Hominid Robot Charlie and Humanoid Robot AILA

- Mechatronic Design and Control Approaches -

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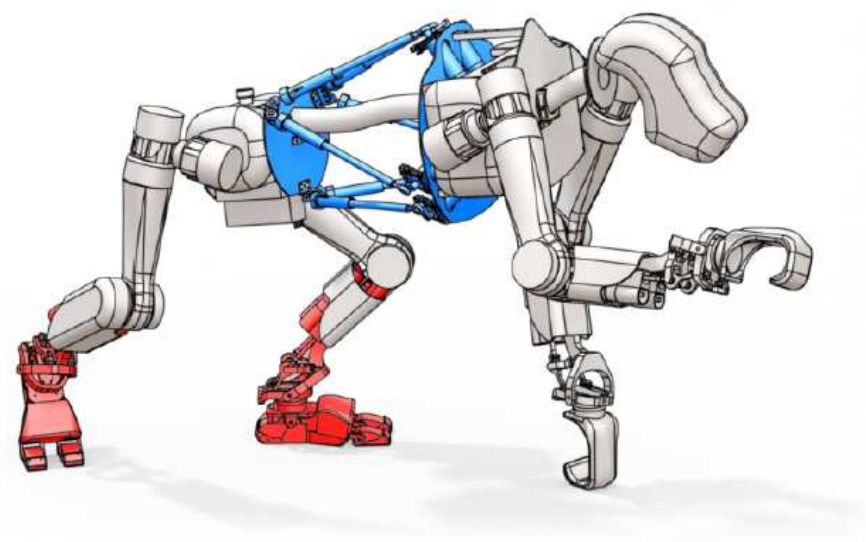
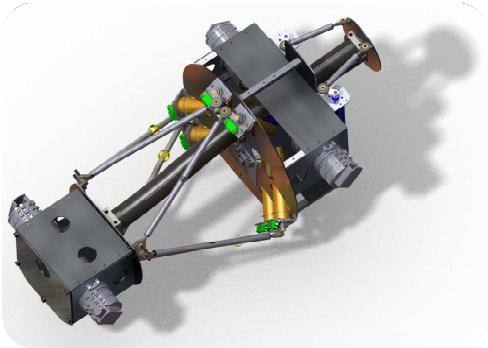
Charlie - Motivation

- Improve locomotion
  - Energy efficiency
  - Mobility -> transition from quadrupedal to bipedal walking
- Biological inspiration from chimpanzees (*Pan Troglodytes*)



- First element: Actuated spine-like structure
  - Most multi-legged robots used a rigid central part
  - Possible uses: shifting while walking, standing up, diagonal walking, climbing, shifting CoM, …



Charlie - Motivation

- Second element: Actuated feet
  - Static and dynamic quadruped and bipedal walking required
    - Single point contact foot (SPCF) is not sufficient
  - Multi-point-contact feet (MPCF)
    - Usually, planar MPCF feet are used, limited to indoor environments

  - Charlie‘s design:
    - Active and passive elements to adapt to rough terrains
      - » Partly flexible, partly rigid design
    - Foot composed of five rigid bodies connected via passive joints
    - 3-DOF ankle joint (two active, one passive)

Charlie - Specification

- Degrees of Freedom

3 x Hip / Shoulder	x 4 = 12
1 x Knee / Elbow	x 4 = 4
3 x Ankle (2 active, 1 passive)	x 2 = 6
2 x Toes	x 2 = 2
6 DoF Spinal column	x 1 = 6
6 DoF Head	x 1 = 6
	36 DoF

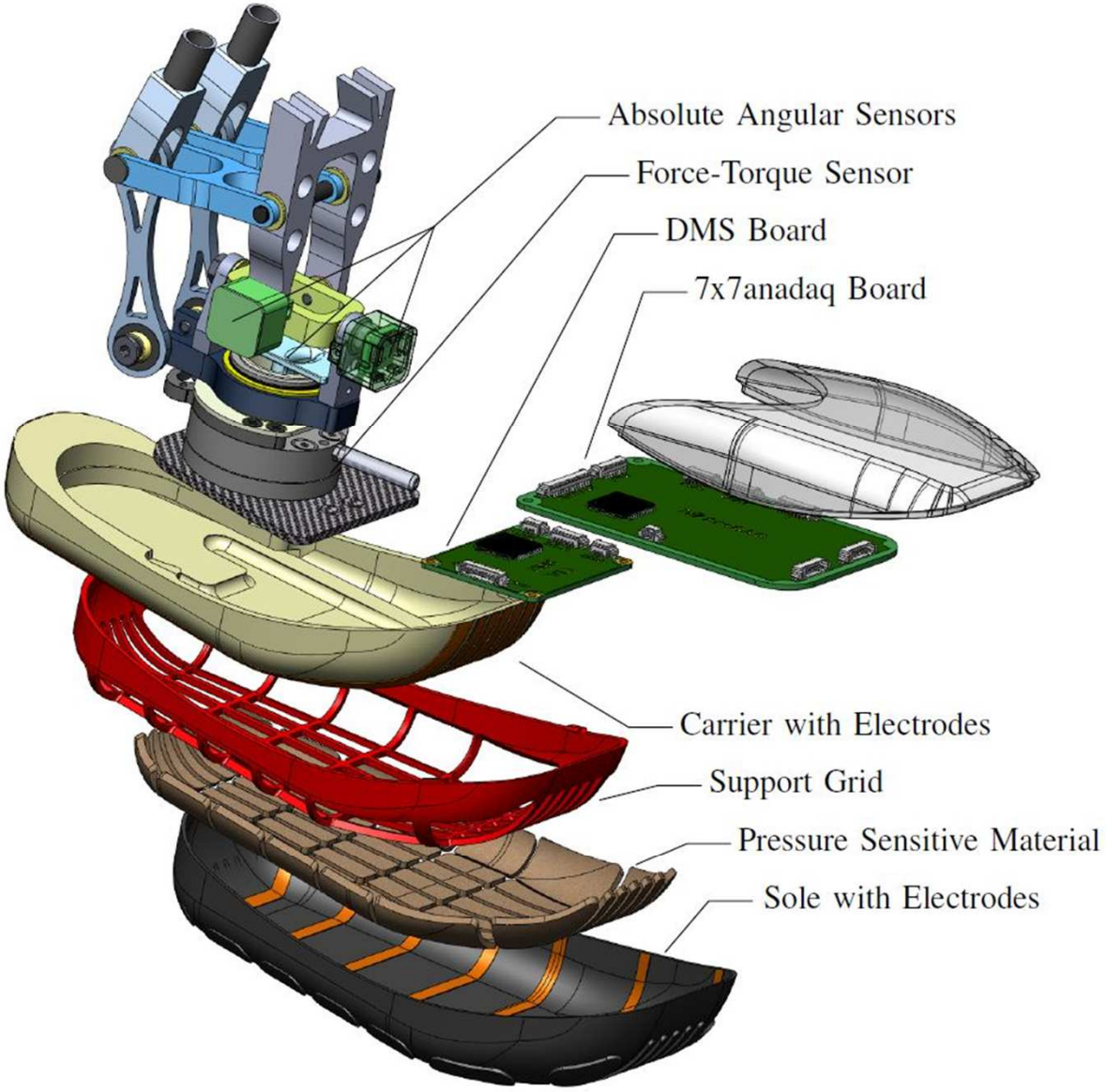
- Weight: 22kg
- Dimensions:
  - Front height: 750mm
  - Rear height: 660mm
  - Body length: 540mm
  - Bipedal posture: 1300mm

- Walking speed:
  - Currently, ½ body length per second

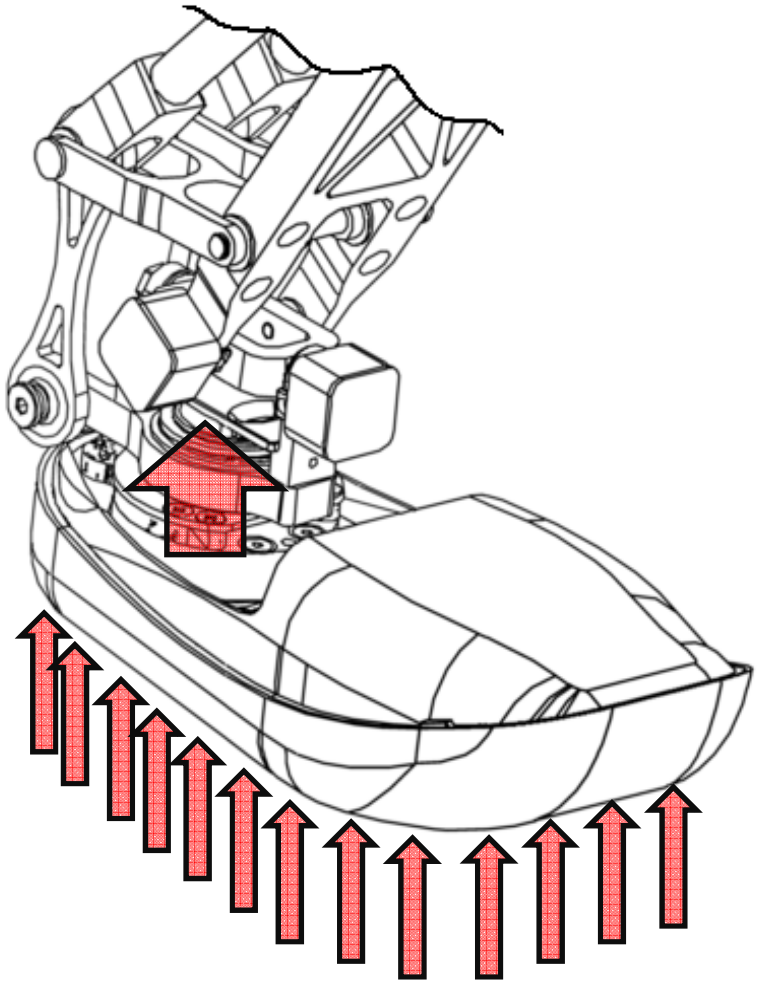
- 1 hour of operation (48V, 2.4Ah)

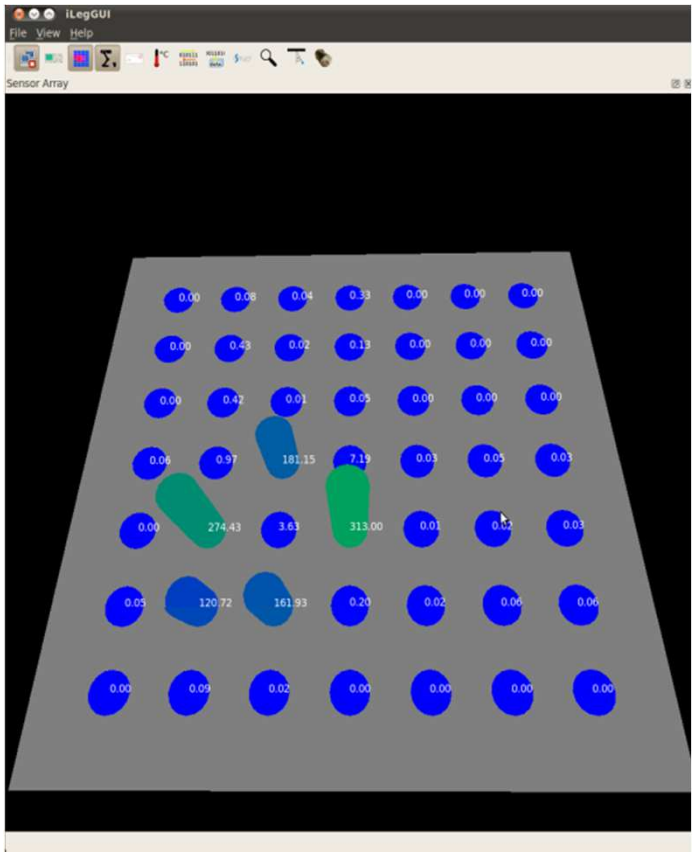
Charlie - Sensors

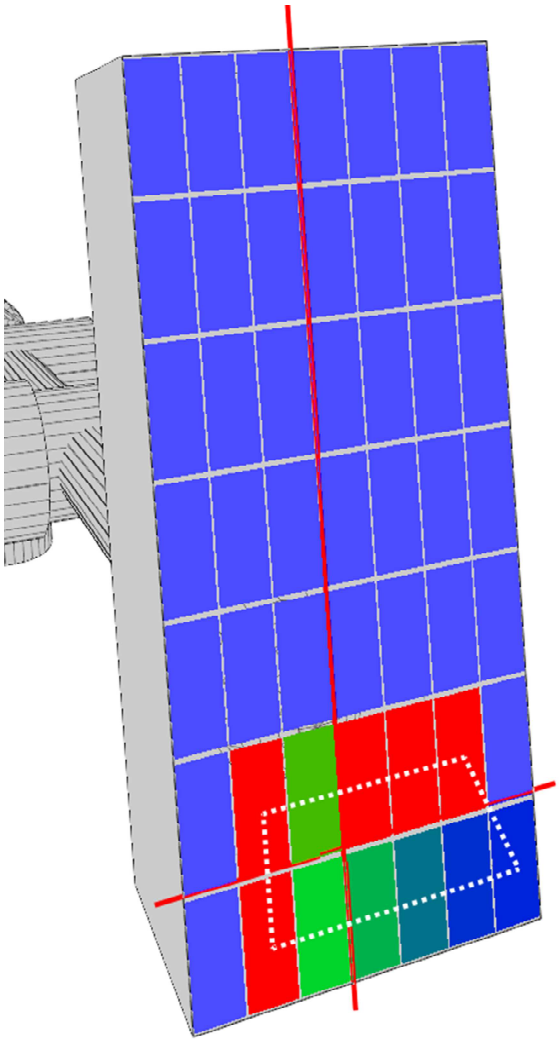
- Further sensors
  - Acceleration
  - Distance
  - Temperature



Charlie - Sensors





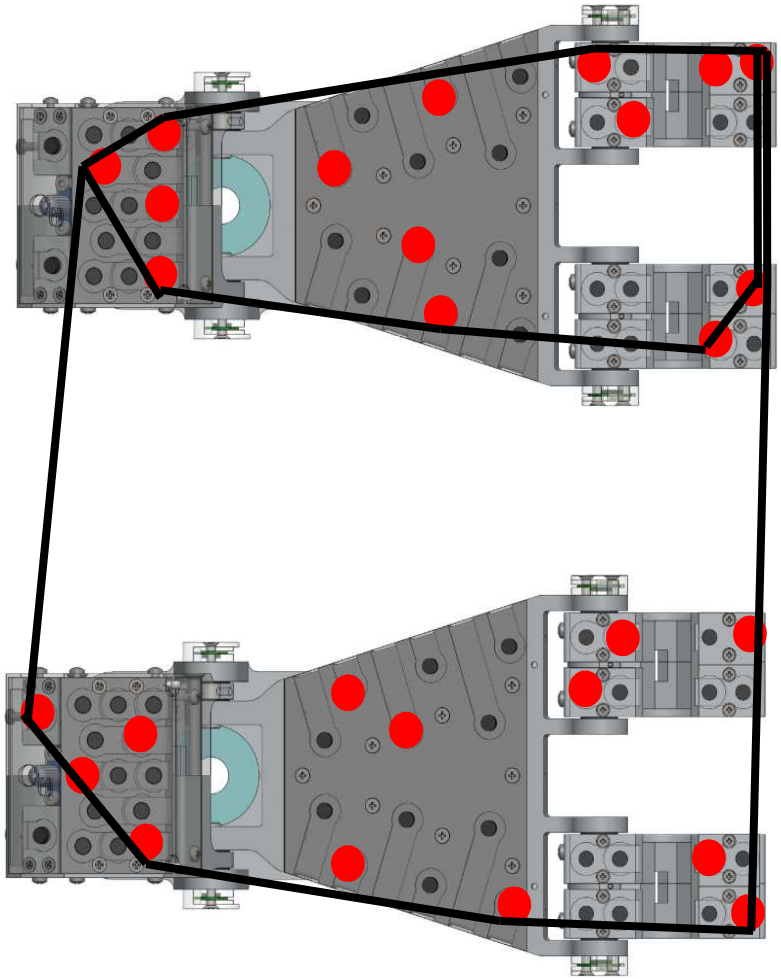


Single force

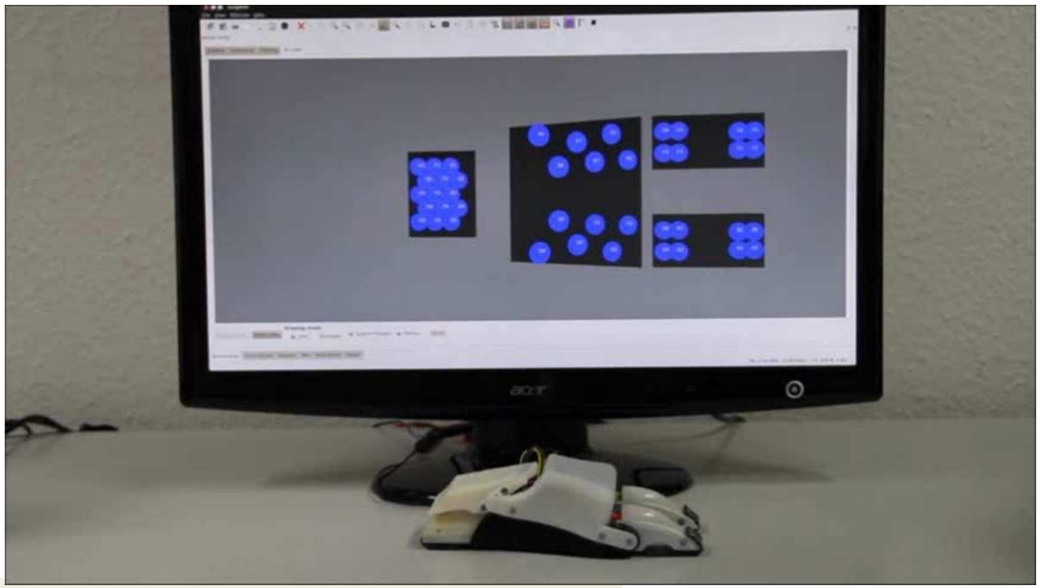
Resulting flow of forces

Center of pressure

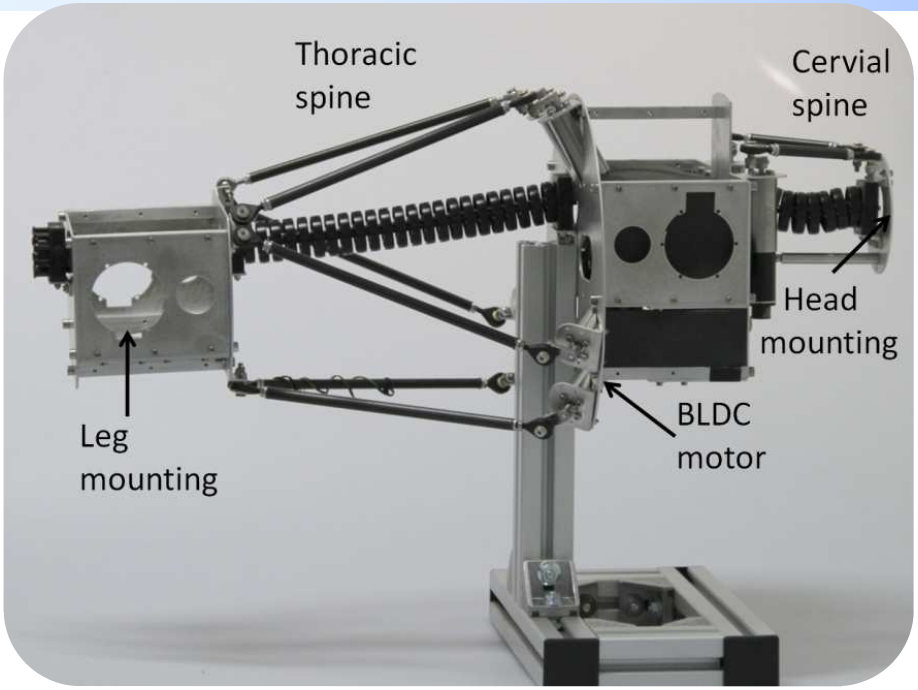
Charlie - Sensors



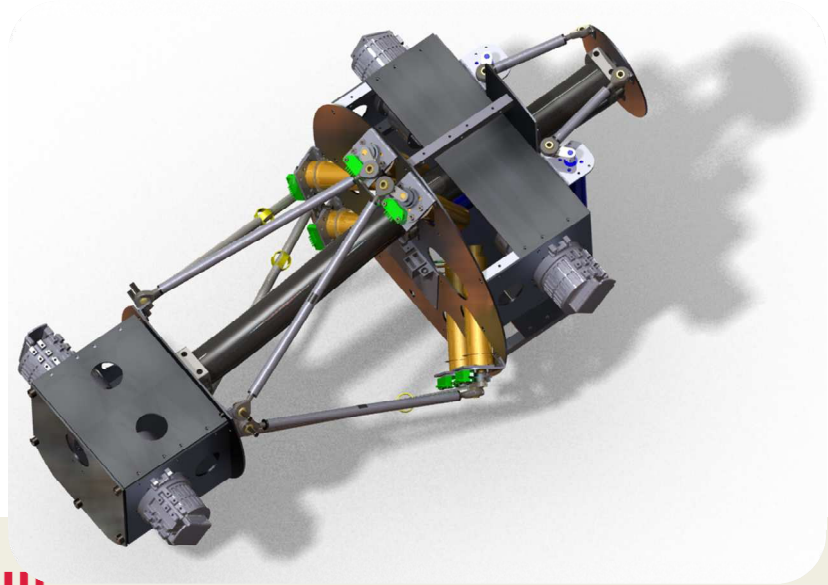
- Local (in each rear foot):
  - Support polygon calculation
  - Center of pressure
- Global:
  - Foot sends coordinates of the sensors forming the local SP

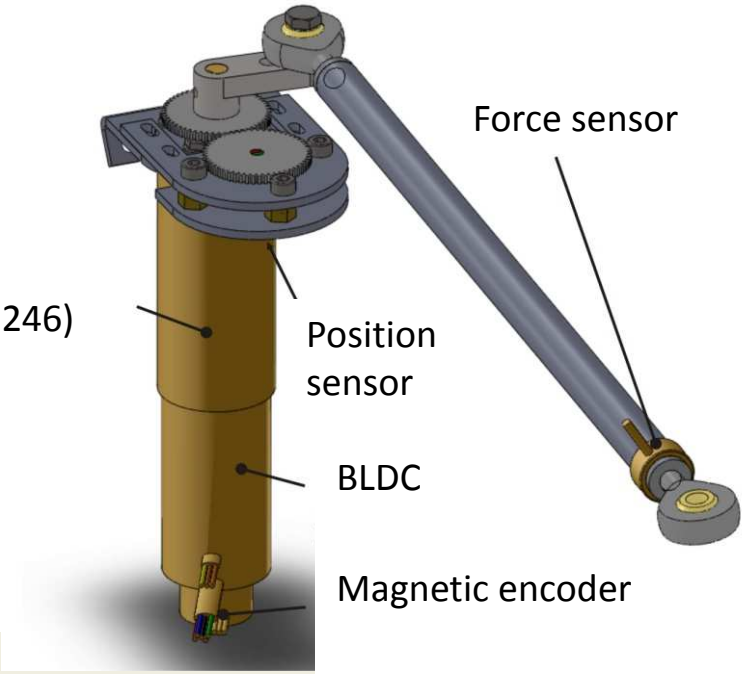


Charlie - Spine Concept

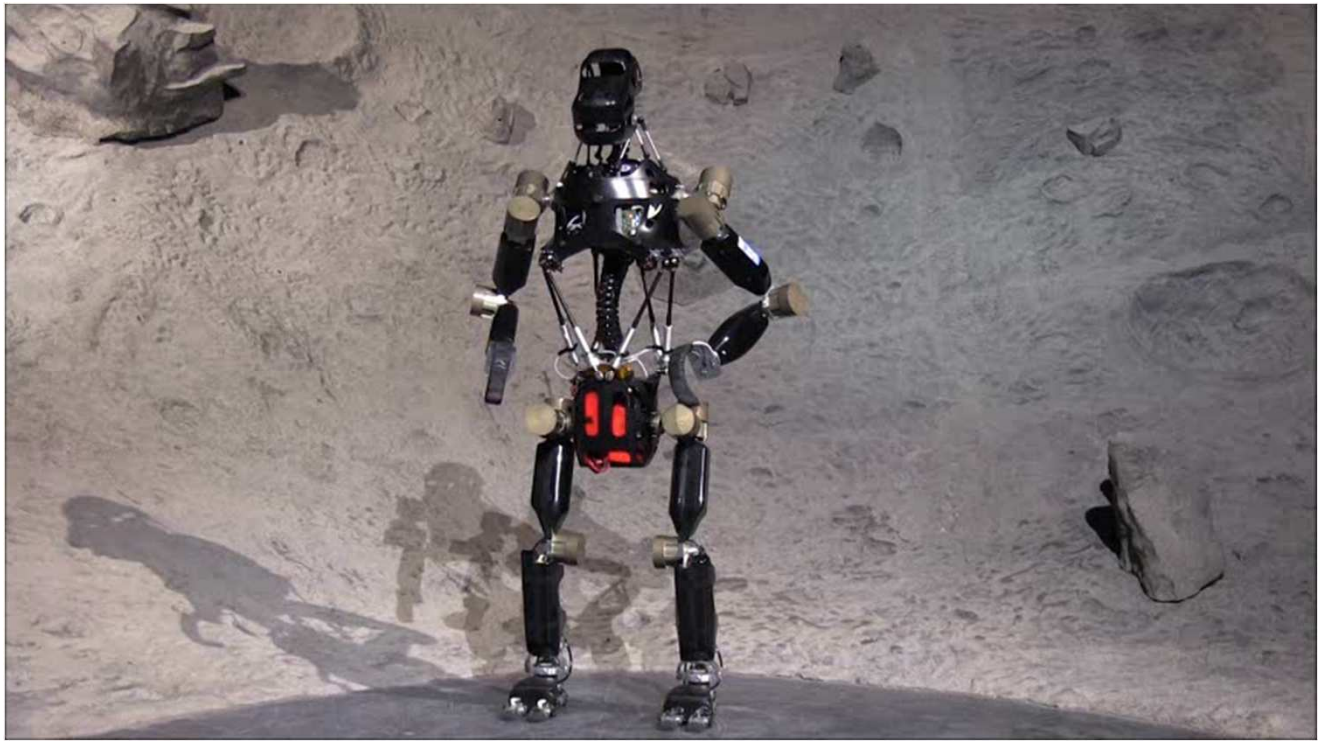


- Characteristics of the spine
  - Lightweight
  - 6 drives
  - BLDC joints
  - Circular motion possible (energy efficient)

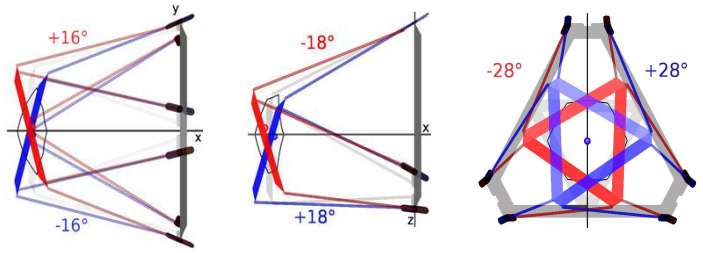




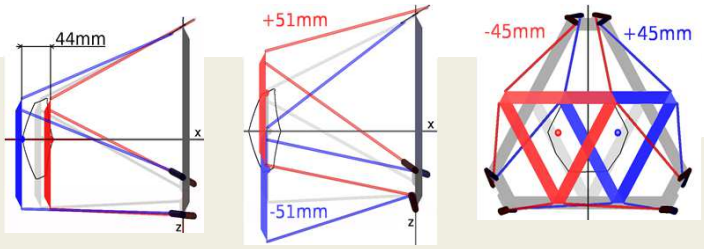
Charlie - Range of Motion



Top-view Lateral-view Rear-view



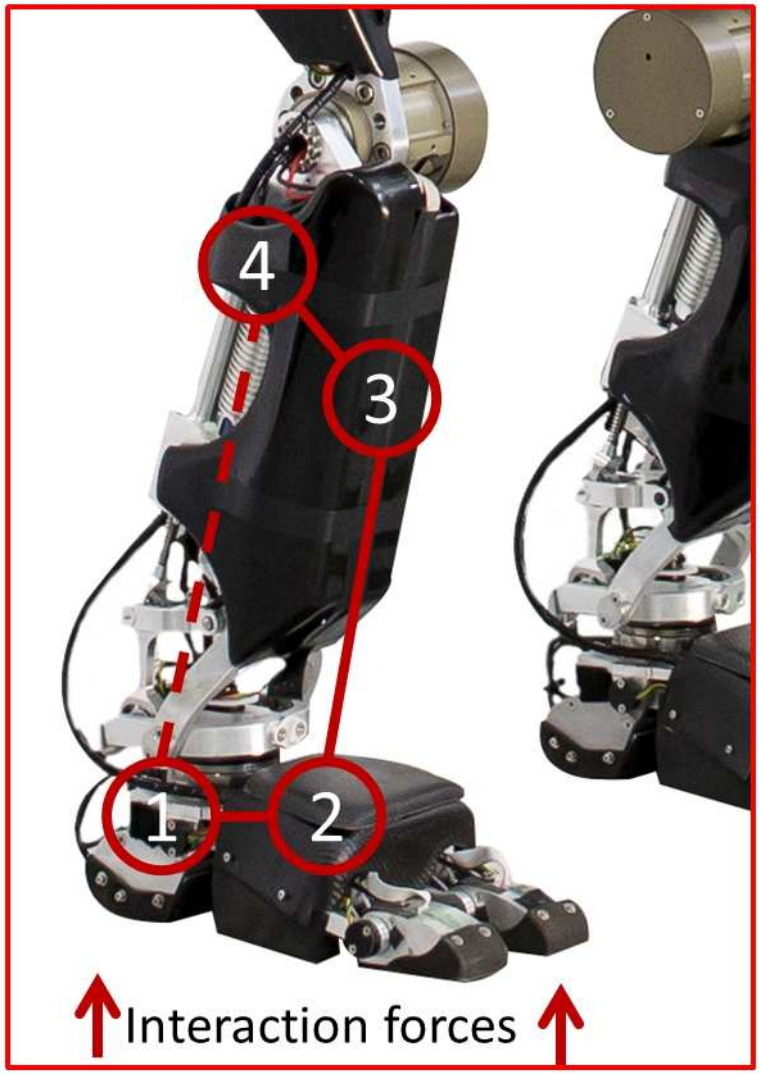
Rotation



Translation

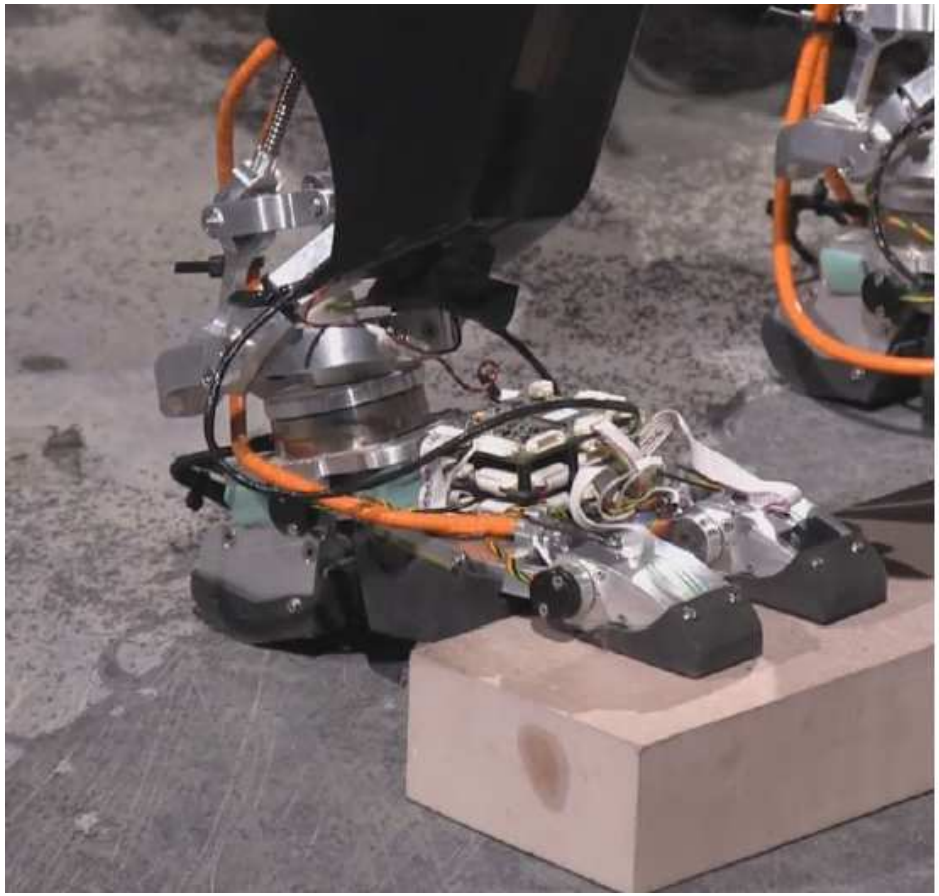
Charlie - Local Control Loop

- Active damping of the foot as a reaction on external load.
- Angular offset corridor to desired values
  - -30 to 30°pitch
  - -18 to 18°roll
- Damping depends on walking cycle progress

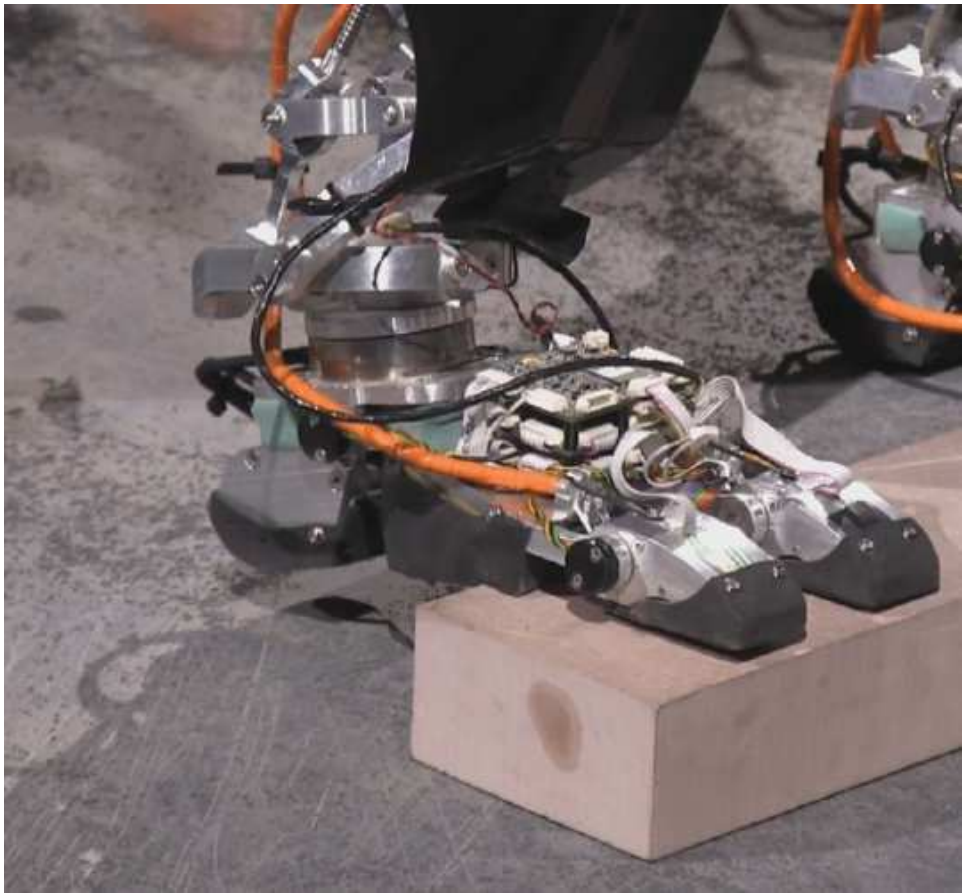


Charlie Balancing

Charlie - Local Control Loop

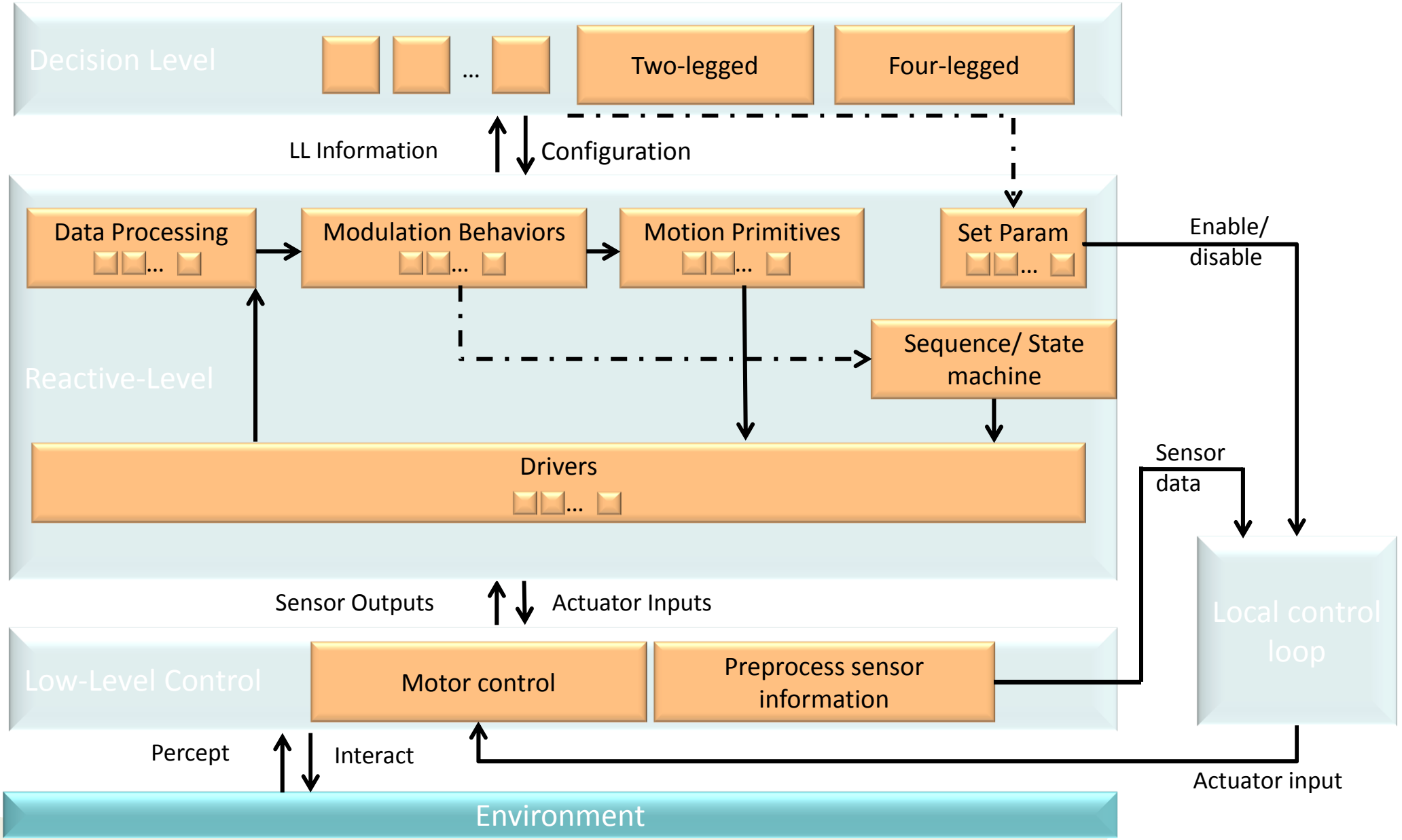


The virtual spring is active.



Without the virtual spring being active, no adaption is taking place.

Charlie - Control



Humanoid AILA

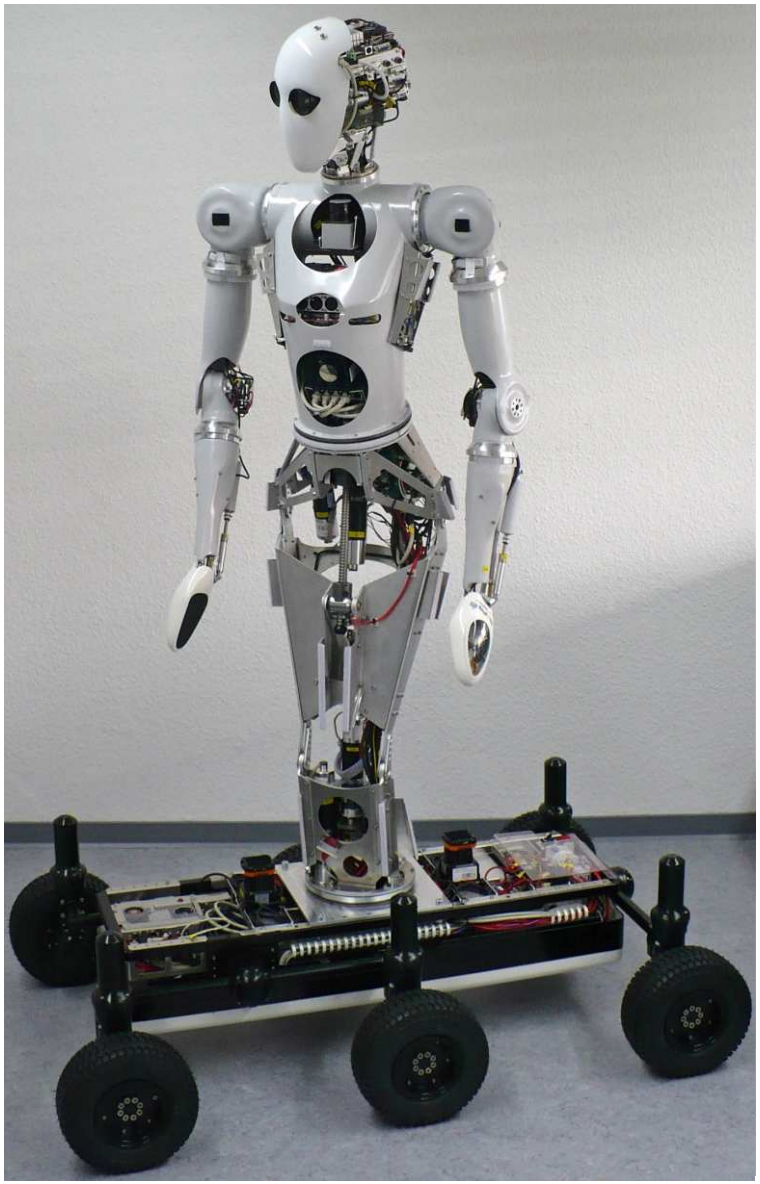
AILA - mechatronic design goals

Arms
- Joints based upon previous development
- Payload to weight ratio > 1
  - Low weight and moment of inertia
  - Stiff structure

Mobile base
- Holonomic
- Indoor and slightly rough terrain
- Synergy to space related project

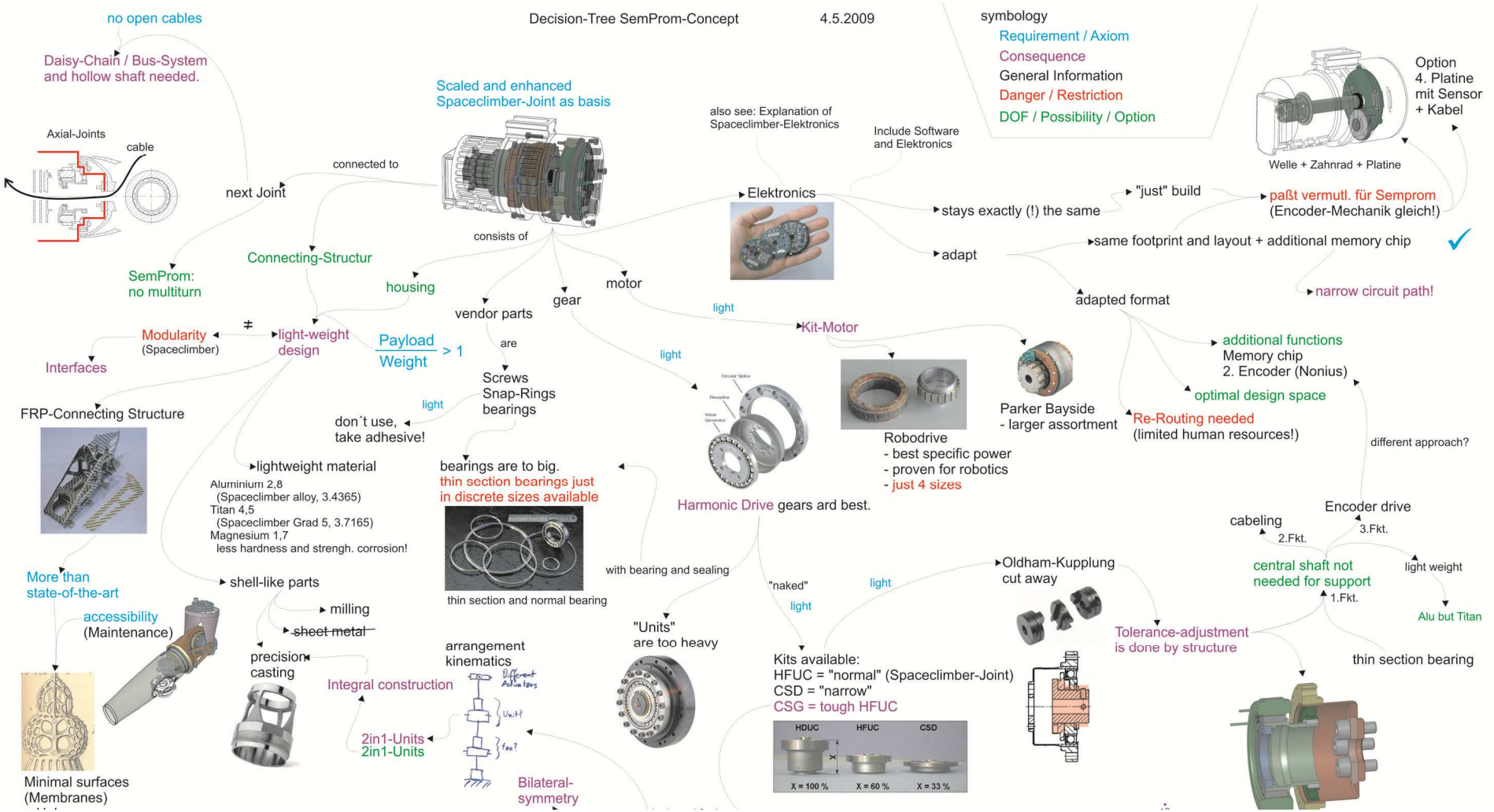
Torso
- Height-adjustment of the arms

Overall
- Anthropomorphic
- Nice appearance
- One year timeframe

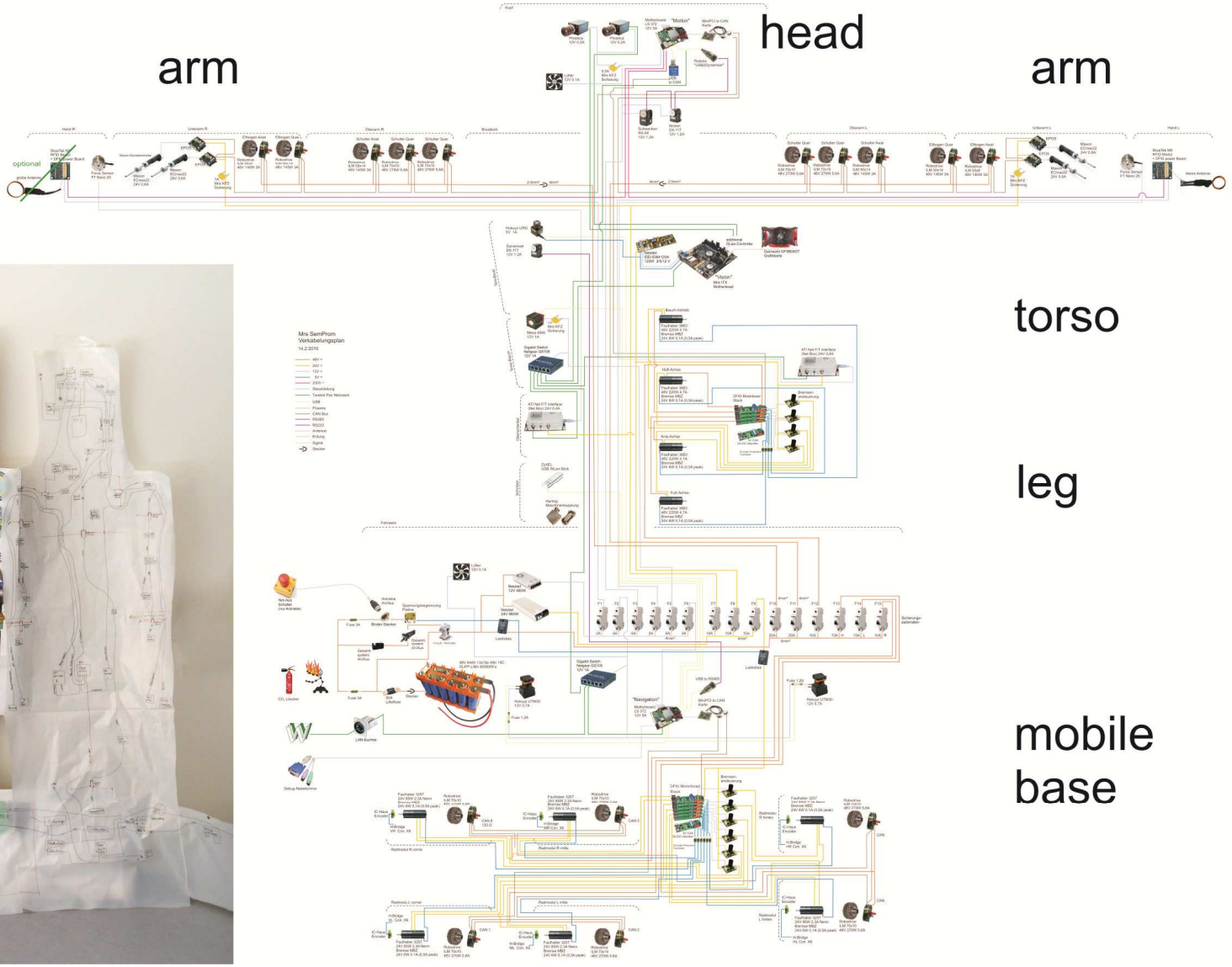


AILA - Concept

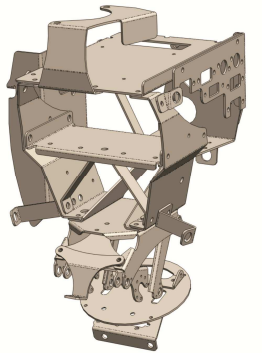
Options and Decision Tree



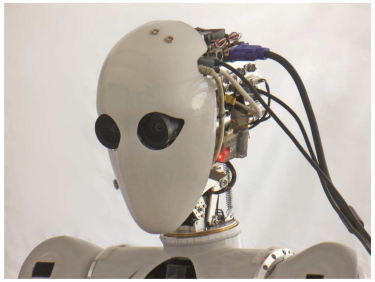
AILA - Principle Design



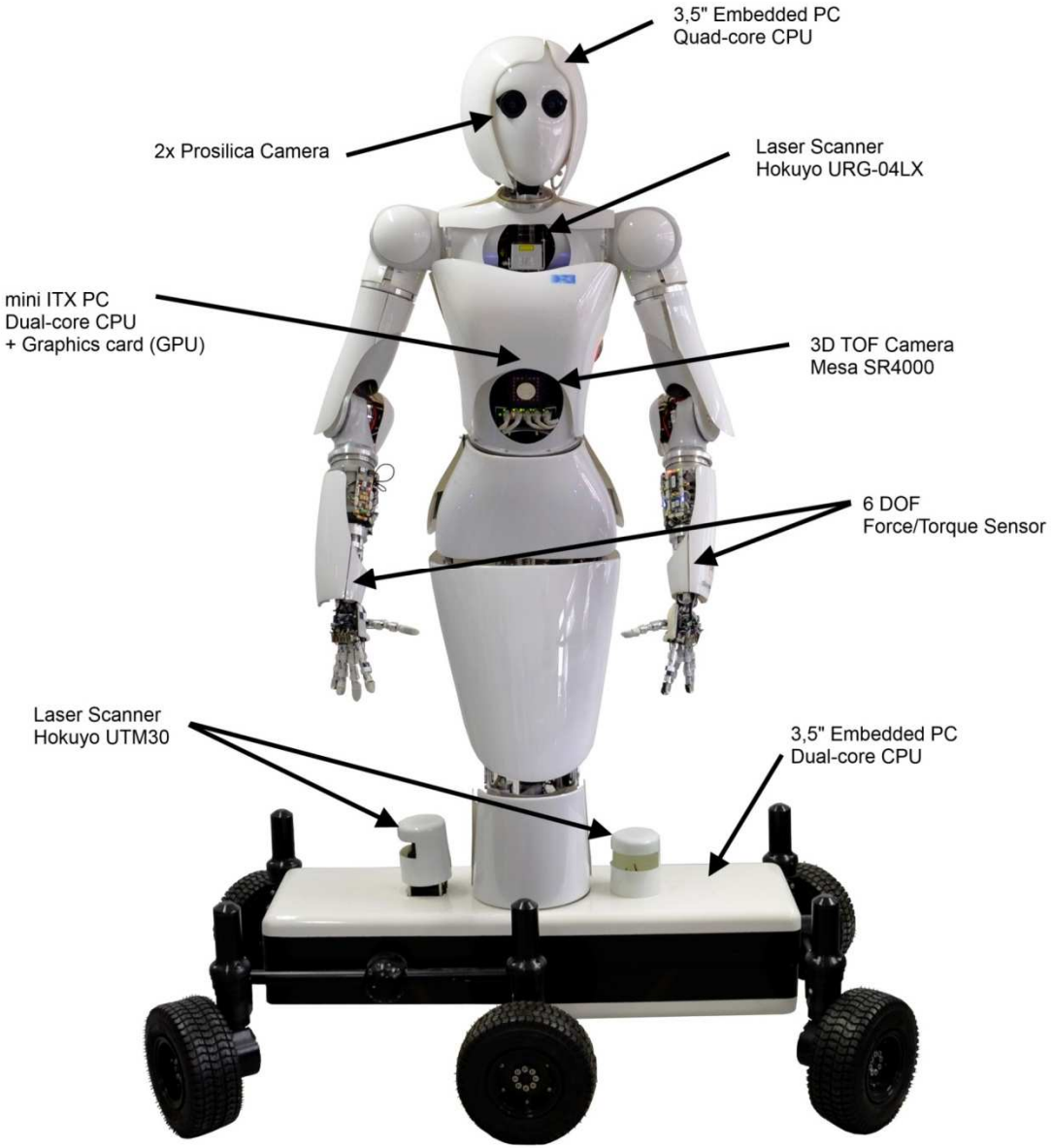
AILA - Features

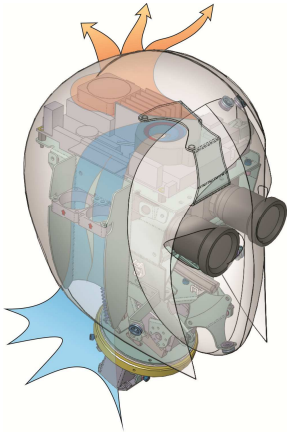


head chassis



debug cabling

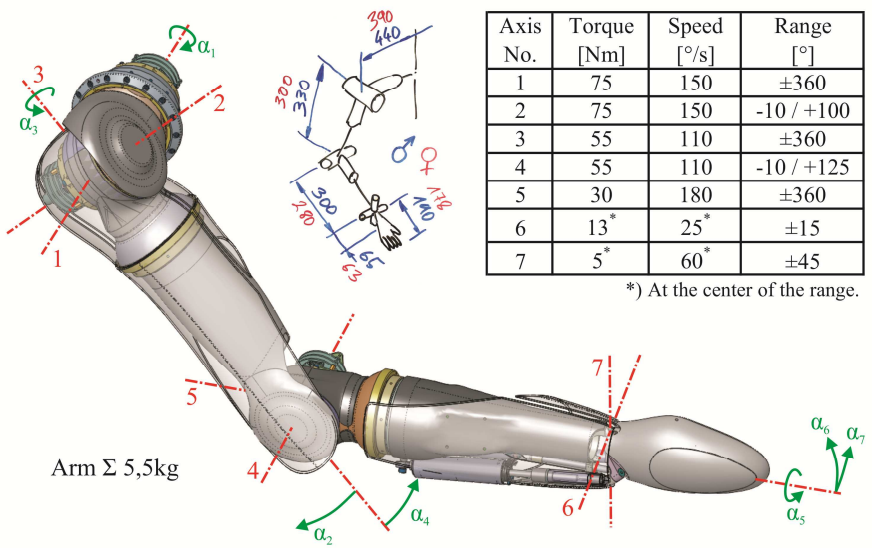




cooling air

- ease of maintenance by modular disassembly
- thermo-formed scratch-resistant rip-off shell

AILA - Degrees of Freedom

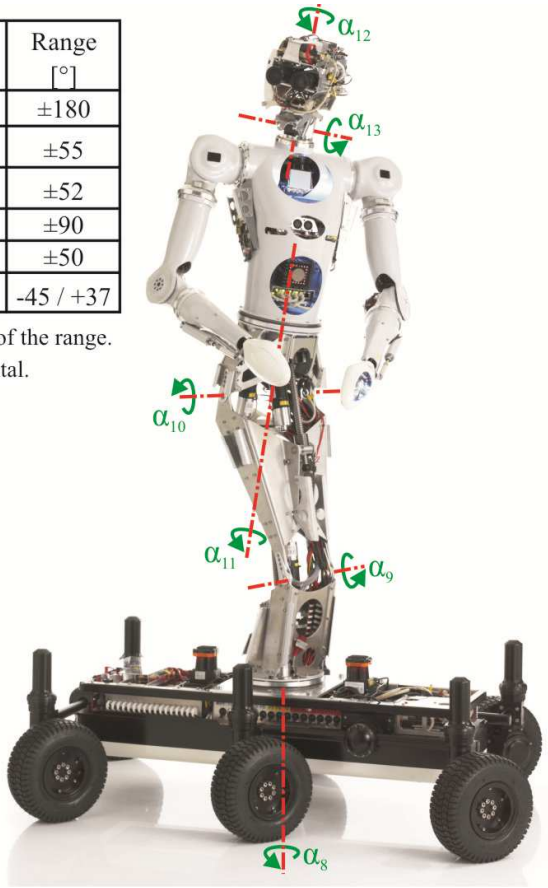


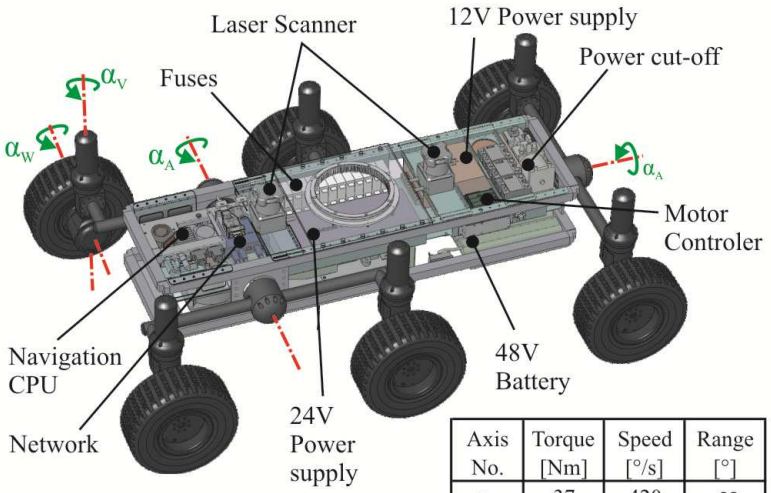
Axis No.	Torque [Nm]	Speed [°/s]	Range [°]
1	75	150	±360
2	75	150	-10 / +100
3	55	110	±360
4	55	110	-10 / +125
5	30	180	±360
6	13*	25*	±15
7	5*	60*	±45

*) At the center of the range.

Axis No.	Torque [Nm]	Speed [°/s]	Range [°]
8	129	200	±180
9	420*	25*	±55
10	370*	30*	±52
11	129	200	±90
12	2,7	120	±50
13	2,7**	210**	-45 / +37

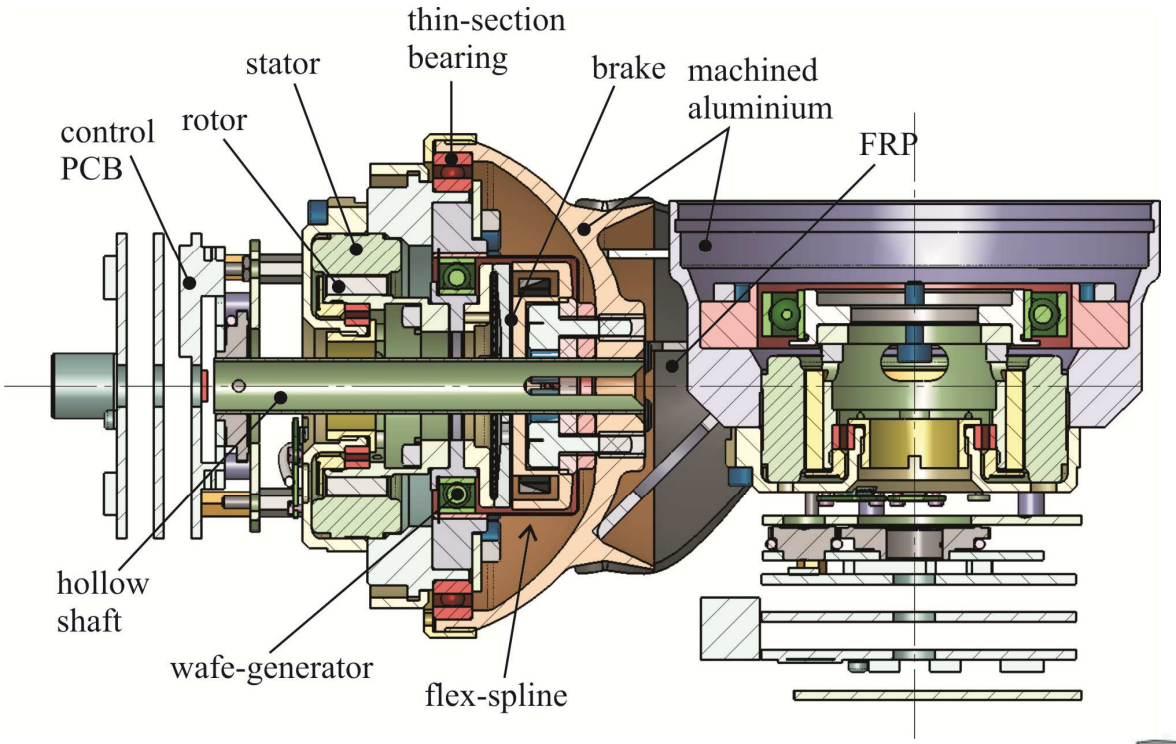
*) At the center of the range.
**) Eyes horizontal.

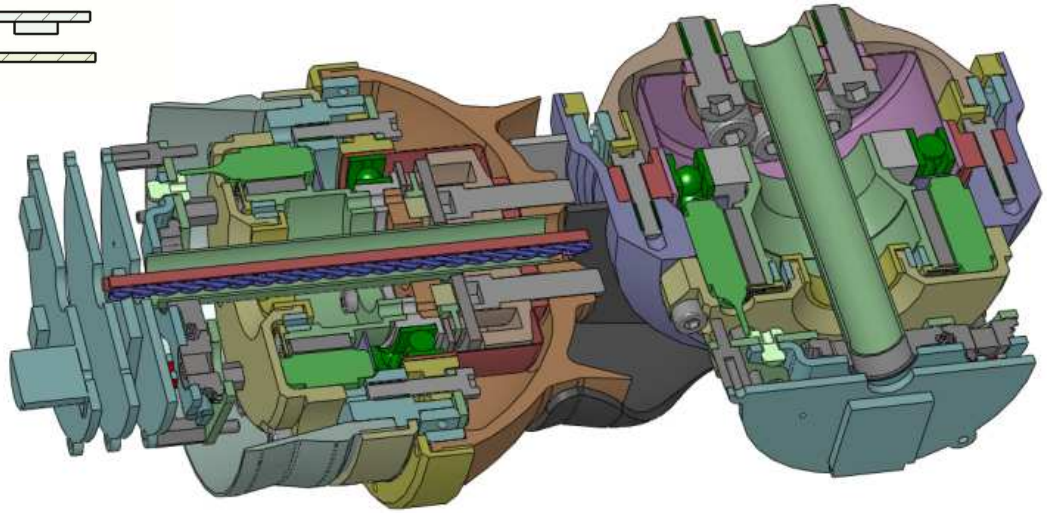




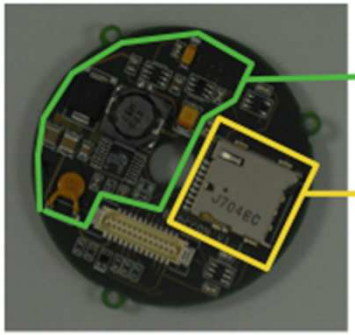
Axis No.	Torque [Nm]	Speed [°/s]	Range [°]
a_w	37	420	∞
a_v	7	360	±180
a_A	-	-	±10

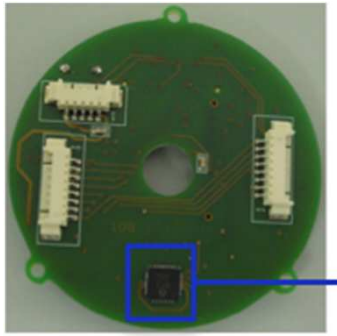
AILA – Joint Mechanics

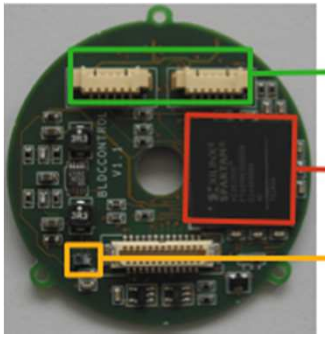


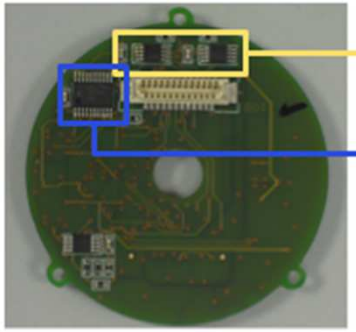


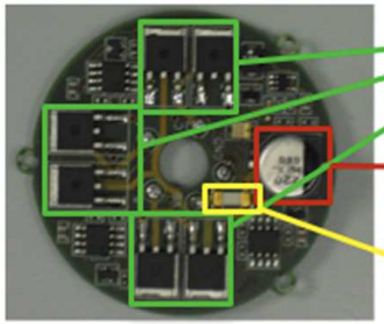
AILA – Joint Electronics

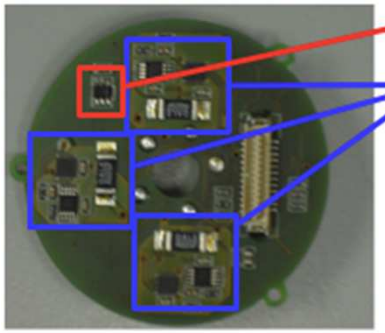






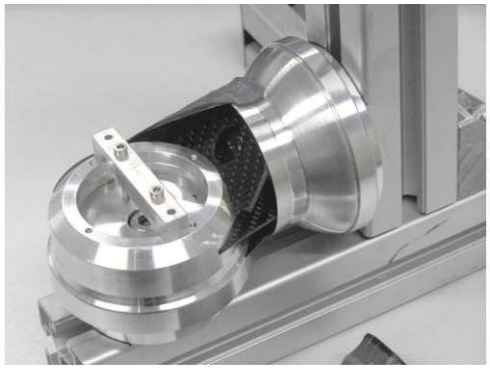


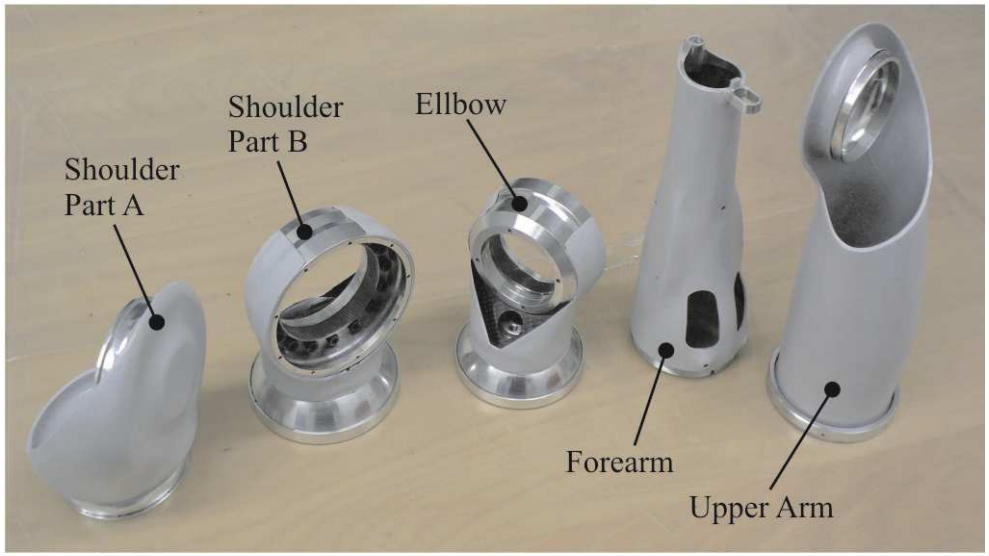


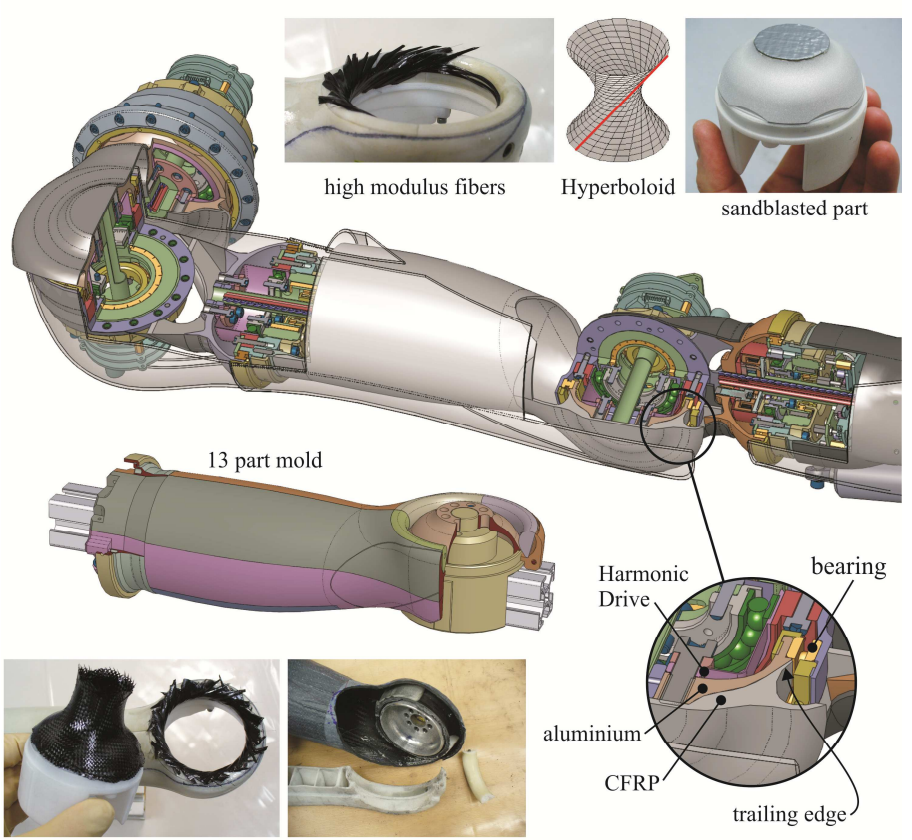


AILA - Arm Structure

Aluminium + Carbon-Fiber-Reinforced Plastic (CFRP)

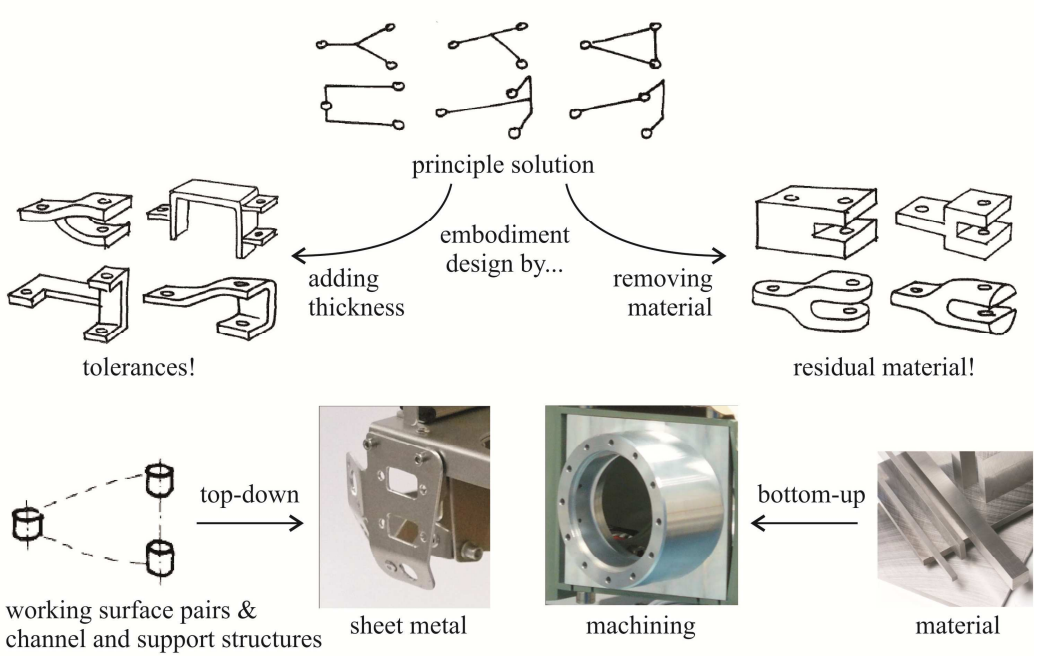




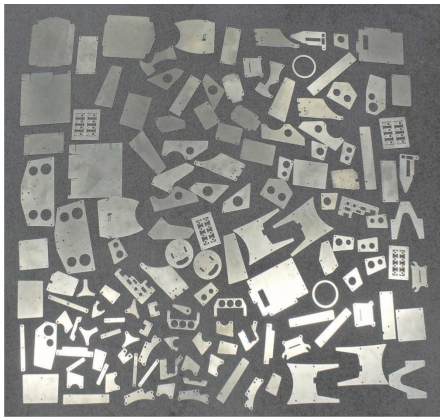


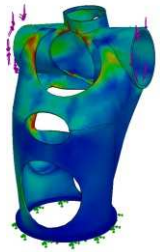
AILA - Body Structure

Sheet metal



Machining





Thank you for your attention!