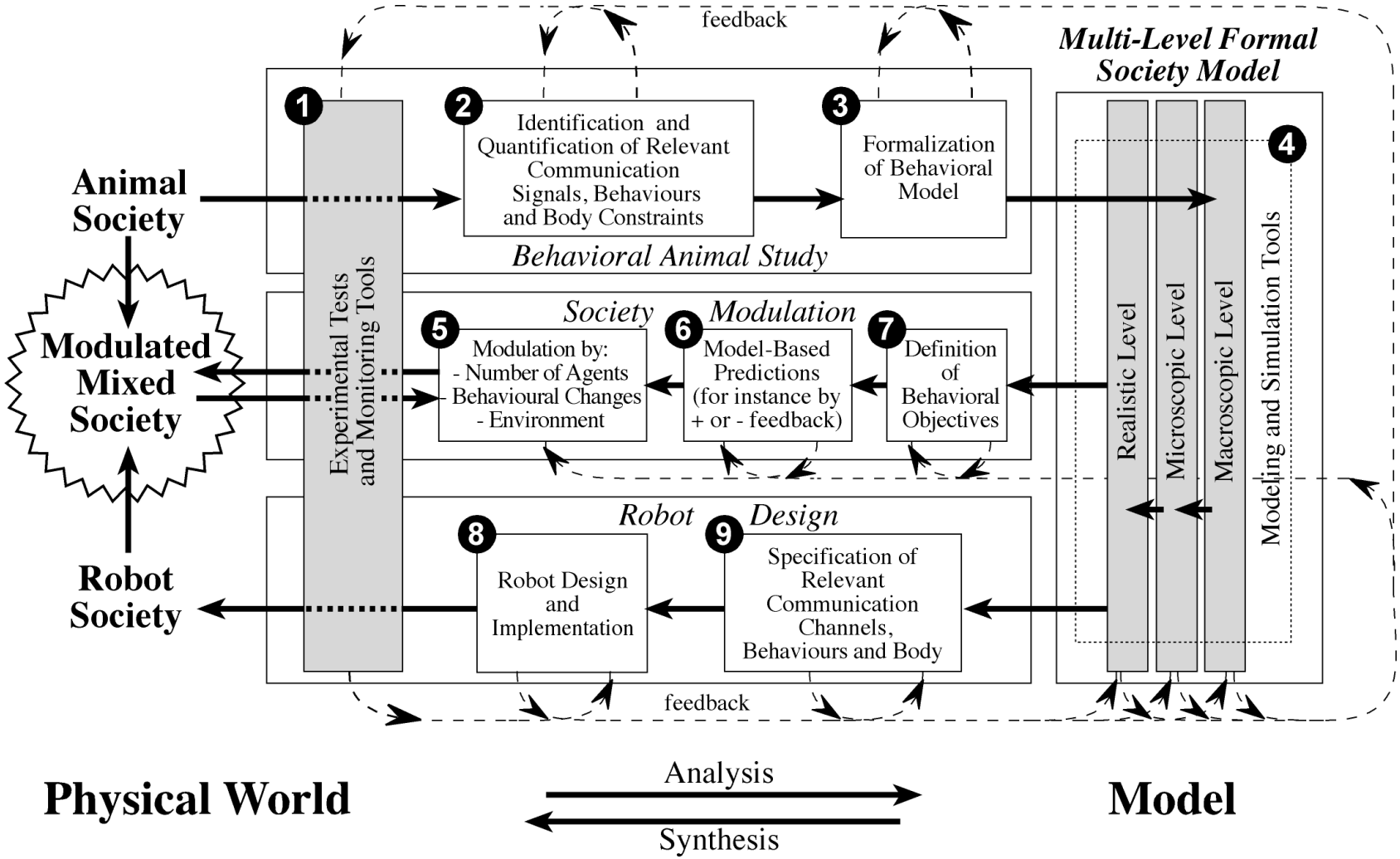
The customer / the market

- Our colleagues biologists

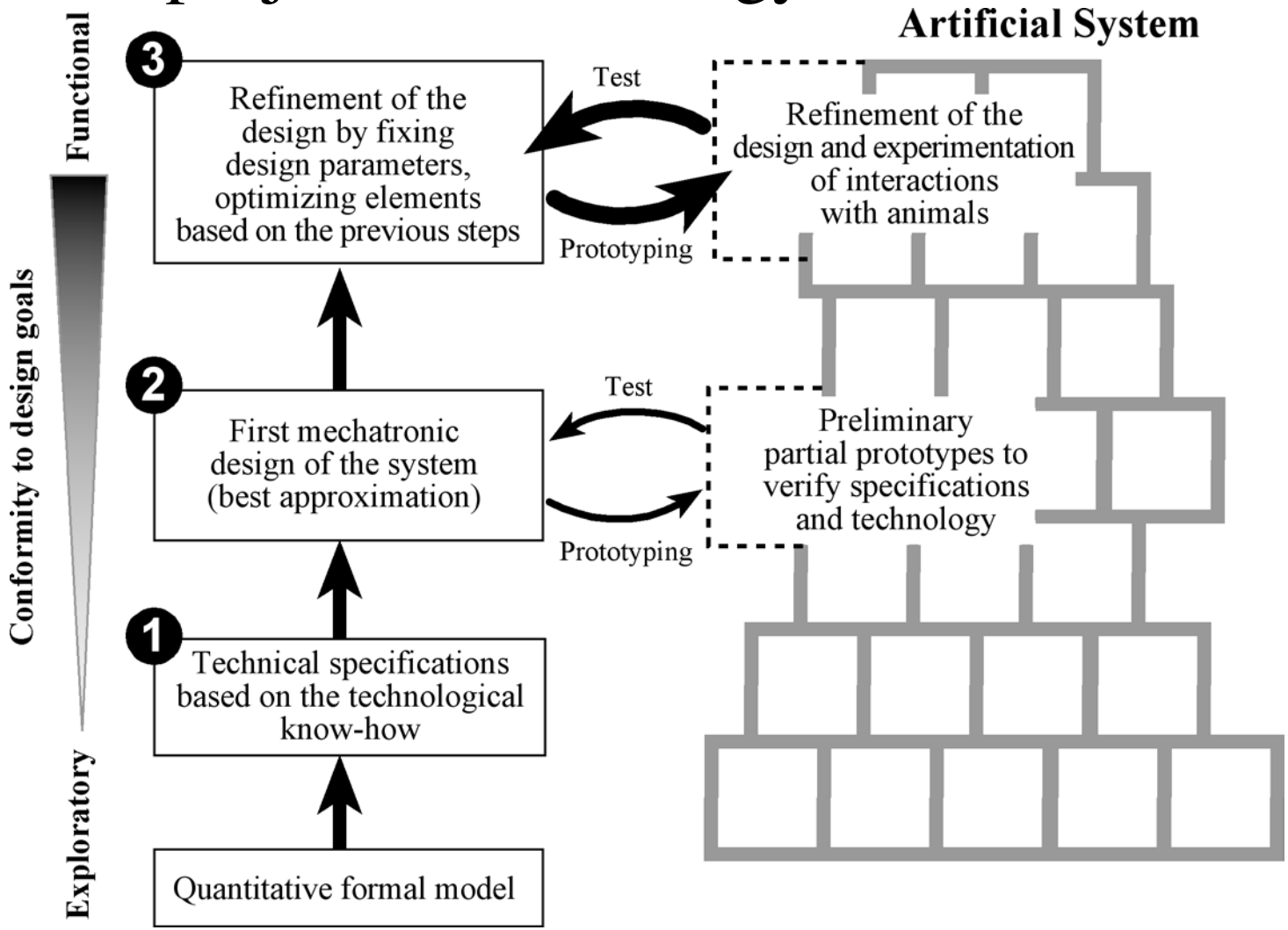
Specification sources

- Defined during the project, following the methodology

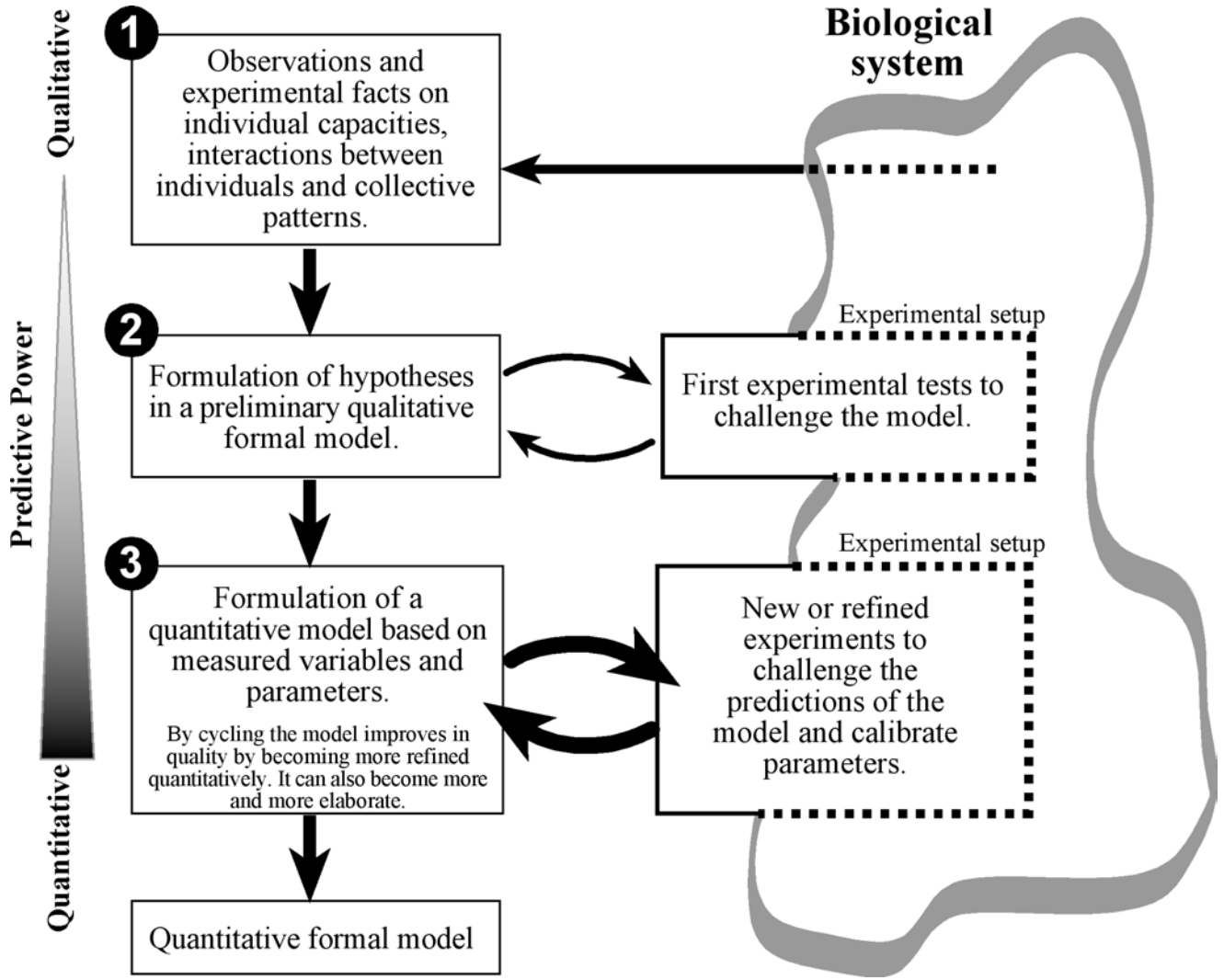
Leurre project: methodology



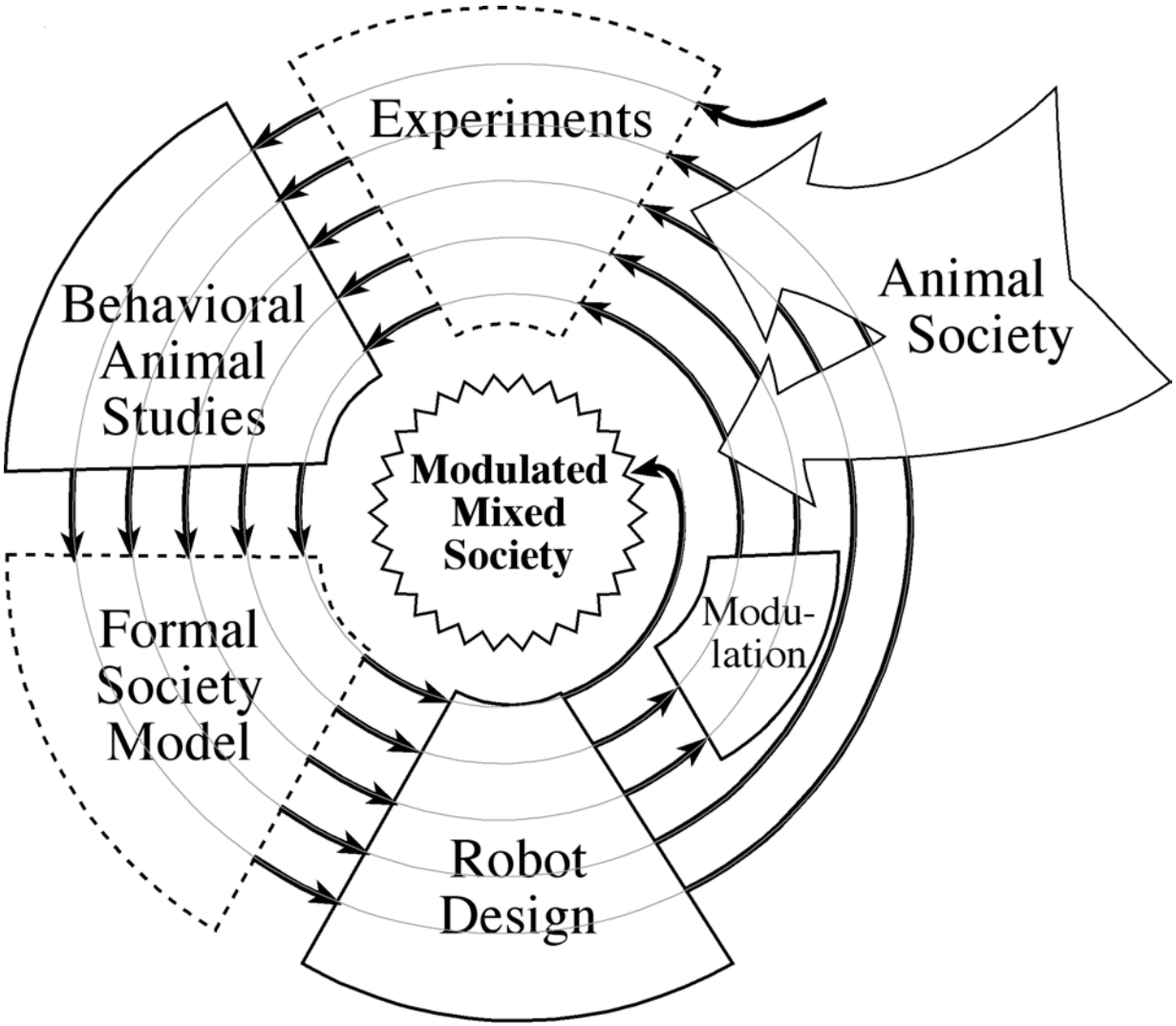
Leurre project: methodology



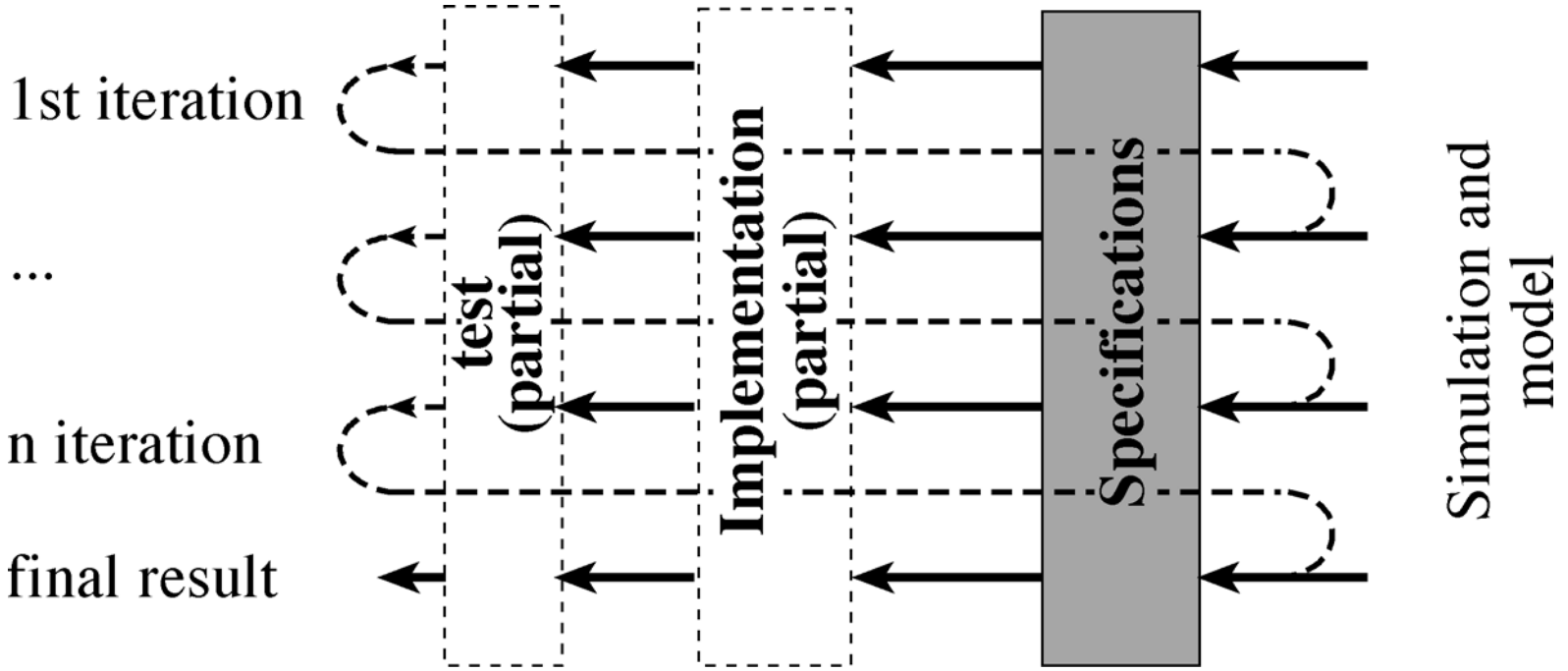
Leurre project: methodology



Leurre project: methodology



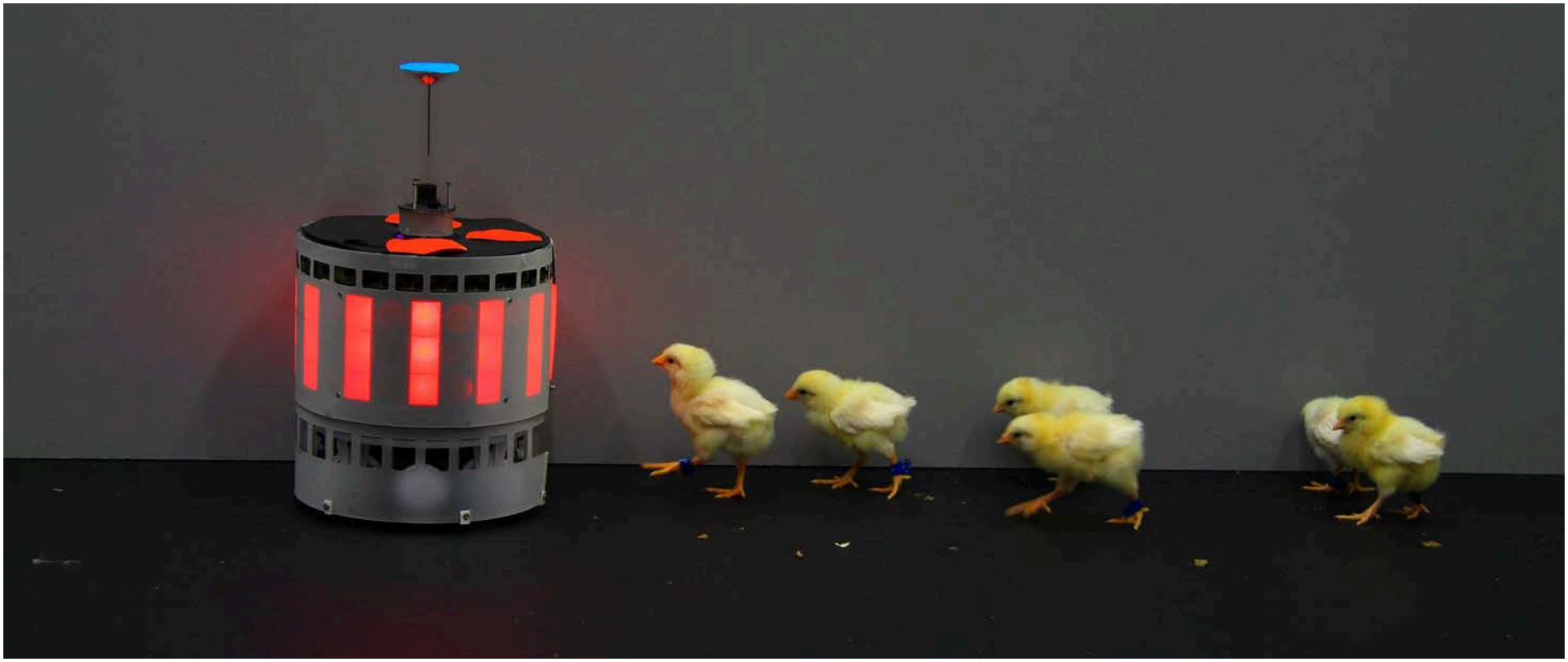
Leurre project: methodology



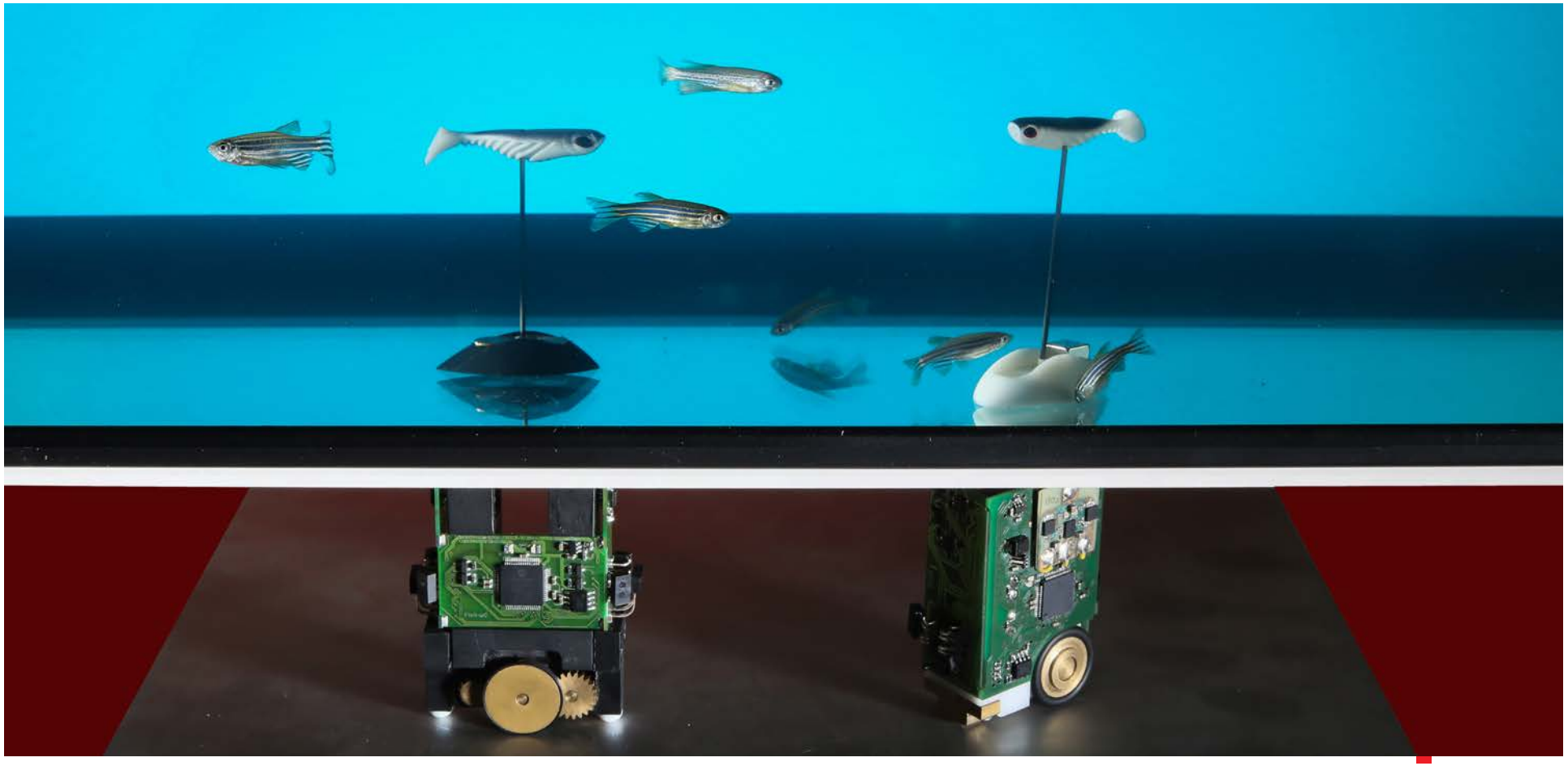
Selling the idea

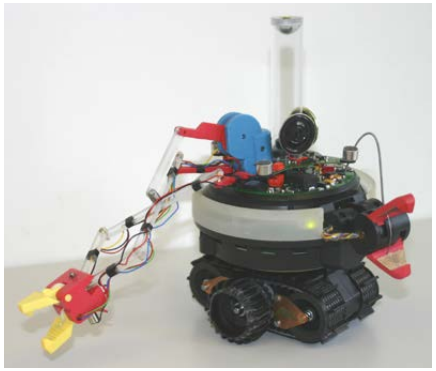
- Impact on people imagination
- Based on scientific impact (SCIENCE publication)

Research activities



Research activities





Swarm-bots

Achievements

- Most advanced robotic collective system (number of sensors, actuators, self-assembling ability)
- New knowledge on swarm systems
- Creation of a dedicated research platform

Impact

- Swarm-bots project seen as “success story” by FET
- Large number of publications
- s-bot ranked on position 39 in the list of “The 50 Best Robots Ever” (fiction or real) by the Wired Journal in 2006

Swarm-bots

The customer?

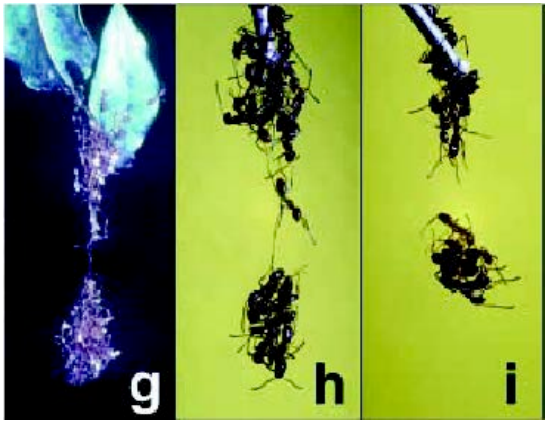
- Colleagues in the project (CS)
- Reviewers

Specifications?

- Long and hard process…

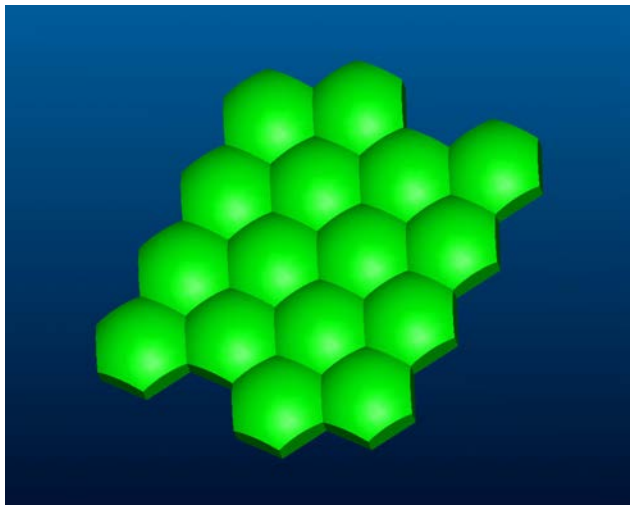

l


c

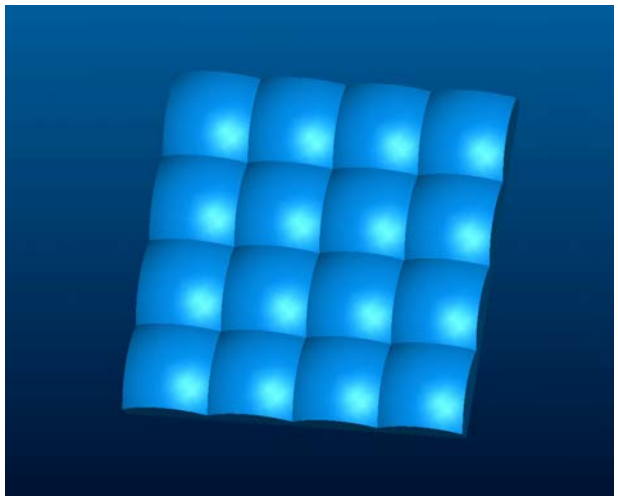

g
h
i

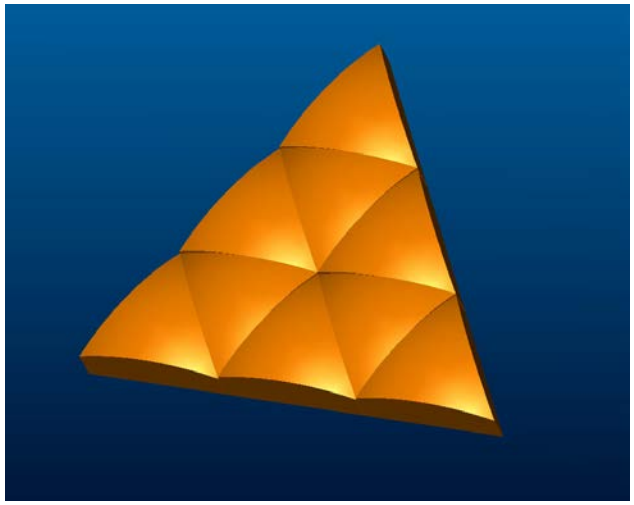

b

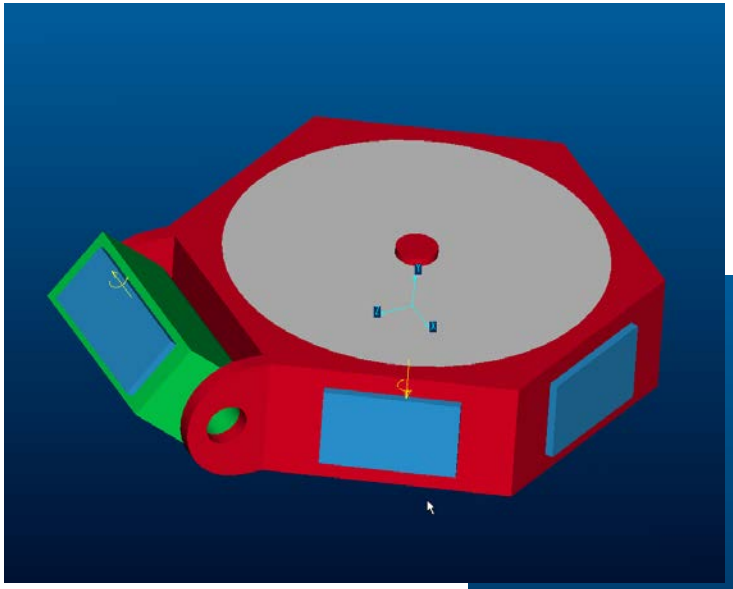

m

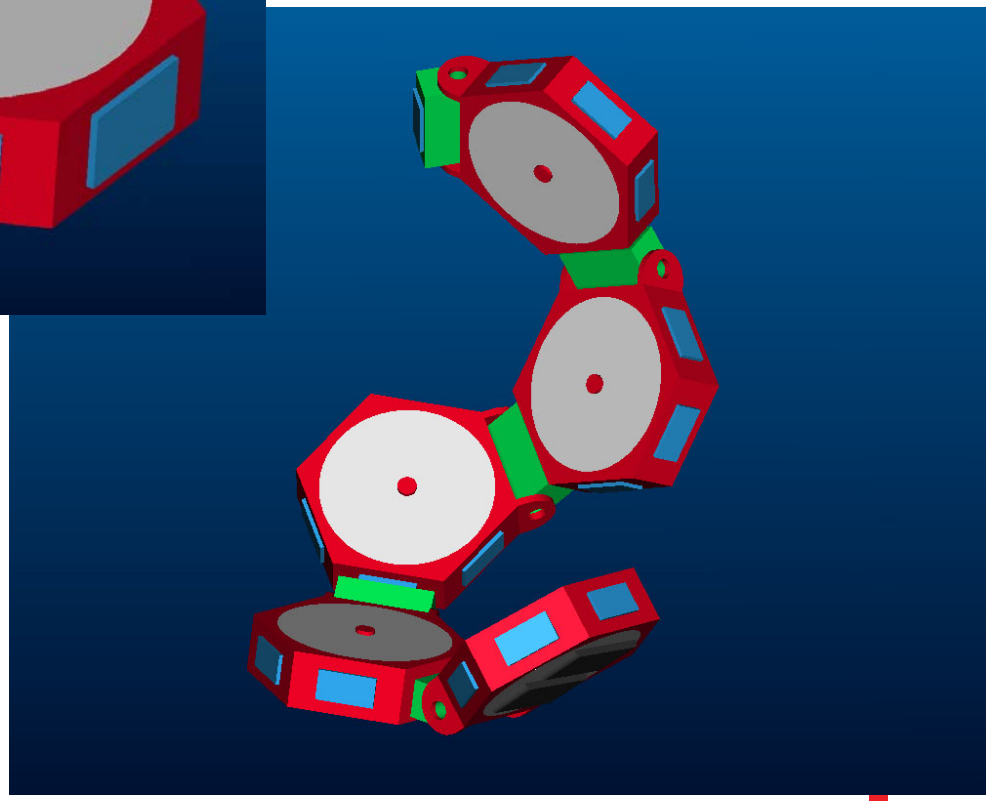


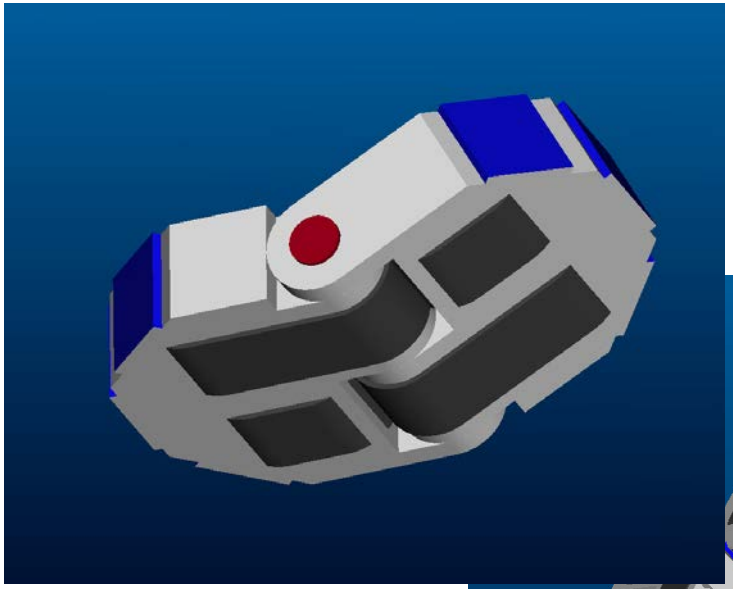
?

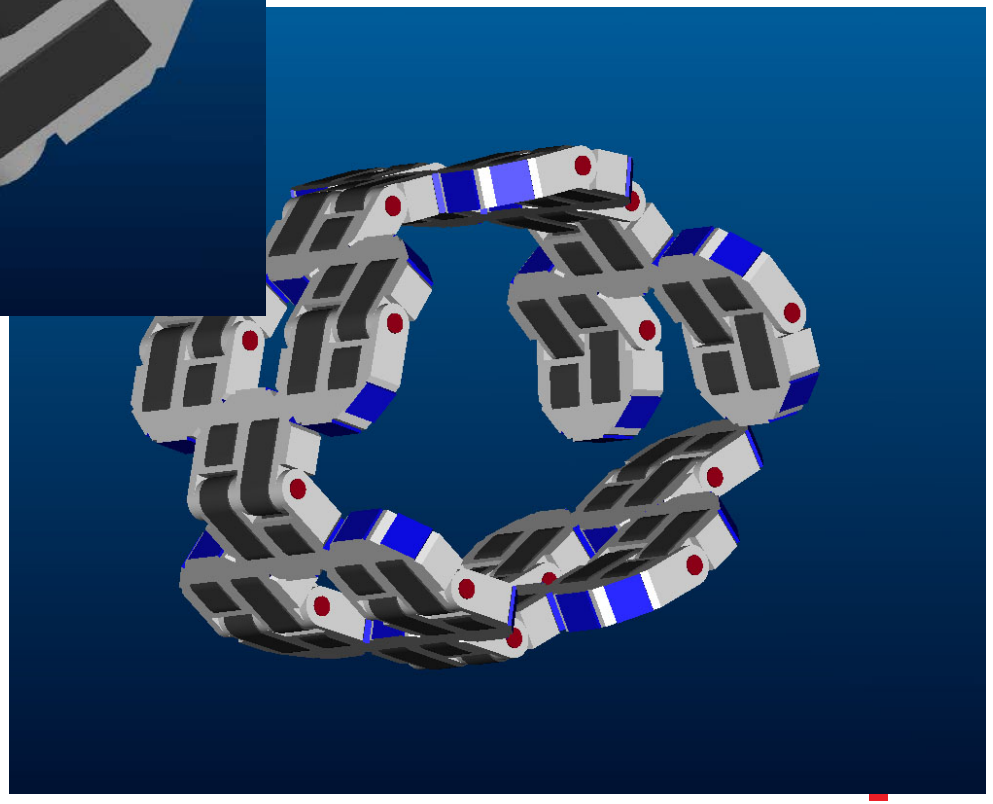


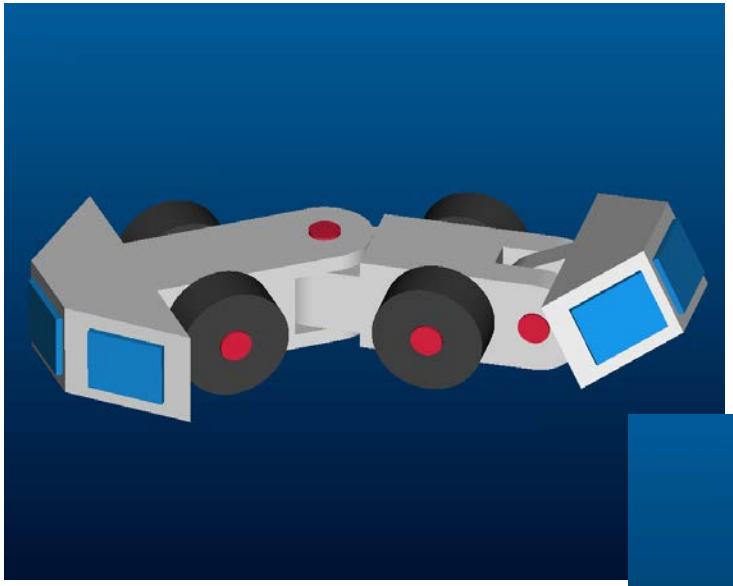


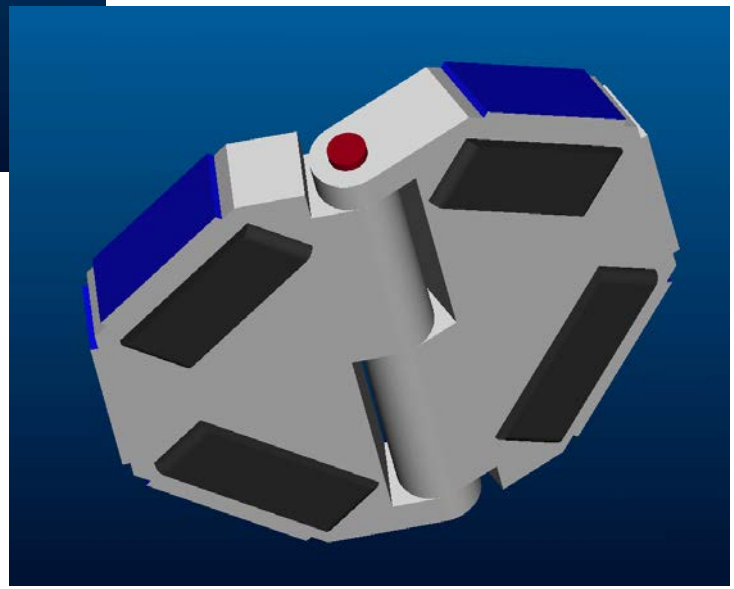


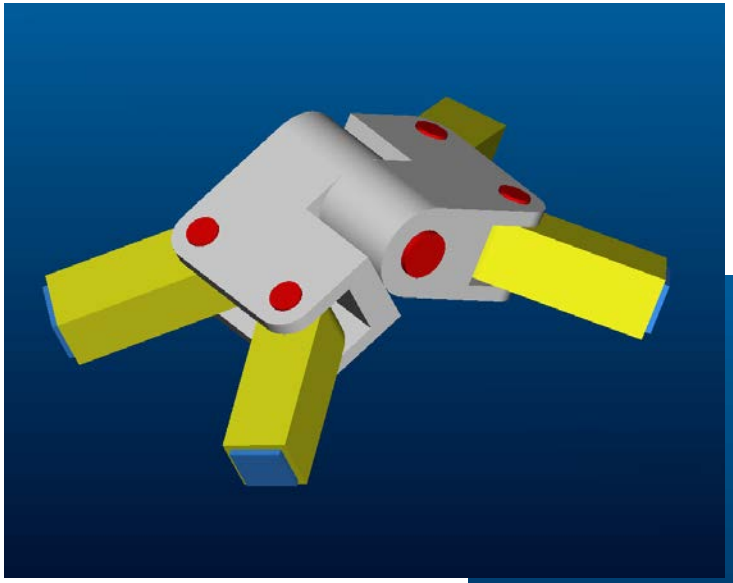


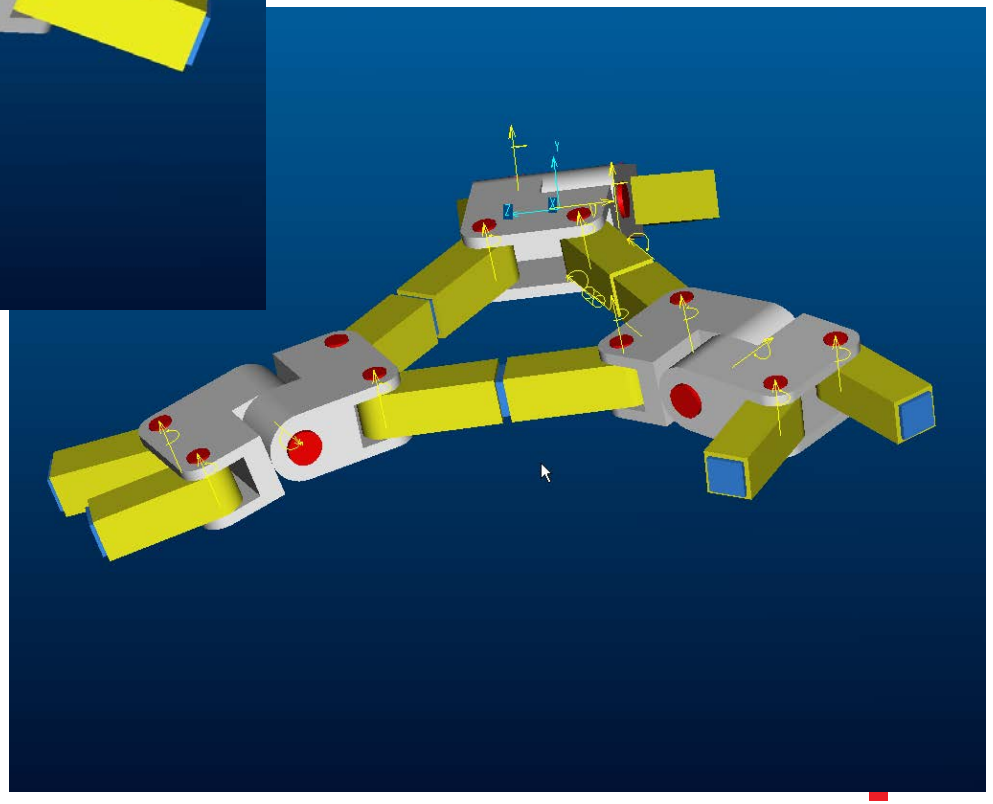


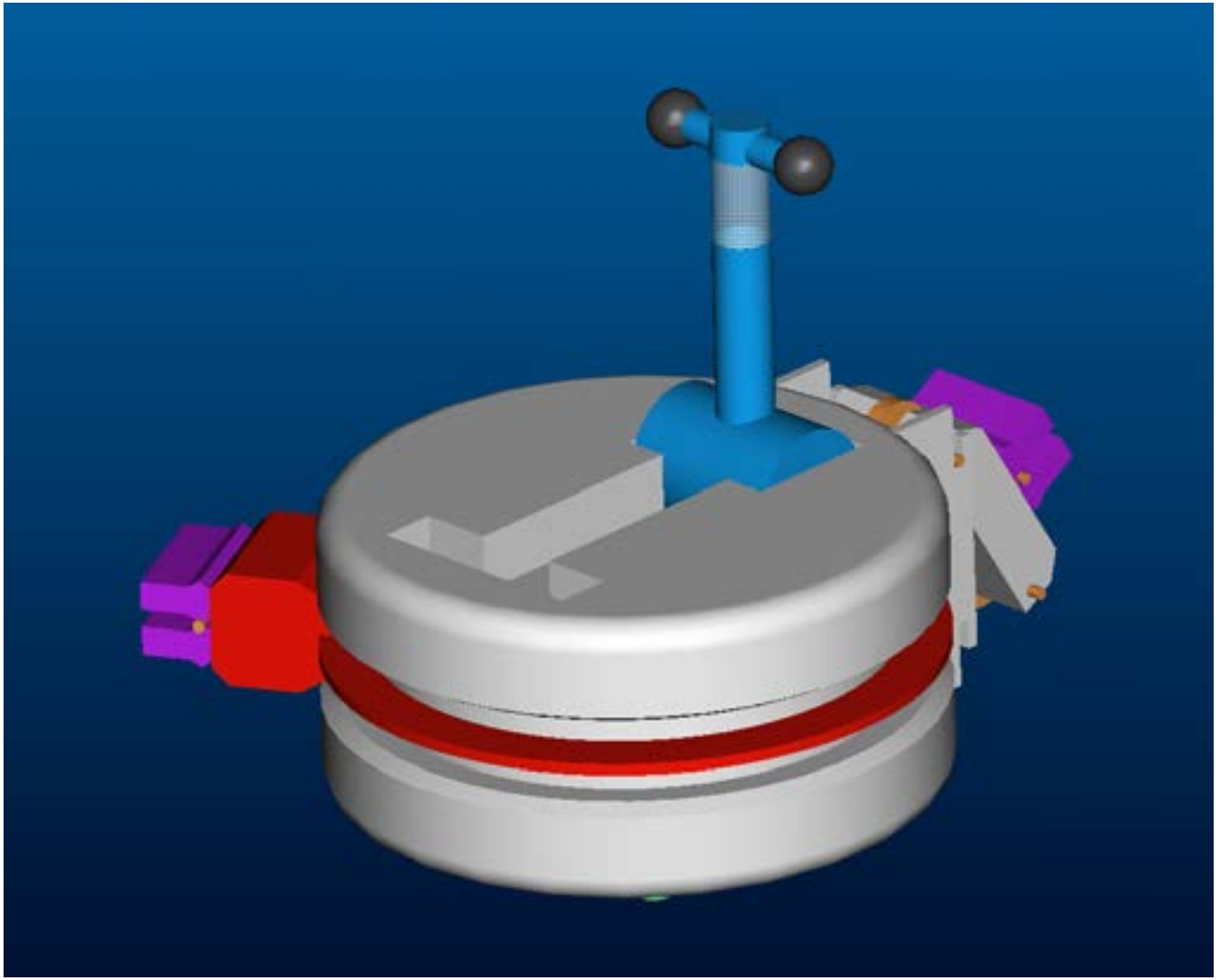




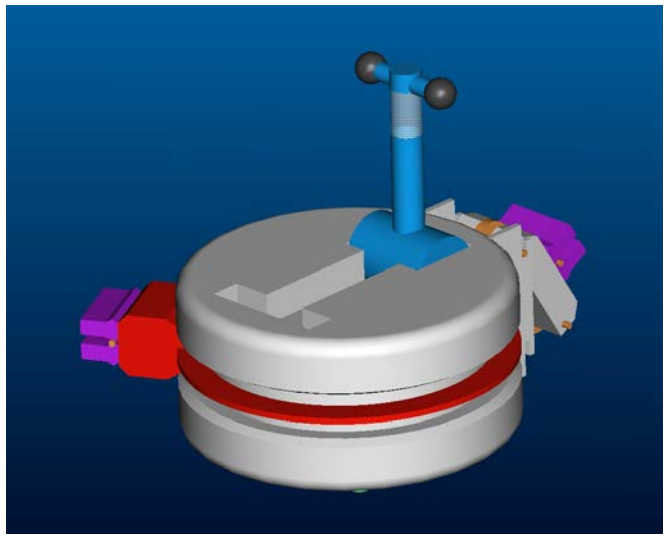


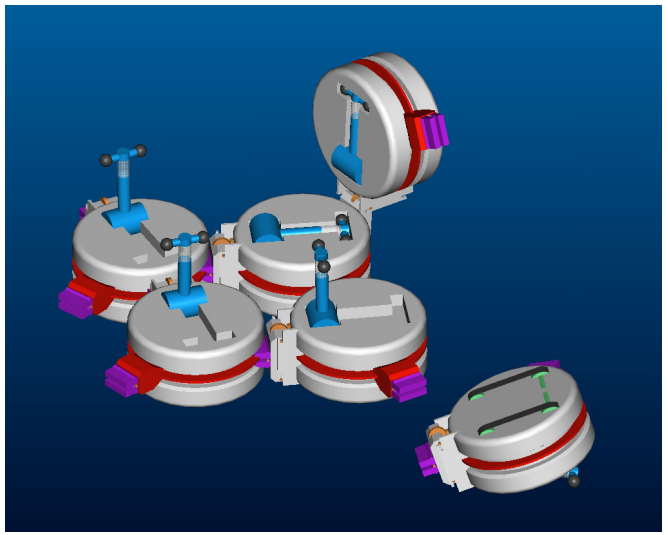


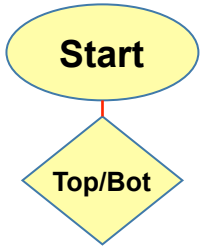




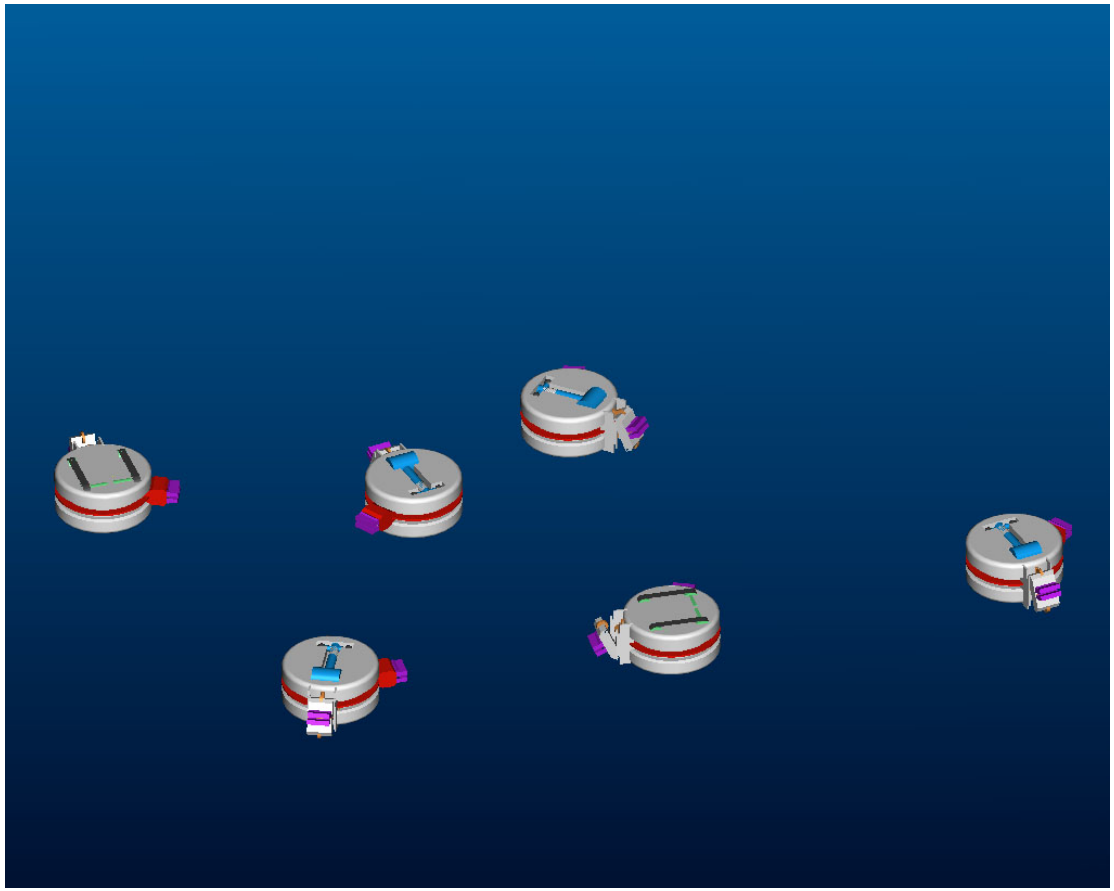
S-Bot versus Swarm-Bot

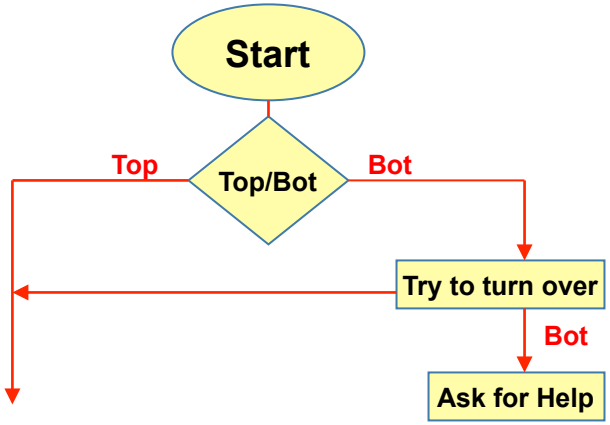




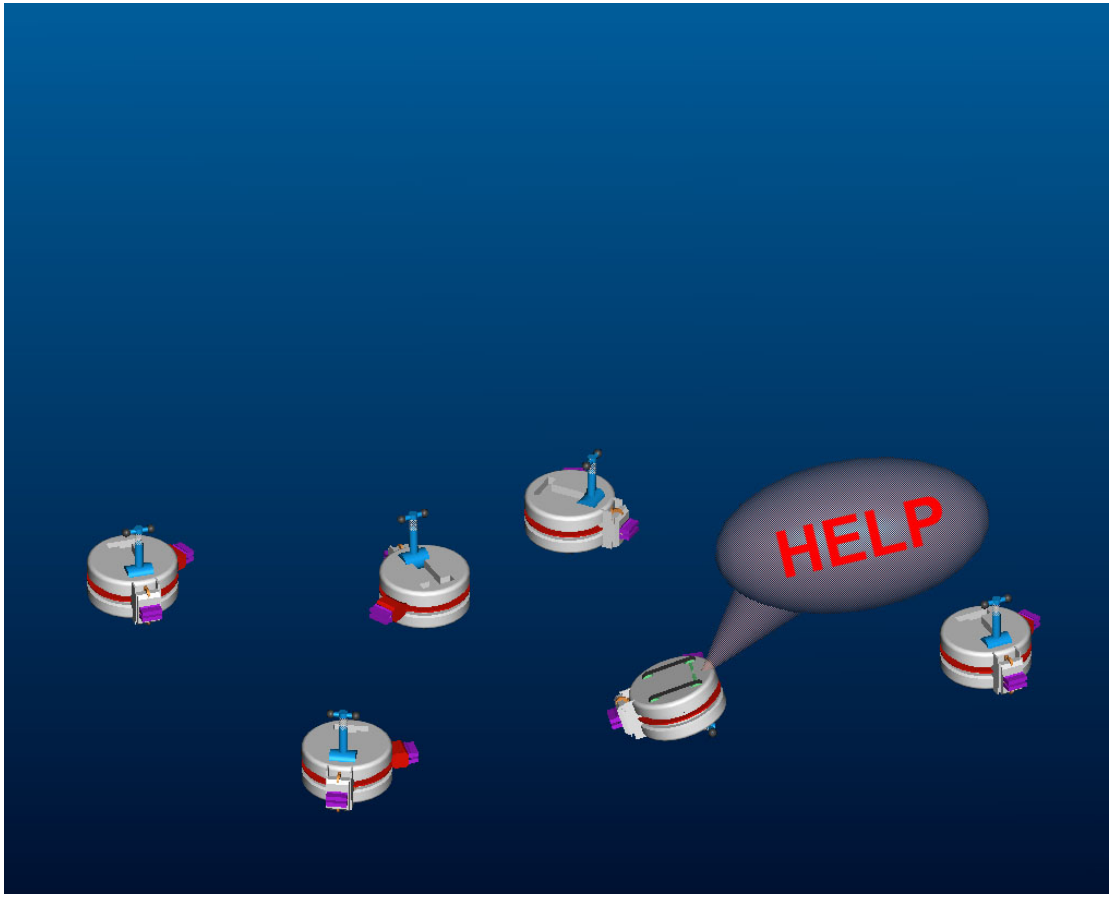


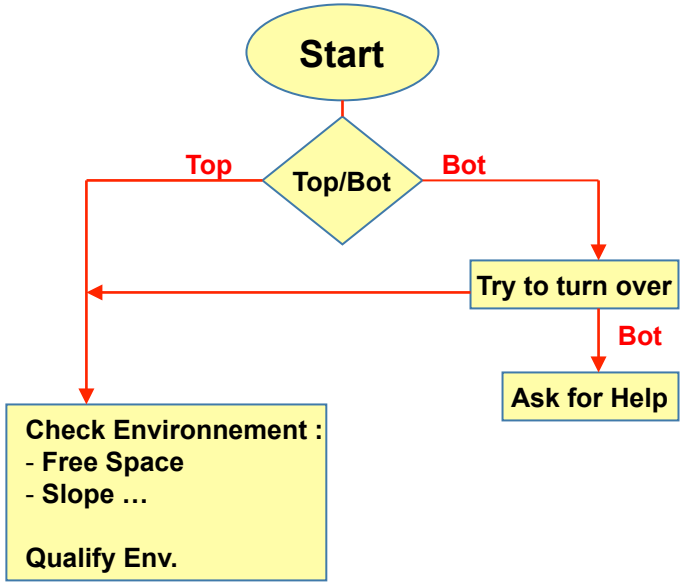
Demo scenario



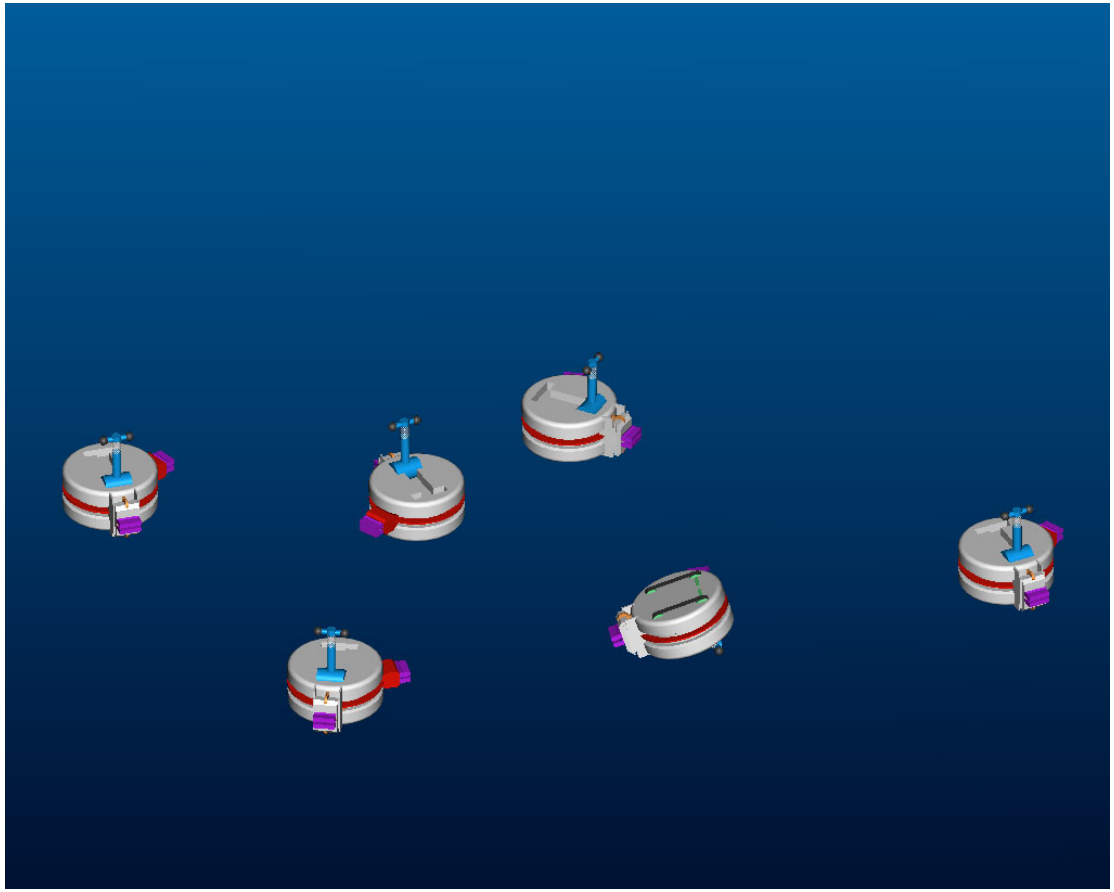


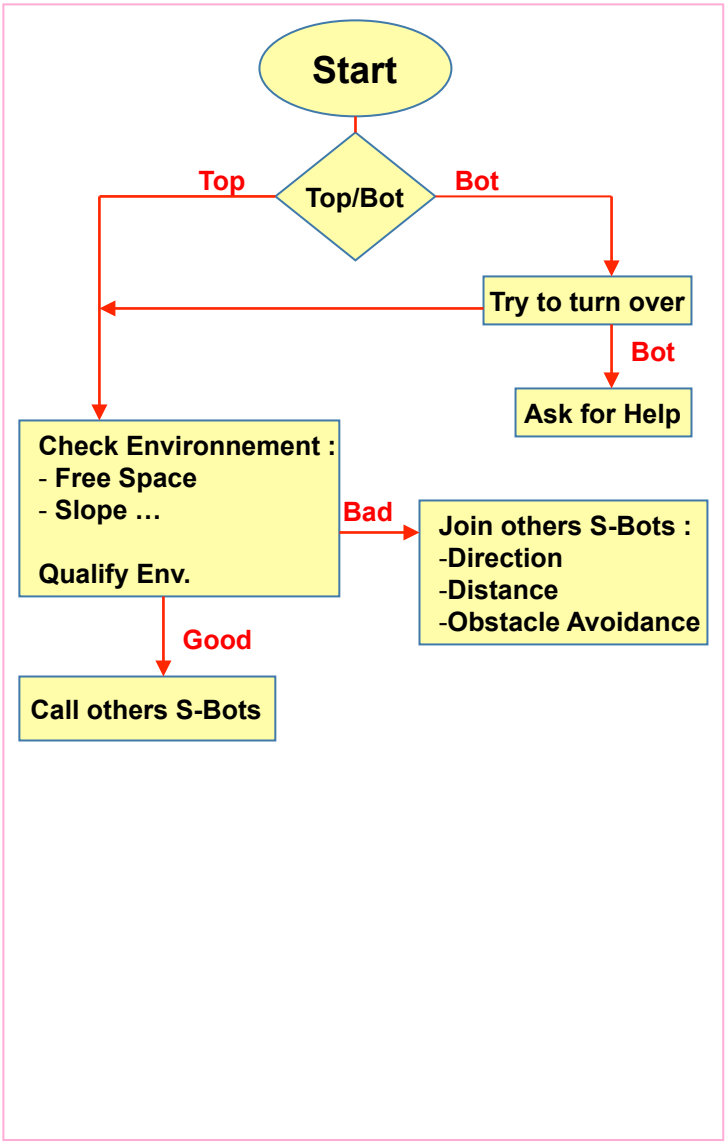
Demo scenario



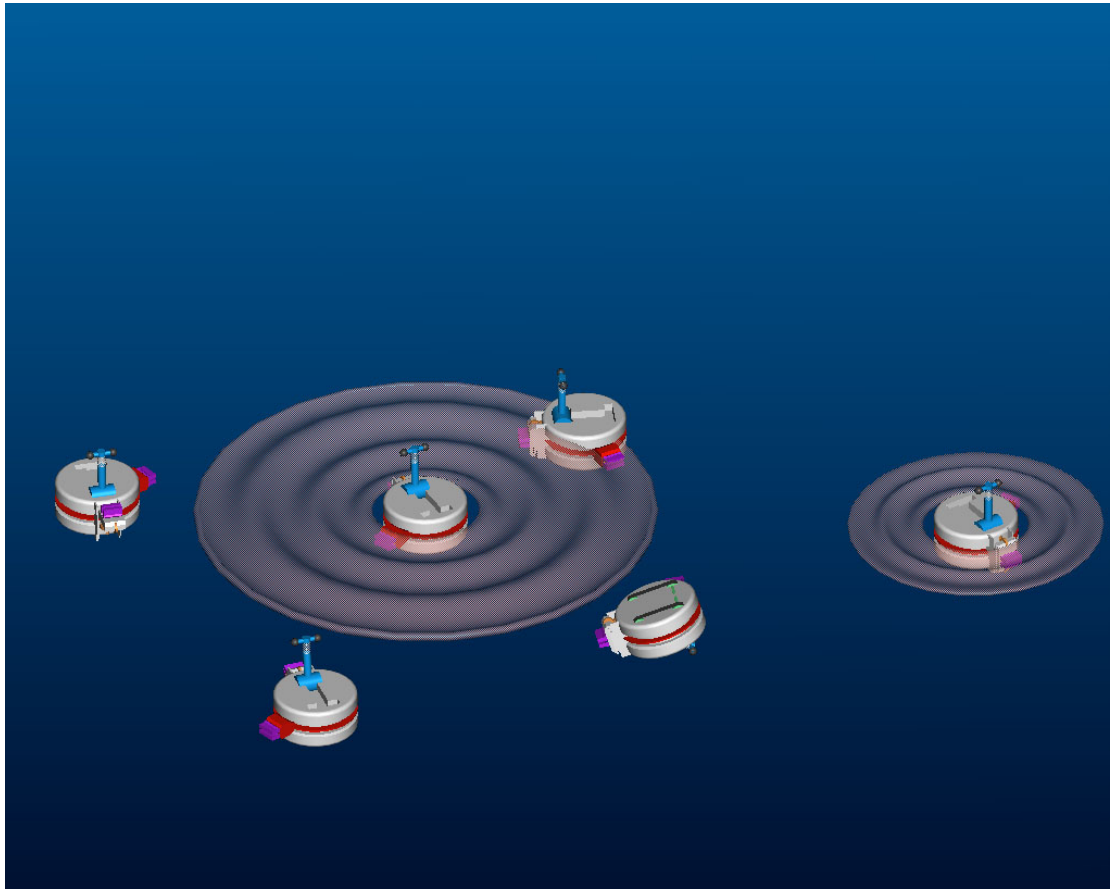


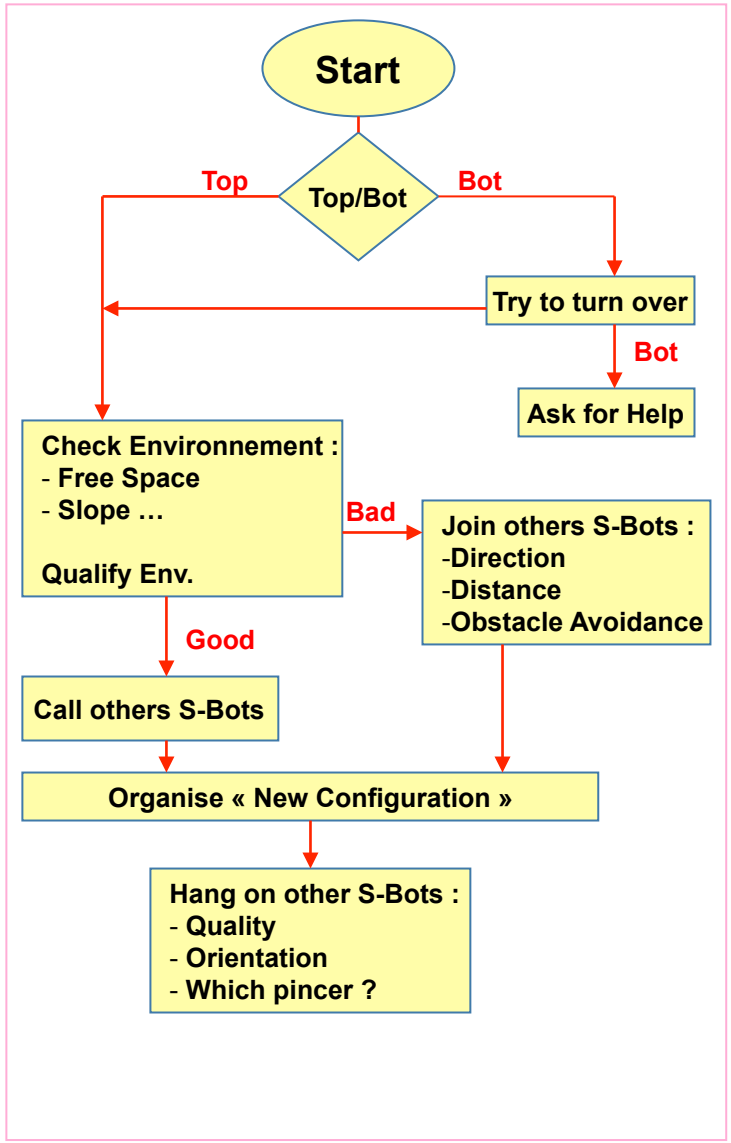
Demo scenario



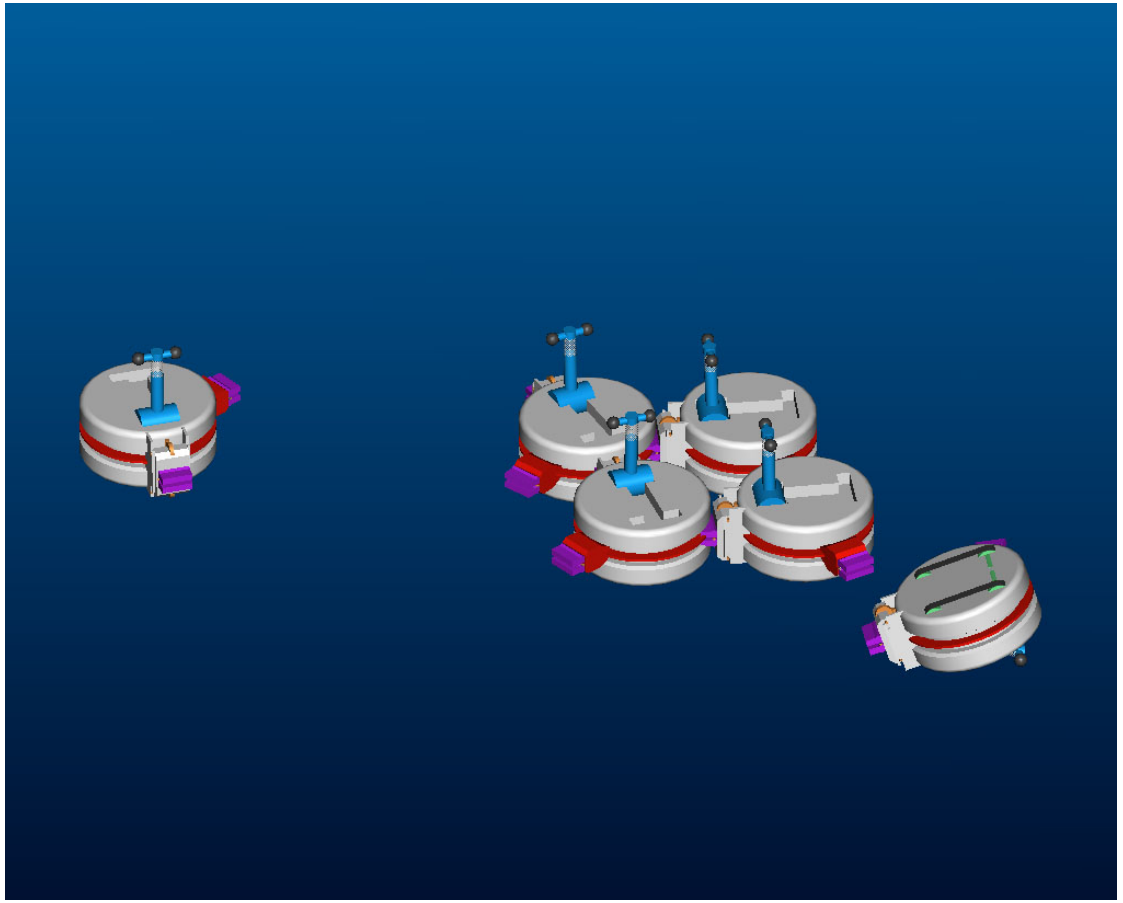


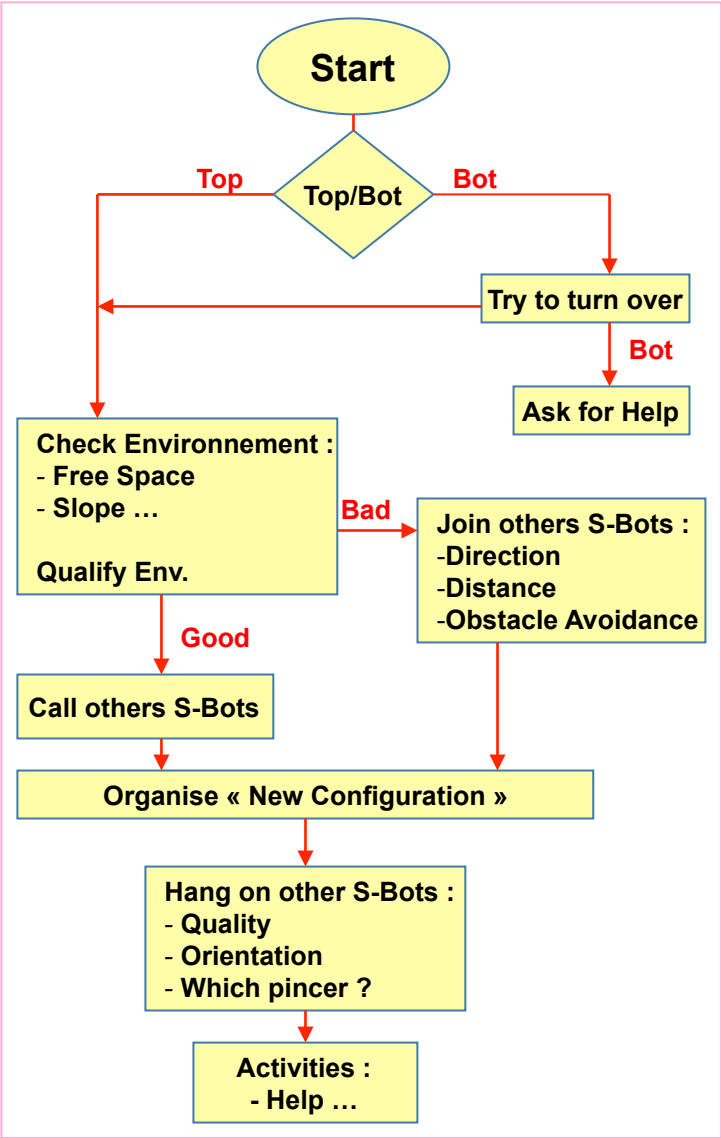
Demo scenario



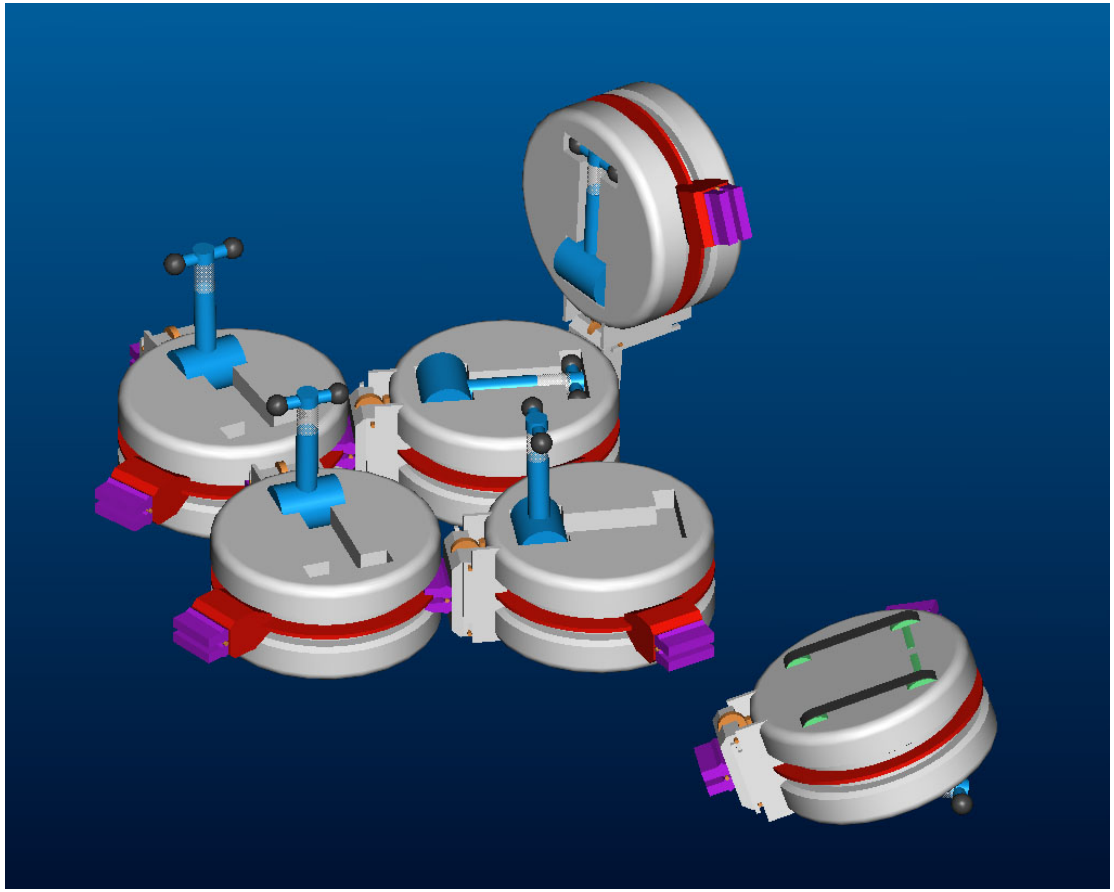


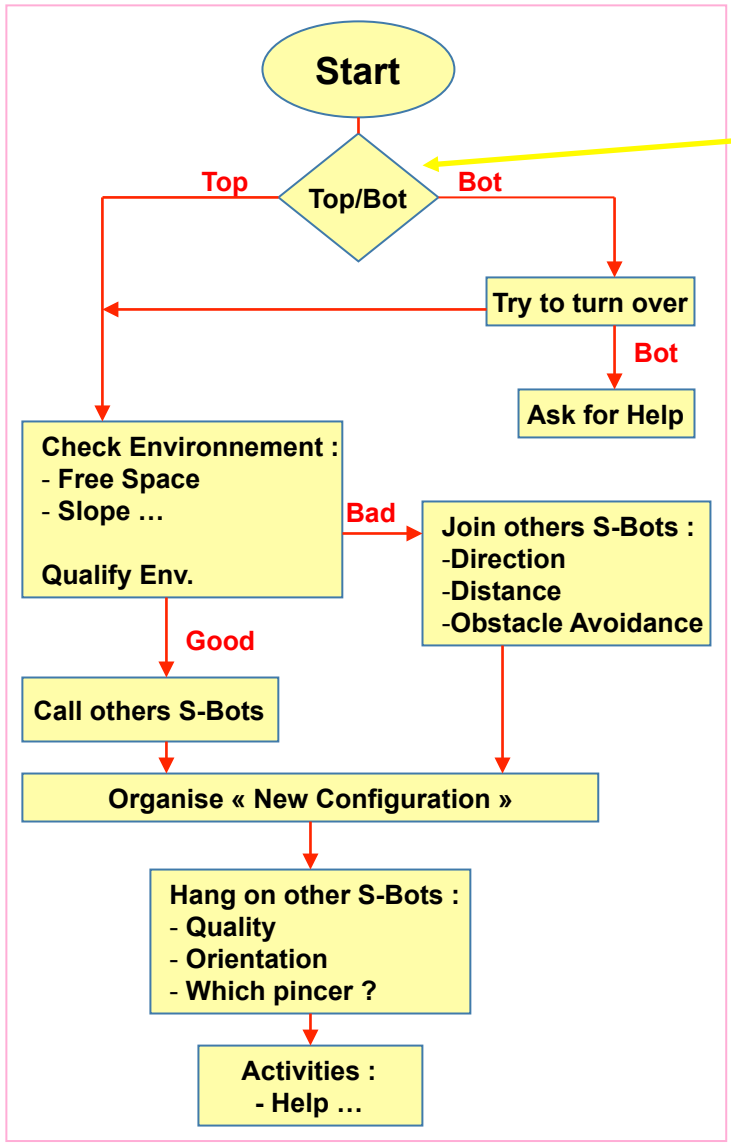
Demo scenario





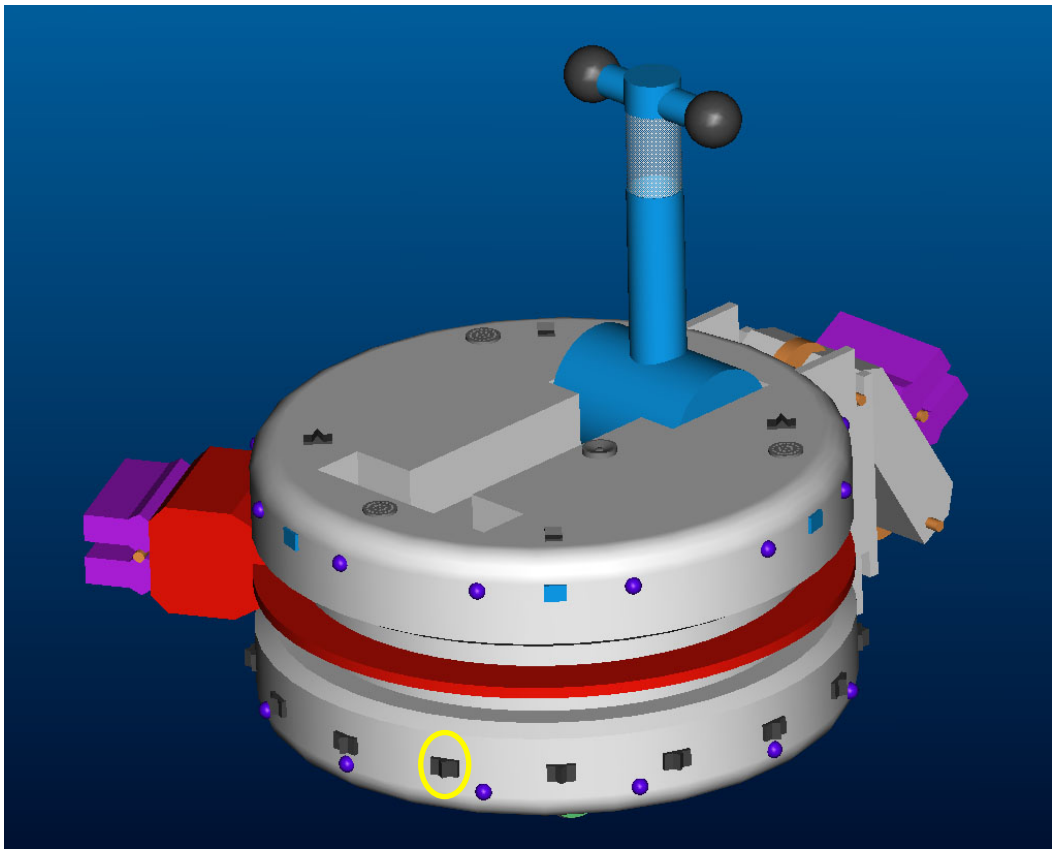
Demo scenario

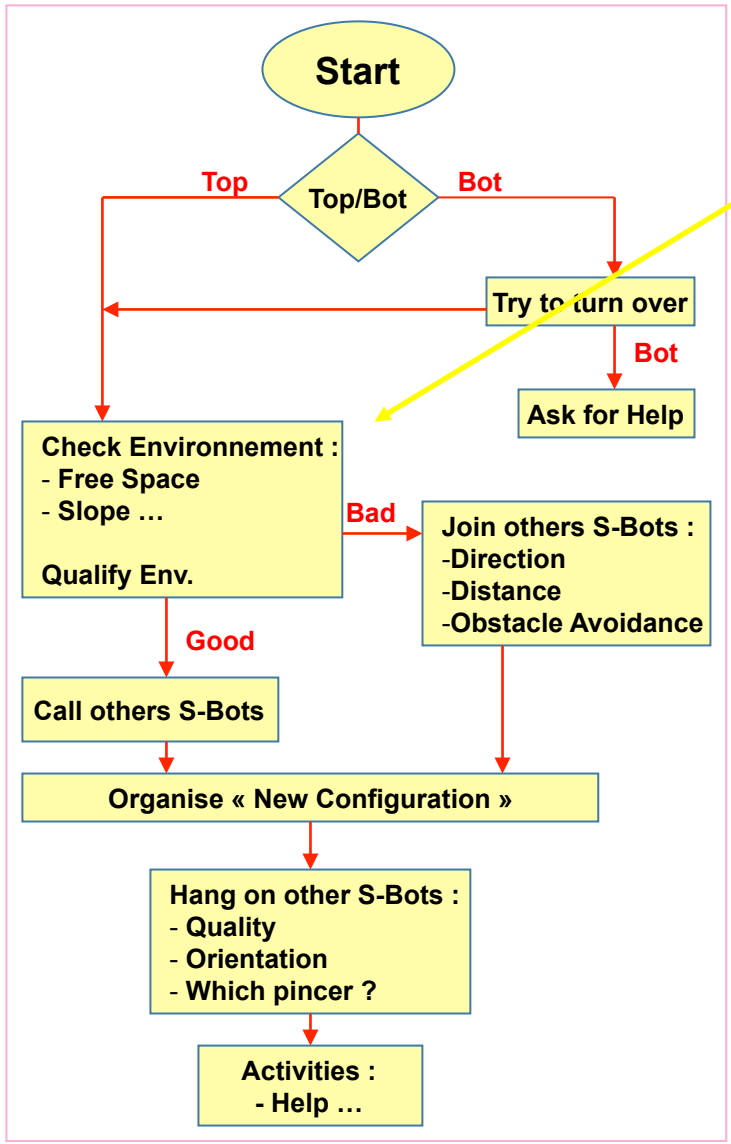




Demo scenario

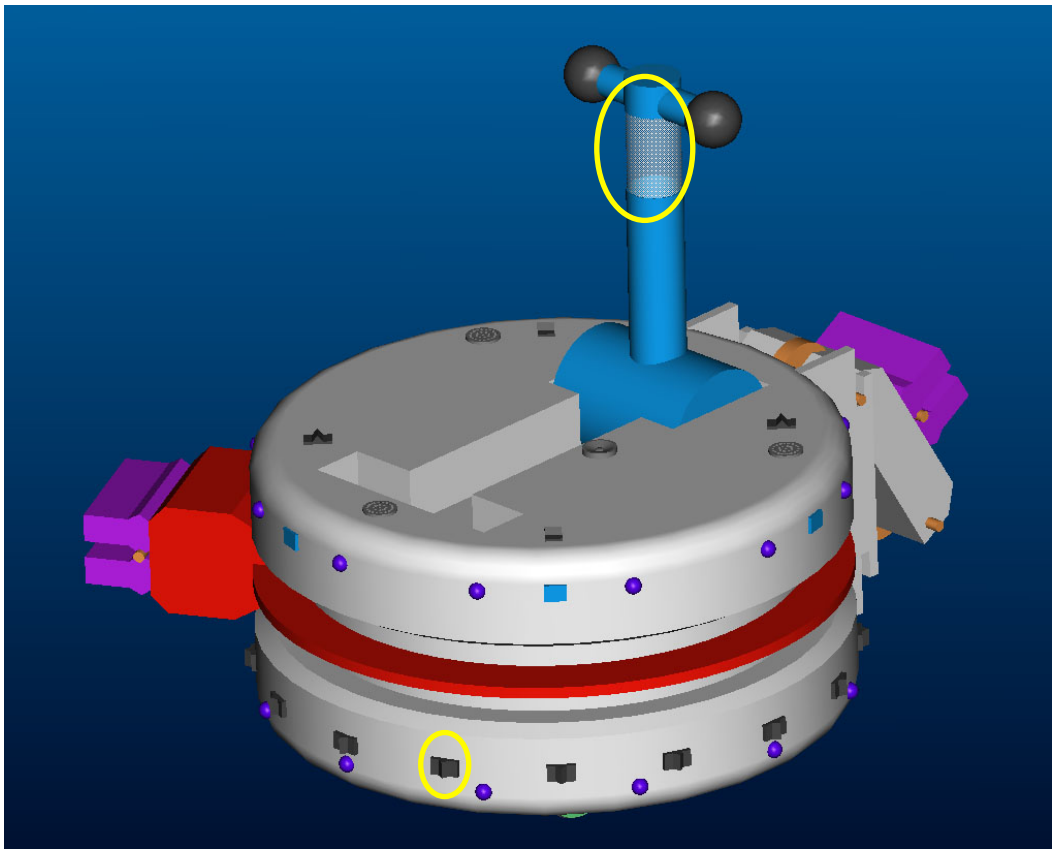
Inclinometer + Irs

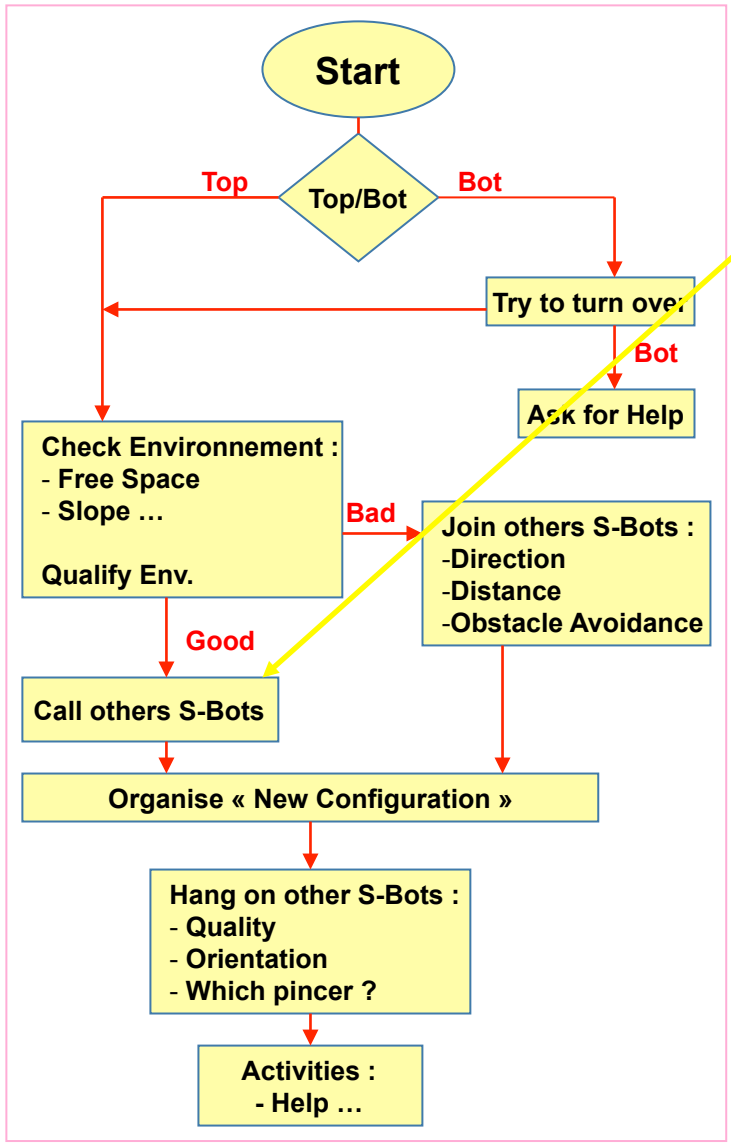




Sensors

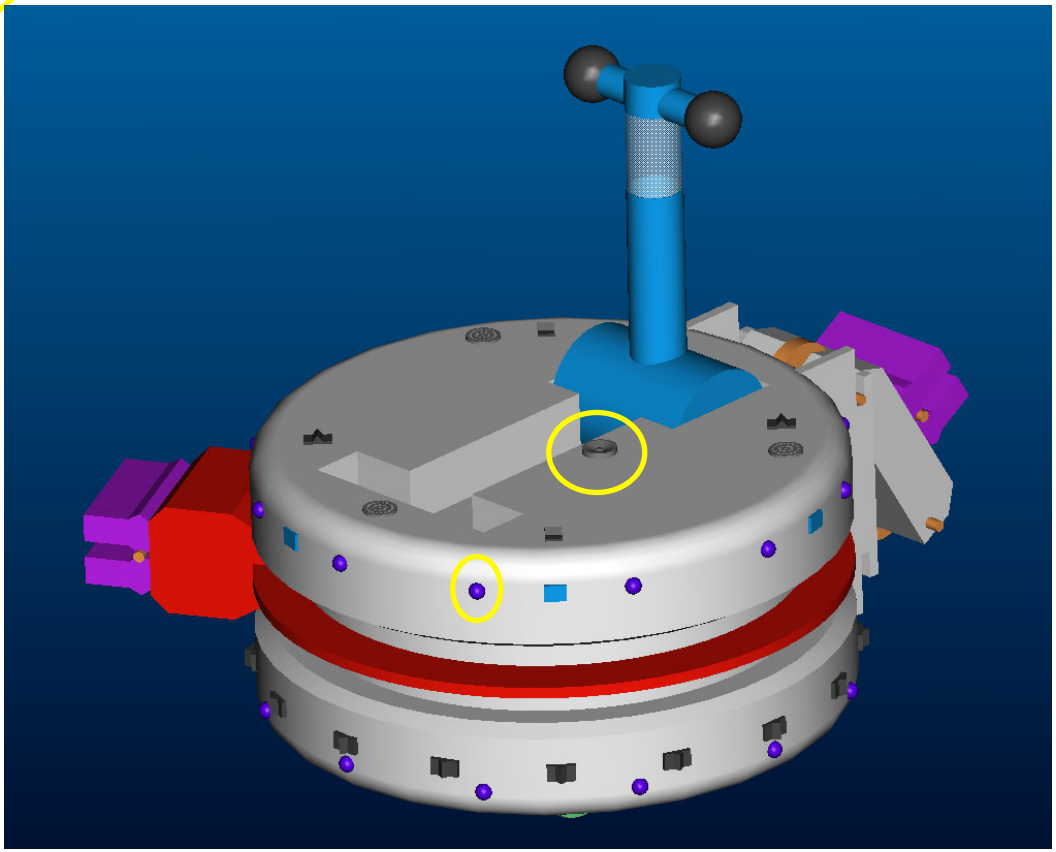
360° Camera + Inclinometer + Irs

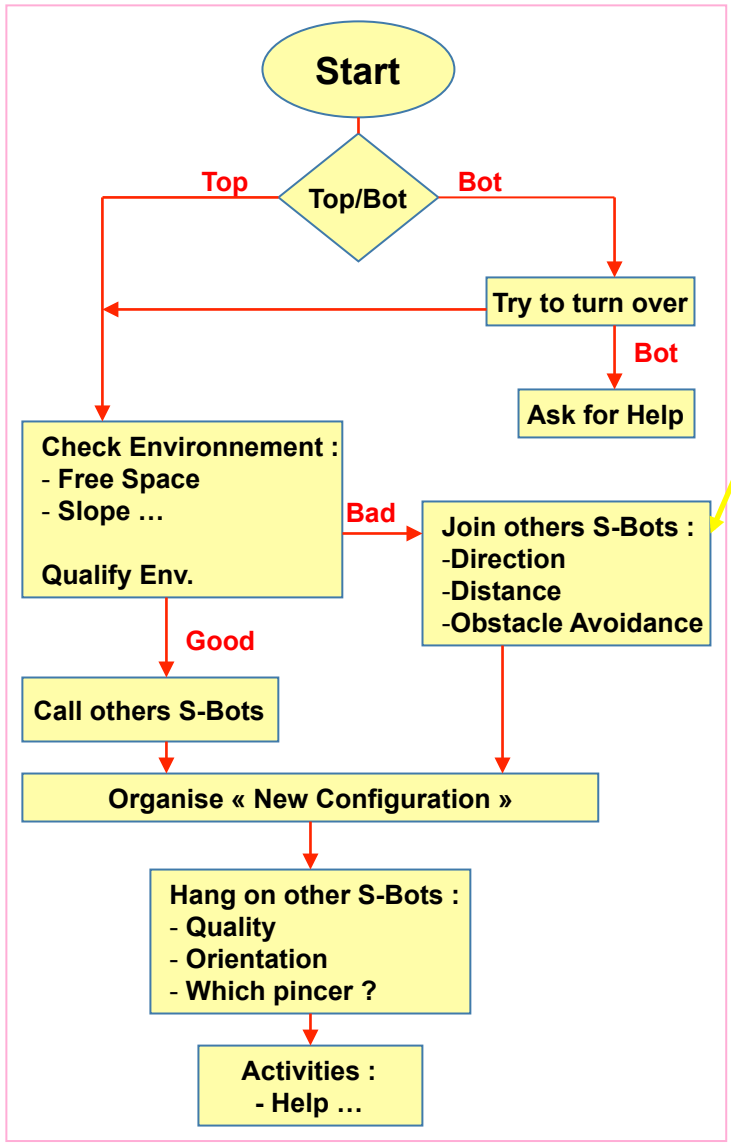




Sensors

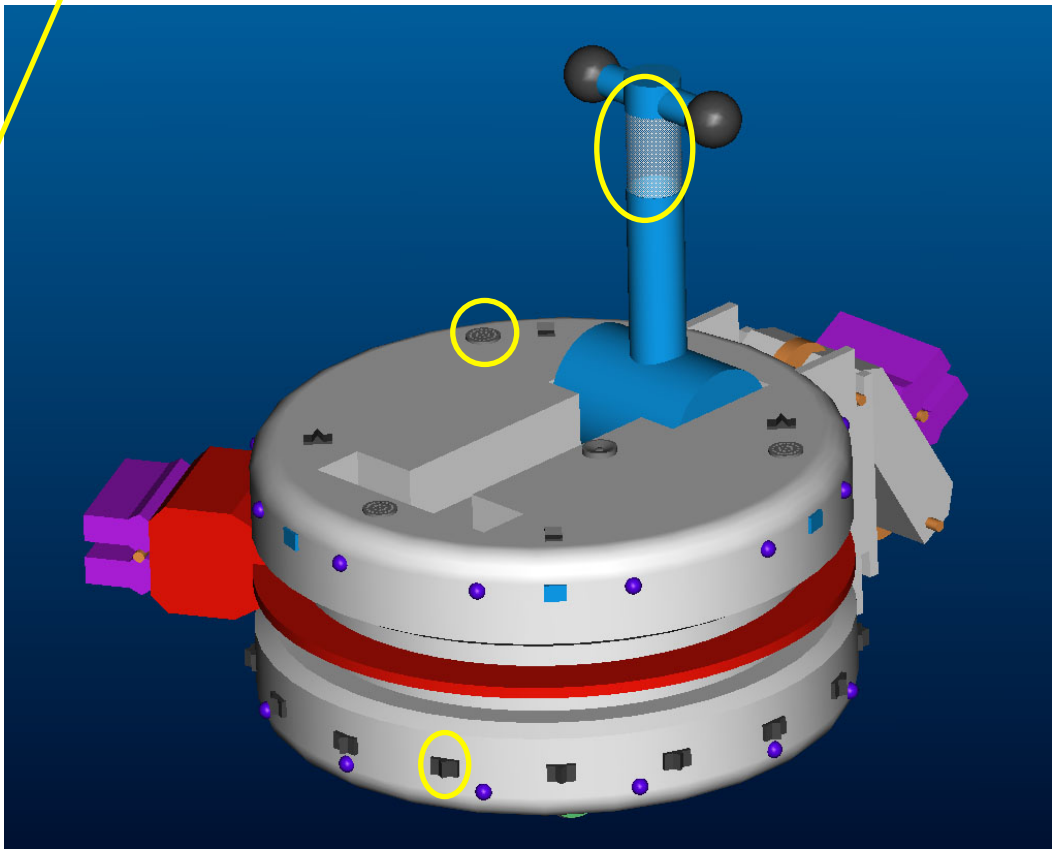
Speaker + Leds Multicolor

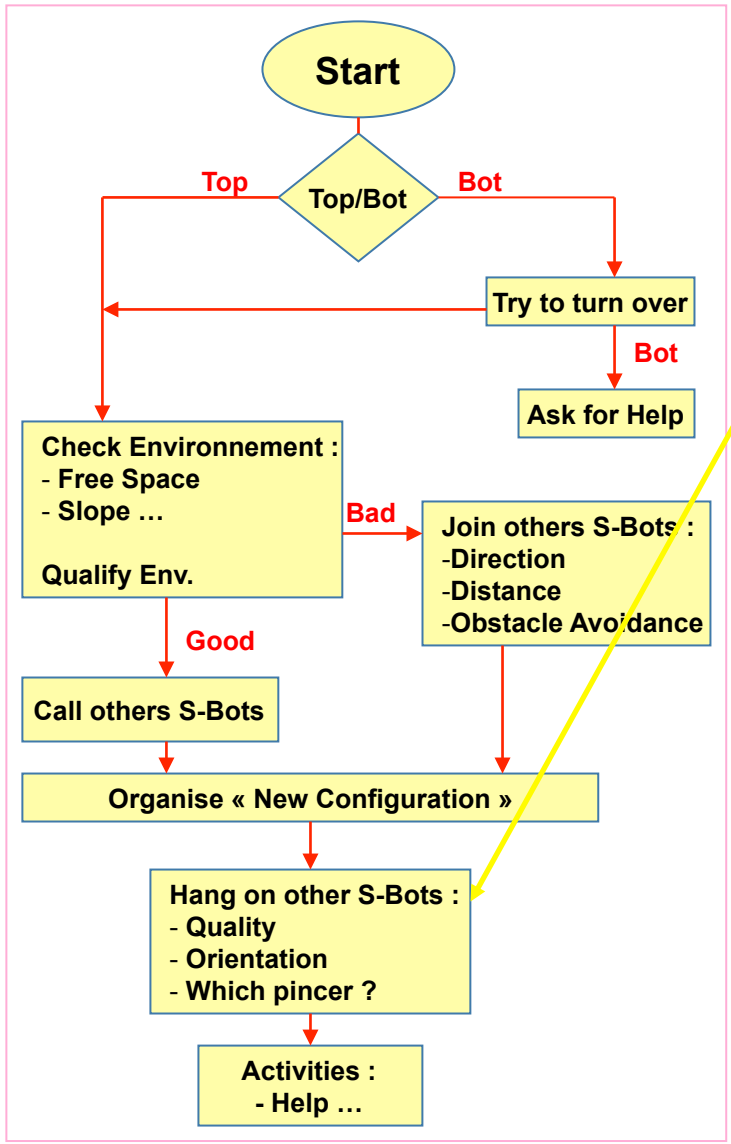




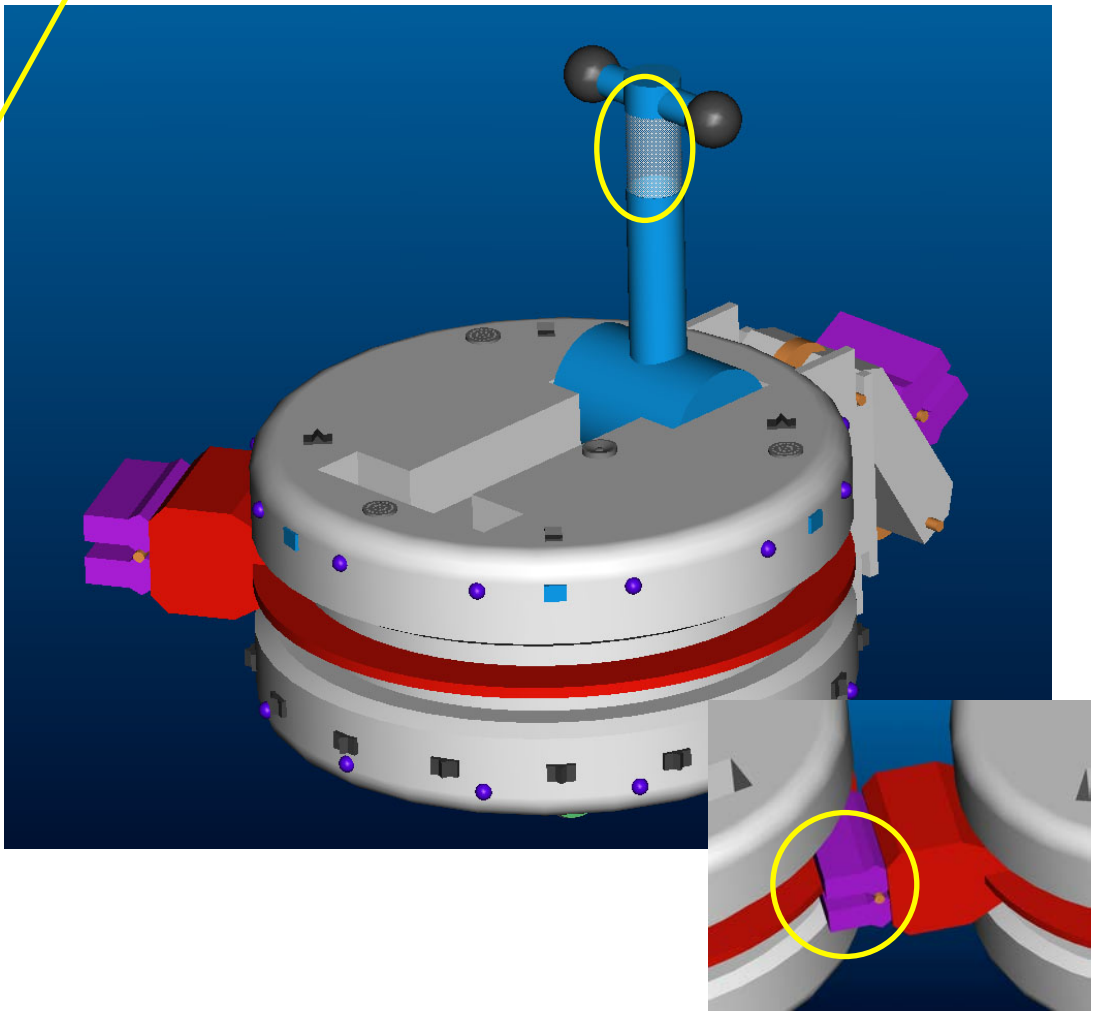
Sensors

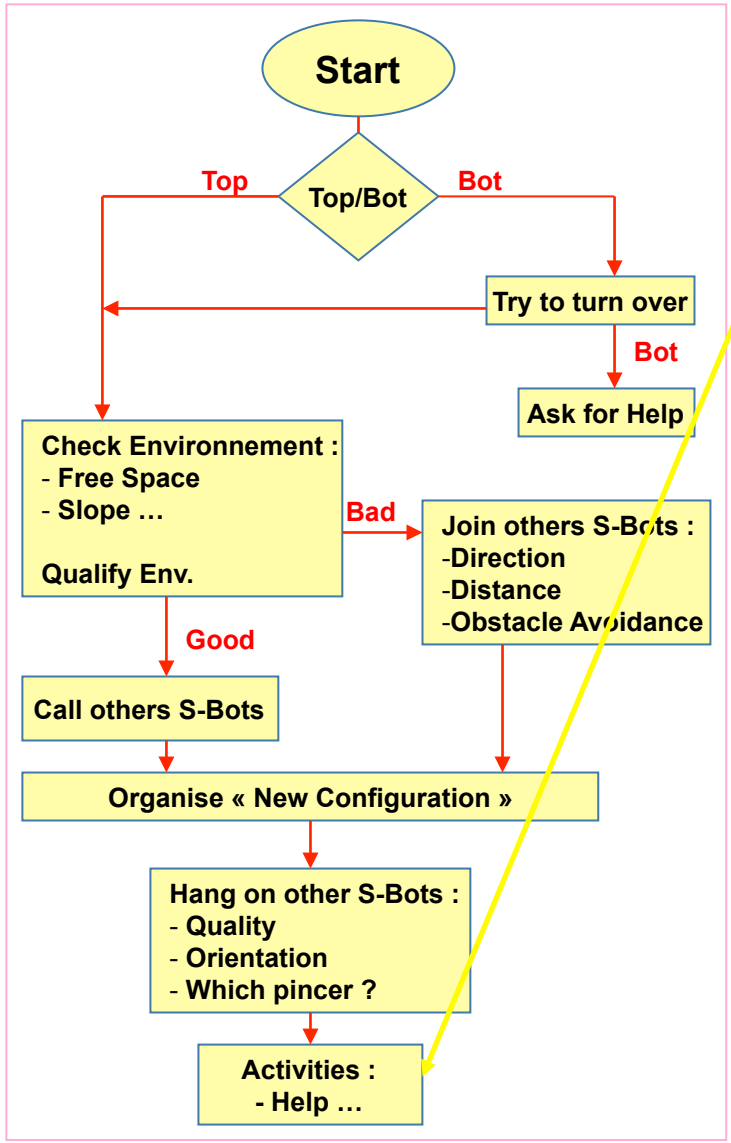
Micros + 360° Camera +IRs





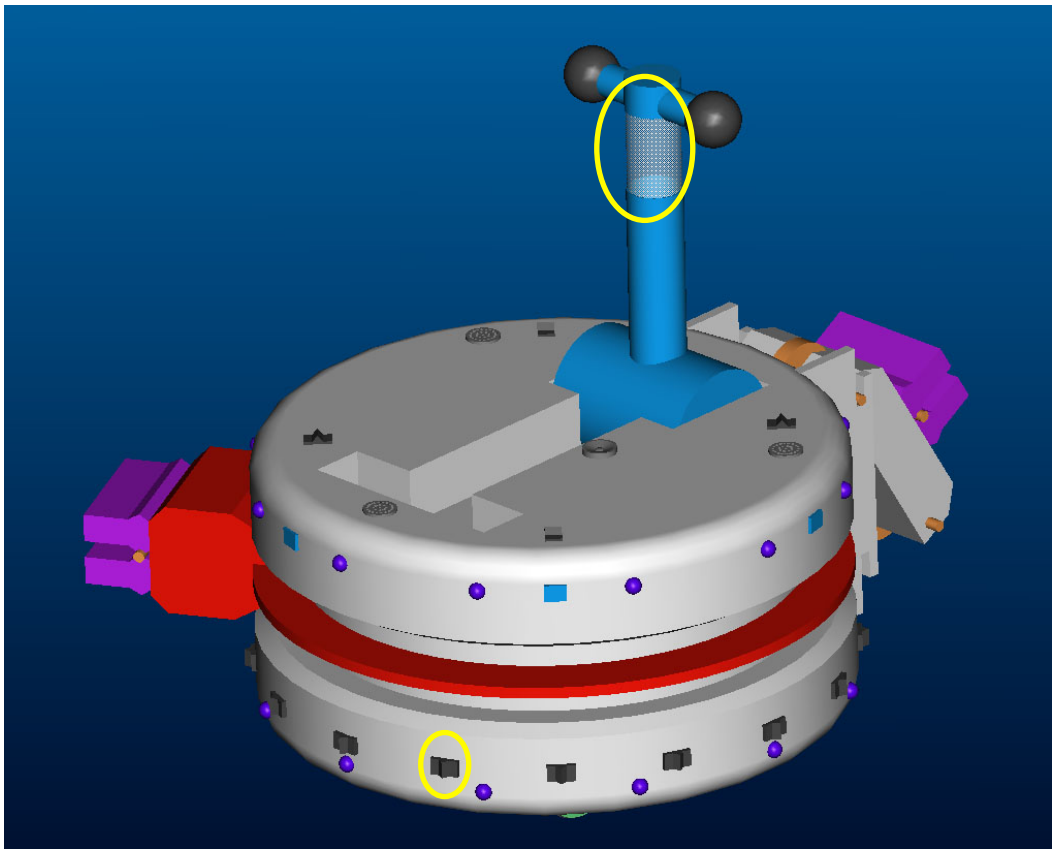
360° Camera + Inclinometer + Emitter/Receiver in gripper

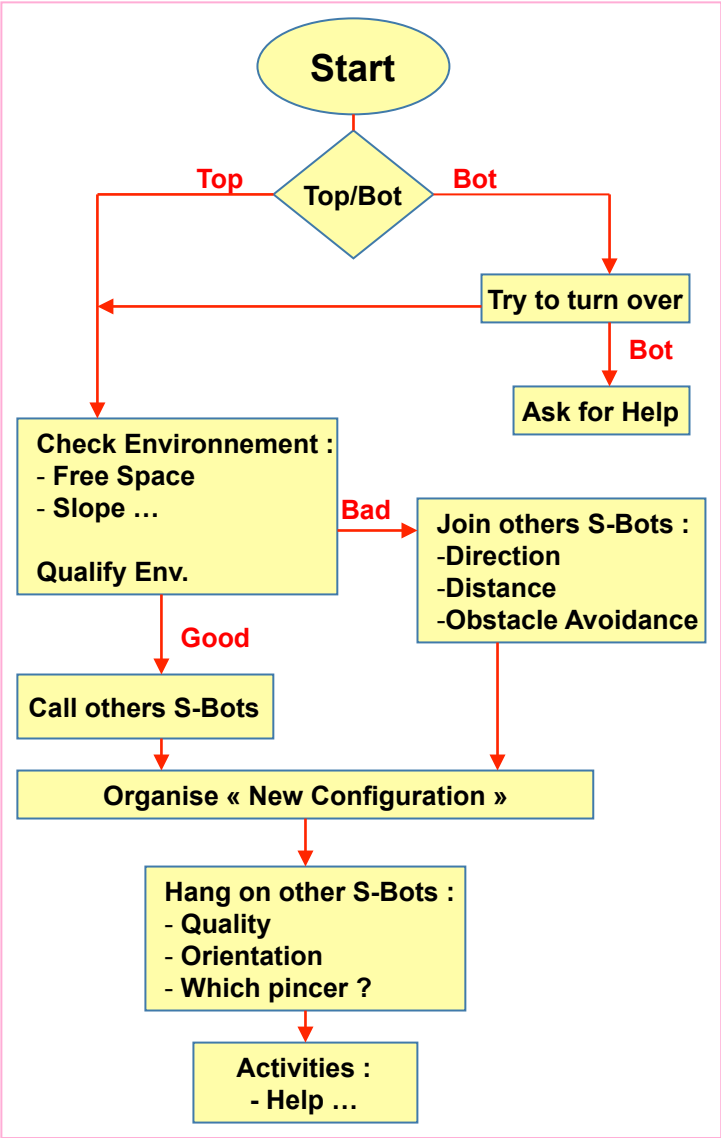




Sensors

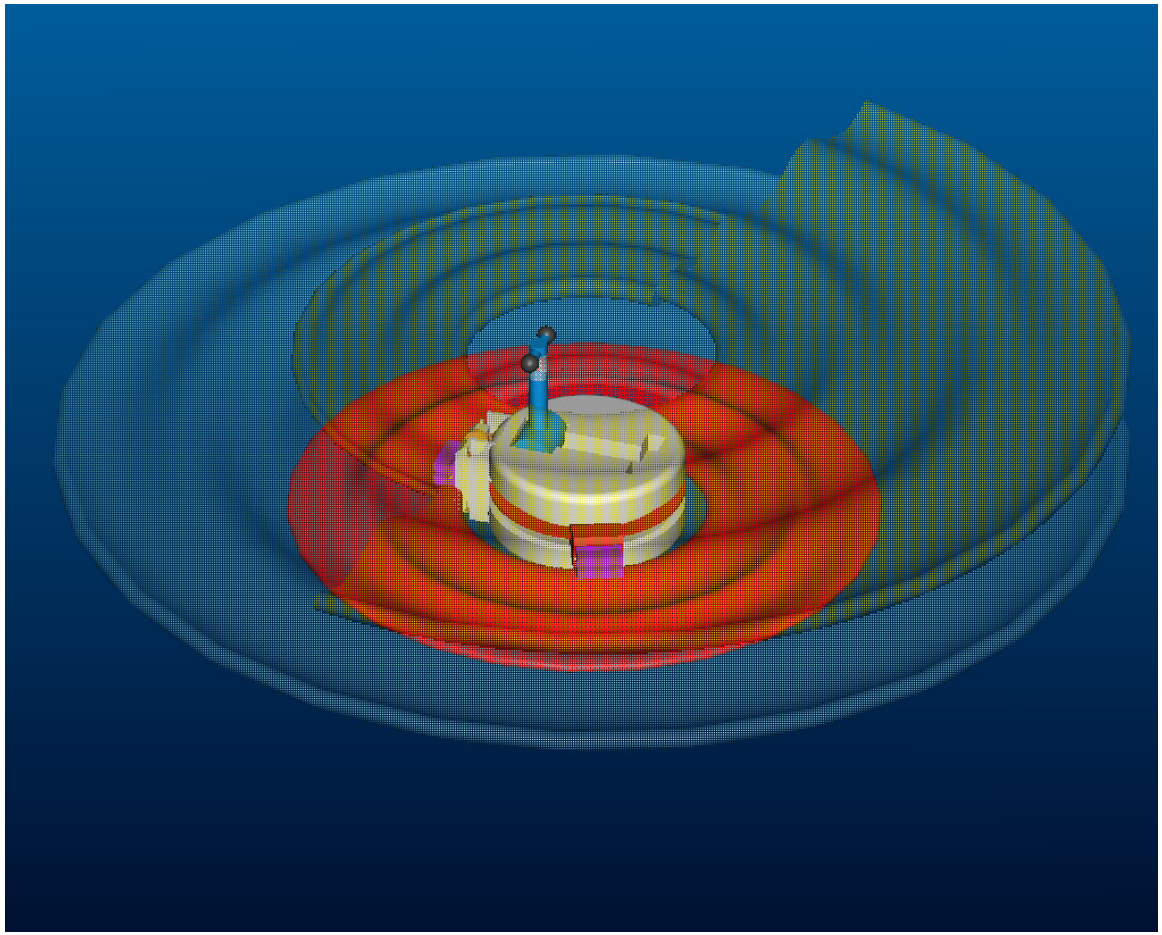
360° Camera + Inclinometer + IRs





Optional sensors

Temperature
Pyro
Custom light
Bar code (already camera…)
Humidity
Compass
(Real Time Clock)

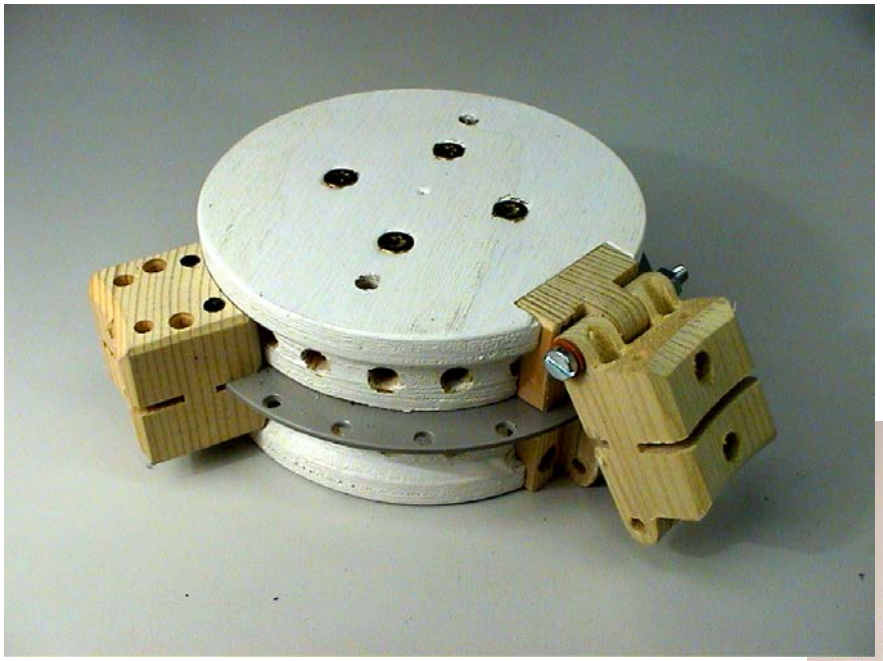


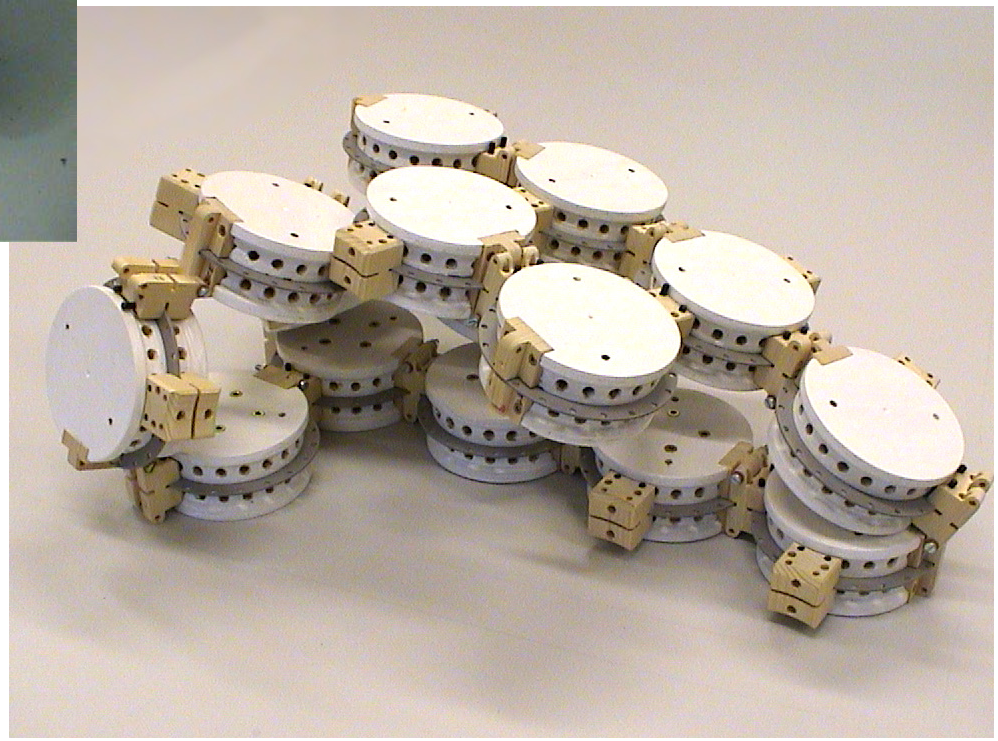
360° Camera

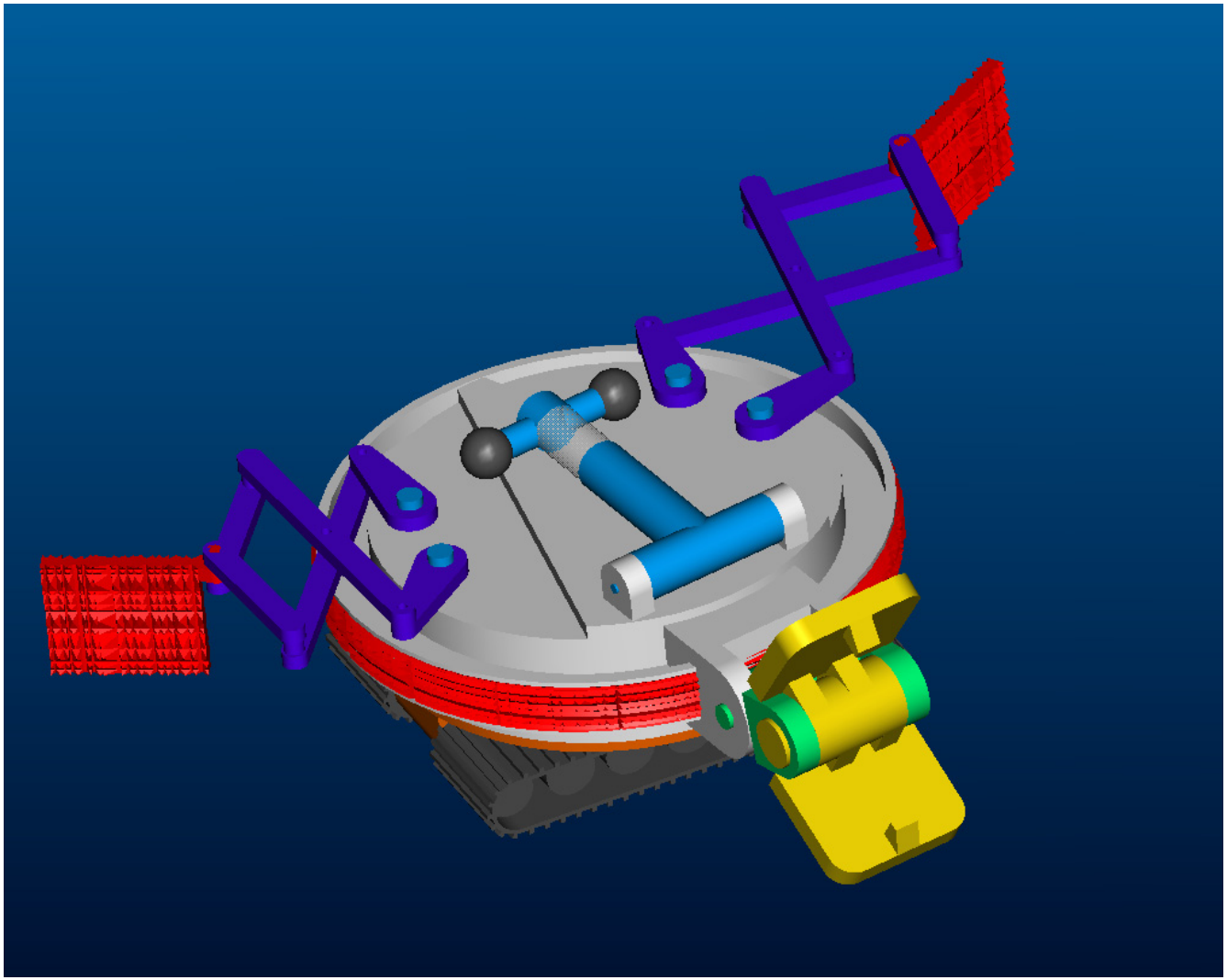
Leds

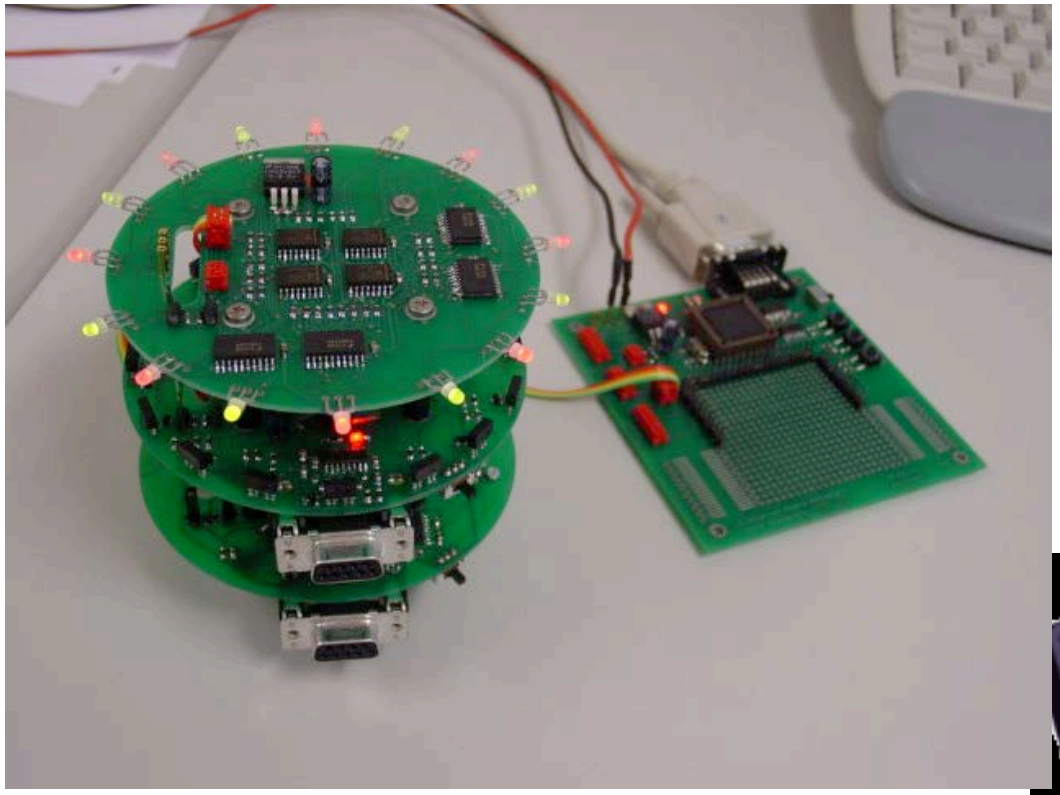
Sound

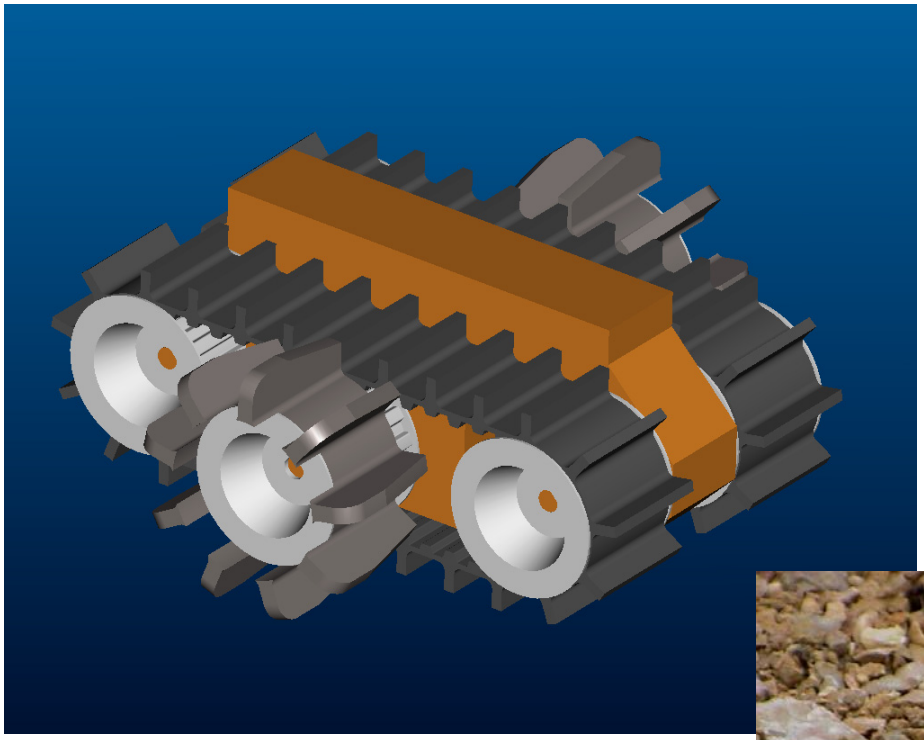
IRs





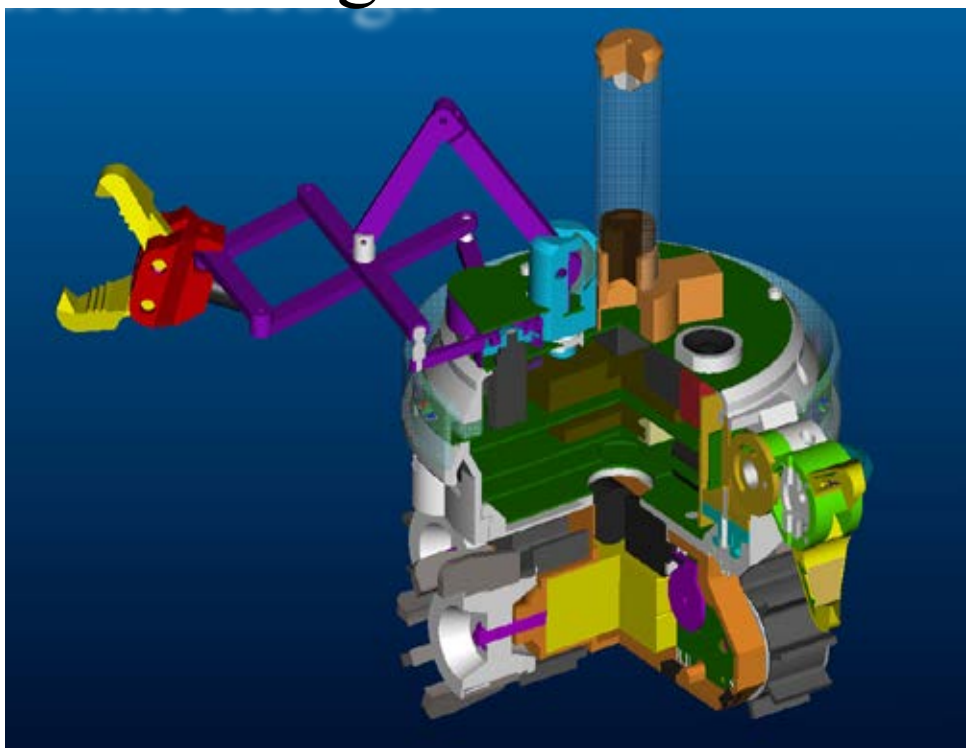


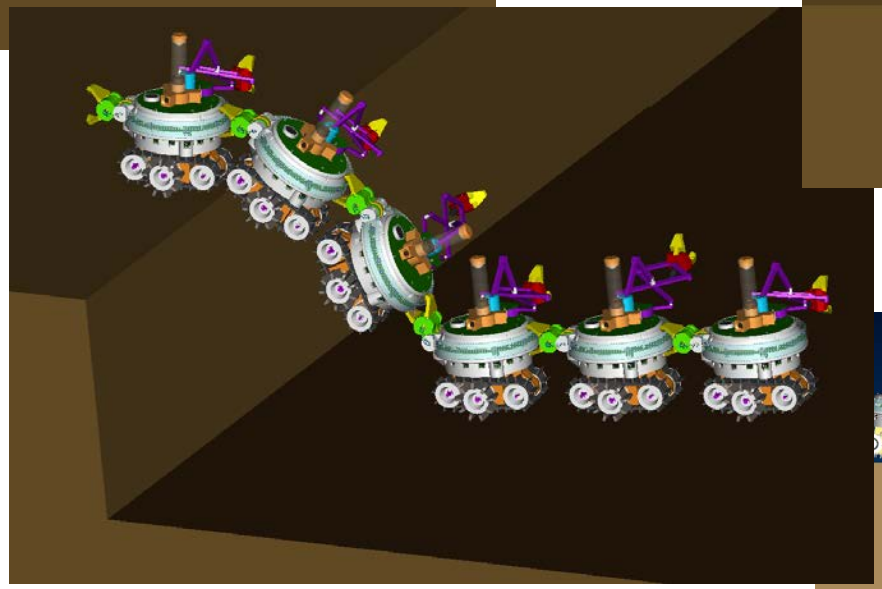


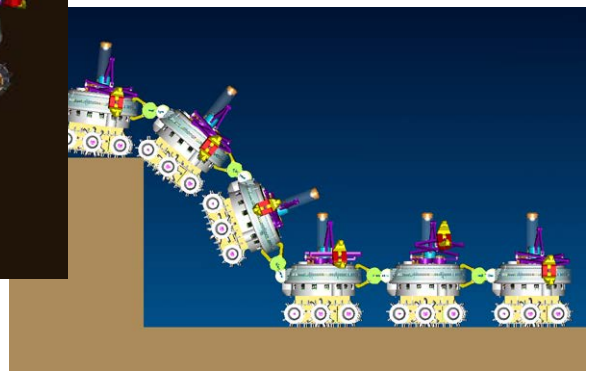


Hardware overview

- Mechatronic design

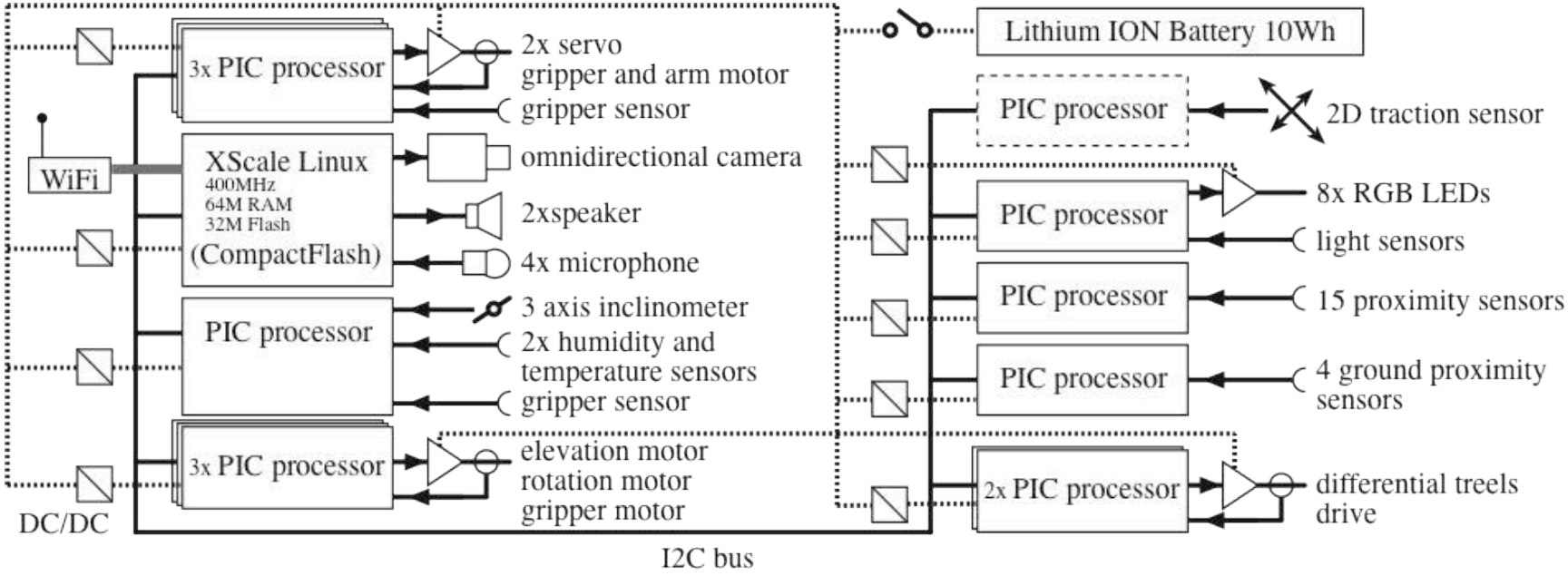




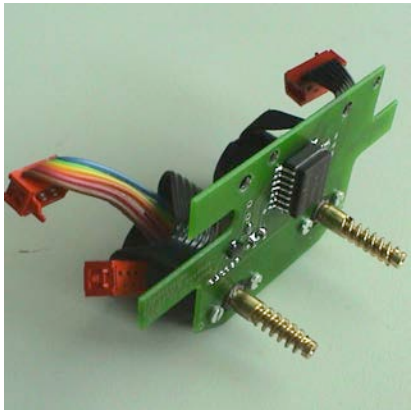


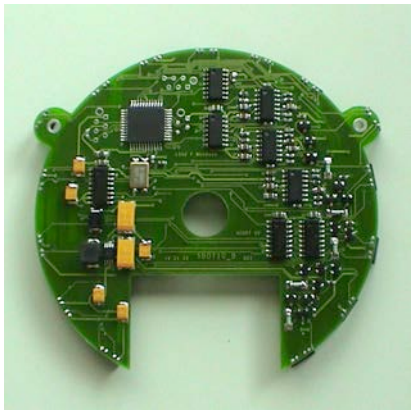
Hardware overview

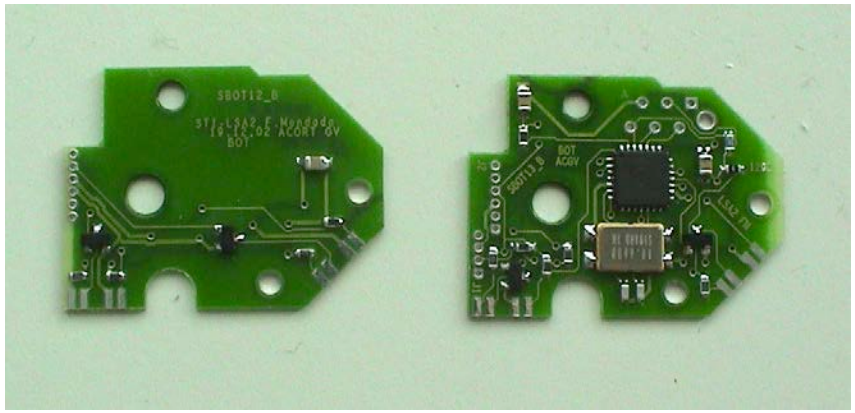
- Electronic structure







Turret rotation
Rigid gripper


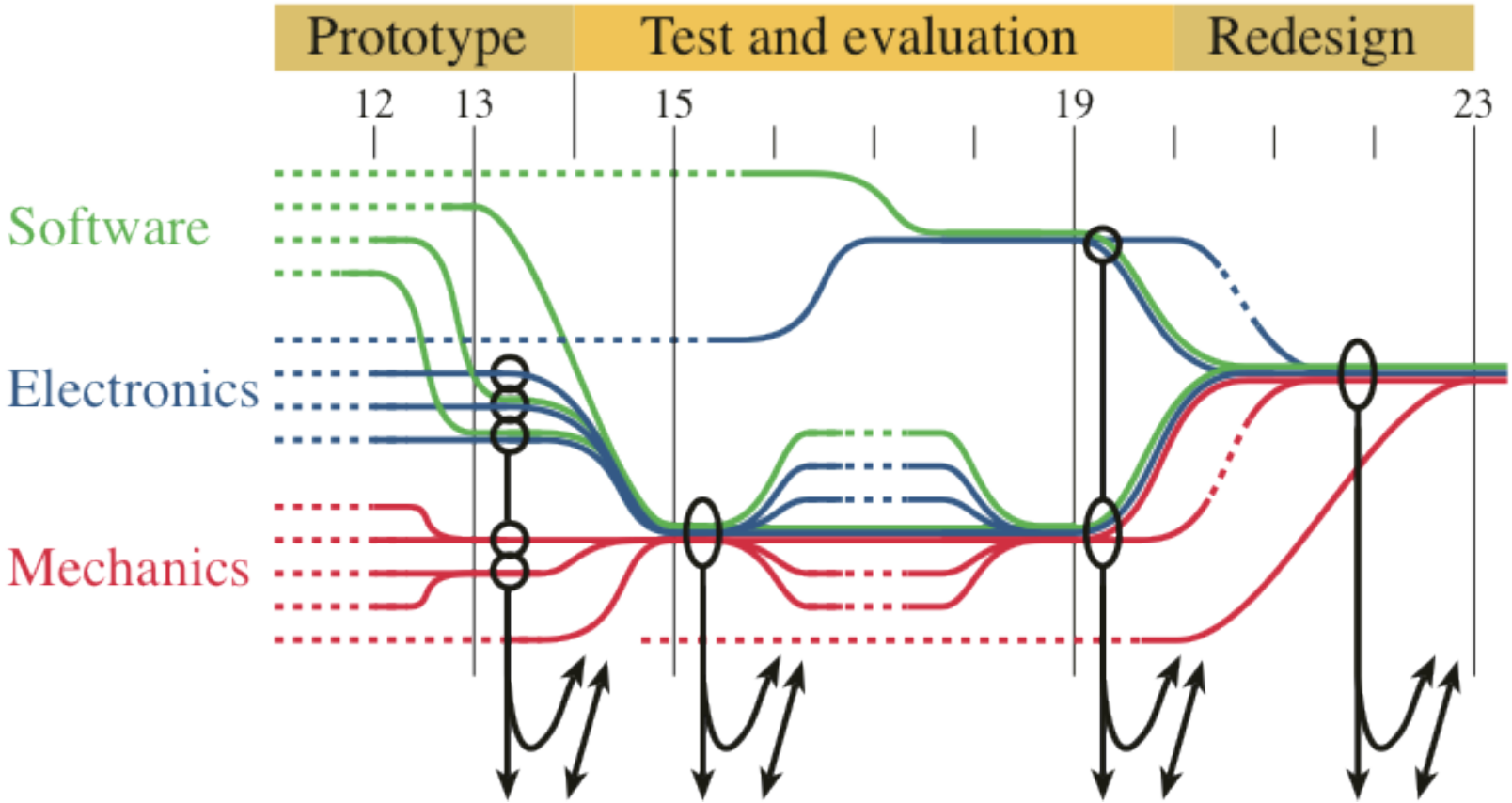
Track 2
Track 1


Swarm-bots

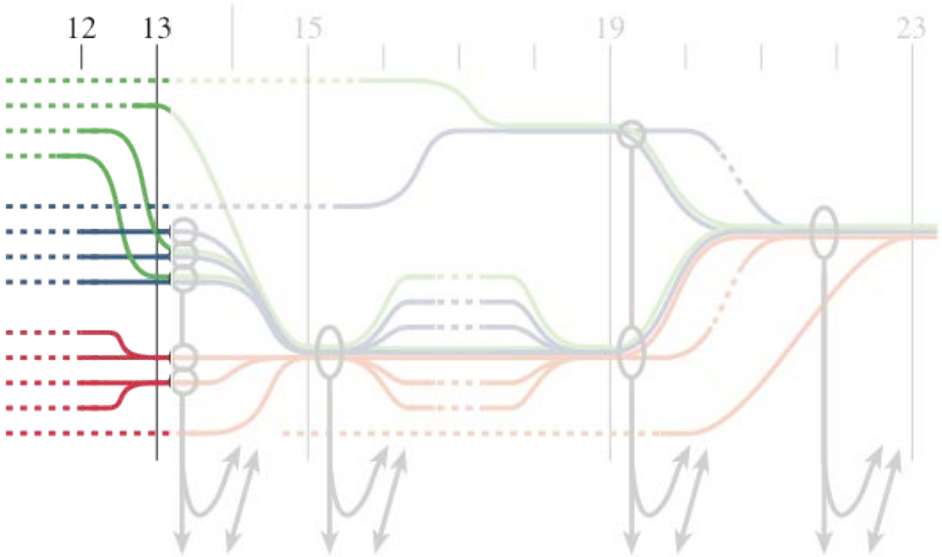
Methodology?

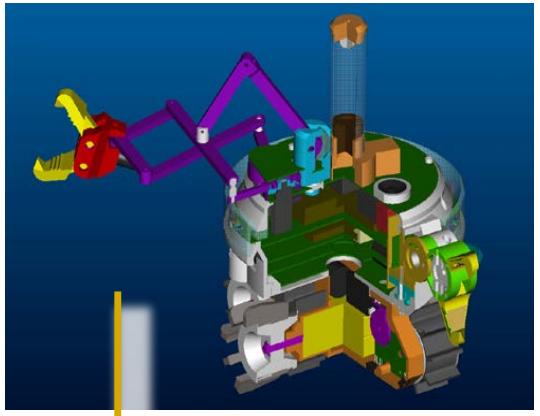
- Based on project milestones
- Iterative

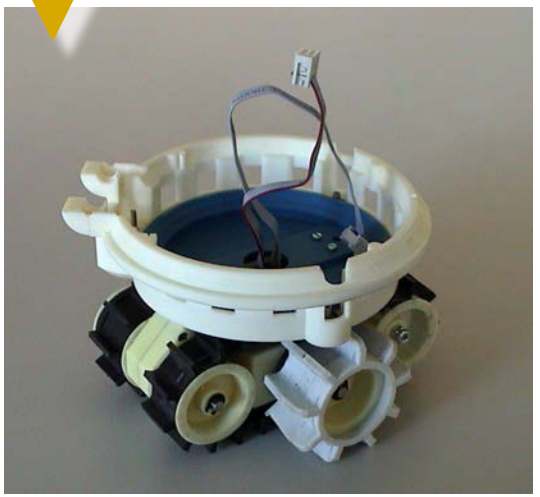
Overview of the second year activity



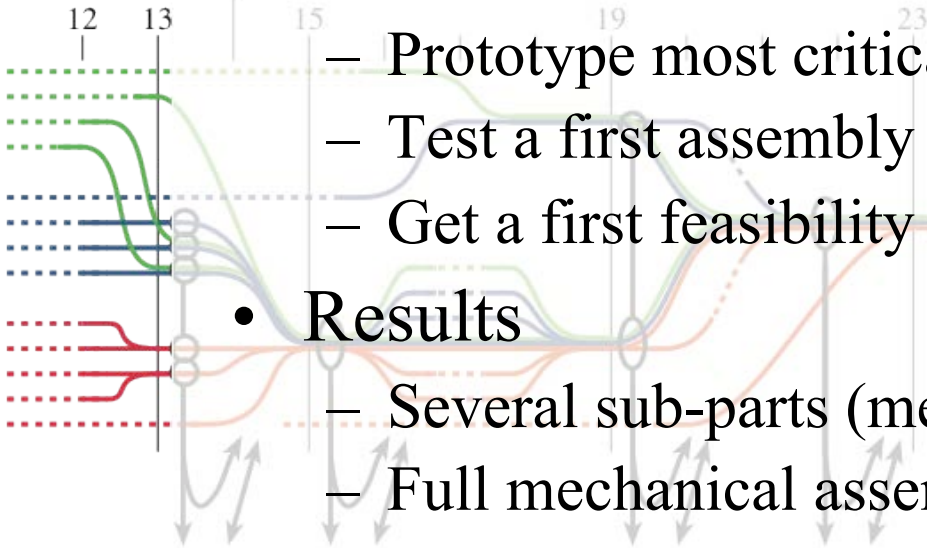
From design to prototype 0





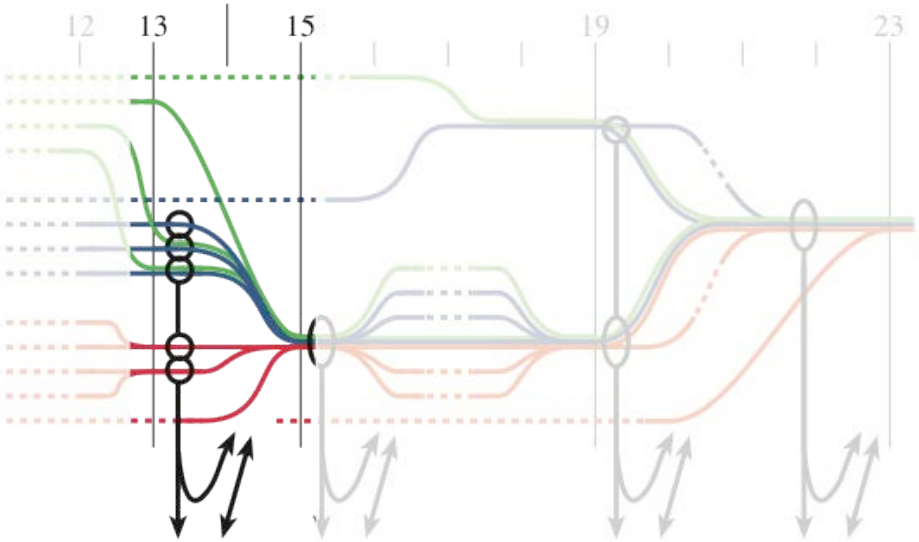


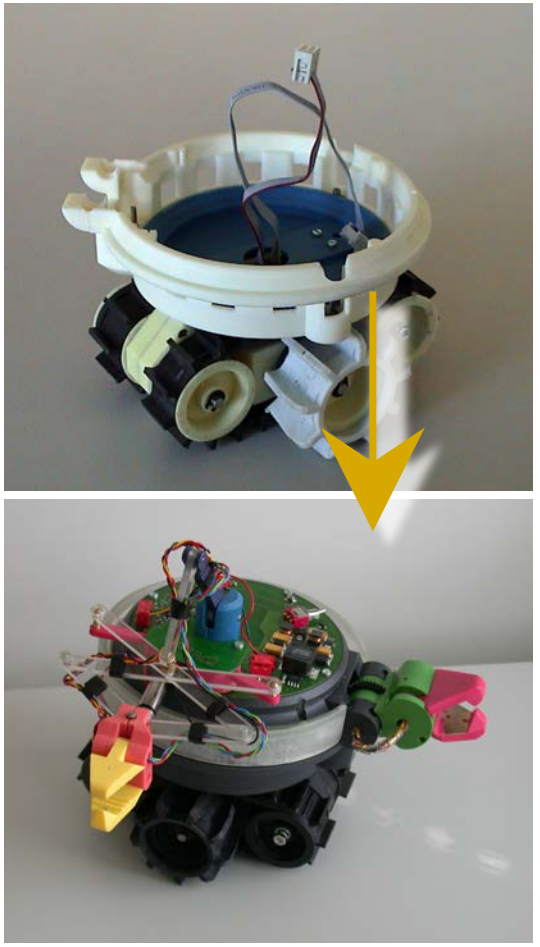
From design to prototype 0



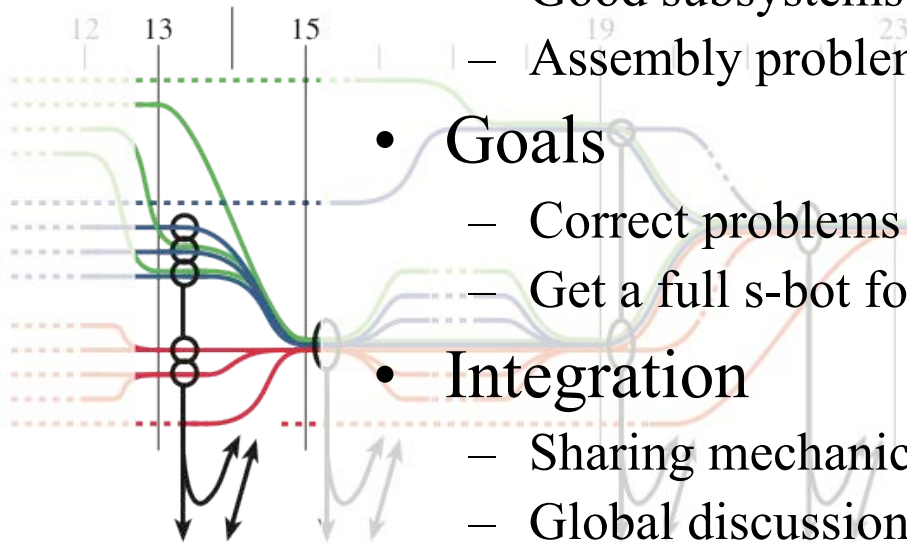
- Goals
  - Prototype most critical parts
  - Test a first assembly
  - Get a first feasibility feedback
- Results
  - Several sub-parts (mechanics+electronics) assembled
  - Full mechanical assembly impossible
  - All electronics (excepted main CPU) designed
  - No programming

From prototype 0 to prototype 1



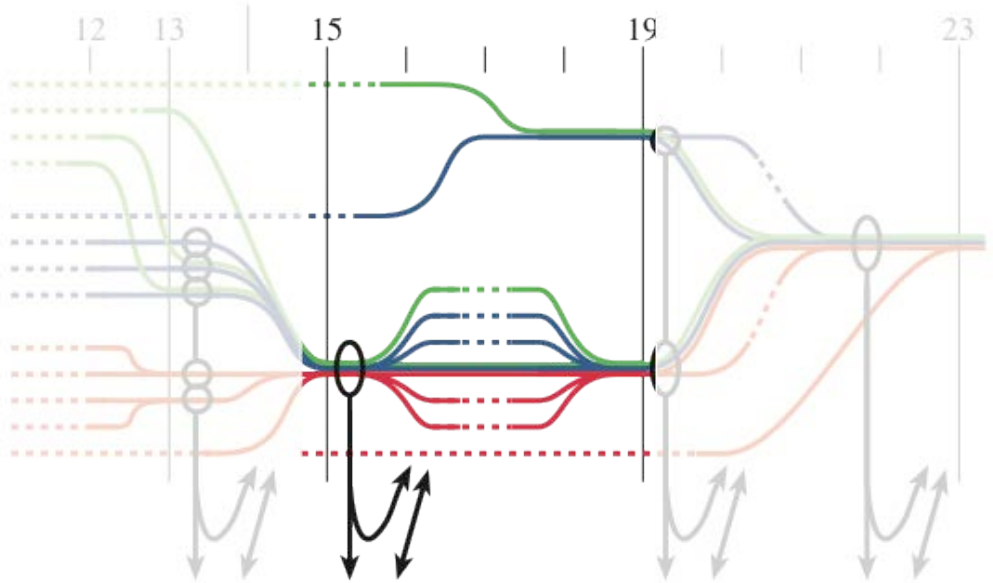


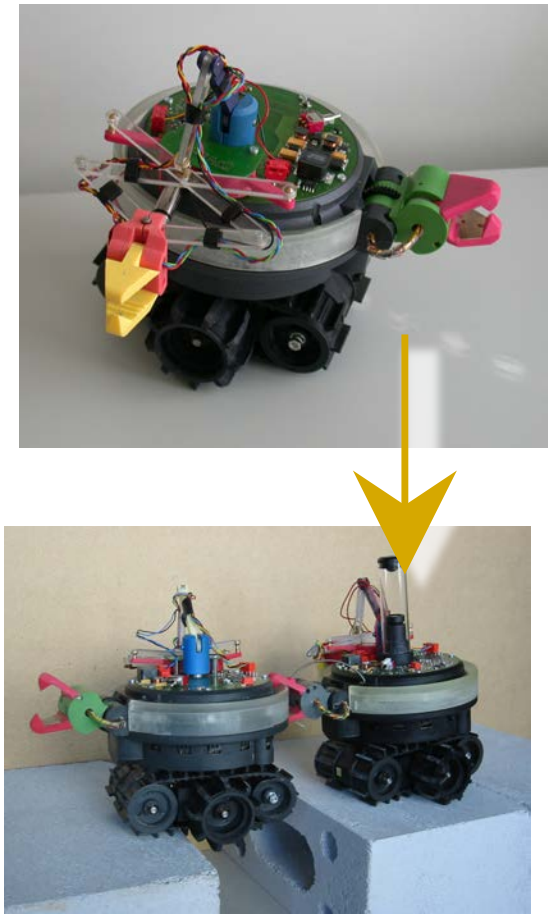
From prototype 0 to prototype 1



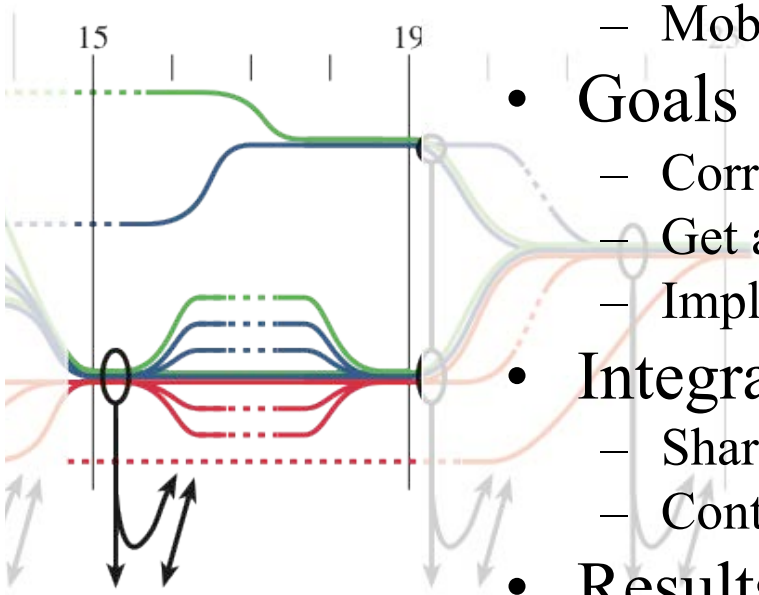
- Tests
  - Good subsystems (treels©, gripper parts, electronics)
  - Assembly problems (electronic components, fixation, etc)
- Goals
  - Correct problems found in test phase
  - Get a full s-bot for complete testing
- Integration
  - Sharing mechanical informations
  - Global discussion about sensors / actuators
- Results
  - Assembly of the whole mechanics
  - Implementation of the slave electronics (no main CPU)
  - Programming of the slave electronics

From prototype 1 to prototype 2





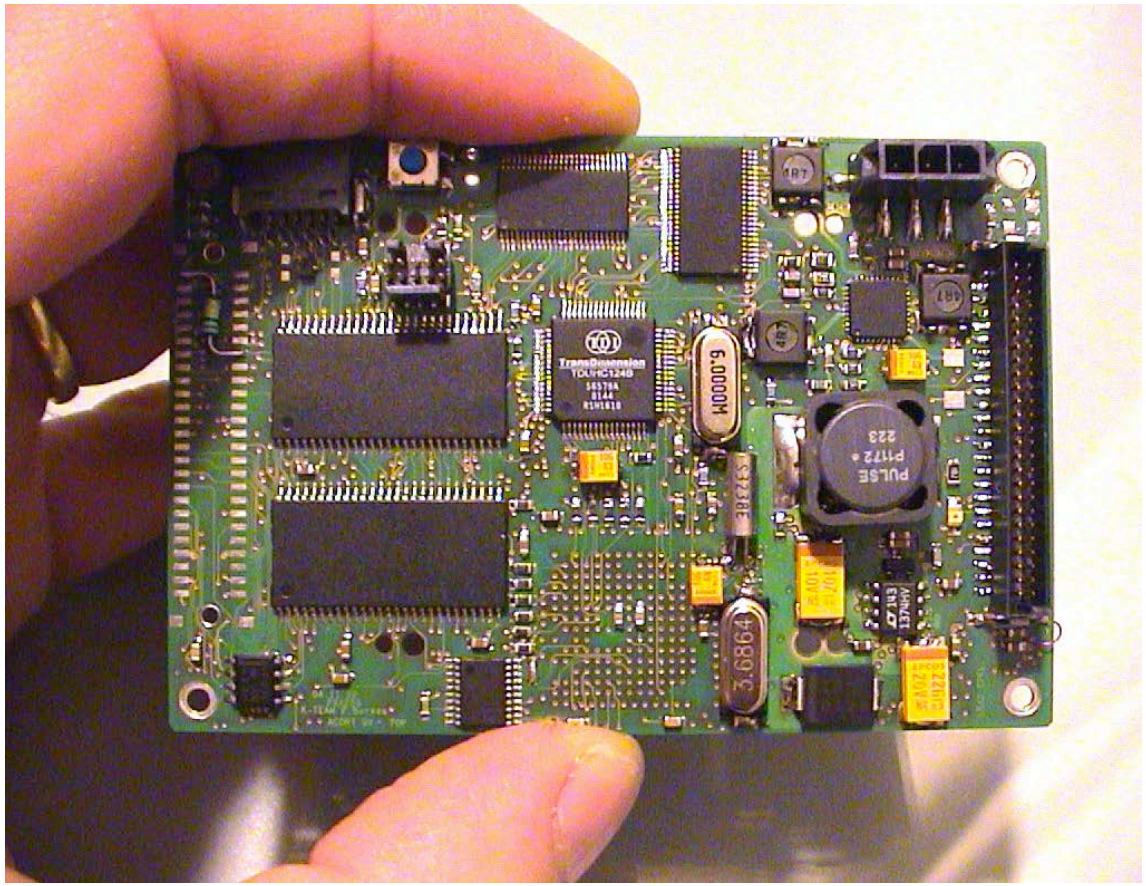
From prototype 1 to prototype 2



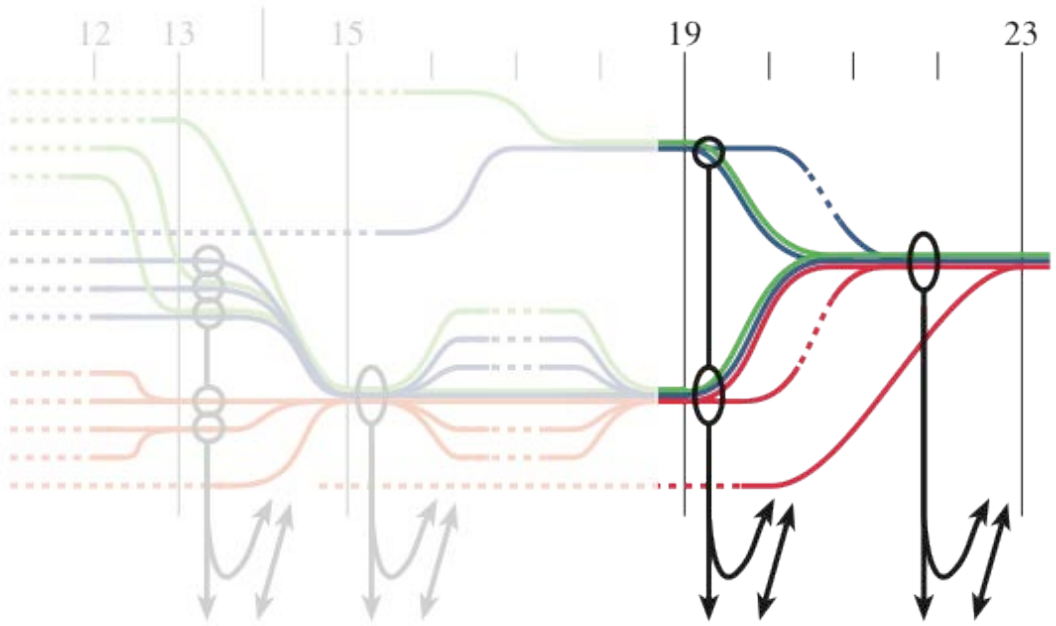
- Tests
  - Functional (gripper, arm) and electronics problems
  - Mobility (sensors/actuators) functionality ensured
- Goals
  - Correct problems found in test phase (priority gripper)
  - Get a second s-bot for swarm-bot configurations
  - Implement the main CPU / camera / sound prototype
- Integration
  - Sharing mechanical / control informations
  - Continous discussion about sensors / actuators
- Results
  - Improved design ensuring swarm-bot fuctionality
  - Core CPU design and realization (external hard + soft)
  - Implementation of API

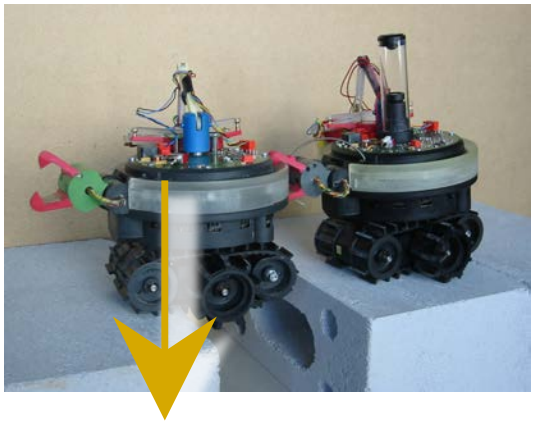
From prototype 1 to prototype 2

- Results
  - Xscale board
    - 400Mhz
    - 64M RAM
    - 32M flash
    - WiFi on CF
    - USB master
  - LINUX
  - S-bot API

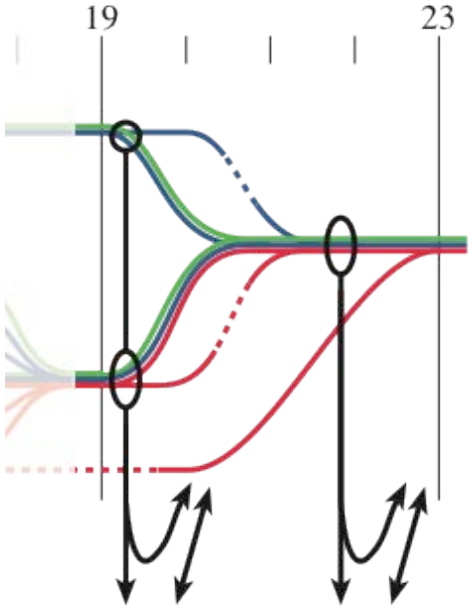


From prototype 2 to production



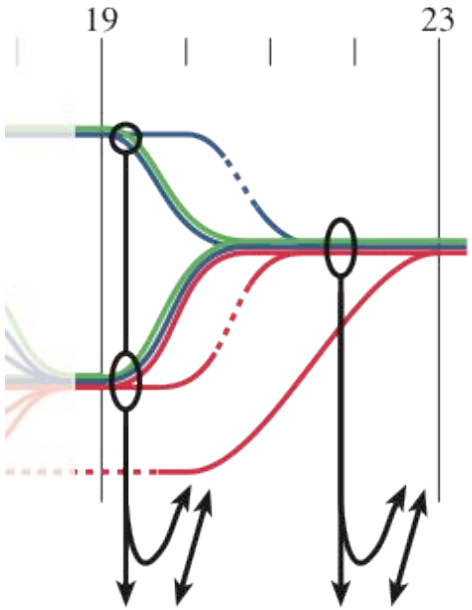


From prototype 2 to production



- Tests
  - Minor problems with tracks/gripper and master USB
  - Good functionality of gripper elevation and CPU
- Goals
  - Correct all problems found in test phase
  - Integrate core CPU / sound / camera into s-bot
  - Design and test 2D force sensor
  - Start production
- Integration and test
  - Sharing detailed control information
  - Give data on sensors and discuss traction sensor design
- Results
  - Fully embedded system
  - Matching with simulation
  - Production s-bot fully defined and production started

From prototype 2 to production

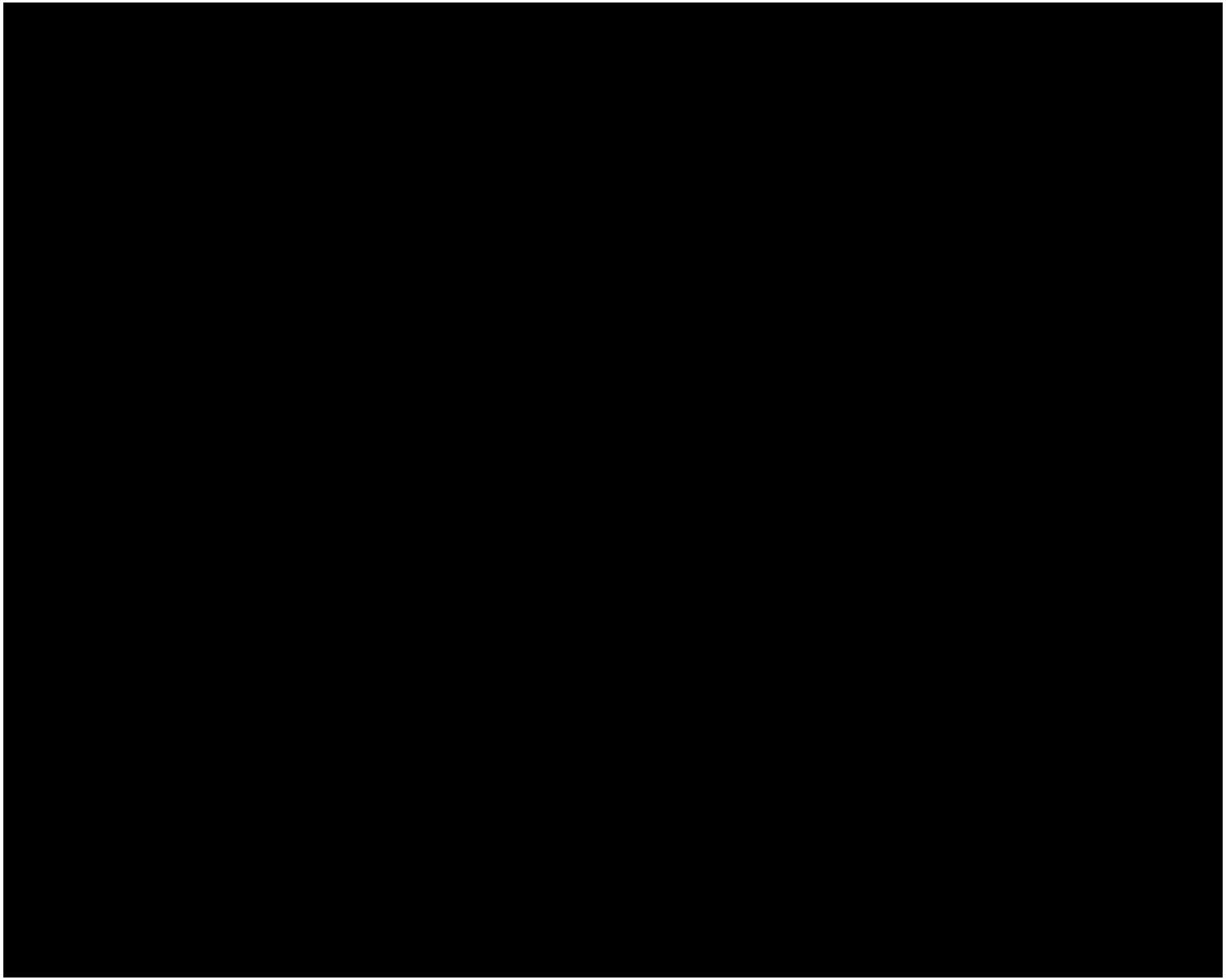


- Status on month 23
  - LINUX camera drivers still under development
  - Camera optics redesigned and under construction
  - 35 s-bots under production (10 with higher priority)
- Hardware conclusion
  - S-bot is a very unique robot
    - Inter-robot connection ability
    - Large dimension in actuators (9) and sensors (~50)
    - Worldwide better ratio performances / size
    - Powerful parallel computationl structure (Xscale + 13 PICs)
    - Software tools (LINUX, WiFi) used in much bigger robots
  - Strong bidirectional interaction with simulation
  - Innovative technical solutions

Swarm-bots

Selling the idea:

- people imagination
- selling the hardware
- videos



marXbot: improvement of s-bot

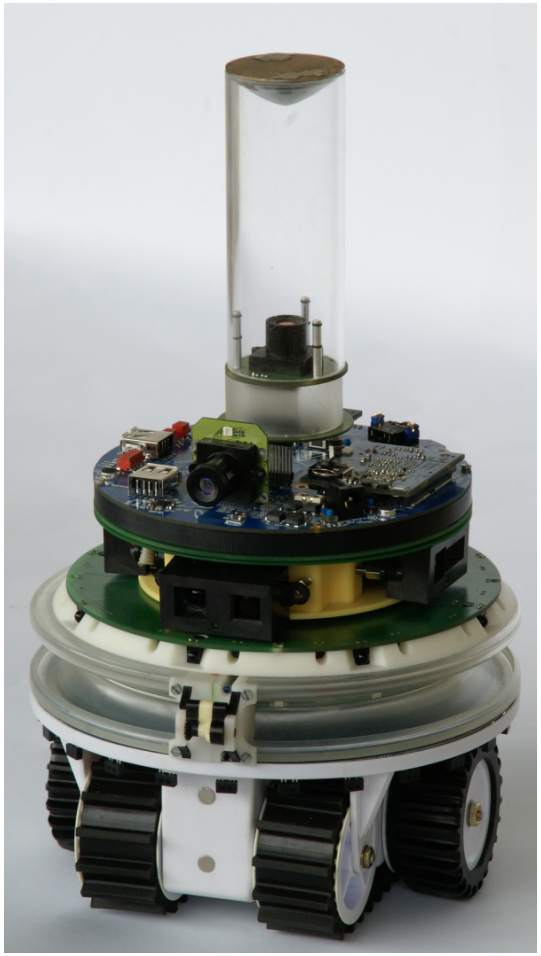
- Learn from problems found in the s-bot
  - Correct them
  - Adapt solution to new challanges
- Allow its use in a set of projects
  - Make it modular
  - Include larger set of sensors

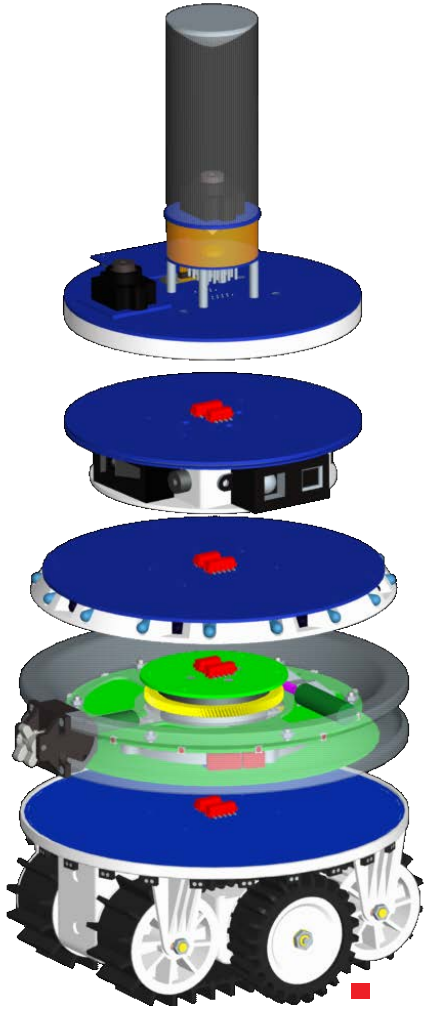
marXbot: features

All terrain
CPU
Modularity
Sensors
Distance sensor
Vision
Energy manag.
Wireless
Stability
Price

marXbot: features

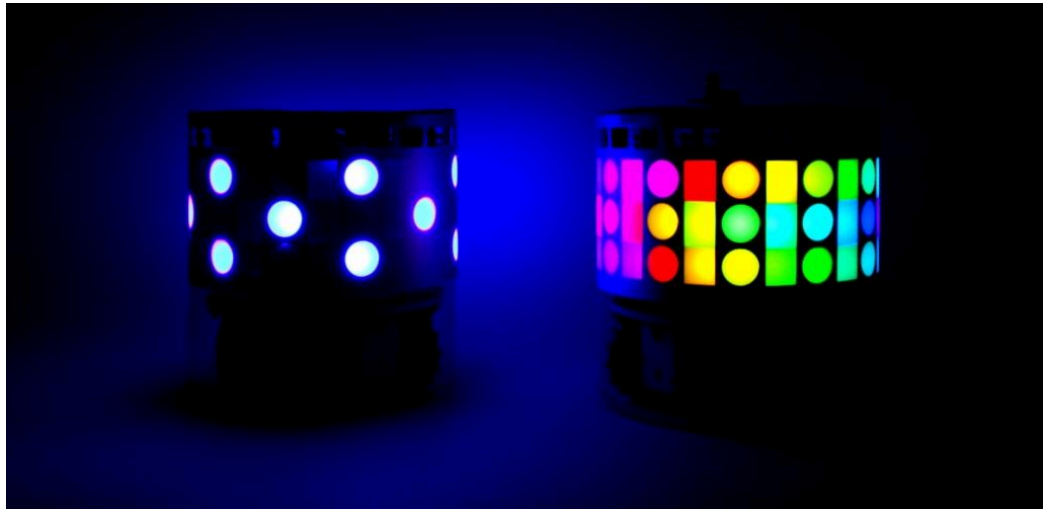
All terrain
CPU
Modularity
Sensors
Distance sensor
Vision
Energy manag.
Wireless
Stability
Price

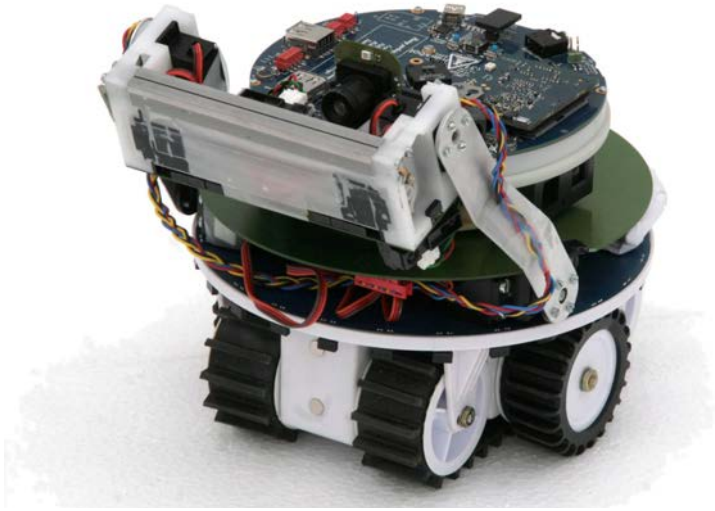




marXbot: features

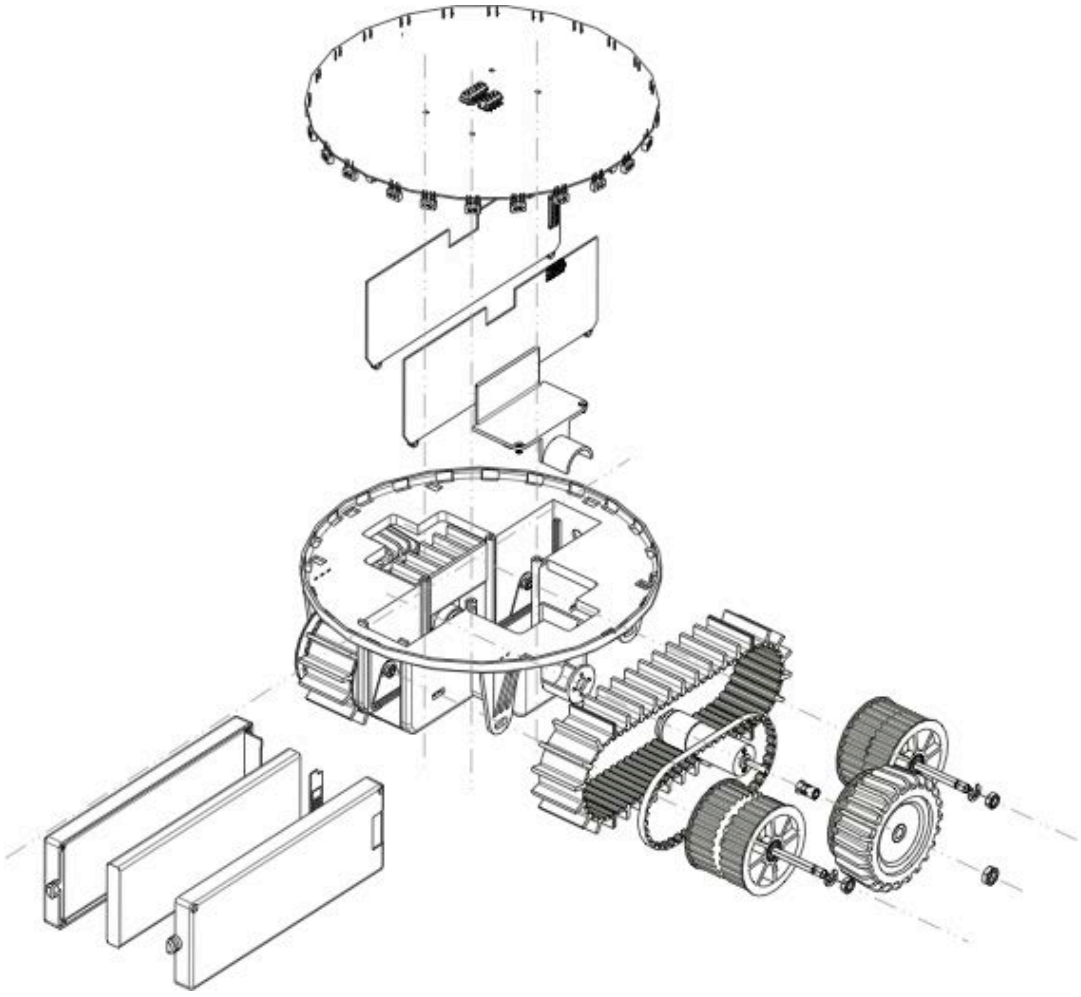
All terrain
CPU
Modularity
Sensors
Distance sensor
Vision
Energy manag.
Wireless
Stability
Price





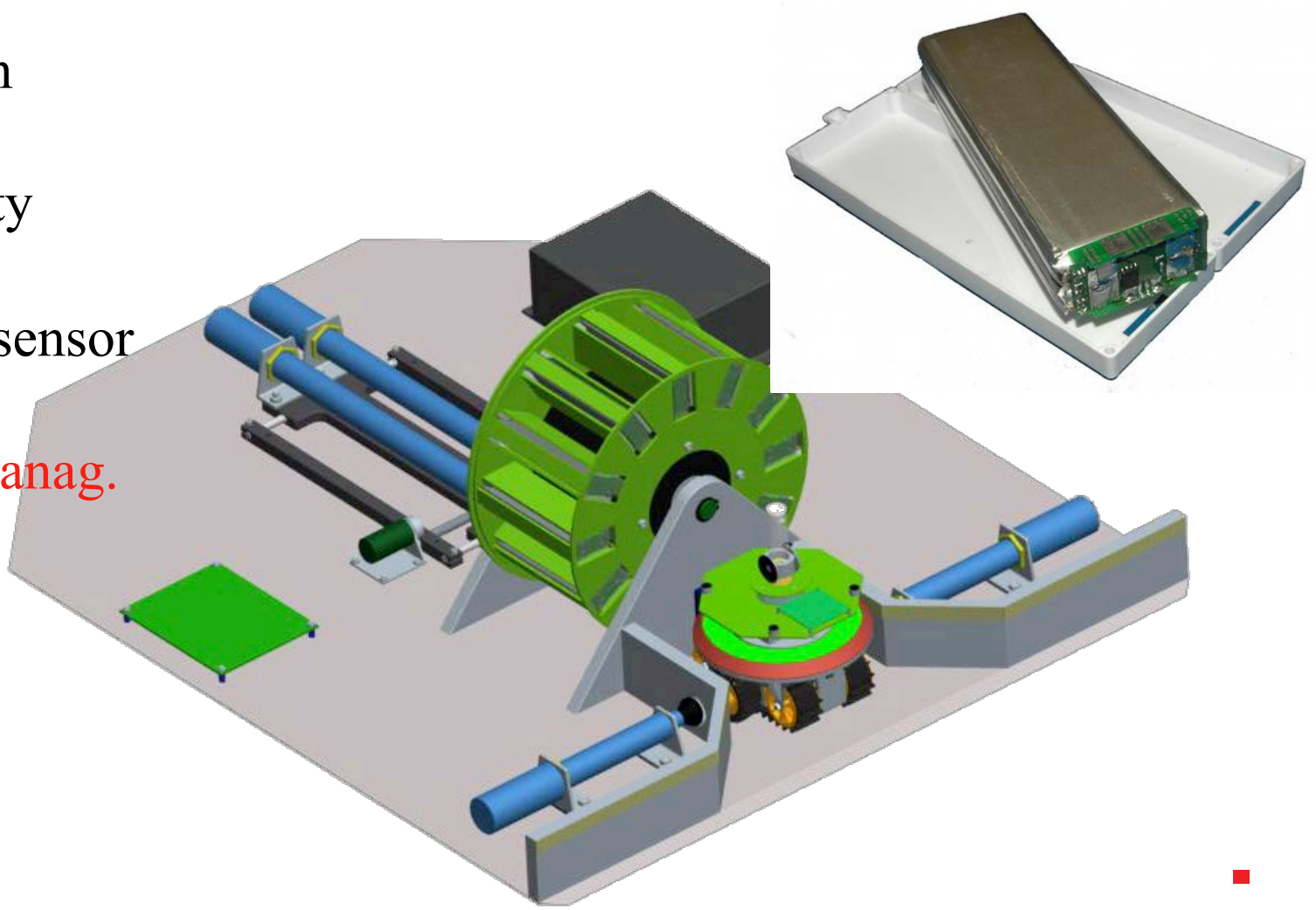
marXbot: features

All terrain
CPU
Modularity
Sensors
Distance sensor
Vision
Energy manag.
Wireless
Stability
Price



marXbot: features

All terrain
CPU
Modularity
Sensors
Distance sensor
Vision
Energy manag.
Wireless
Stability
Price



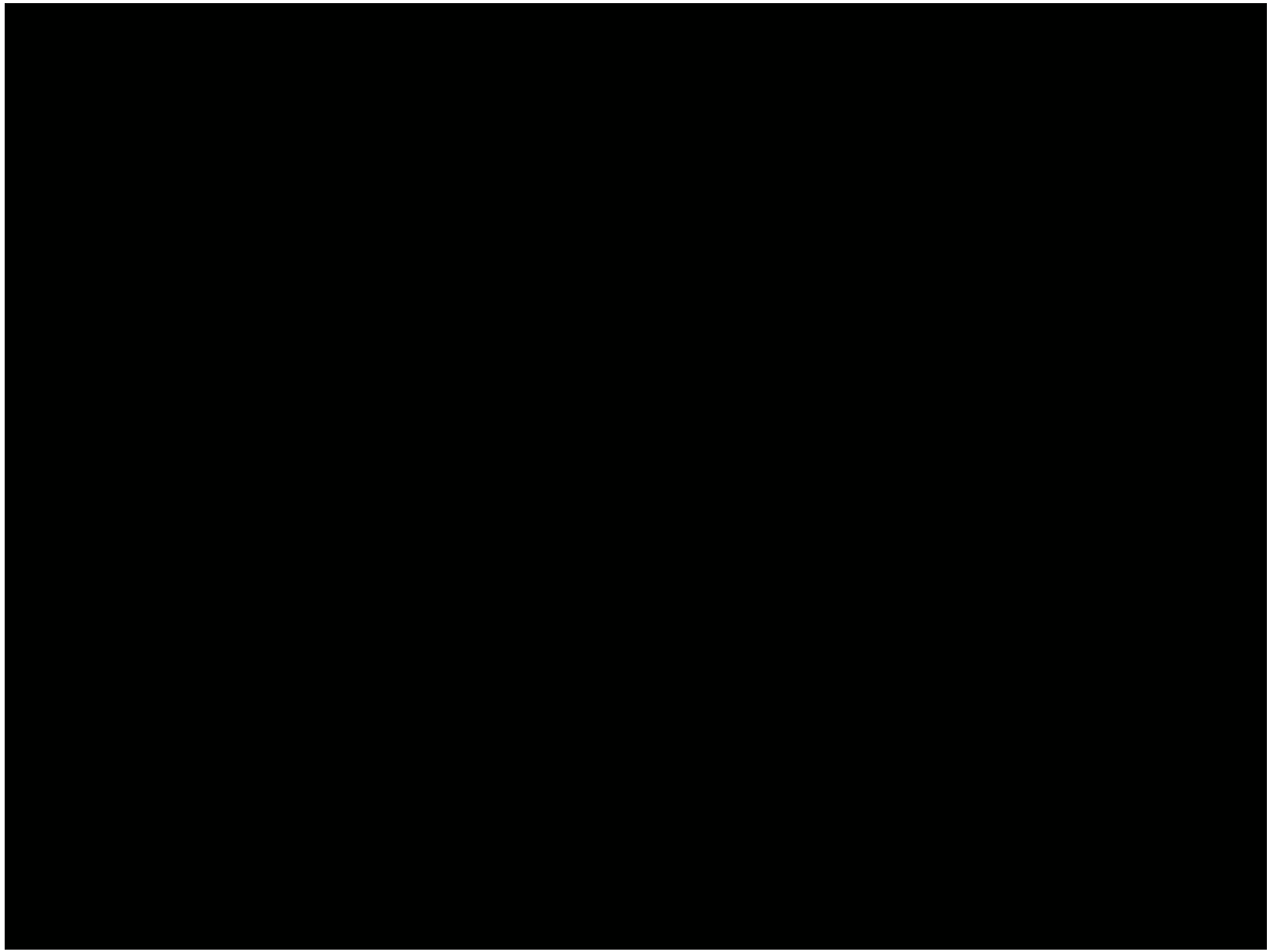
marXbot: features

All terrain
CPU
Modularity
Sensors
Distance sensor
Vision
Energy manag.
Wireless
Stability
Price

Robotic glasses

- How will robotic enter in our daily life?
  - Humanoids?
  - Home of the future?
- What type of interaction with robots?
  - Human-based
  - Machine-based
  - How will robots understand our needs?


Cloth Grasp Point Detection
based on Multiple-View Geometric Cues
with Application to Robotic Towel Folding
Jerem
Marco
Department of Electric
University of Ca
nd Computer Science
Berkeley
International Conference on Robotics and Automation, 2010



Ranger

Conclusion:

1. If you have good ideas, share them
2. Focus on implementation, not ideas
3. Look for the real specification of your system
4. Plan and set milestones
5. Exploit all possibilities to sell your ideas
6. Contribute to open projects
7. Keep the priorities in the right order
8. How to « sell » technical work in a thesis?

Assignements:

- Robotics-related needs of primary school teachers
- Methodology and motivation for your robot design
- Comparison of methodology between art / design / engineering
- Open hardware strategy / analysis of impact in an open project
- ...