



Robotic Components for Space ROKVISS and DEXHAND

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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

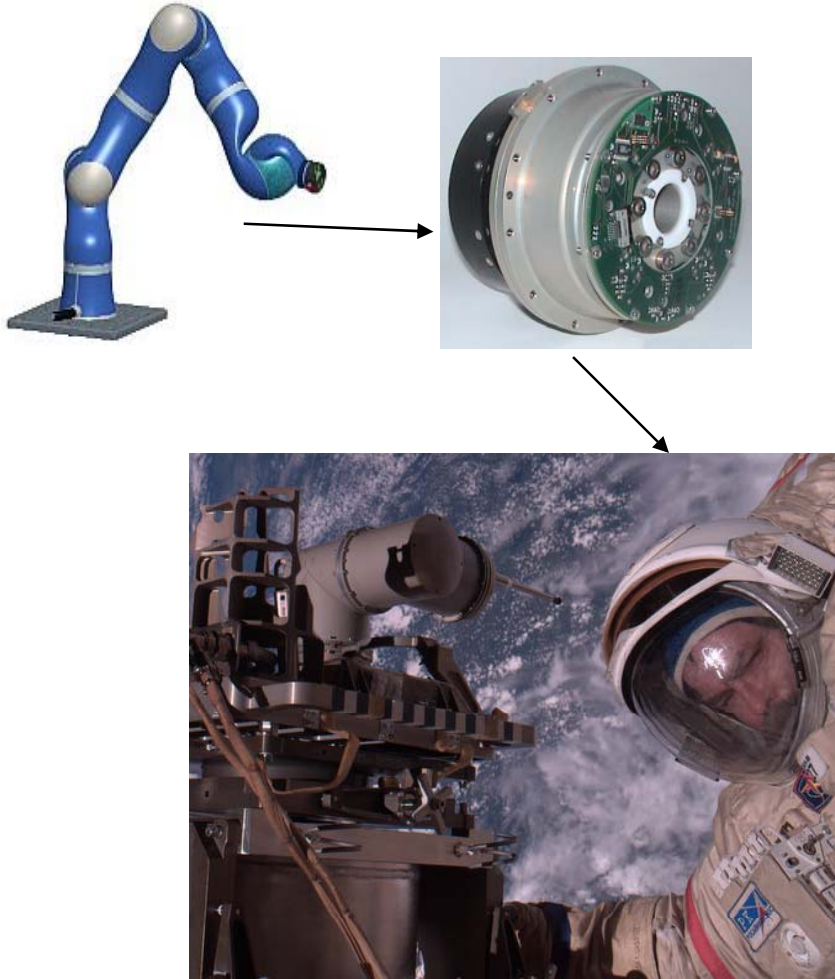
- Shock and vibration

Political Aspect

Qualification

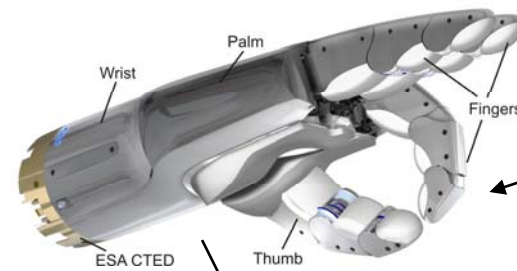
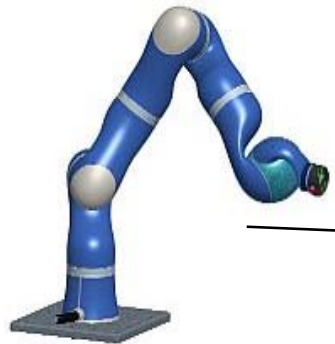


Strategy





Strategy





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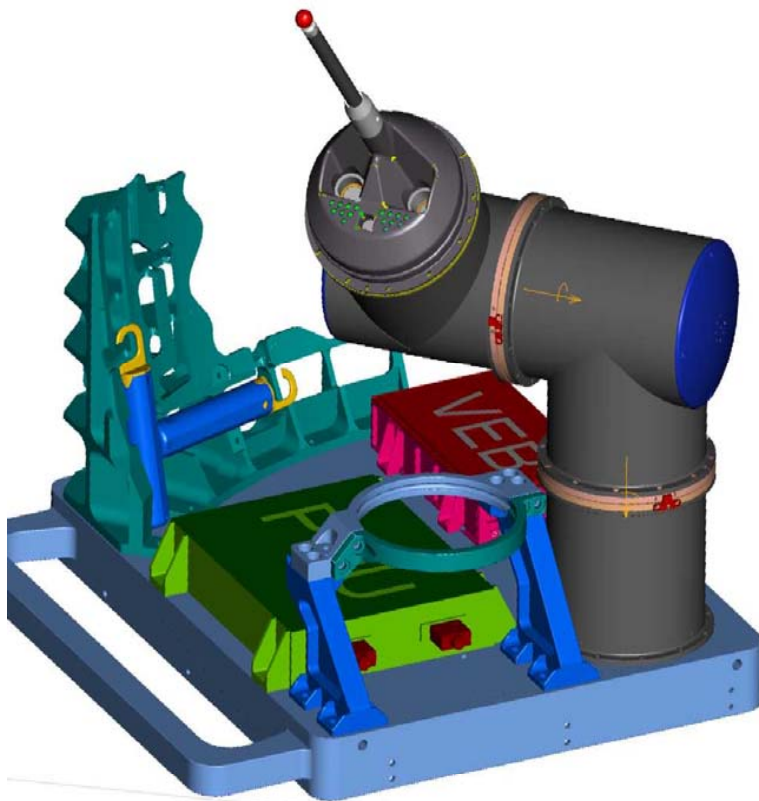


ROKVISS Concept

- 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

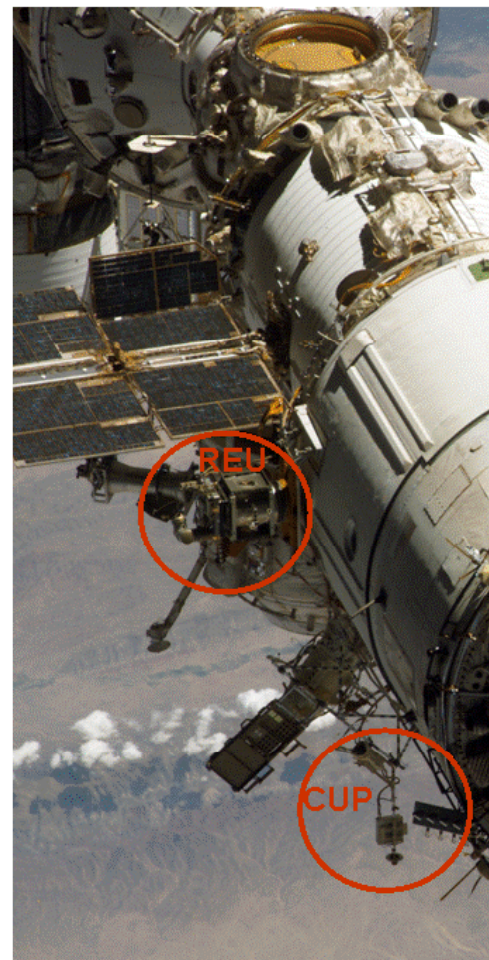
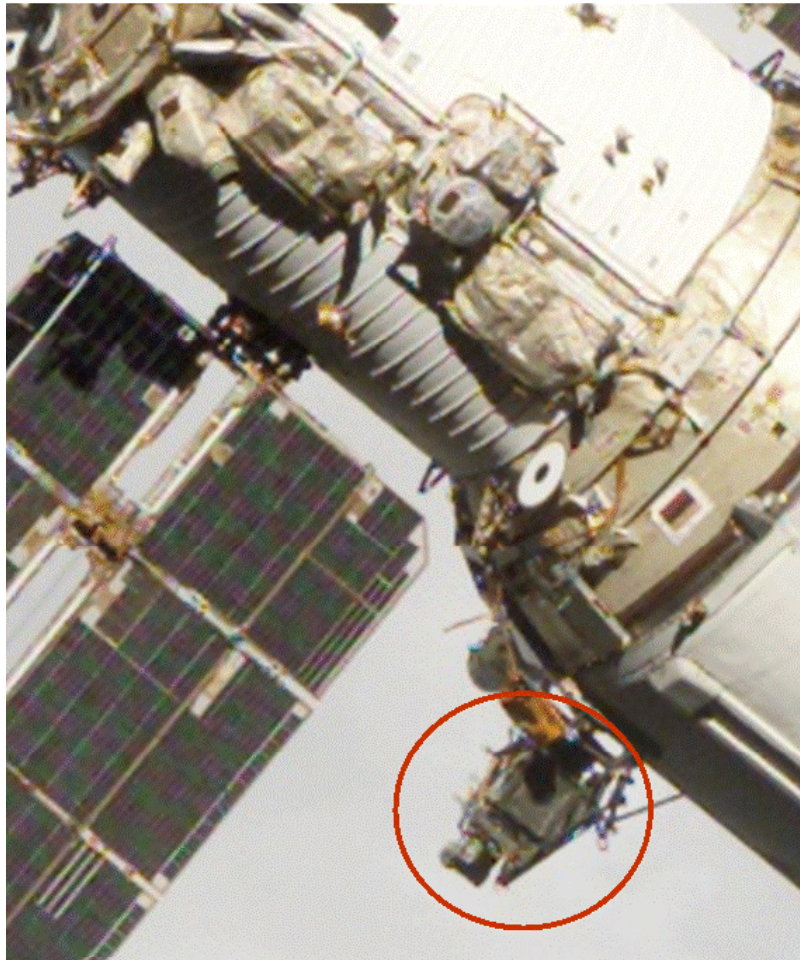
ROKVISS Specifications



- 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

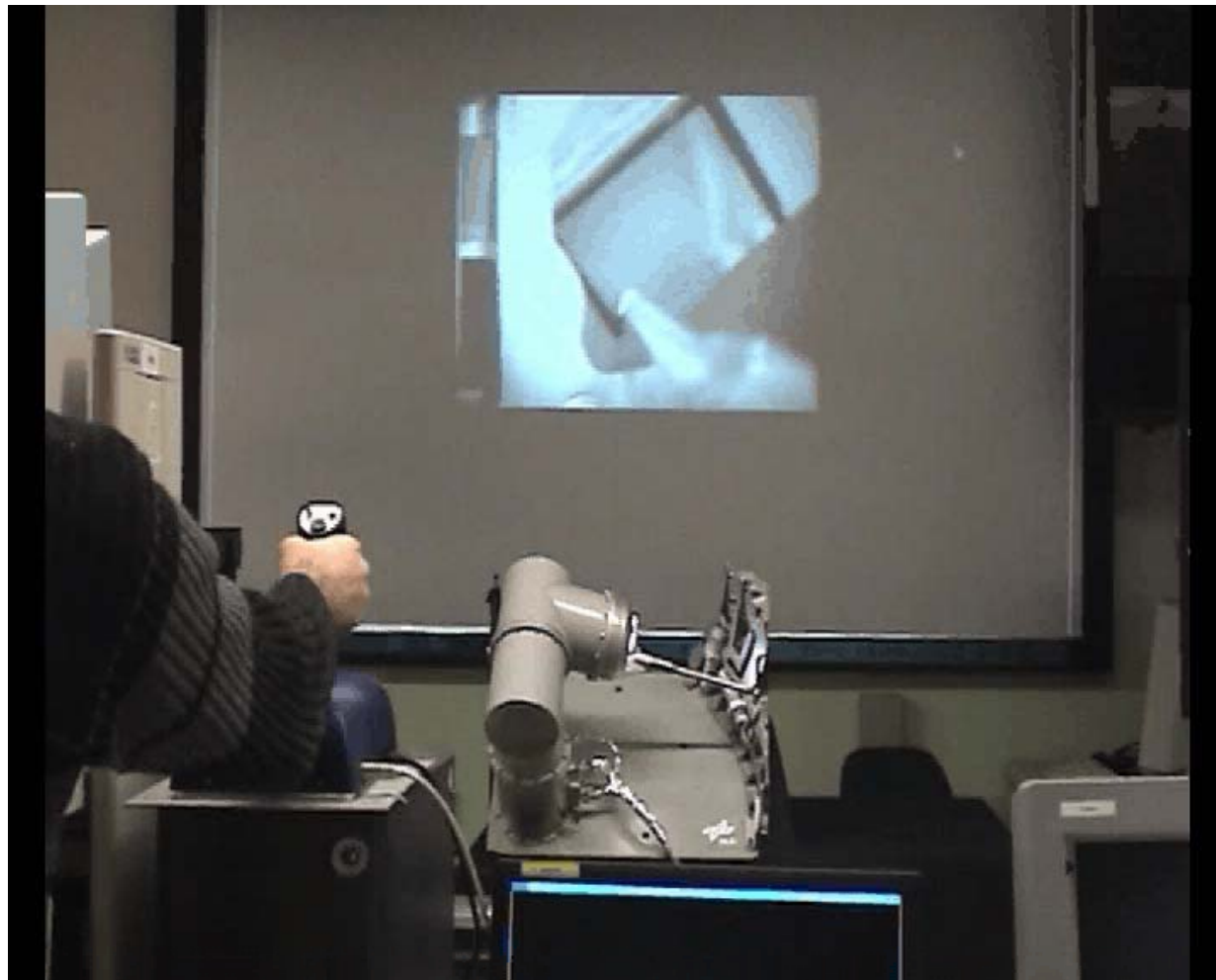
ROKVISS Communication System



- 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

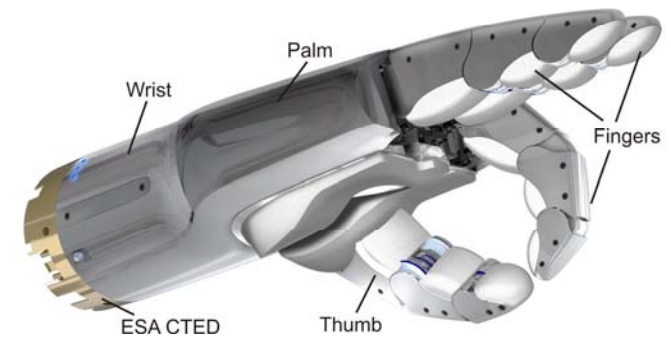
Requirement:	OPS-1
<p>The DEXHAND shall be able to grasp the following EVA tools:</p> <ul style="list-style-type: none">• Pliers, and support their operations• Scissors, and support their operations• Small cutter and support its operations• Brush, and support its operations• Hammer, and support its operations• 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 <p>Comment: Successful operation of the tools implies force closure of the grasp. Note that preferably form closure should be achieved.</p>	



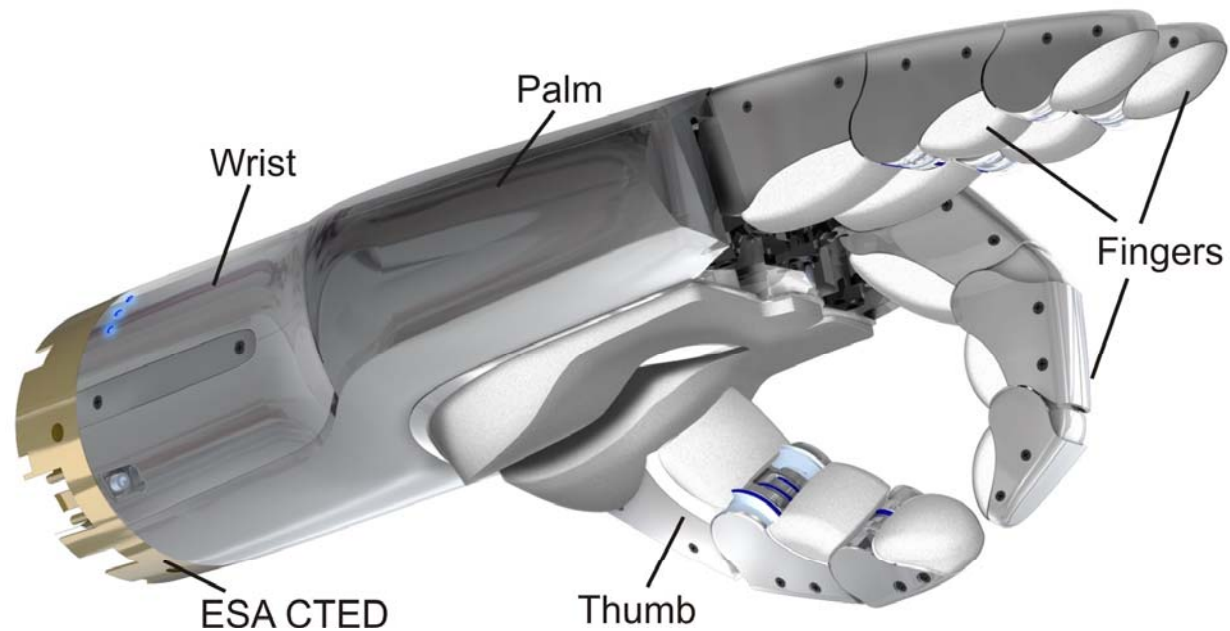


DEXHAND Concept

- 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



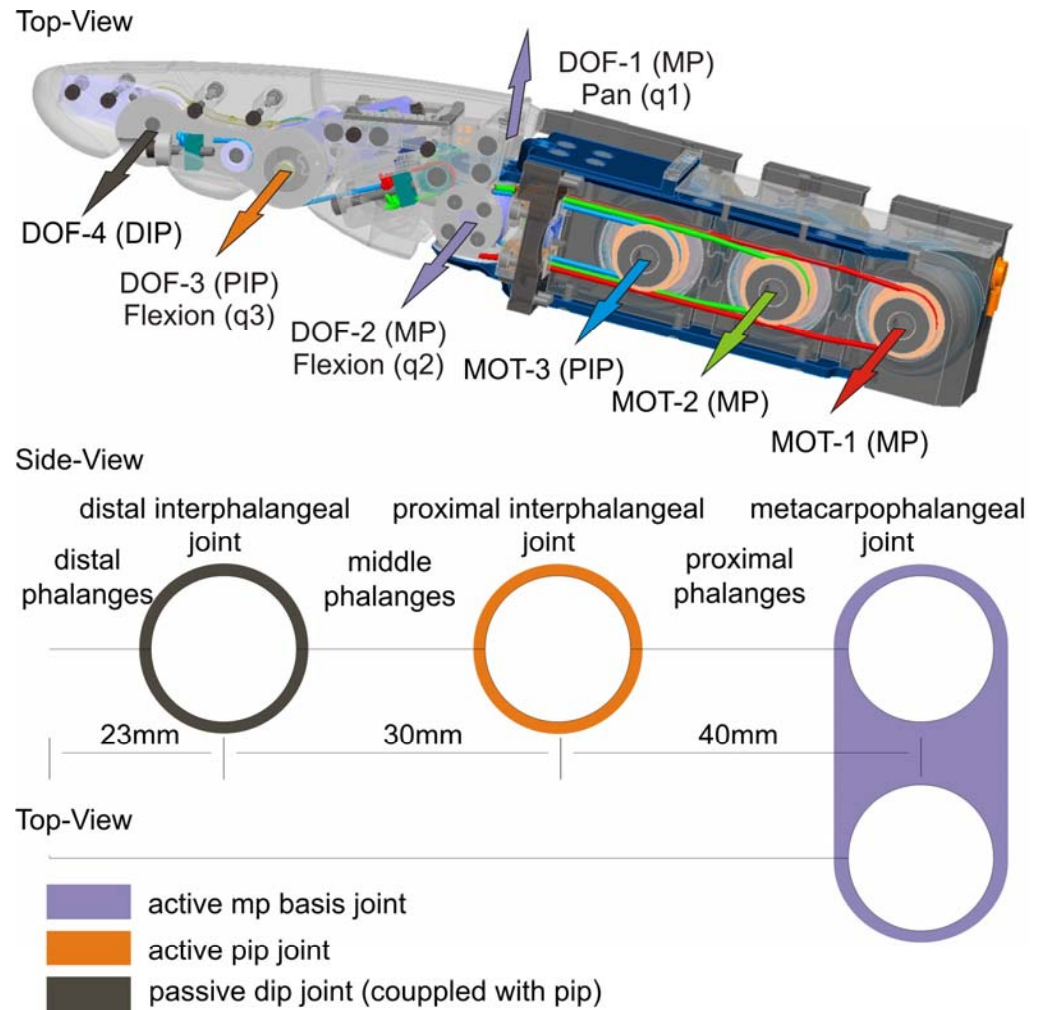
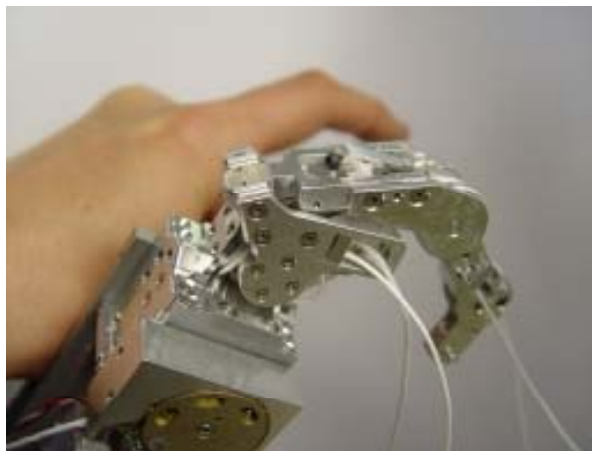
DEXHAND Overview



- 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) - stretched out

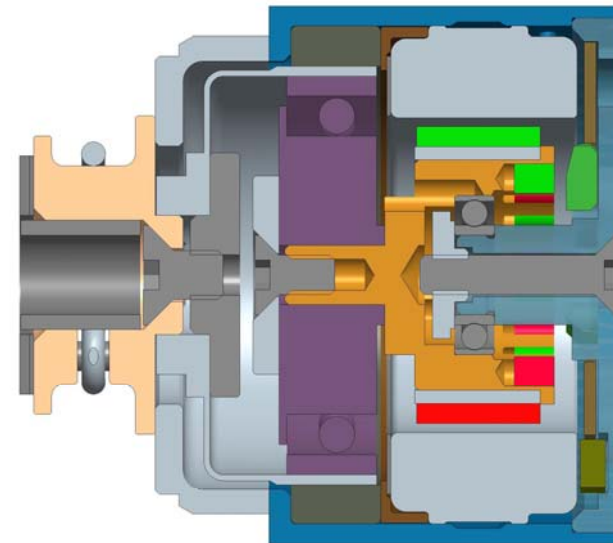
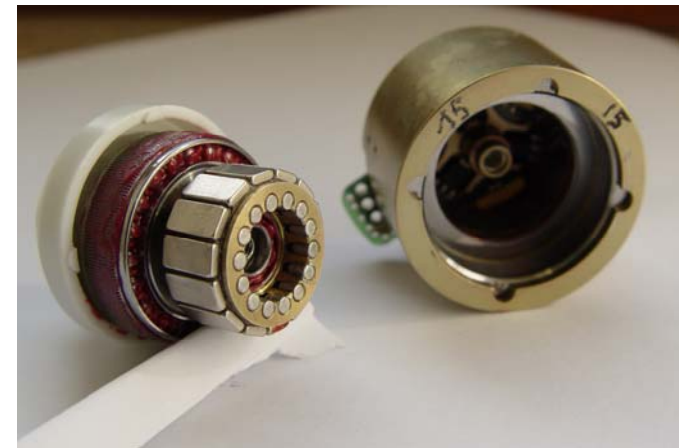
DEXHAND Finger Kinematic

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

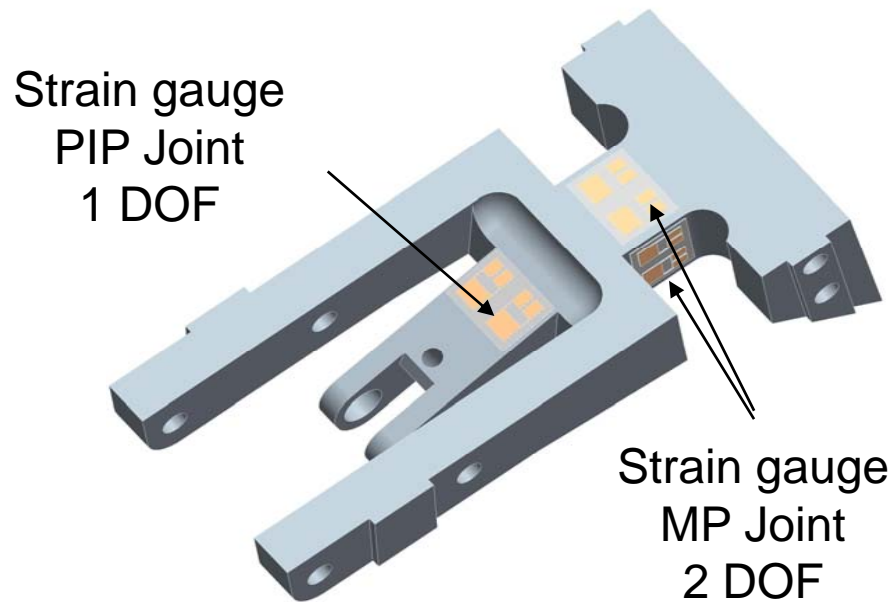


DEXHAND Actuator Modules

- 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)

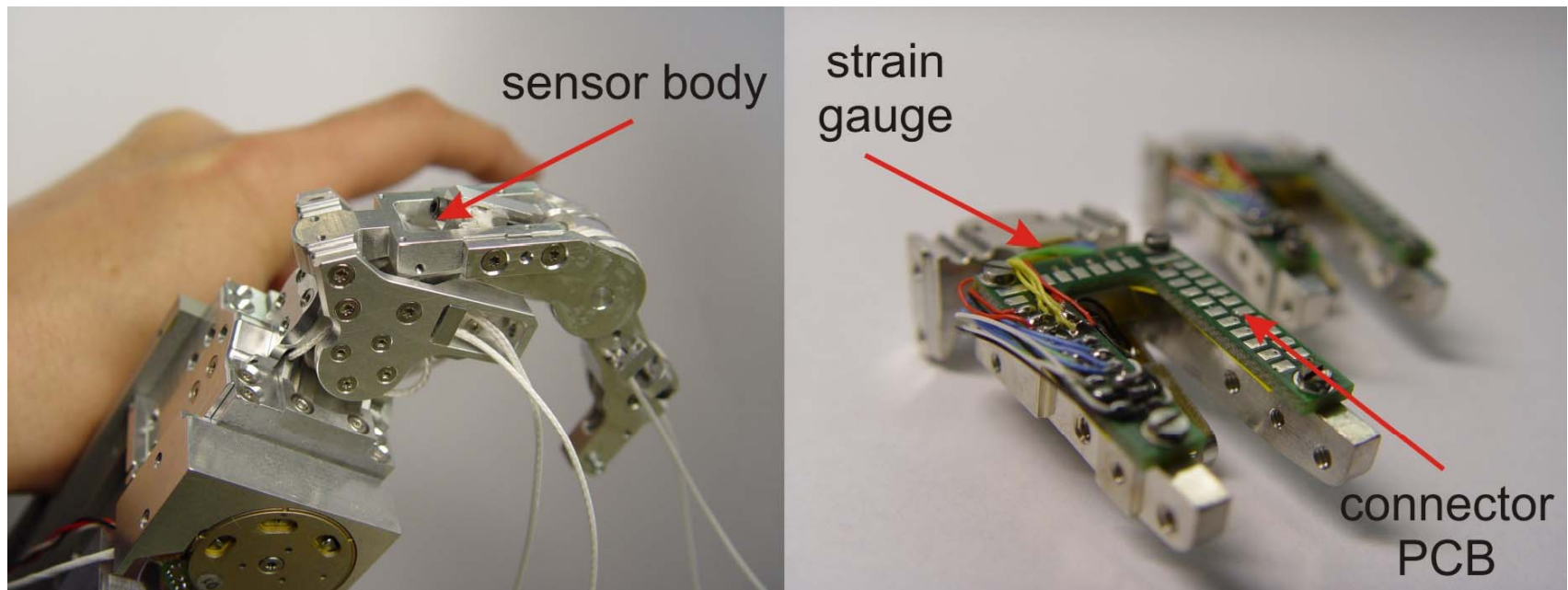


DEXHAND Finger Sensor Concept



- 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

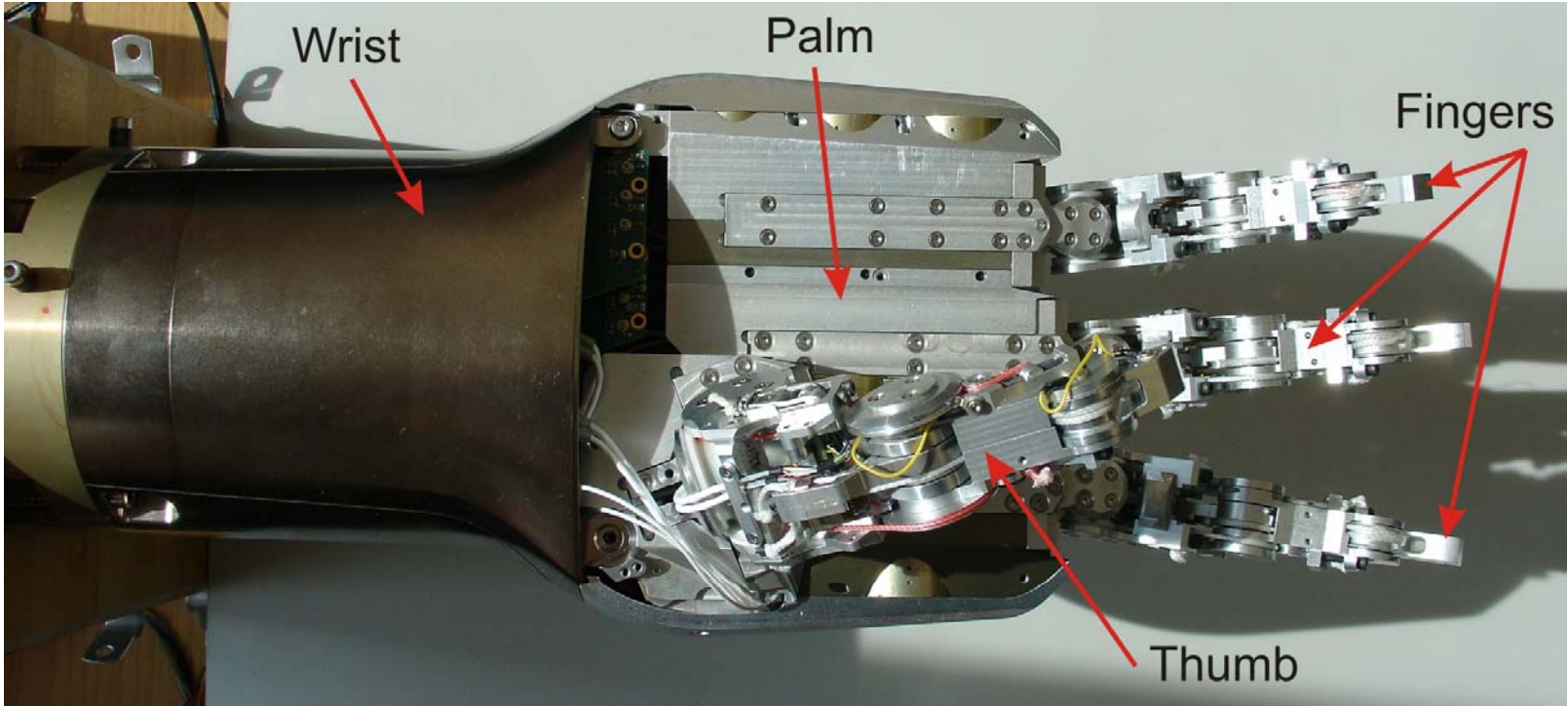
DEXHAND Finger Sensor Concept



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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

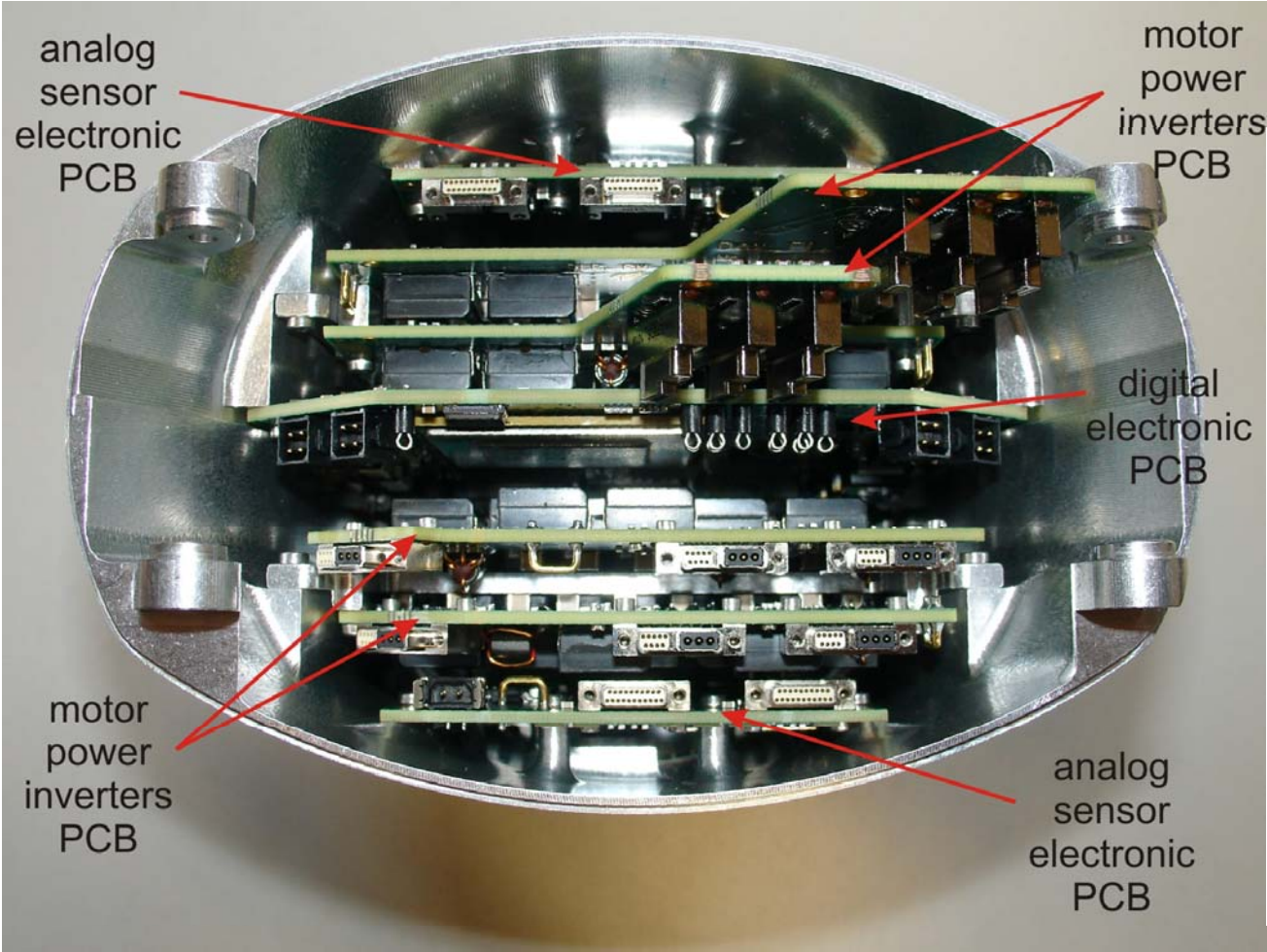


DEXHAND Shielding and EMC Compatibility

- 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

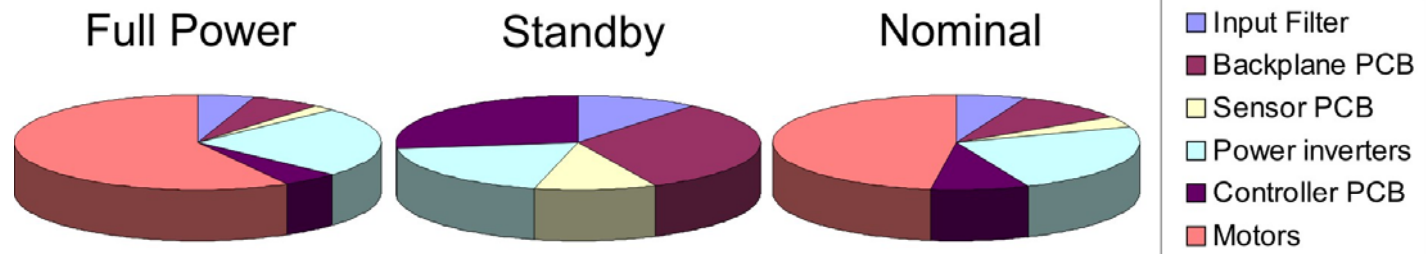
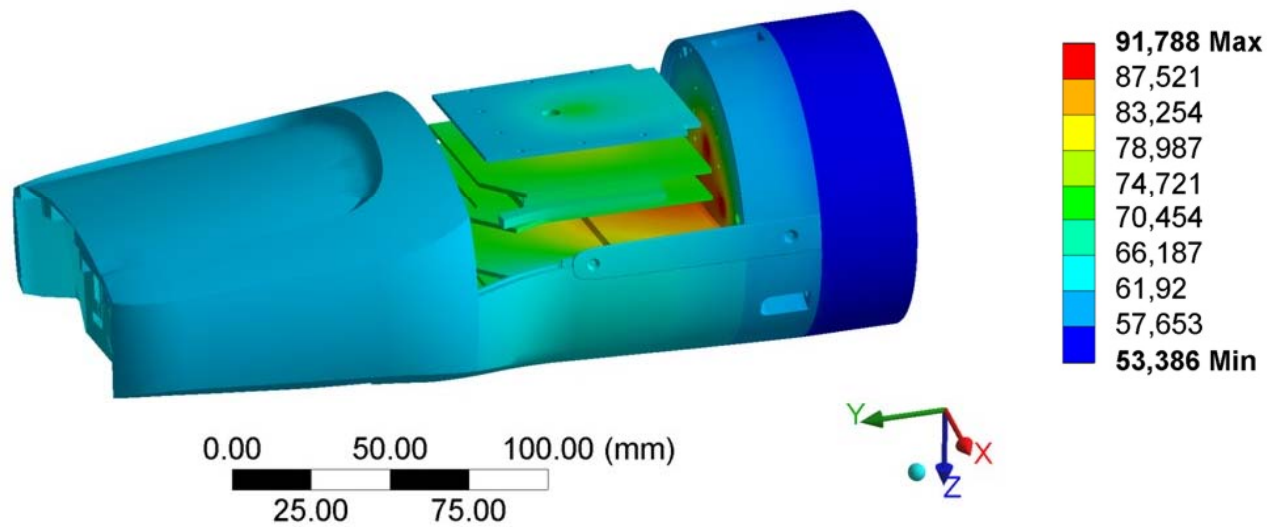


DEXHAND Electronic compact housing

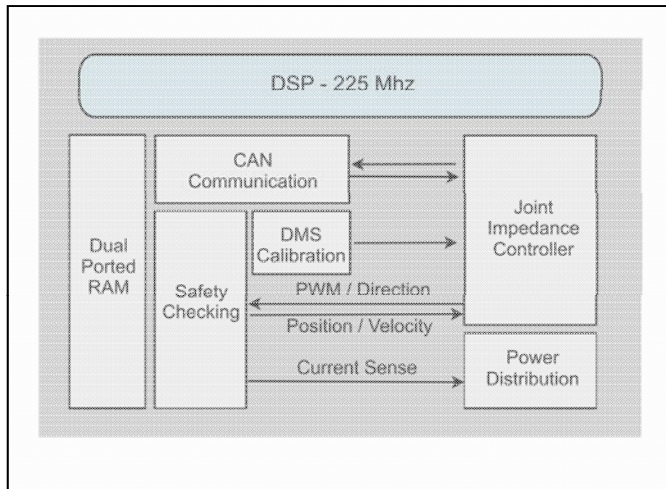




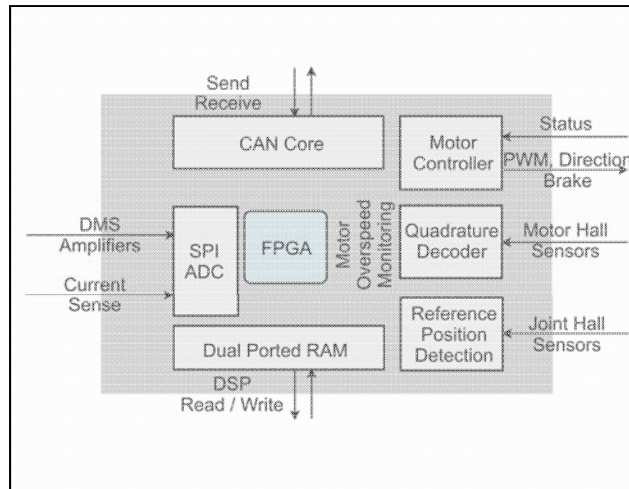
DEXHAND Power and heat dissipation



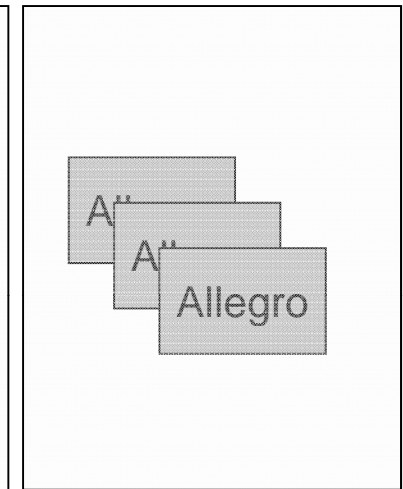
DEXHAND Control architecture



DSP



FPGA



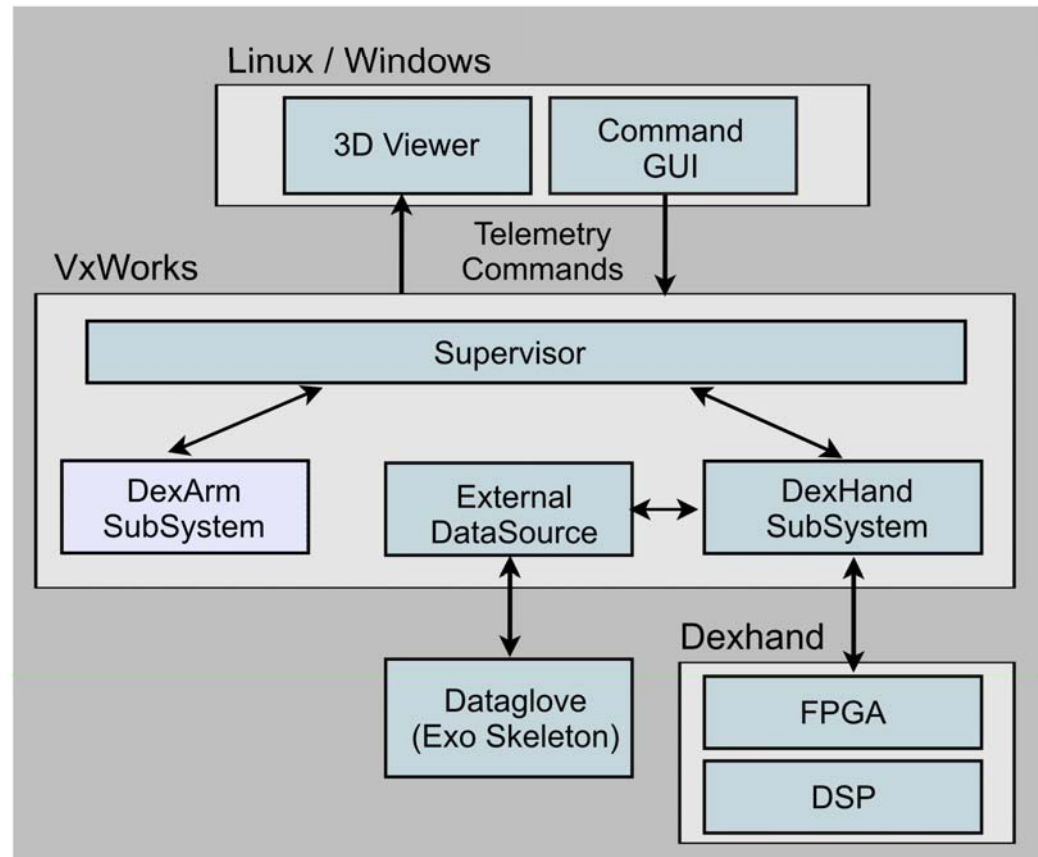
Motor Controller

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 !



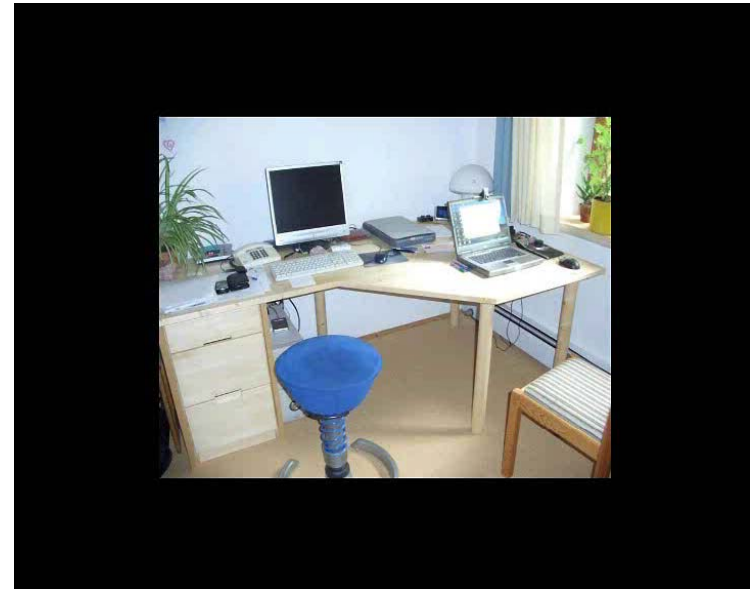
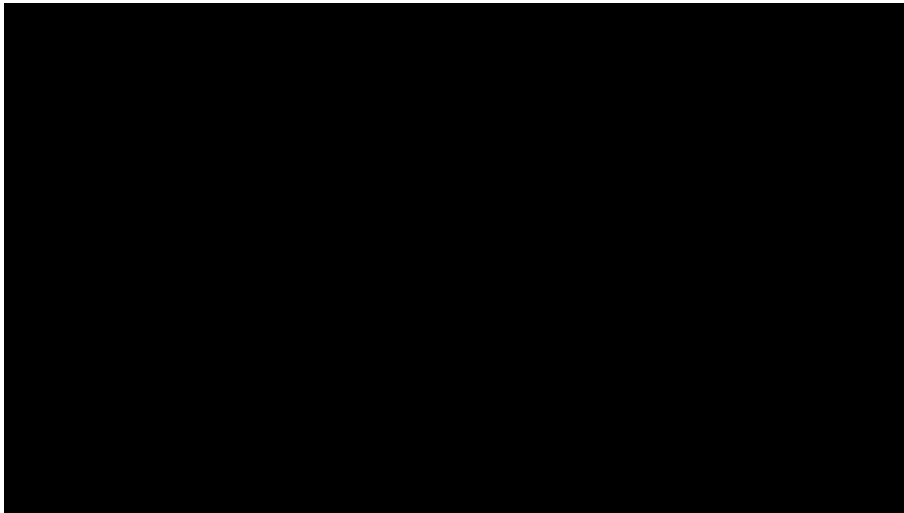
Thank you for your attention!!!



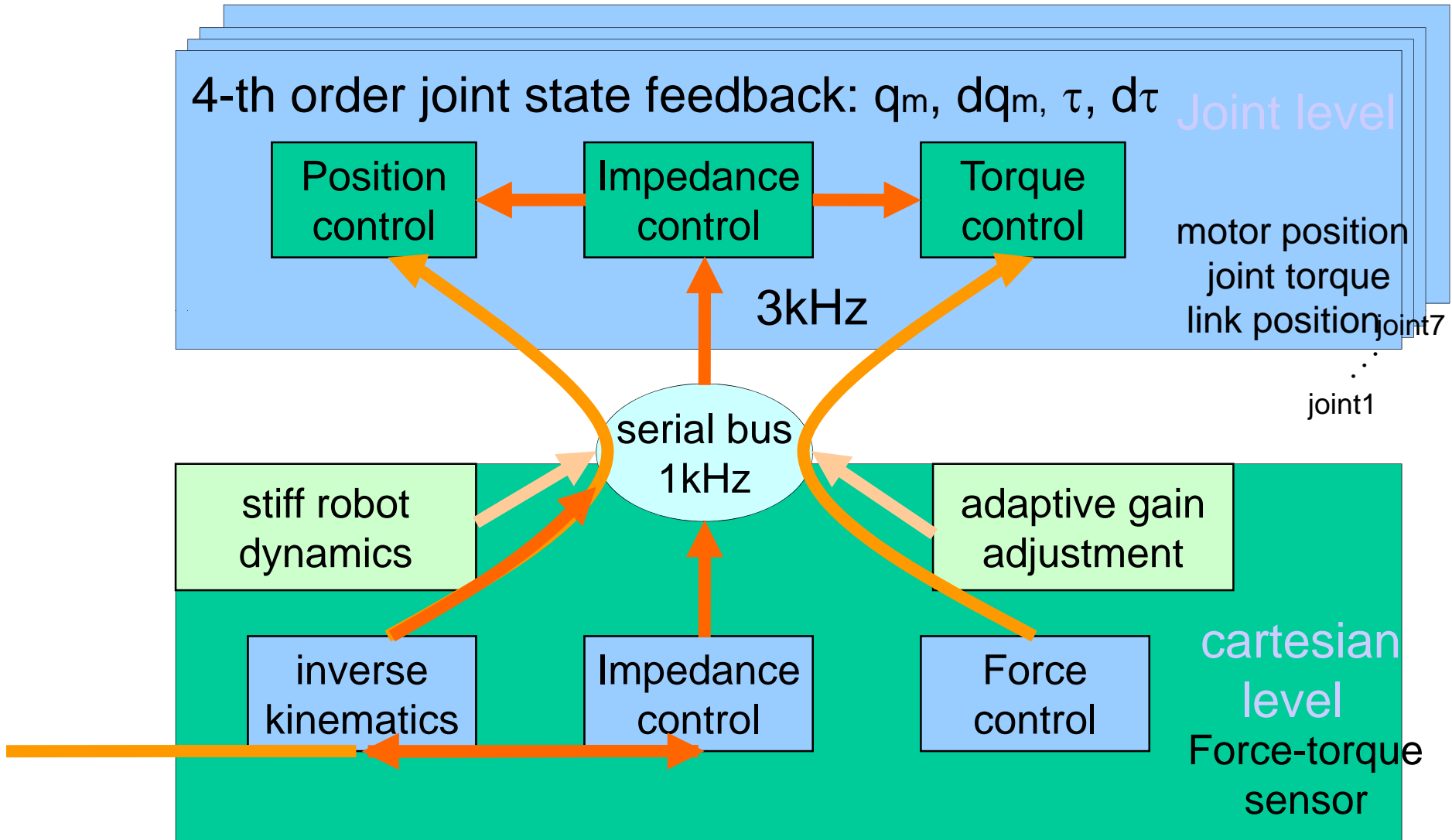
- The DEXHAND Team has been over two years min. about 15 person
 - The project has been financed by the ESA Contract No. 21929/08/NL/EM



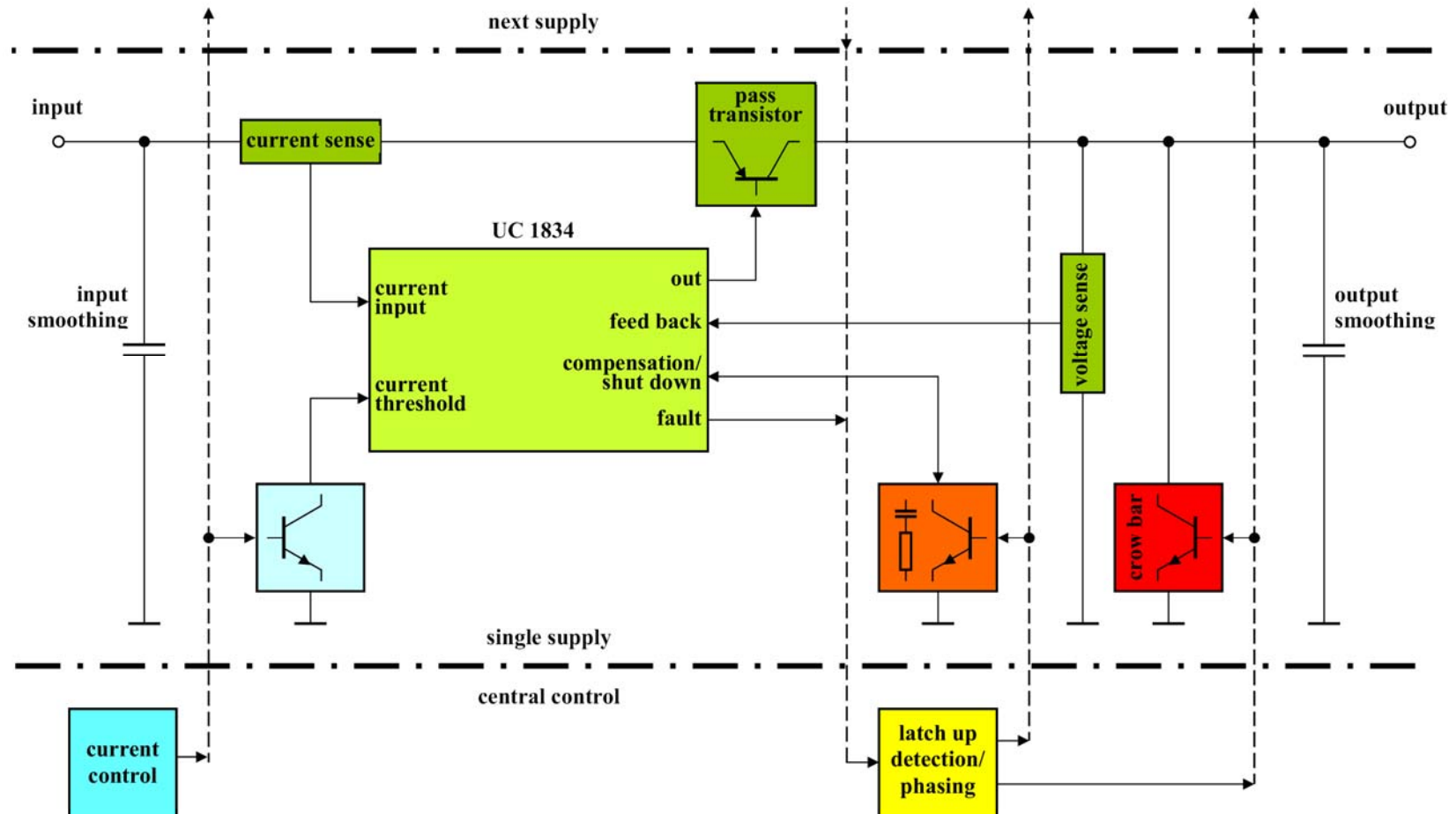
Question and Videos



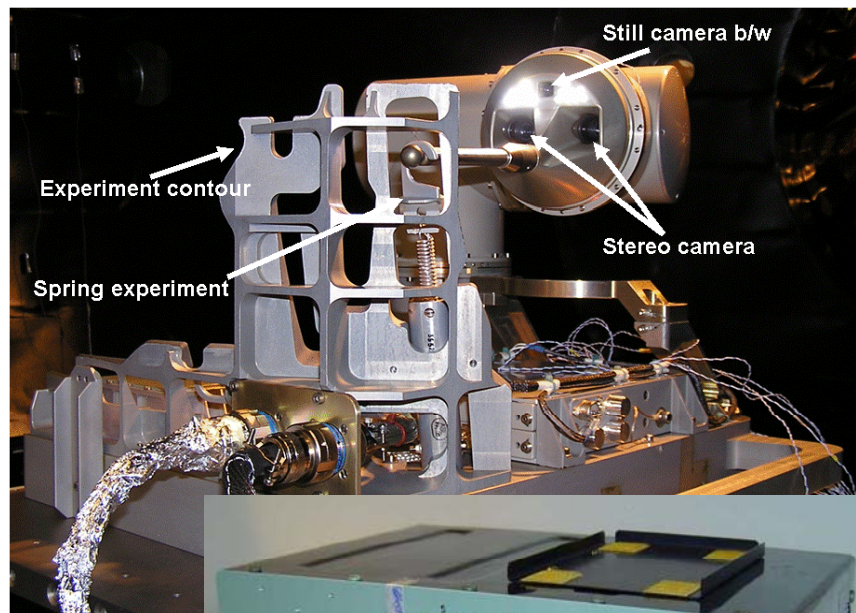
Control architecture



Latch-up Protection Circuit

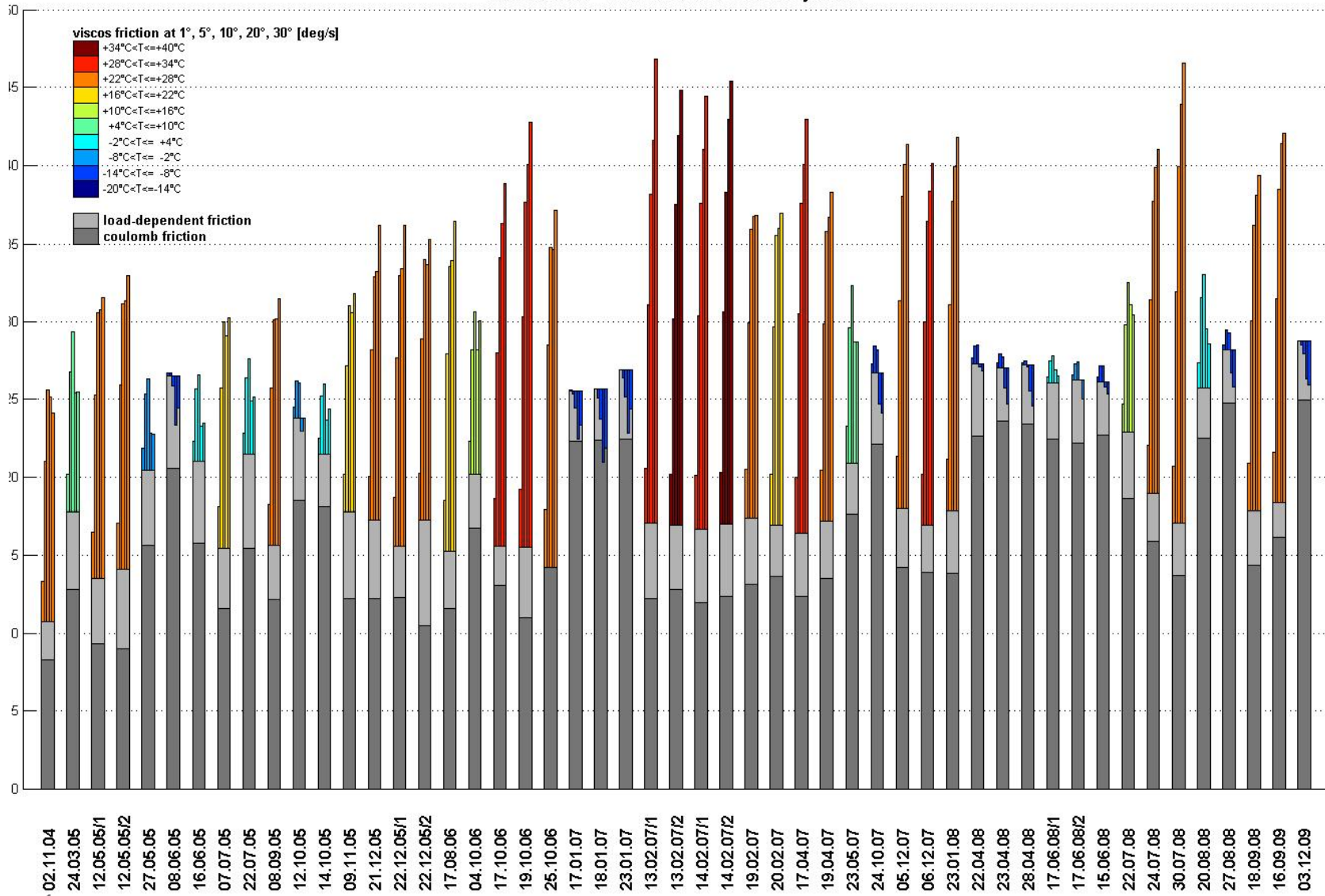


ROKVISS External Unit (REU) and On Board Computer (OBC)



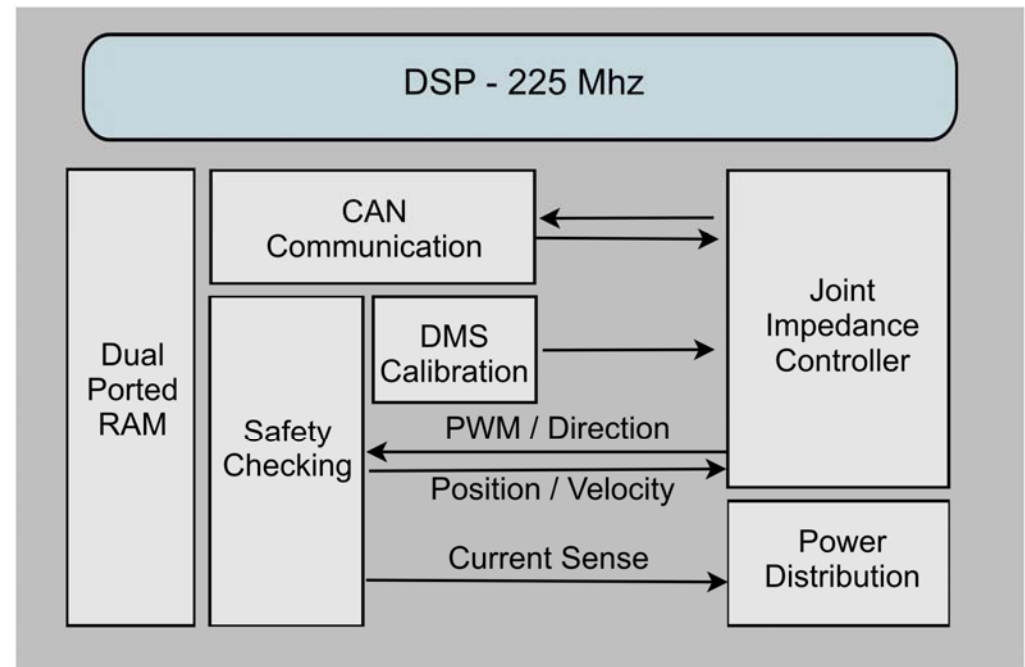


ROKVISS - friction identification joint 2



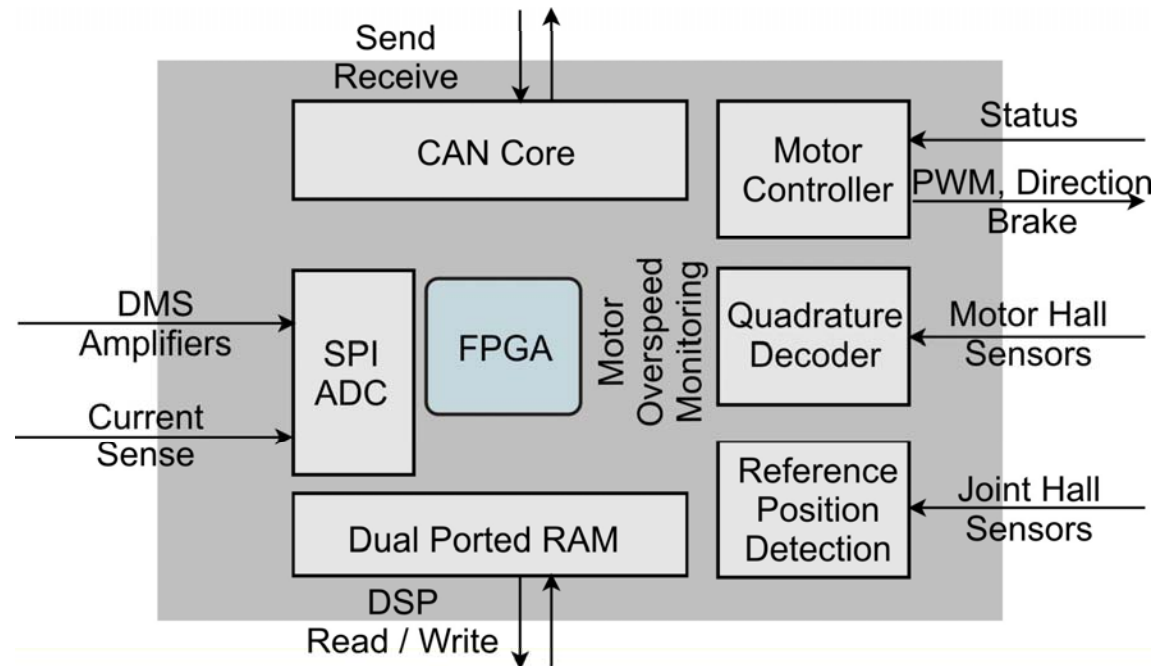
DSP functions

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



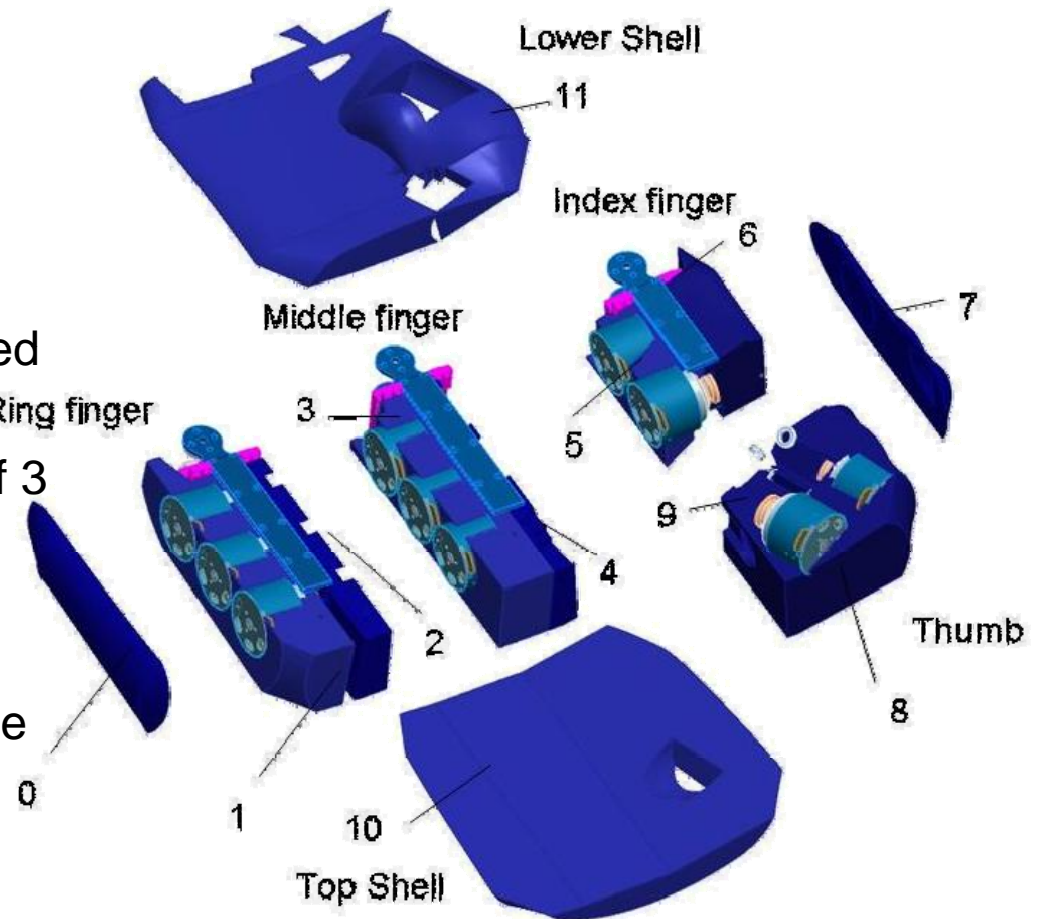
FPGA functions

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

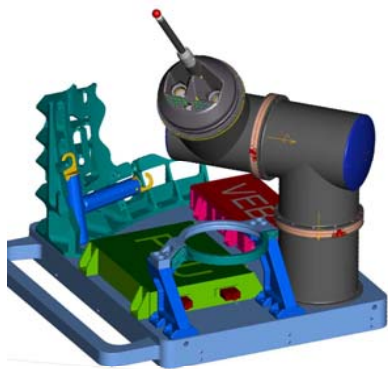


Palm Structure

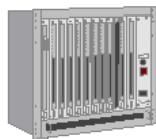
- The Palm consists of 13 parts
- These parts are assembled together to 4 finger units
- Each finger unit consist of 3 ILM 25 actuator units with HD HFUC8 gearings
- Each finger unit contains guidings and pulleys for the tendon routing



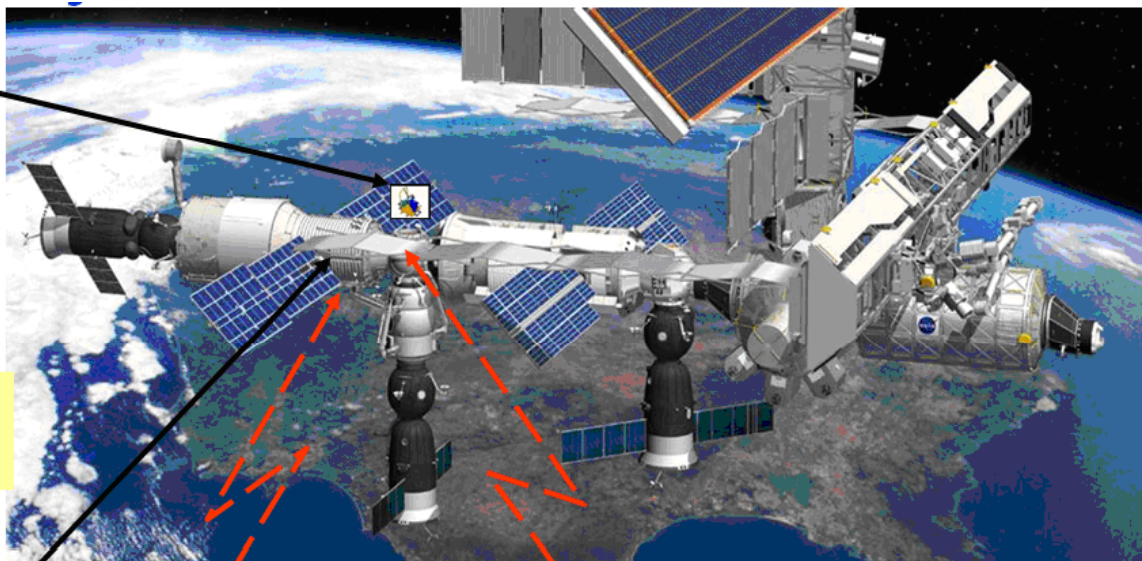
ROKVISS System Overview



**Robotic External Unit
(outside the Russian Service Modul)**



**On-board Computer
(inside the Russian Service Modul)**



**ISS Ground station
ZUP, Moscow**

**Russian Standard
Ground Link**

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



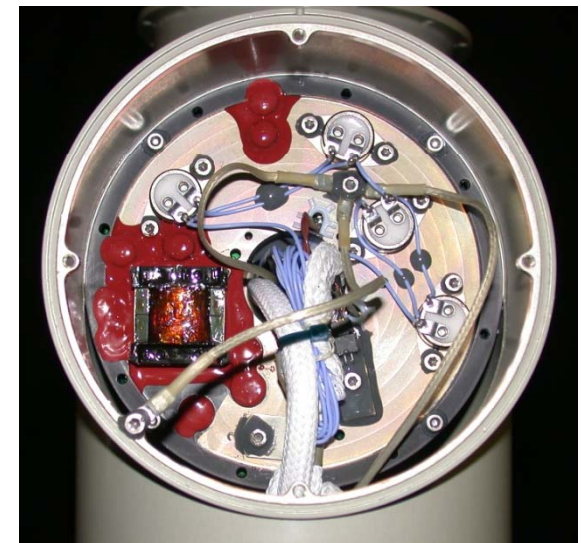
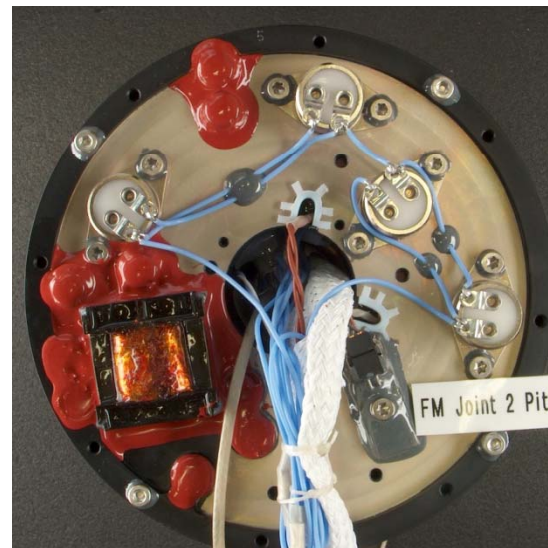
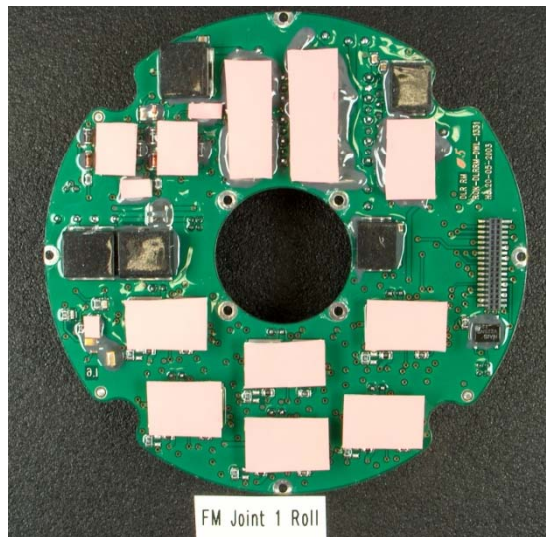
**Antenna and
Robotic Ground
Station
GSOC / Weilheim**

Link between ZUP - GSOC

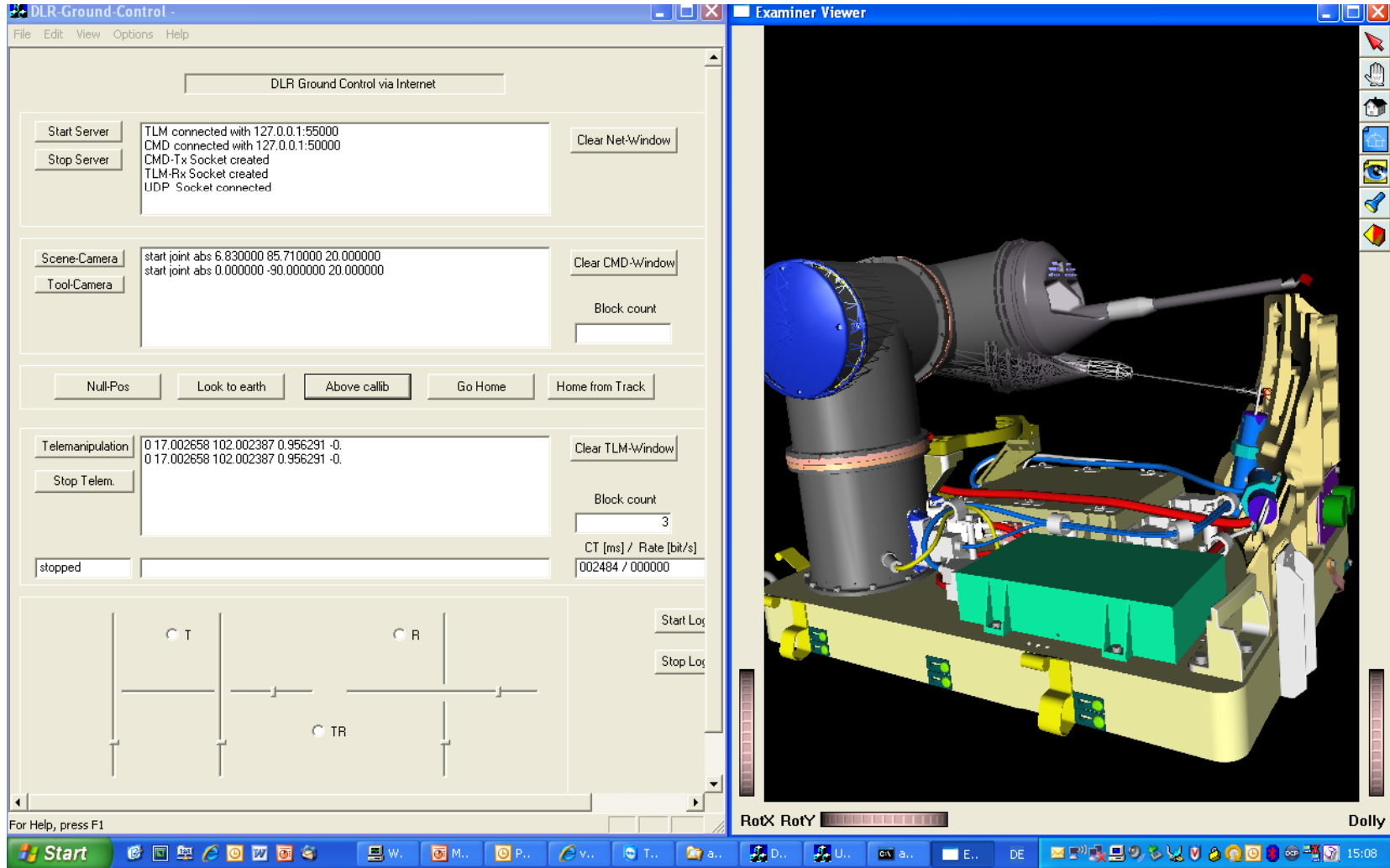


Modifications

- 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

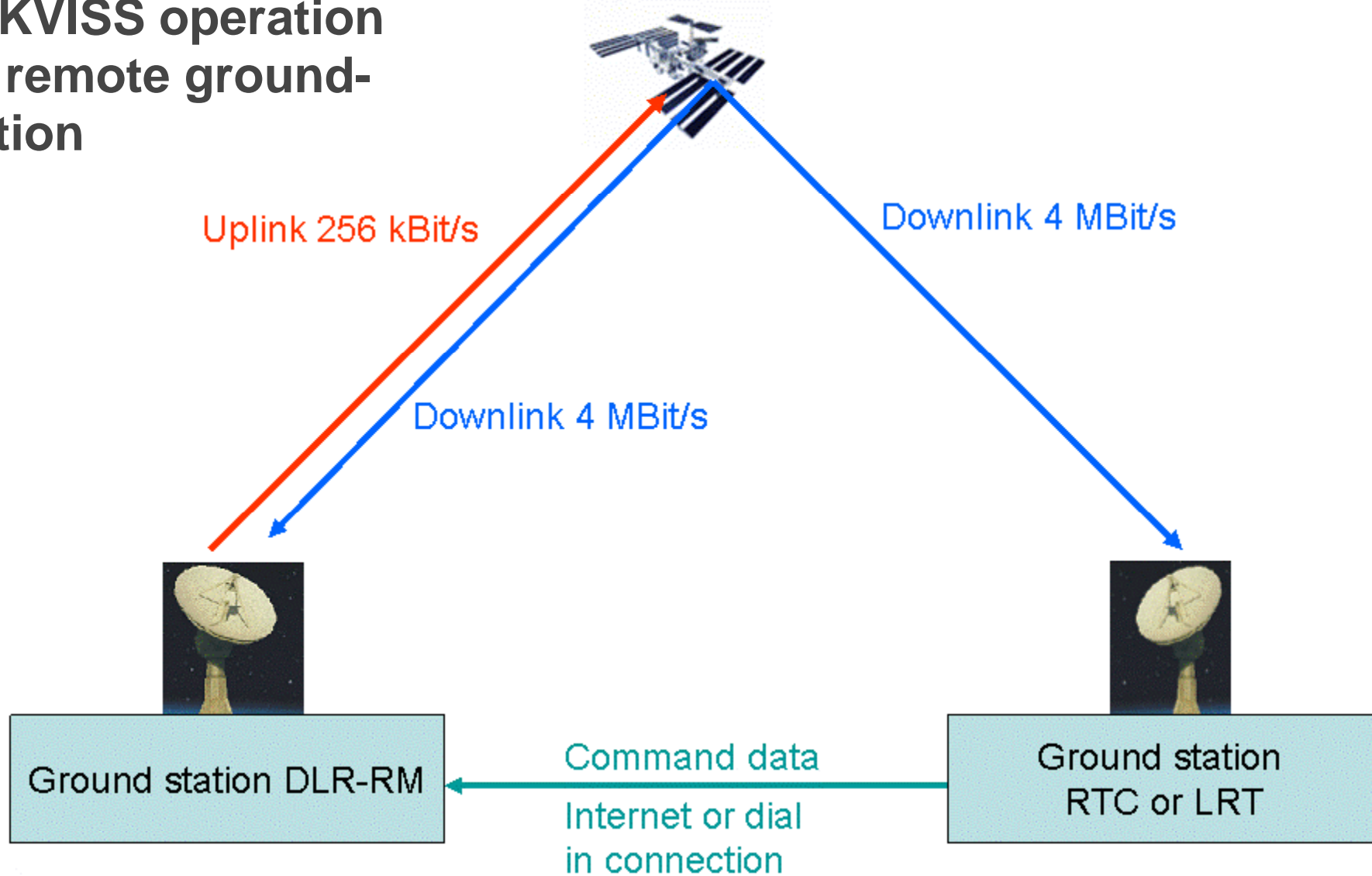




- **In November 2010 the ROKVISS flight hardware was dismounted. The two joints will be delivered to DLR-RM for a detailed analysis in June 2011.**

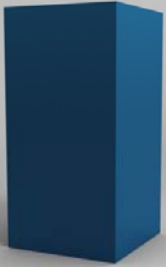

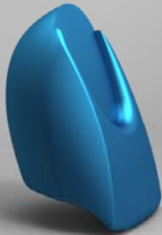
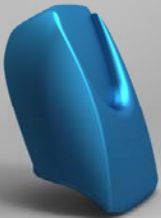


ROKVISS operation via remote ground- station





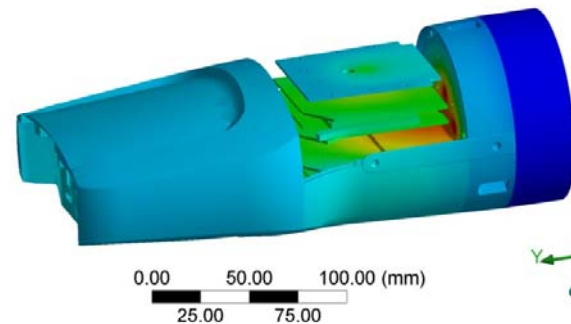
Fingertip design

	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

