Robotic Components for Space ROKVISS and DEXHAND

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ICRA2011. May 13 2011 , Shanghai China

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Content

- Space Robotics
  - Objectives
  - Challenges
  - Strategy

- ROKVISS Robotic Component Verification
  - Concept
  - Experiment
  - Results

- DEXHAND
  - Mechanics
  - Electronics
  - Software and Control

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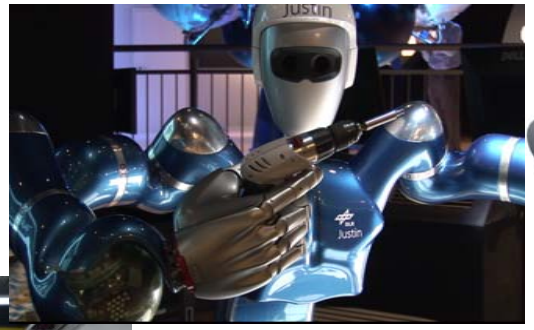
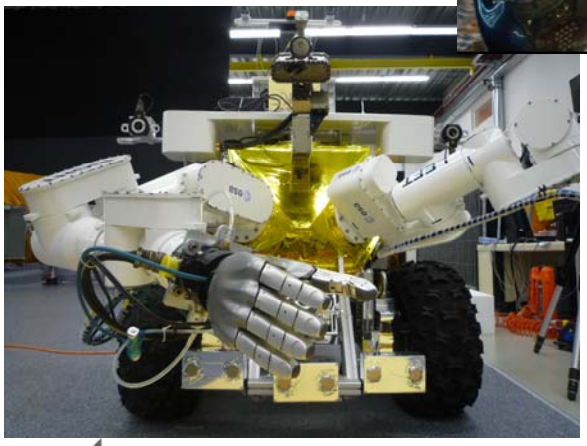
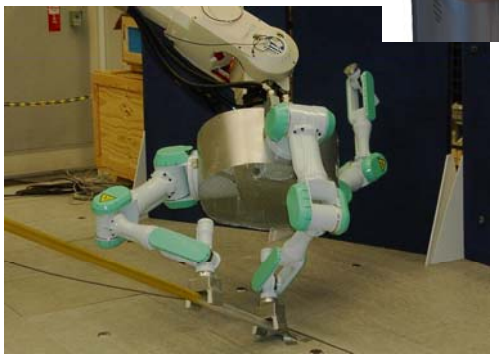
Objectives

- e.g. ISS Environement → To suport EVA activities
- Use of tools designed for humans
- Humanoid robots facilitate the handling within a telerobotic scenario







Challenges

Environment

- Vacuum (Cooling + Materials)
- Temperature difference (one side hot other side cold).
- Radiation

Communication

- High round trip time (RTT)

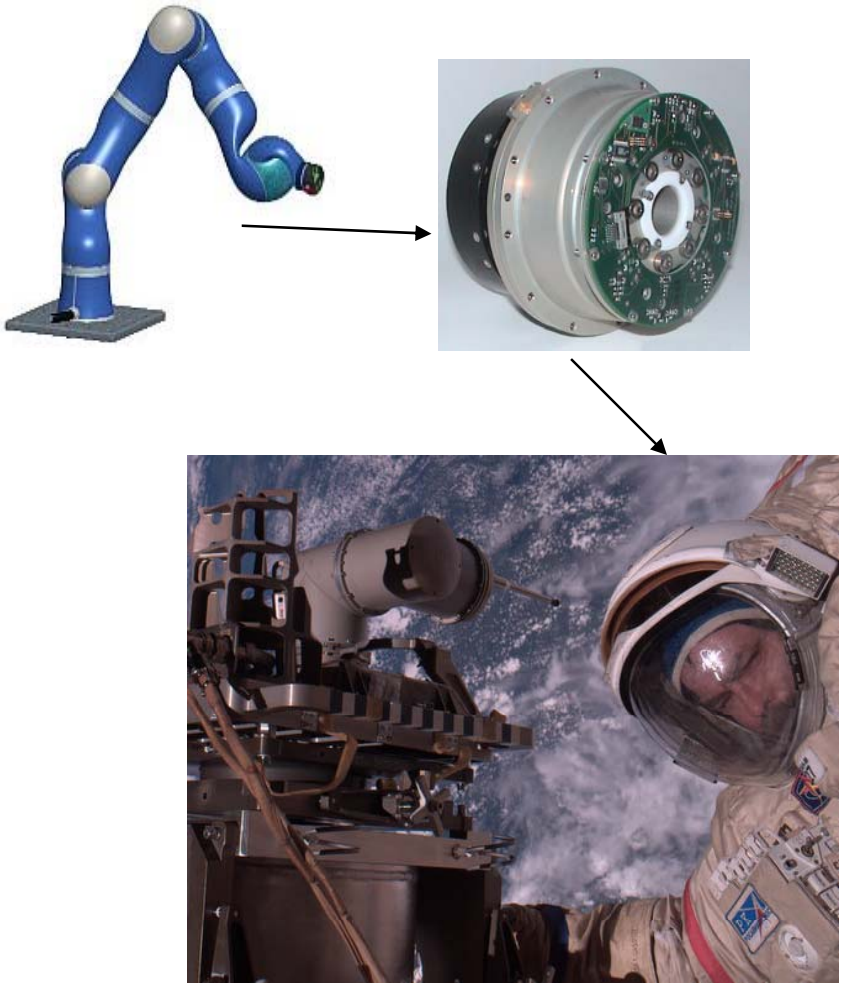
Launchloads

- Shock and vibration

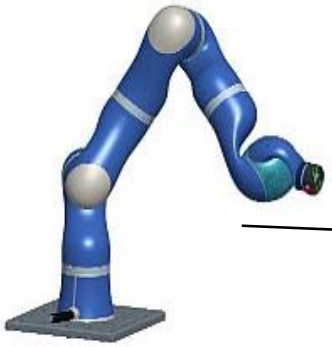
Political Aspect

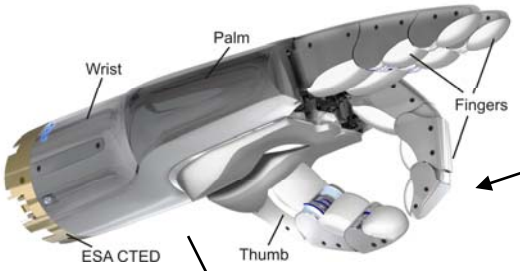
Qualification

Strategy



Strategy





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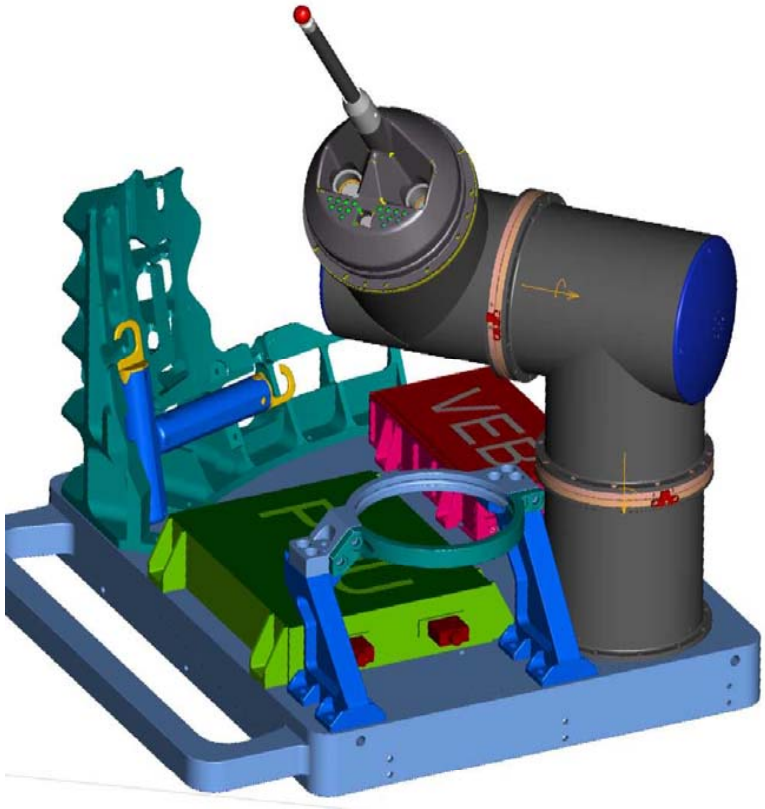
ROKVISS Concept

- The verification of torque-controlled robotic joints in free space, under realistic mission conditions
- The joints are identical to those used in DLR LWR.
- Joint parameter identification
- Contact dynamics experiments
- The verification of force-reflecting telemanipulation to verify the applicability of telepresence methods for future maintenance and servicing tasks.

ROKVISS Robot



ROKVISS Experiment

- Each joint element is equipped with the following sensors:
  - Motor position
  - Gear output position
  - Motor input current
  - Output torque
  - 5 temperature sensors

- The following control modes are implemented on joint level:
  - Position (3kHz)
  - Torque (3kHz)
  - Impedance (3kHz)

- Cartesian control (via main computer, 1 kHz)

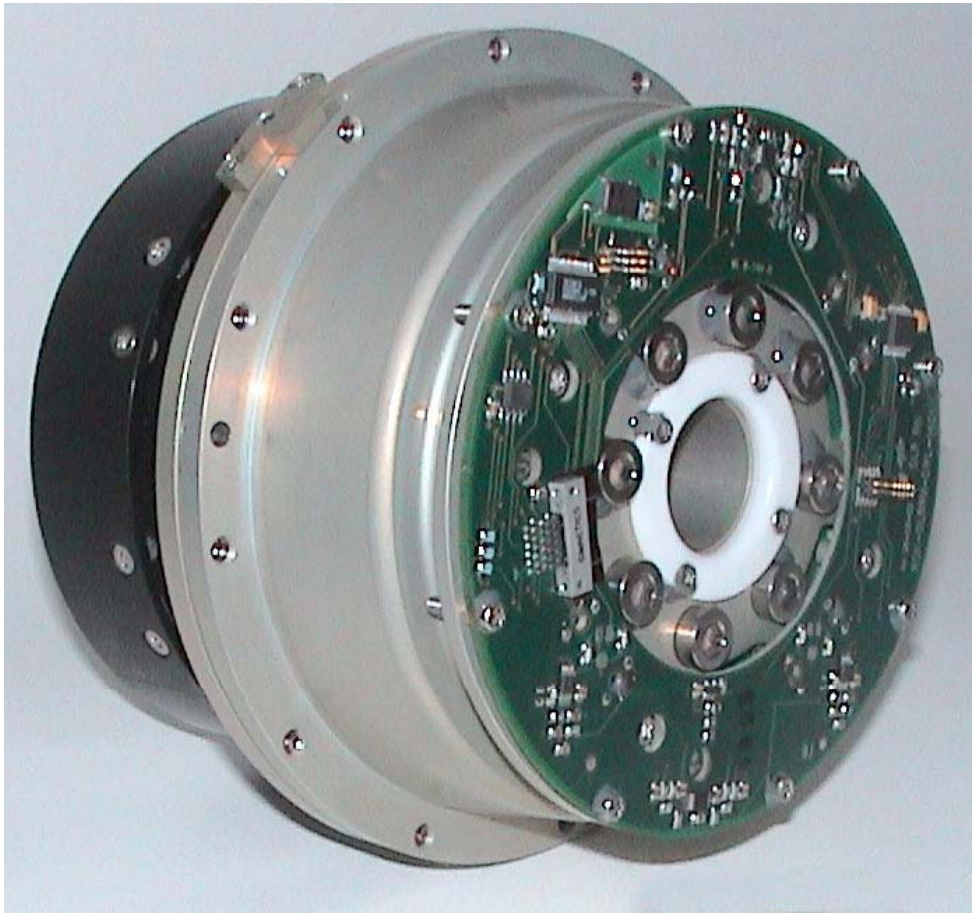
ROKVISS Design modifications

No problem in principle:

Radiation, EMC and thermal test

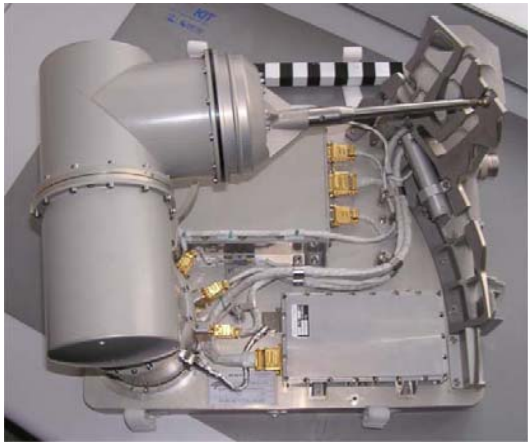
- Exchange cross roller bearing against two angular roller bearings
- Exchange all electrolytic capacitors against tantalum types
- A potentiometer based link position measurement
- A latch-up protected power supply circuit was developed and implemented
- Electronic parts with extended temperature range (-45 C to +85 C) are used (COTS).
- Built with radiation tolerant parts, temperature range: -55 C to + 125 C
- A dedicated software task checks the memory in order to detect and repair bit-flips

ROKVISS Specifications

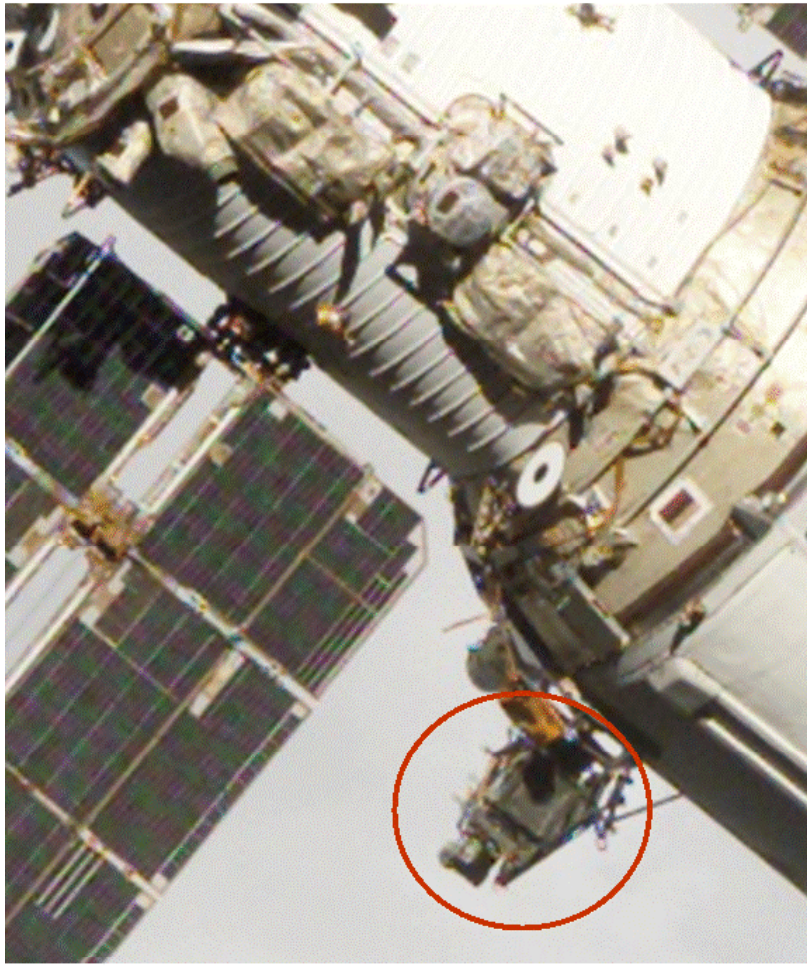


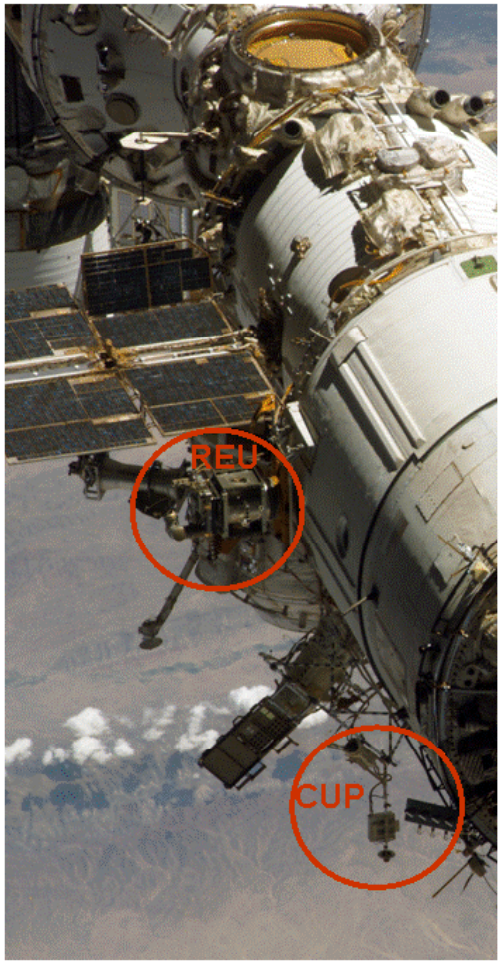
- Mass: 2480 g
- Size: D = 142 mm, L = 108.5 mm
- Gear ratio 160/1 (Harmonic-Drive)
- Output torque: 120 Nm (nominal)
- Max speed: 15 rpm

- **Max. allowed torque during ROKVISS operation: 40 Nm**



ROKVISS on ISS since January 2005





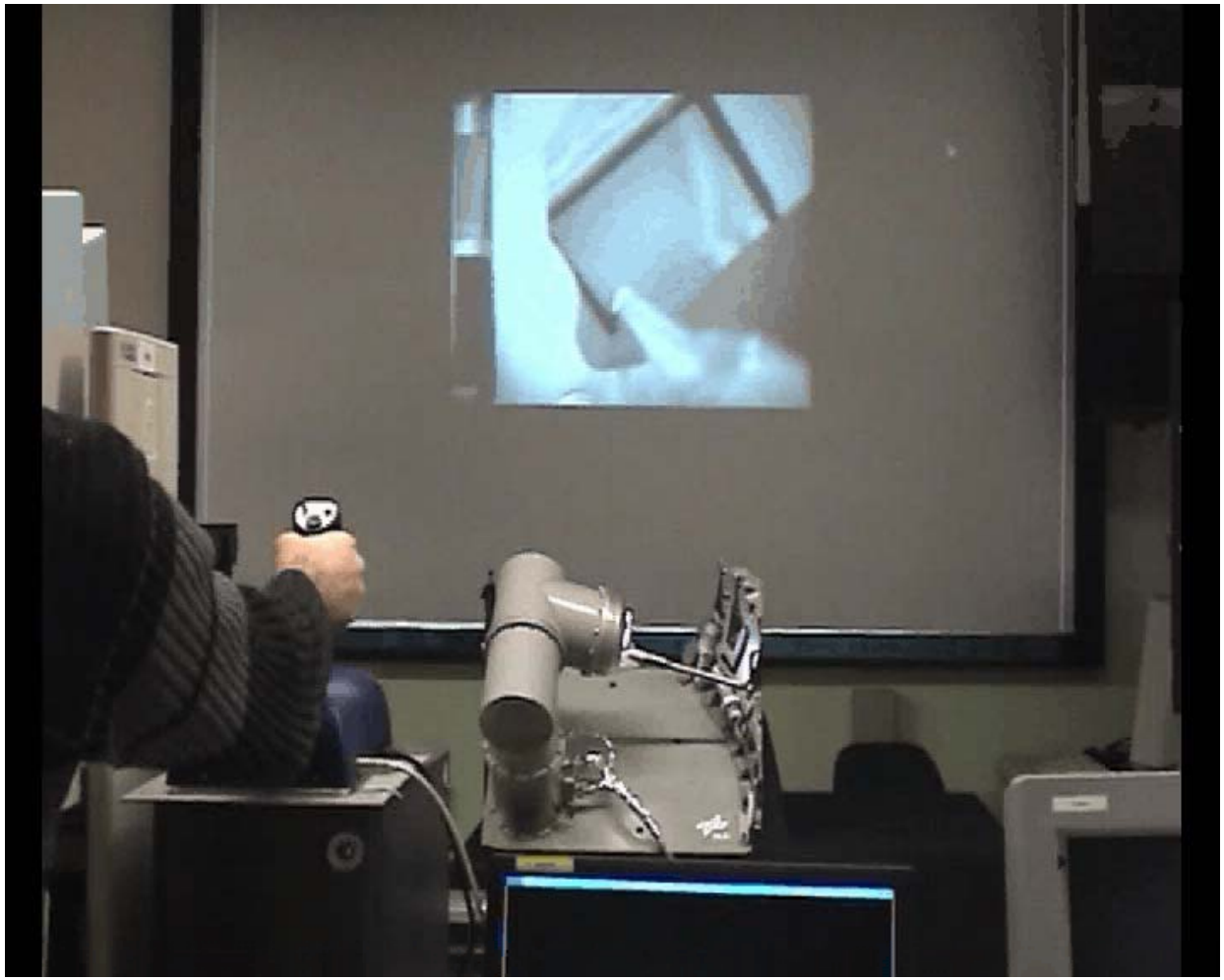
- **Launch:** with Progress M-51 at Dec. 24. 2004 from Baikonur-Cosmodrome
- **Installation:** End of January 2005 during space-walk
- **Location:** Zvezda-Module

ROKVISS Communication System

- In order to keep the round-trip communication time as low as possible, ROKVISS has an own S-band communication system, including an own antenna (Communication Unit for Payloads CUP).
- Uplink data rate: 256 kbit/s
- downlink data rate: 4 Mbit/s, including 3.5 Mbit/s video-data.
- Uplink frequency: 2058.0 MHz
- Downlink frequency: 2234.9 MHz
- Modulation BPSK

- **Round trip time: < 20 ms**

ROKVISS Force Feedback



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DEXHAND Requirements / Tasks and Tools

Requirement:	OPS-1

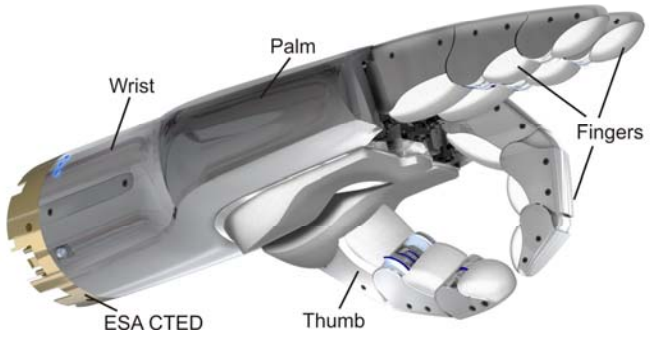
The DEXHAND shall be able to grasp the following EVA tools:

- Pliers, and support their operations
- Scissors, and support their operations
- Small cutter and support its operations
- Brush, and support its operations
- Hammer, and support its operations
- Scoop, and support its operations
- Cutter, and support its operations
- Tether(s), and support its operations
- Allen wrench, and support its operations
- Pistol grip tool (automatic screw driver) and support its trigger switch actuation

Comment: Successful operation of the tools implies force closure of the grasp. Note that preferably form closure should be achieved.

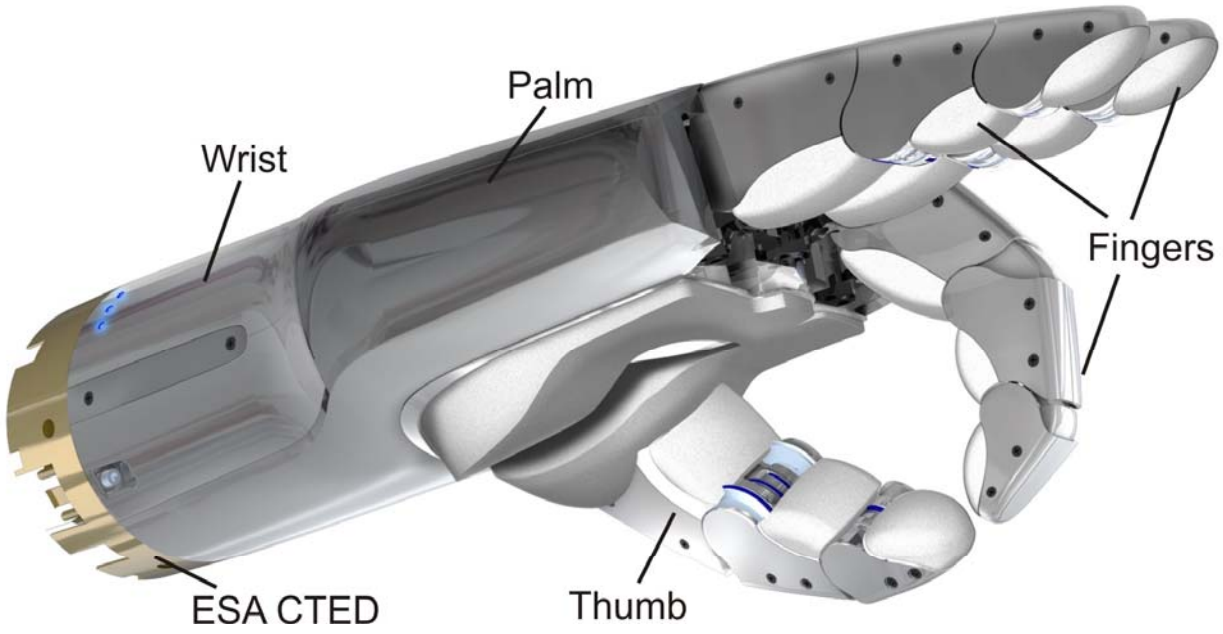
DEXHAND Concept

- Operational modes: telemanipulation / autonomous
- Computation inside the hand
- CAN-bus
- Power supply



- ISS (outside) environment
- EVA glove size
- Real-time impedance control for 12 joints

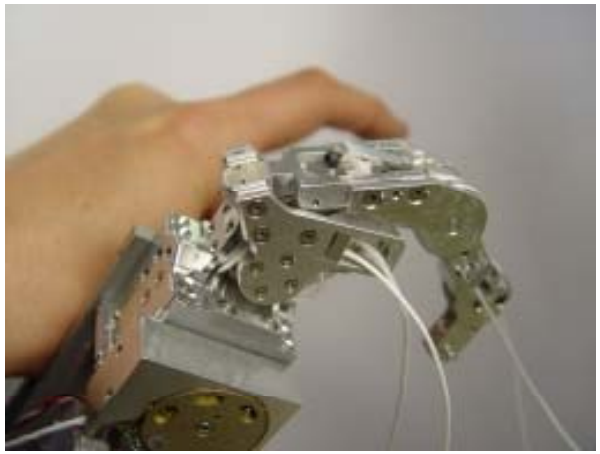
DEXHAND Overview

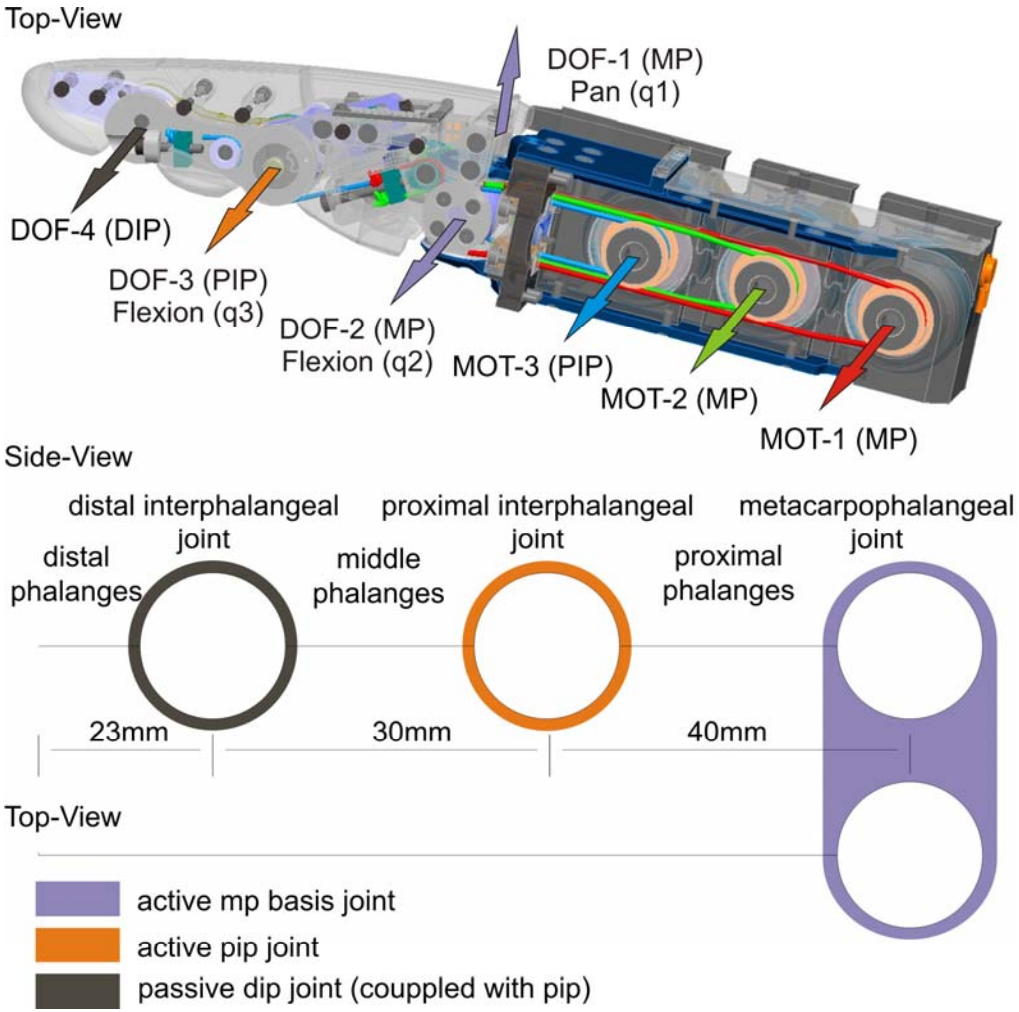


- Less than 3.3 kg
- Finger length 93 mm (Thumb 100 mm),
- DEXHAND length 340 mm (A4 page length)
- 25 N Fingertip force (Thumb 40 N) - streched out

DEXHAND Finger Kinematic

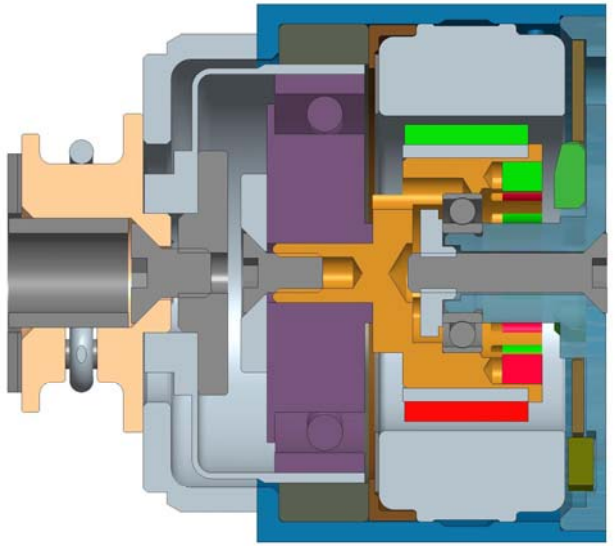
- Tendon driven (Dyneema)
- 4 Joint Fingers with 3 DOF and a coupled PIP-DIP Joint
- Range of motion:
  - DOF-1 = ±30°
  - DOF-2 = 90°
  - DOF-3 = 90°



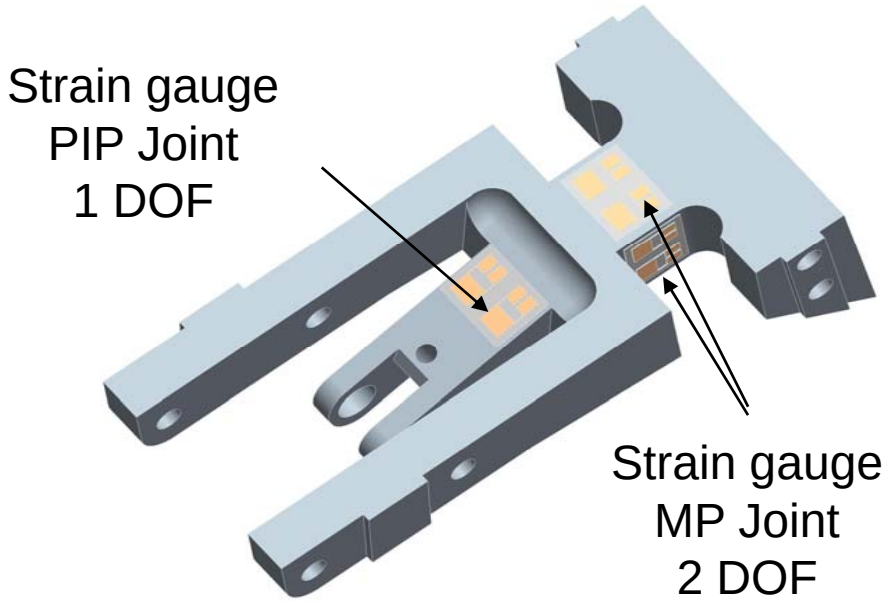


DEXHAND Actuator Modules

- ILM25 Robodrive Motor
- Harmonic Drive HFUC8 special version
- 2,4 Nm nominal, 4,8 Nm peak, 9 Nm collision Torque
- 46 g mass of the whole unit
- 8000rpm (HD limited)
- dia. 27mm x 17,5mm length (motor and gear housing, without the pulley)

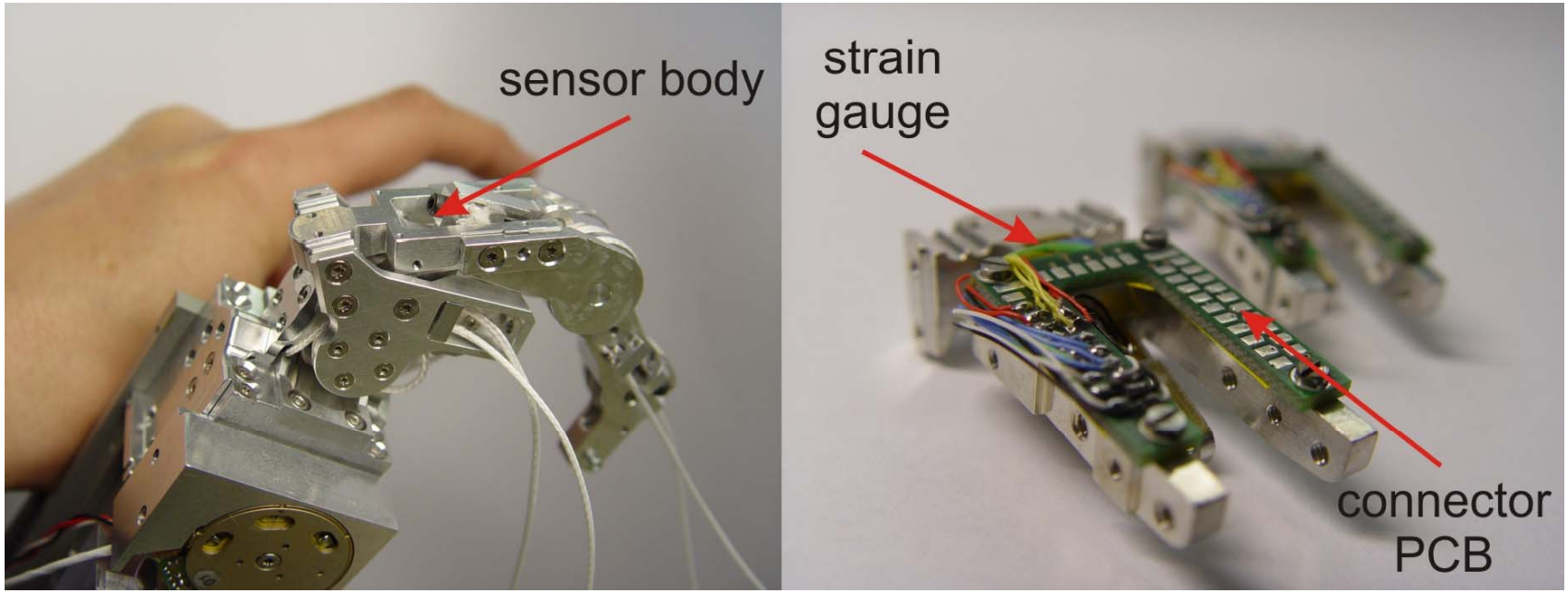


DEXHAND Finger Sensor Concept



- Drive side full bridge strain gauges
- 5 kOhms for good signal noise ratio
- Except of reference hall sensors, temperature sensors and strain gauges no electronics outside the conductive shell of 2mm

DEXHAND Finger Sensor Concept



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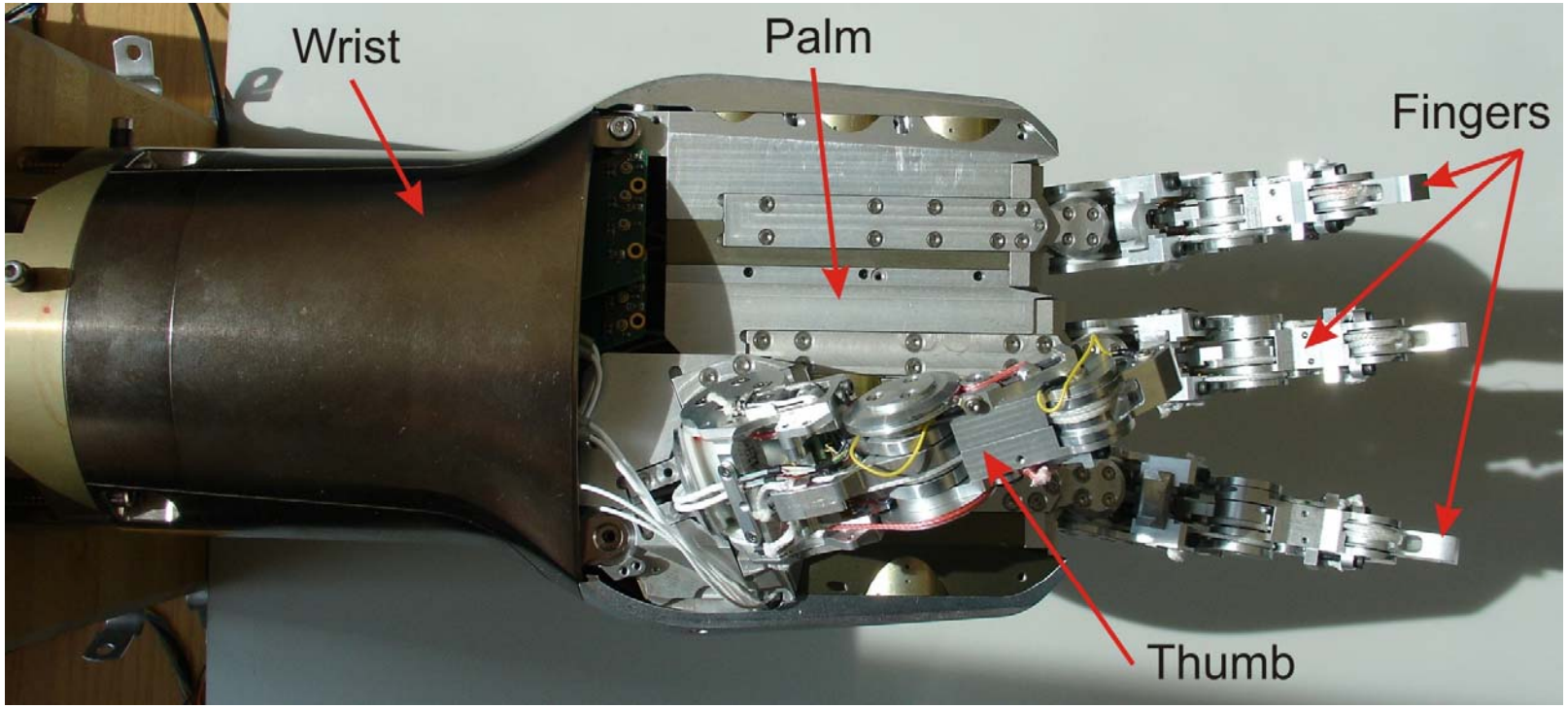
DEXHAND Latest State



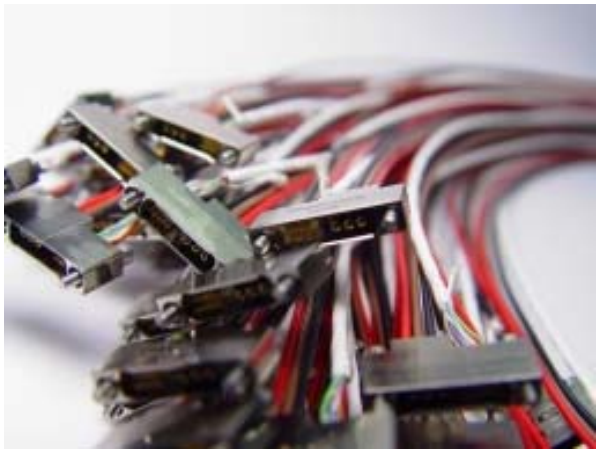
DEXHAND Electronic Design

- radiation tolerance
- sufficient heat dissipation
- size/performance
- power limitation

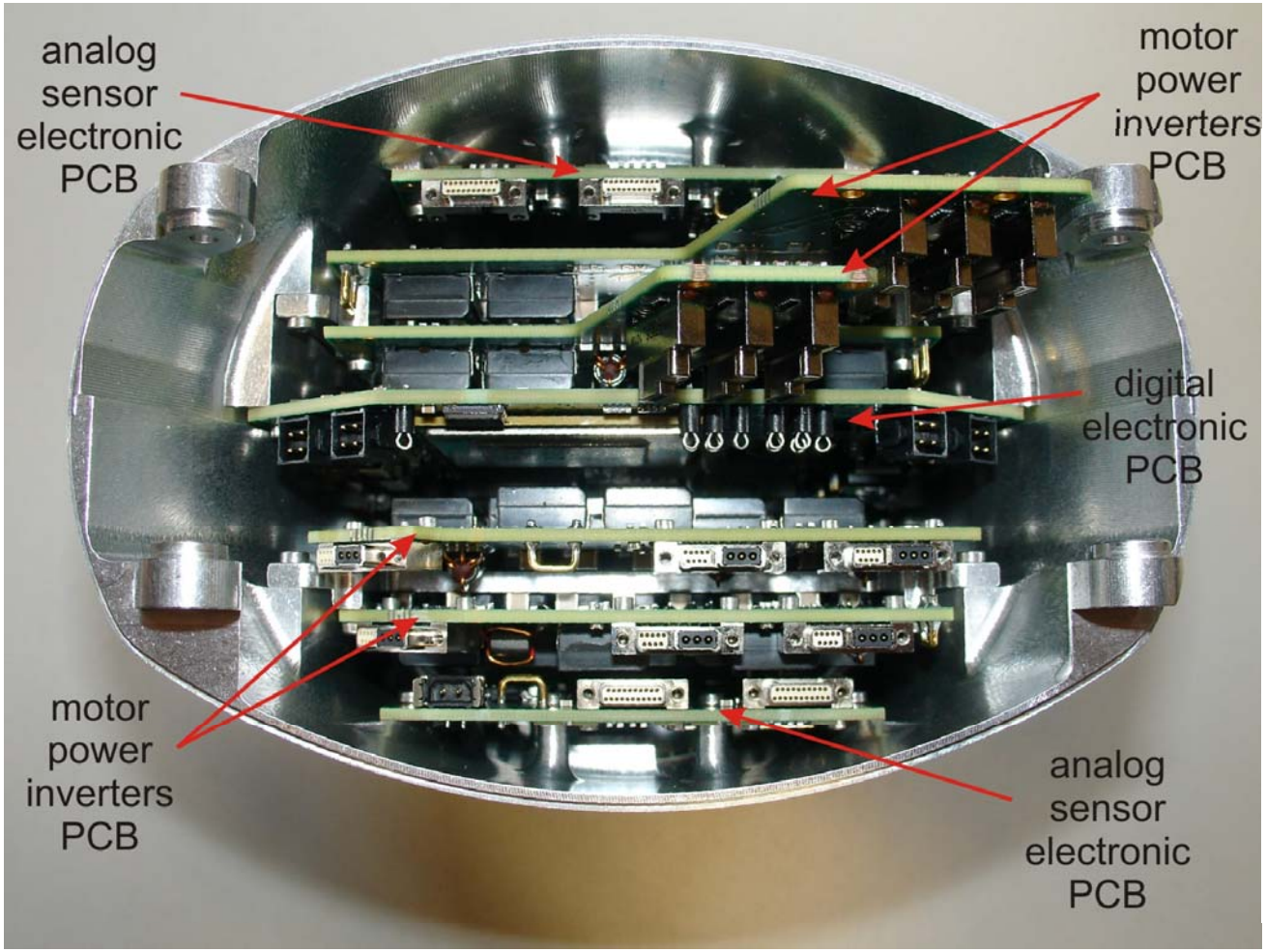
- 12 active joints requires both:
  high-performance and small electronic components
- Motor controller components:
  have been successfully tested in a rad-test-facility under a 120 Gy irradiation
- DSP, FPGA and all other components are in rad-hard or tolerant, size, power and function compatible available

DEXHAND Shielding and EMC Compatibility

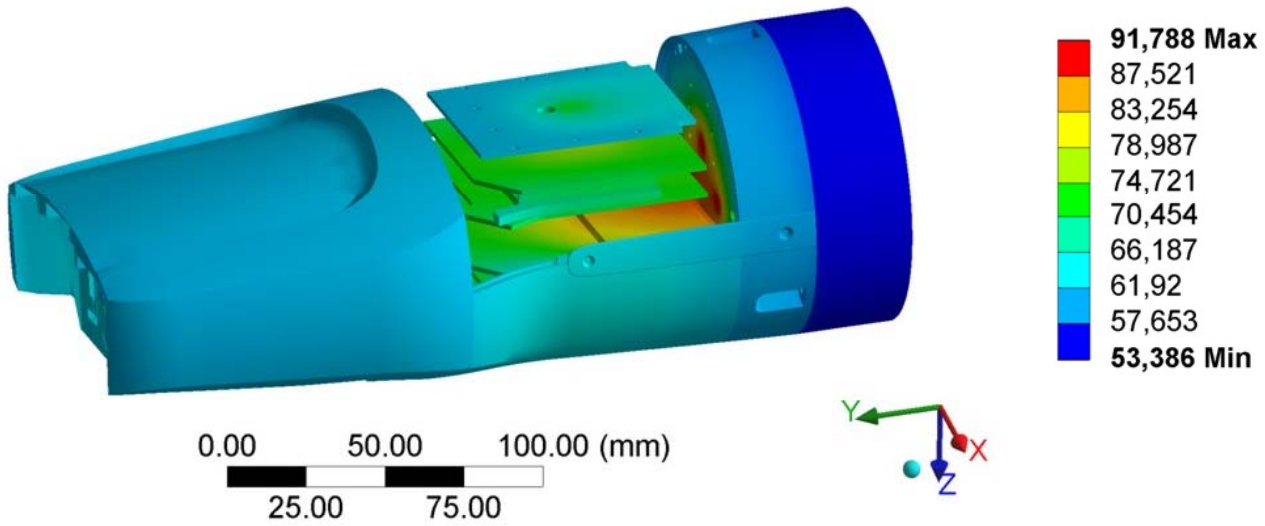
- Internal cables and connectors are shielded
- Special connectors have been designed with power and signal lines (connect the actuator modules with the electronics)
- EMC Test performed with 4 kV spikes

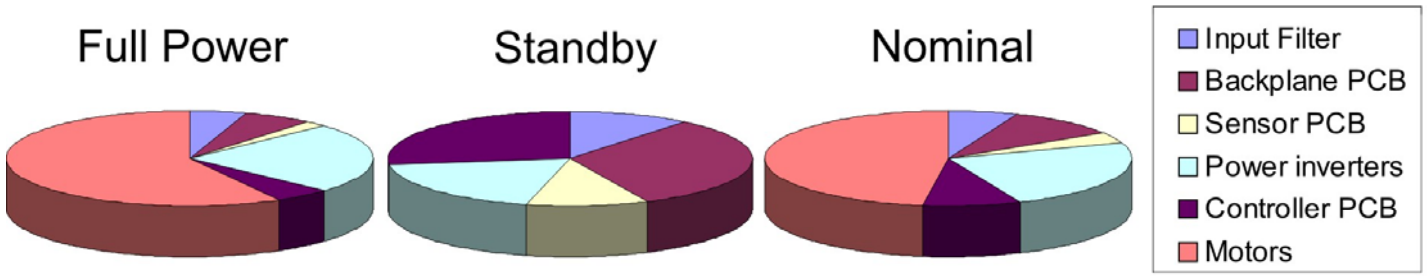


DEXHAND Electronic compact housing

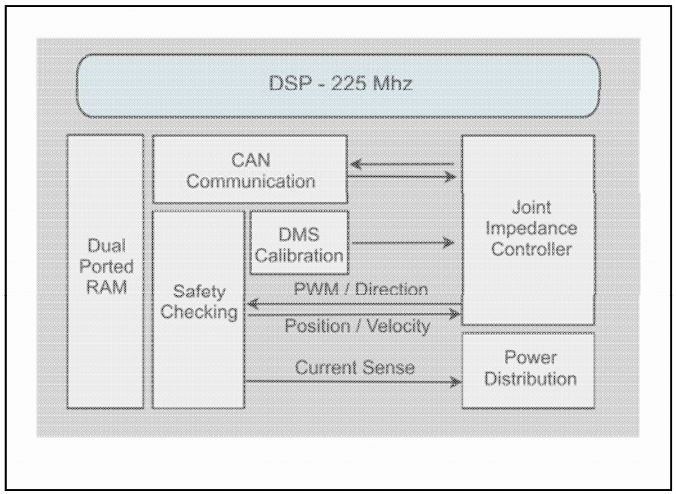


DEXHAND Power and heat dissipation

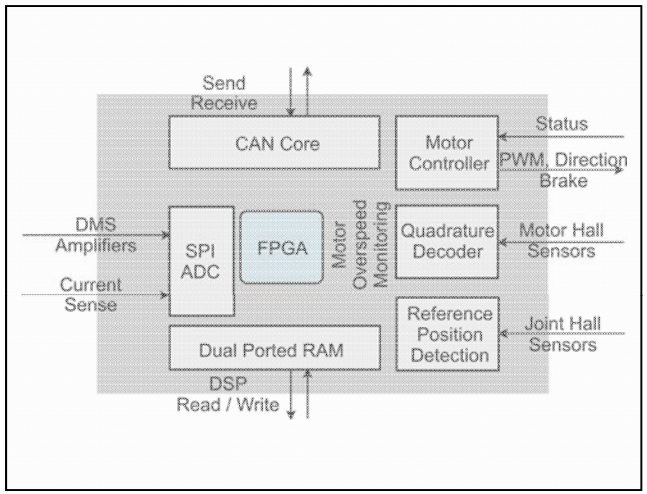




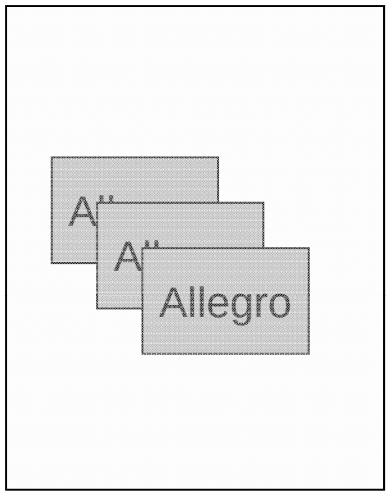
DEXHAND Control architecture



DSP



FPGA



Motor Controller

Control architecture is fully included in the hand :

- 28V Power Supply
- CAN Bus

DEXHAND Deployment Architecture

• GUI with predefined sets of grasps and configurations

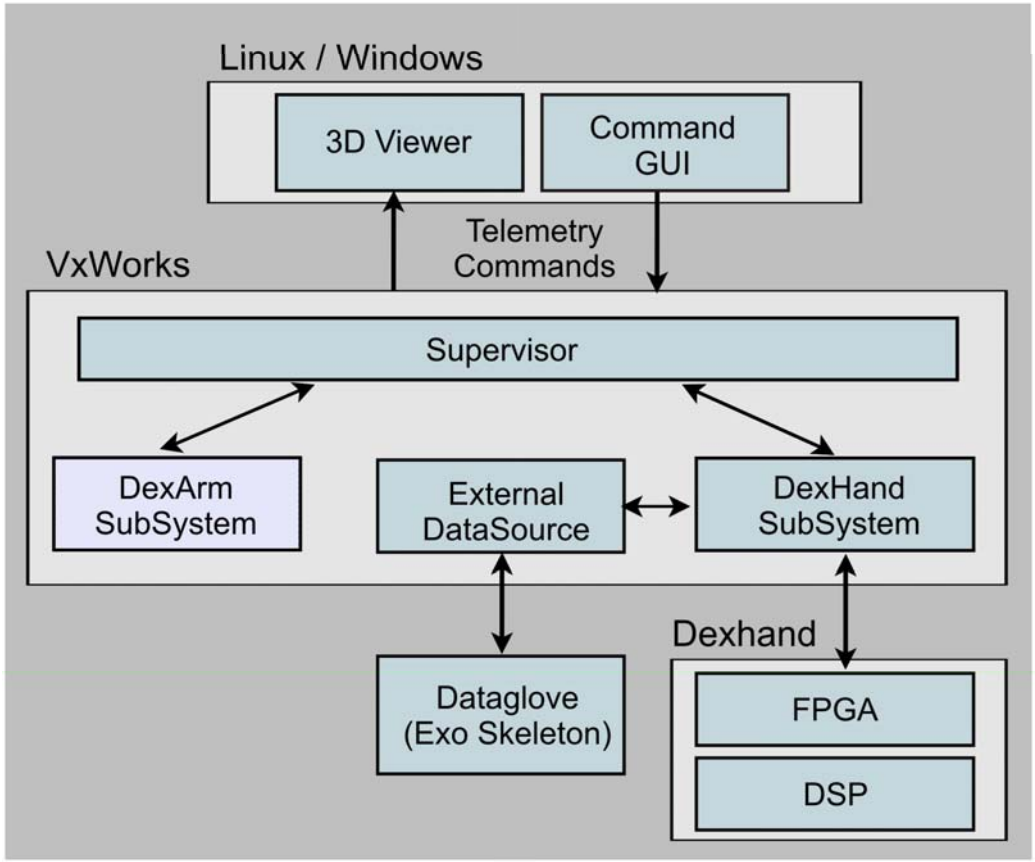
• 3D viewer

• Dataglove : teleoperation

• Real-time interconnection:
- Dexarm
- Two handed manipulation

-…

• HIROSCO: Real-time Framework for Space Robots



Conclusion

• DEXHAND profits from Space robotics knowledge from ROKVISS (Space Robotics Workshop Friday morning)

• The experience of DLR in hand design help in design and manufacture DEXHAND

• Real-time impedance control of 12 joints

• Stronger than a human

• The performances : size, weight, speed are impressive for space technologies

• Design to be integrated in larger scenarios

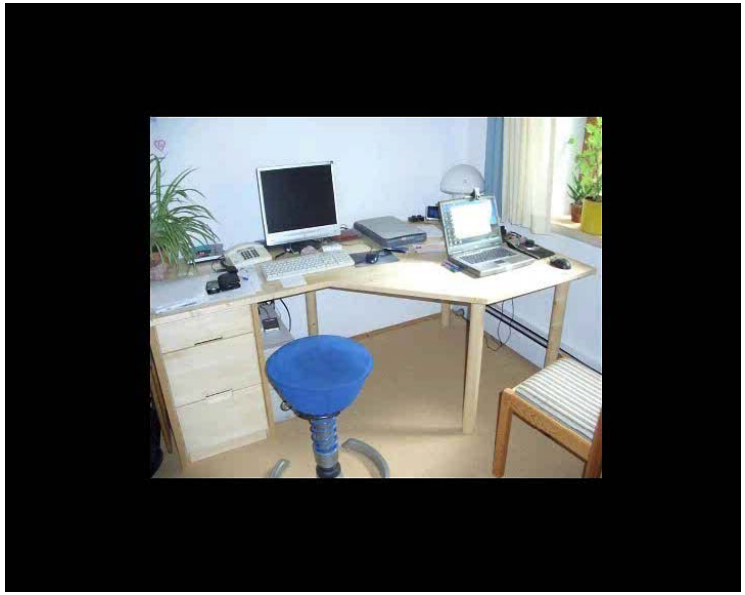
Future steps:

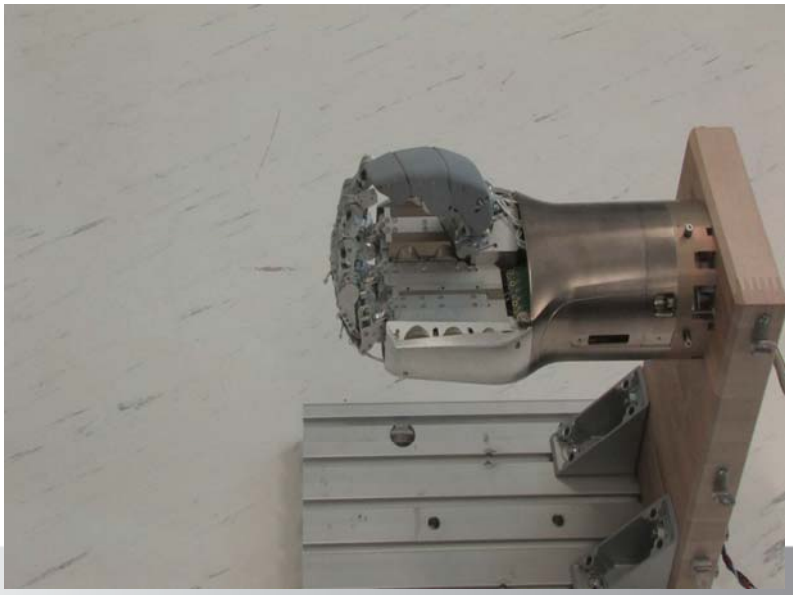
- Verification tests
- Deliver the Hand to ESA
- Fly !

Thank you for your attention!!!

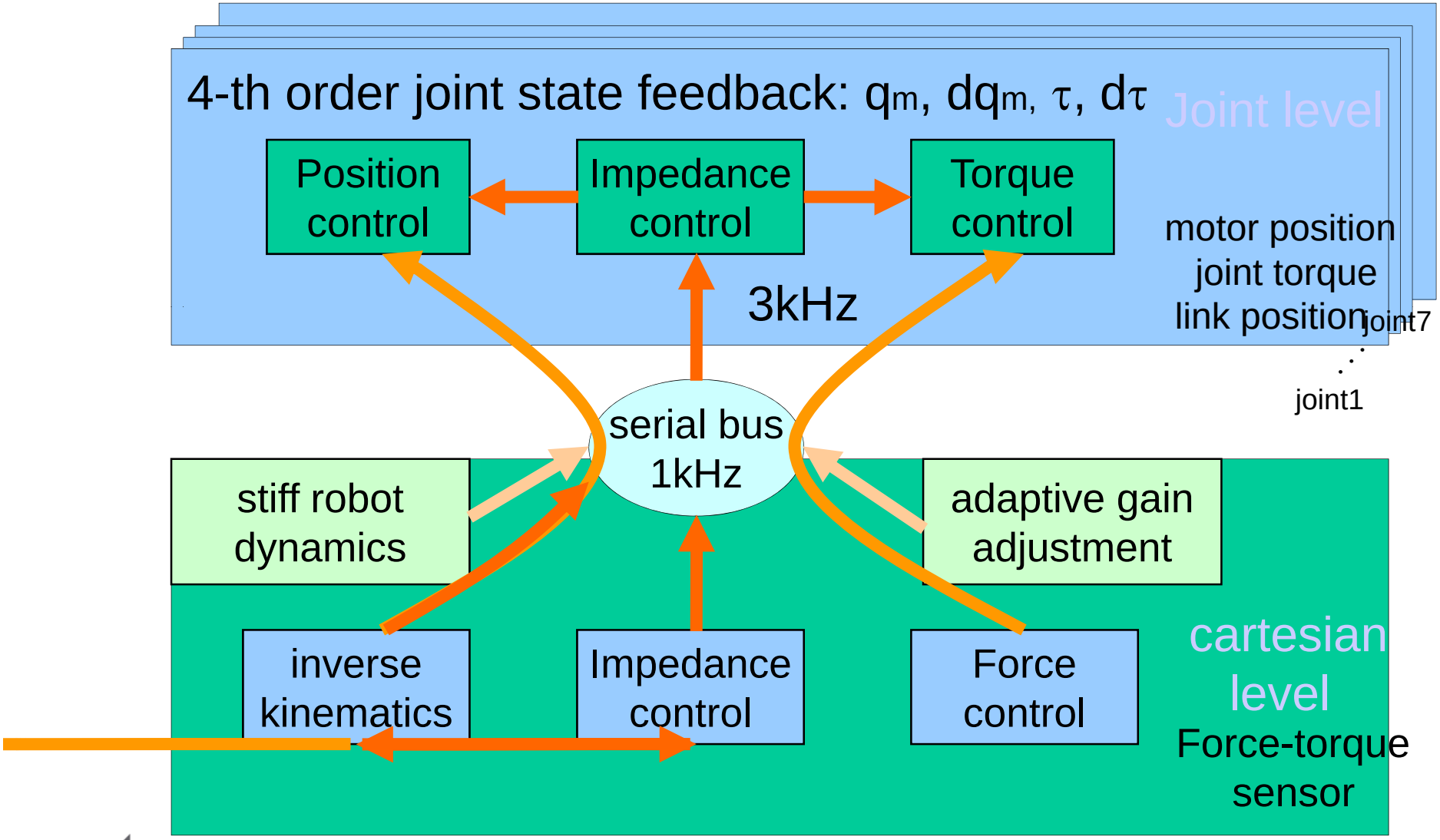
- The DEXHAND Team has been over two years min. about 15 person
  - The project has been financed by the ESA Contract No. 21929/08/NL/EM

Question and Videos

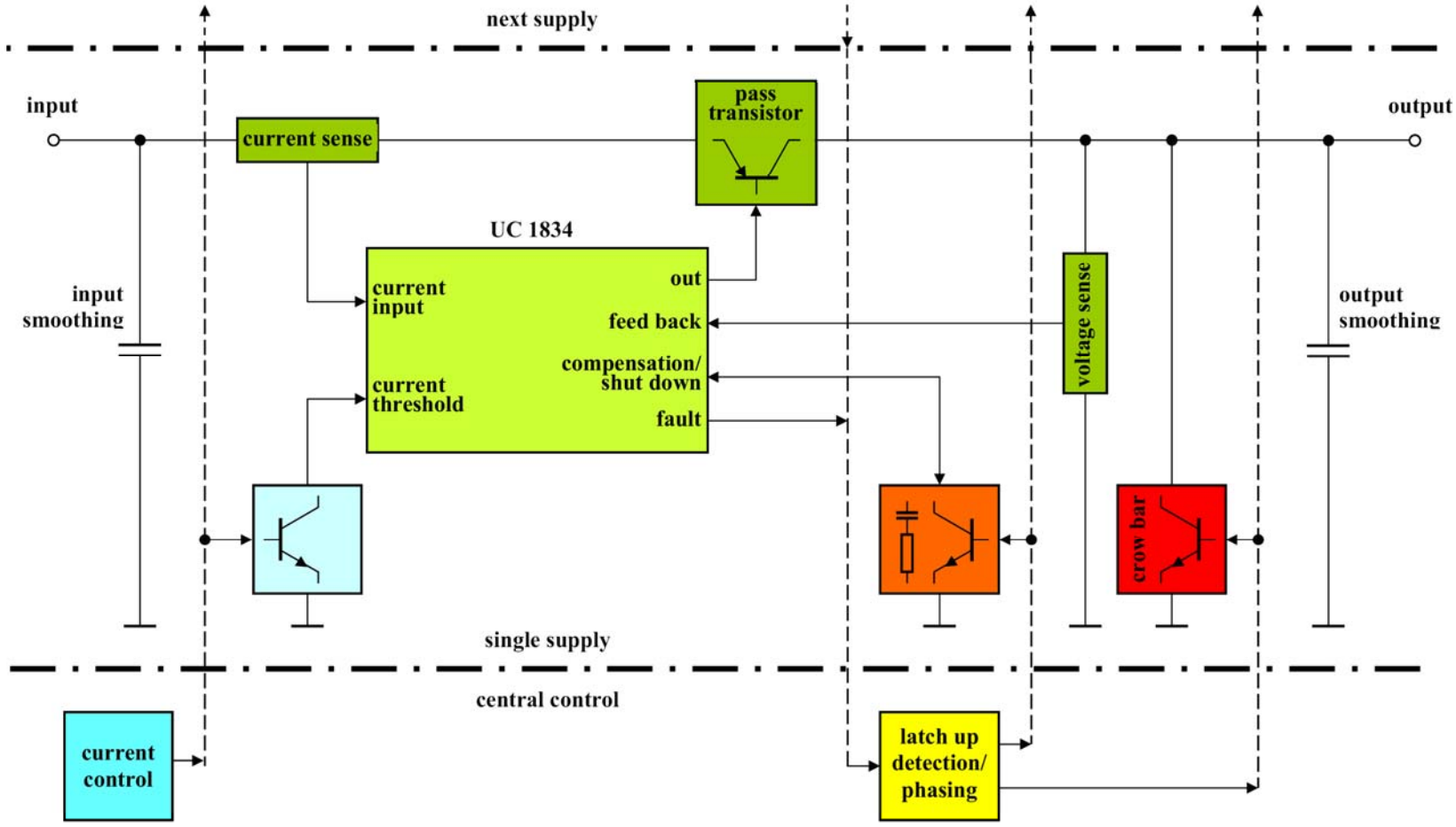




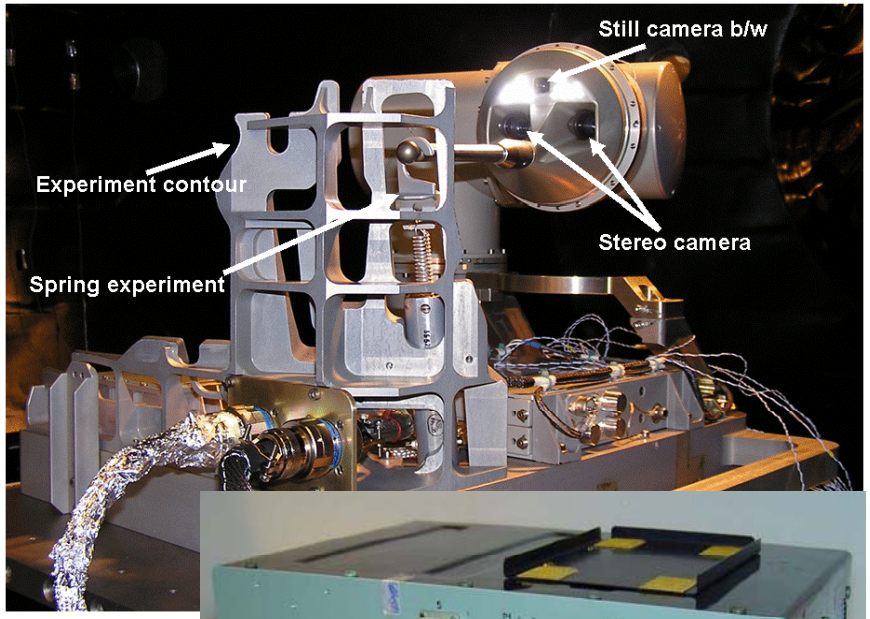
Control architecture

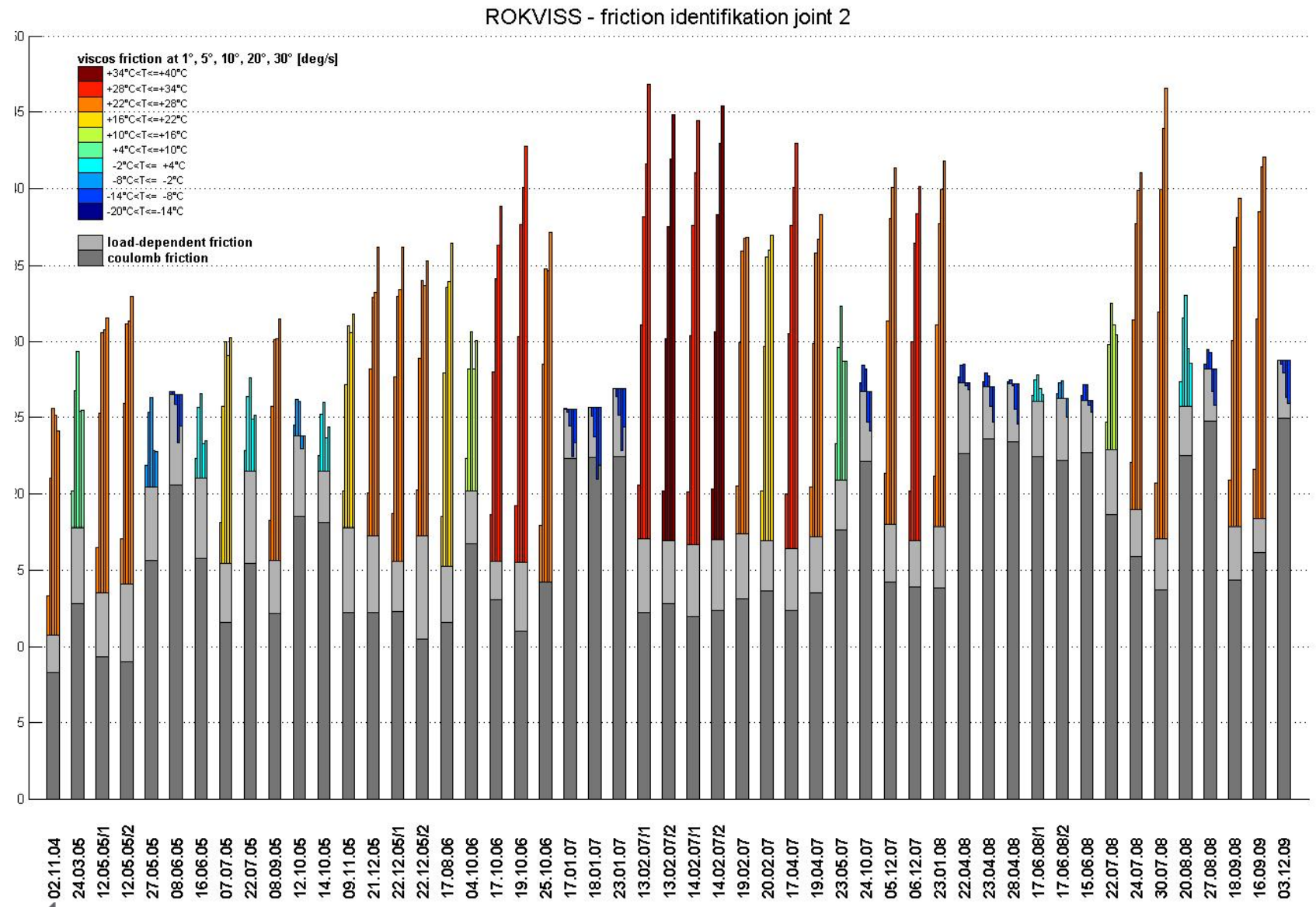


Latch-up Protection Circuit



ROKVISS External Unit (REU) and On Board Computer (OBC)




ROKVISS - friction identifikation joint 2
viscos friction at 1°, 5°, 10°, 20°, 30° [deg/s]
+34°C<T<=+40°C
+28°C<T<=+34°C
+22°C<T<=+28°C
+16°C<T<=+22°C
+10°C<T<=+16°C
+4°C<T<=+10°C
-2°C<T<= +4°C
-8°C<T<= -2°C
-14°C<T<= -8°C
-20°C<T<=-14°C
load-dependent friction
coulomb friction
0
5
0
5
0
5
0
5
0
02.11.04
24.03.05
12.05.05/1
12.05.05/2
27.05.05
08.06.05
16.06.05
07.07.05
22.07.05
08.09.05
12.10.05
14.10.05
09.11.05
21.12.05
22.12.05/1
22.12.05/2
17.08.06
04.10.06
17.10.06
19.10.06
25.10.06
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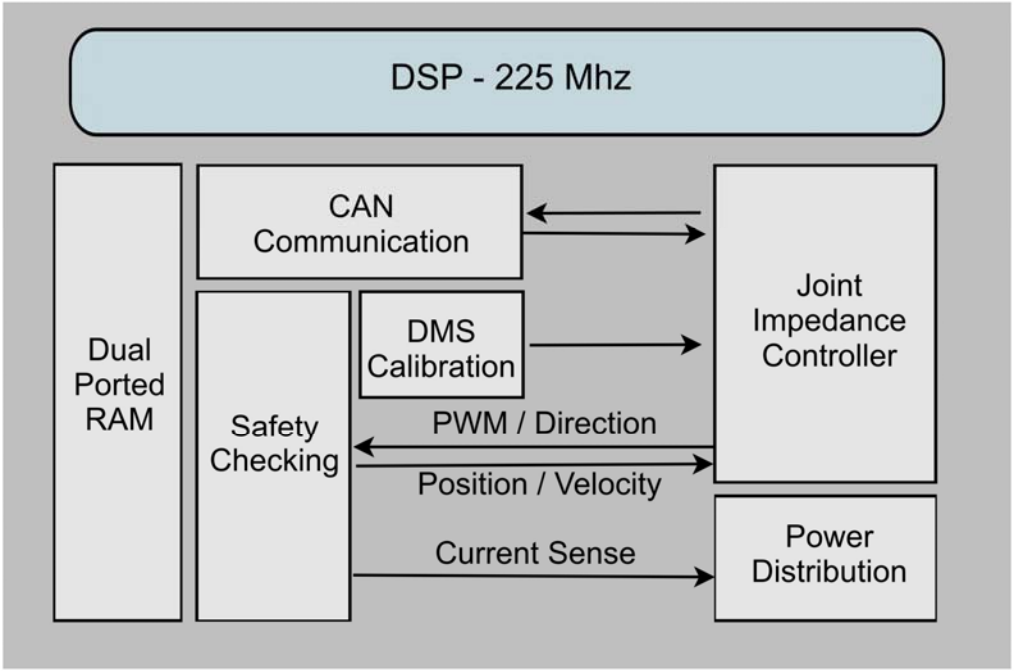
13.02.07/1
13.02.07/2
14.02.07/1
14.02.07/2
19.02.07
20.02.07
17.04.07
19.04.07
23.05.07
24.10.07
05.12.07
06.12.07
23.01.08
22.04.08
23.04.08
28.04.08
17.06.08/1
17.06.08/2
15.06.08
22.07.08
24.07.08
30.07.08
20.08.08
27.08.08
18.09.08
16.09.09
03.12.09

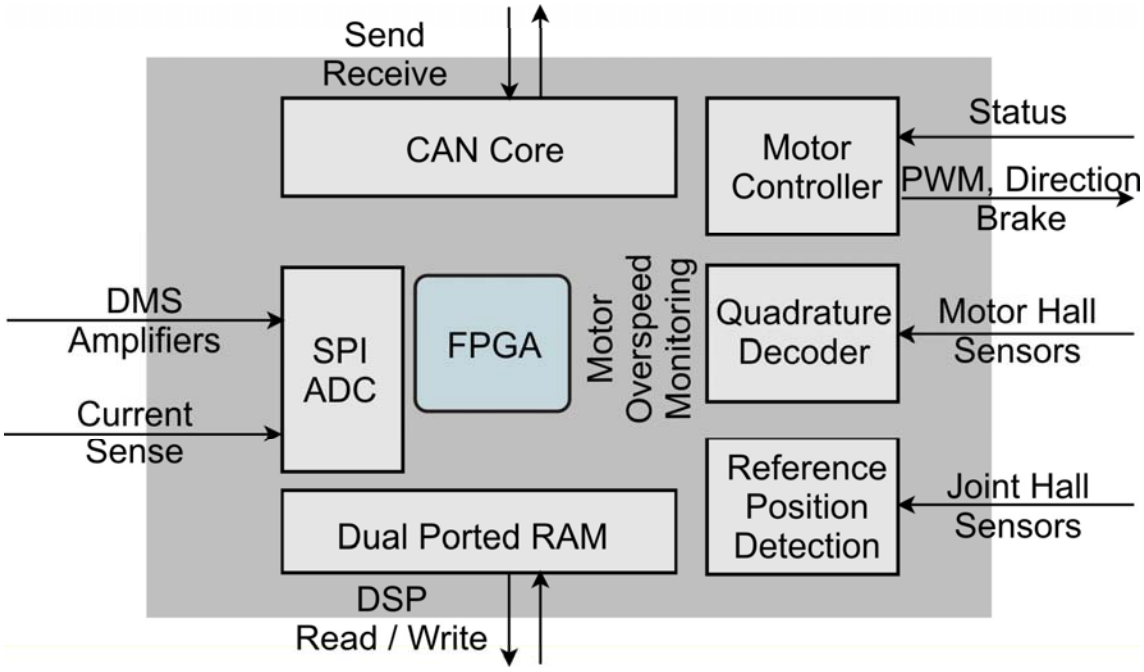
DSP functions

- DSP @ 225 Mhz
- Functions:
  Communication
  Impedance control
  Power management
  Safety functions
- Simulink generated control code



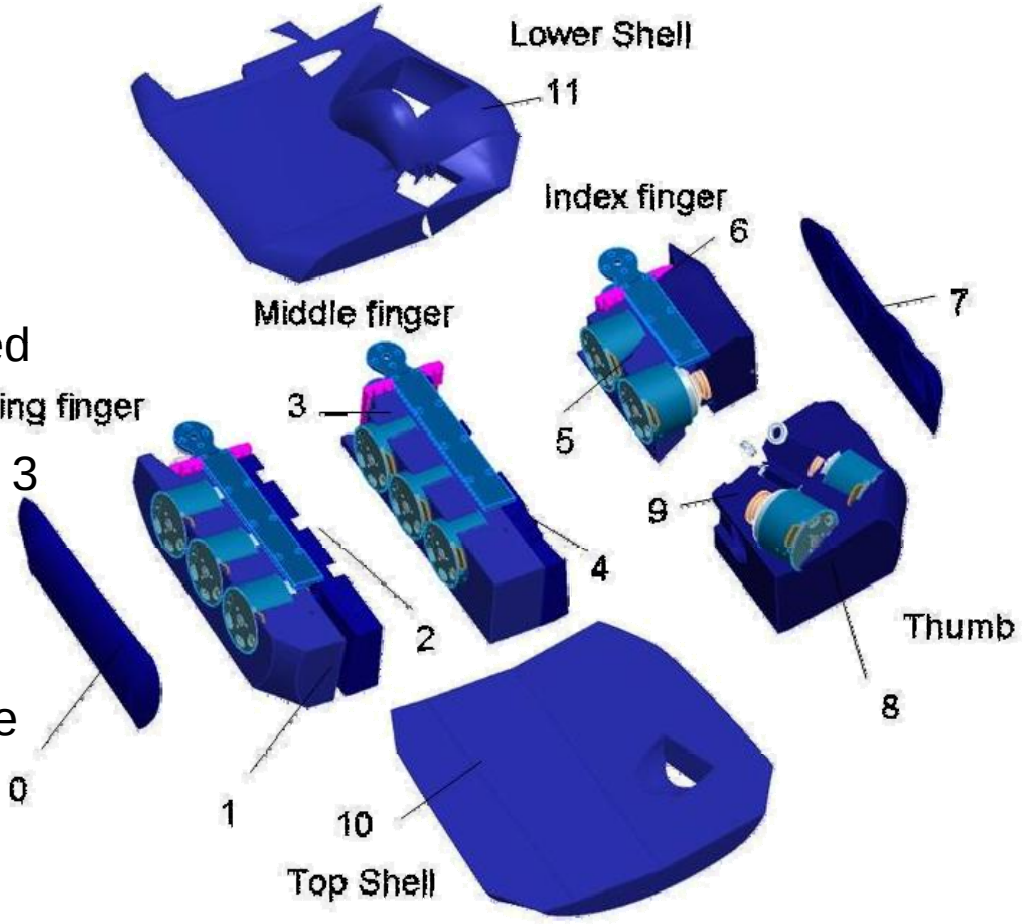
FPGA functions

- Collects sensor signals:
  Strain gauges (SPI)
  Reference position
  Quadrature Encoders
  PWM generation
- Hardware CAN Layer
- Safty functions (Low level)
- DSP interface

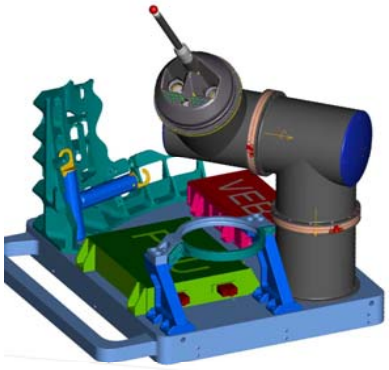


Palm Structure

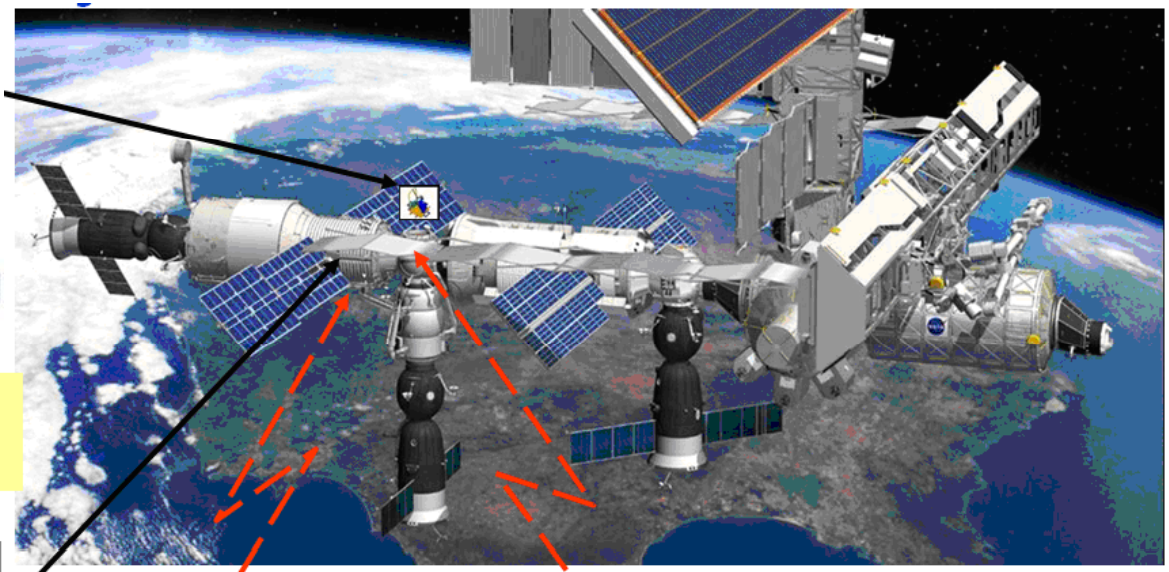
- The Palm consists of 13 parts
- These parts are assembled together to 4 finger units
- Each finger unit consist of 3 ILM 25 actuator units with HD HFUC8 gearings
- Each finger unit contains guidings and pulleys for the tendon routing



ROKVISS System Overview



Robotic External Unit (outside the Russian Service Modul)



On-board Computer (inside the Russian Service Modul)

Russian Standard Ground Link

ROKVISS, Direct Link (S-Band) (4 Mbit/s downlink, 256 kbit/s uplink)

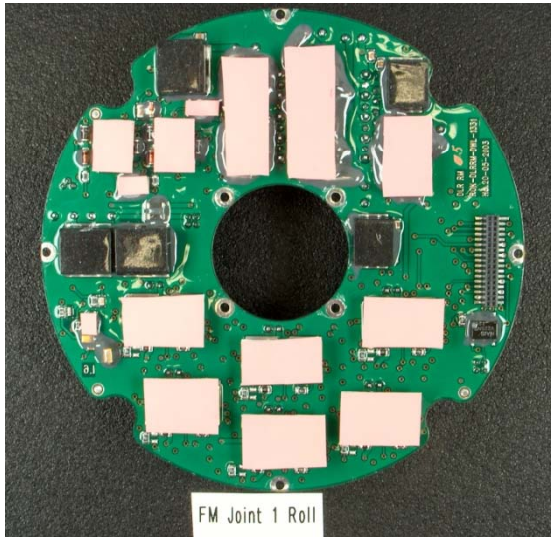
ISS Ground station ZUP, Moscow

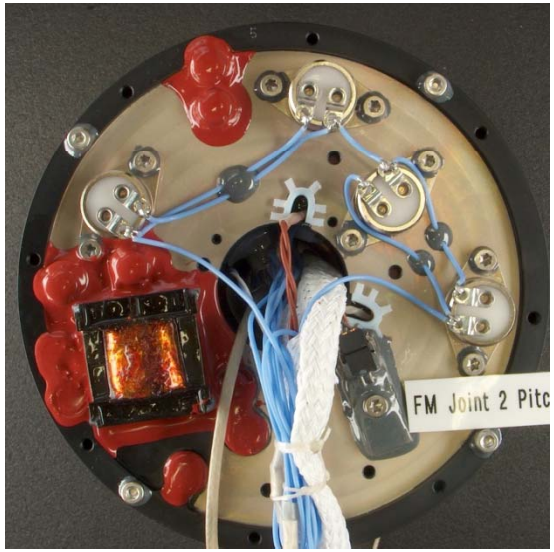
Antenna and Robotic Ground Station GSOC / Weilheim

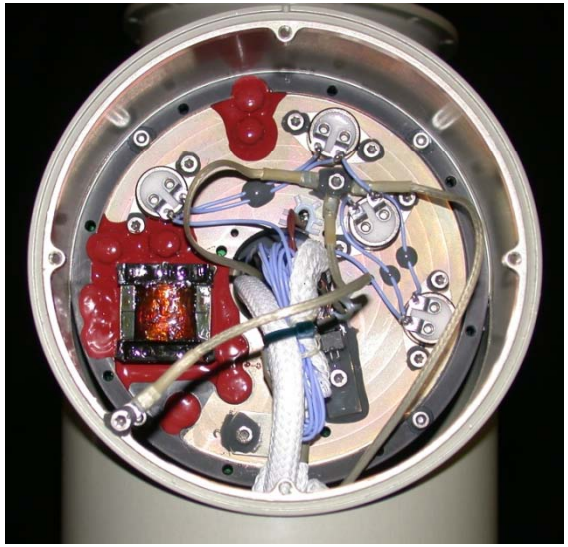
Link between ZUP - GSOC

Modifications

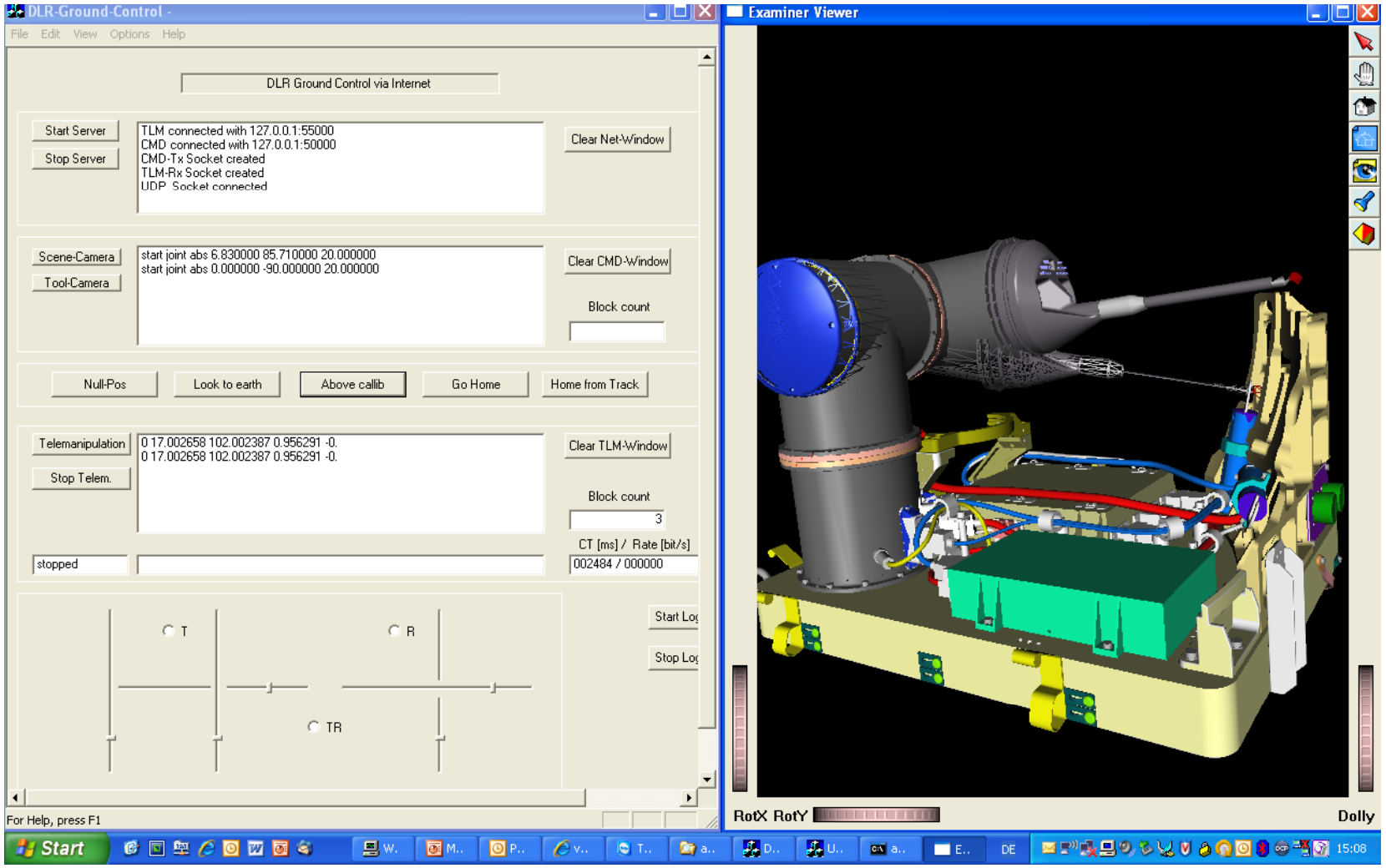
- All heat emitting electronic parts need to be thermally coupled to the robot's structure to allow for heat dissipation
- Thermo switches and heater foils keep the joint within its operational temperature range







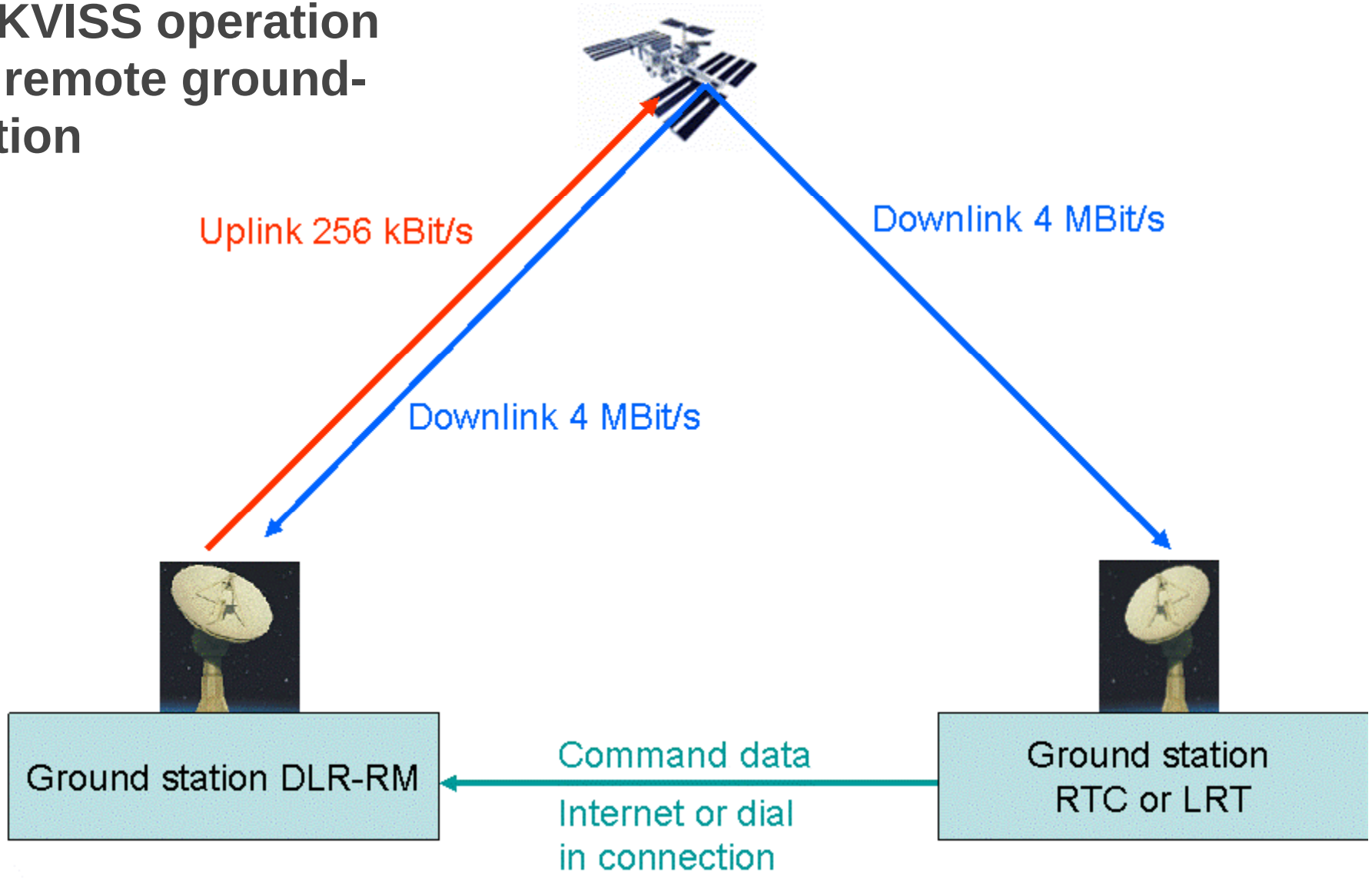
ROKVISS Remote Control with Laptop via DSL



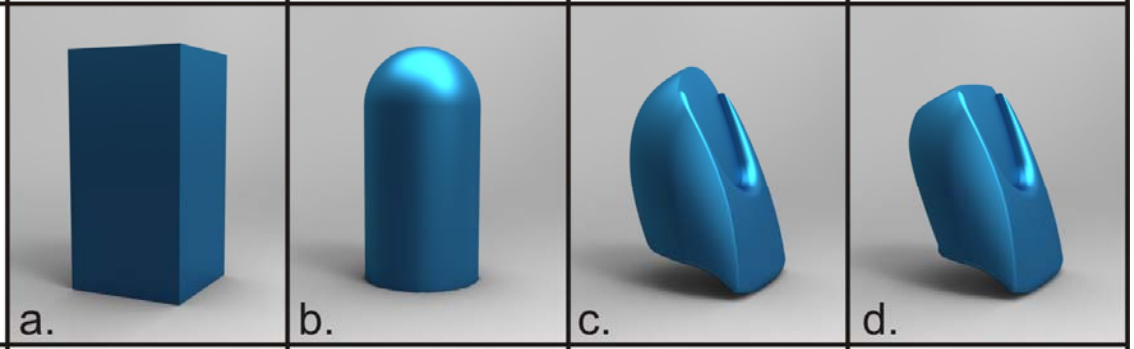
Round-trip-time ~80 ms

- **In November 2010 the ROKVISS flight hardware was dismounted. The two joints will be delivered to DLR-RM for a detailed analysis in June 2011.**

ROKVISS operation via remote ground-station

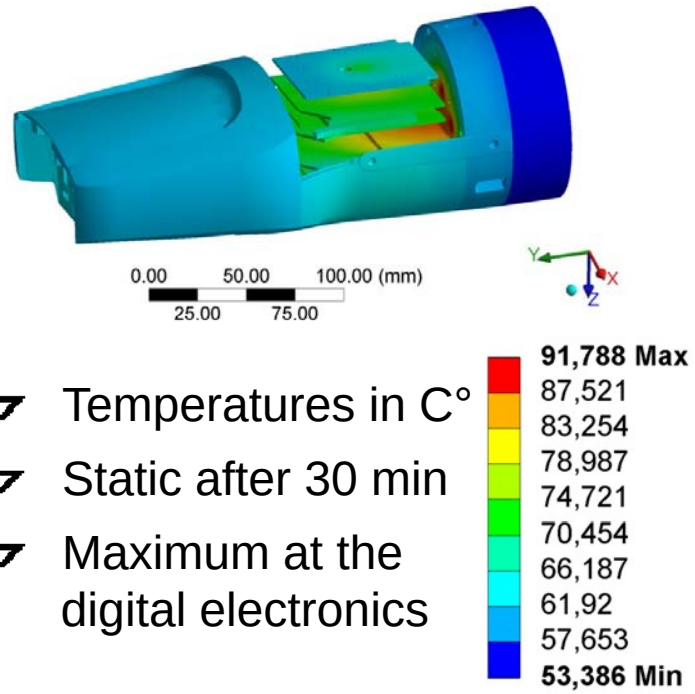


Fingertip design

	Square	Hemi-spherical	Variable curvature	Variable curvature flat end
Finger tip shape	 a. b. c. d.			
Small object picking	+++	-	++	++
Rolling	--	+++	++	++
Maximum load on the finger tip during pinch grasp	++	-	+	+++

DEXHAND Power and heat dissipation

Case	Full-Power	Standby	Nominal
Input filter	5 W	2 W	3,5
Backplane PCB	6 W	6 W	6 W
Sensor PCB	2 W	2 W	2 W
Power inverters	24 W	3,6 W	14 W
Controller PCB	5 W	5 W	5 W
Motors	58 W	0 W	28 W
Total	**100 W**	**18,6 W**	**58,5 W**



- Temperatures in C°
- Static after 30 min
- Maximum at the digital electronics