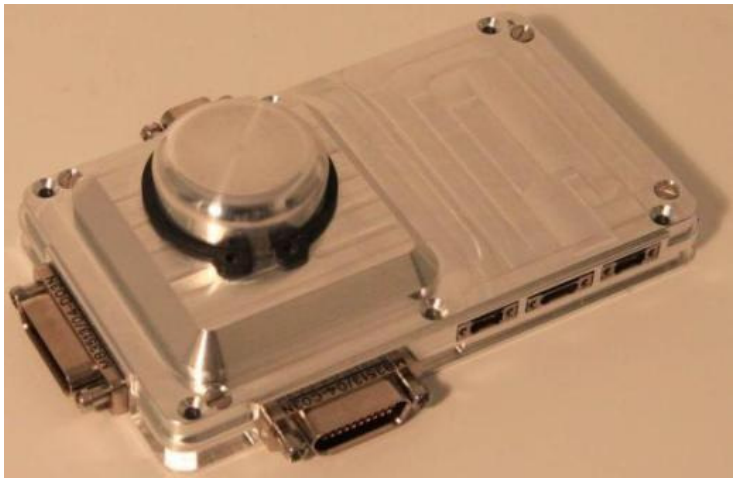

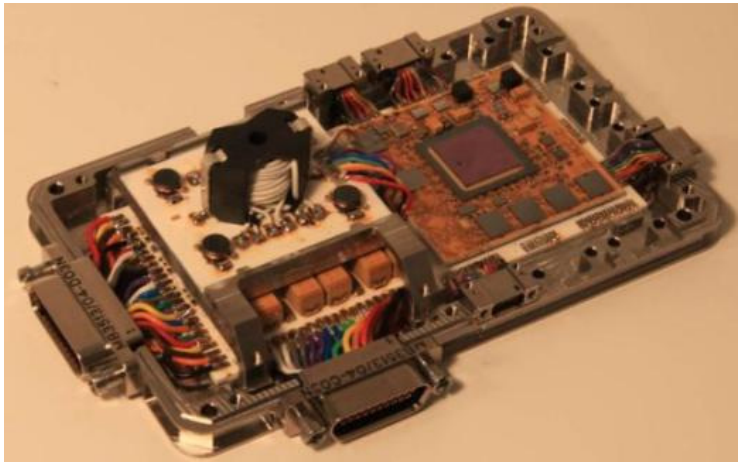

Miniaturized Motor Controller for Space Robotic Applications

"Motion Control Chip"

T. Liljemark, H. Löfgren, E. Lamouruex, (ÅAC Microtec), S. Habinc (Aeroflex Gaisler), G. Gruener (CSEM), A. Rusconi (Selex Galileo), L. Richter (DLR), B. Boyes (Astrium), P. Poulakis (ESA) and J. Köhler (f.m. ESA, SNSB)

April 2011

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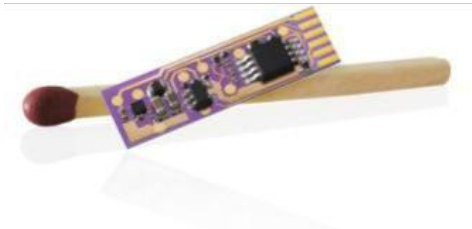
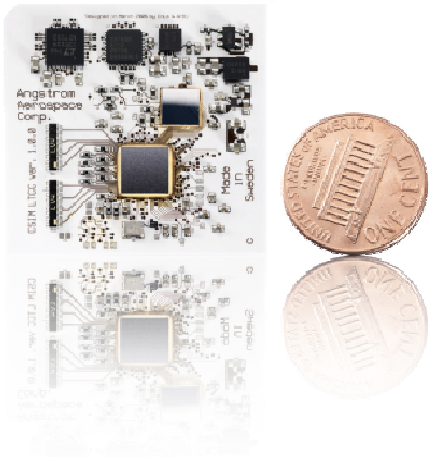
Technical Area Editor, C&DH, Journal of Small Satellites

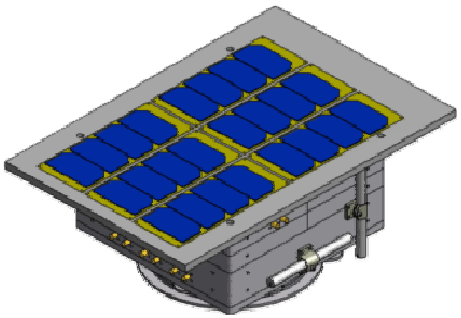
About ÅAC Microtec AB…

- ✓ Formerly named Ångström Aerospace Corporation
- ✓ Two business units
  - **Miniaturized and Robust Industrial Electronics**
  - **Space and Defense**
- ✓ Academic spin-off company from Uppsala University, The Ångström Laboratory
- ✓ Privately owned
- ✓ Internal clean room (class 100 and 1000) and assembly facility
- ✓ Turn over ~3.5 M Euro





- ✓ CEO, Mats Magnell, Ph.D. (f.m. Scania, Mydata, ABB)
- ✓ V.P., Fredrik Bruhn, Ph.D. (co-founder, f.m. Uppsala Univ., NASA JPL)
- ✓ Corporate Board
  - Chairman, Staffan Junel (f.m. V.P. Ericsson, CEO Hasselblad)
  - Sven Löfqvist (f.m. CEO Micronic Laser Systems)
  - Stefan Hanna (f.m. Ericsson M&A, IBM, Industrimatematik)
  - Olof Stjernberg (f.m. CEO Wasakredit)



Motivation

- ExoMars design includes more than 40 electrical motors
- Each motor requires control electronics
- Miniaturization of electronics, out of the hot box
  - Saving in volume, mass, energy

Image courtesy of ESA.

Introduction to MCC

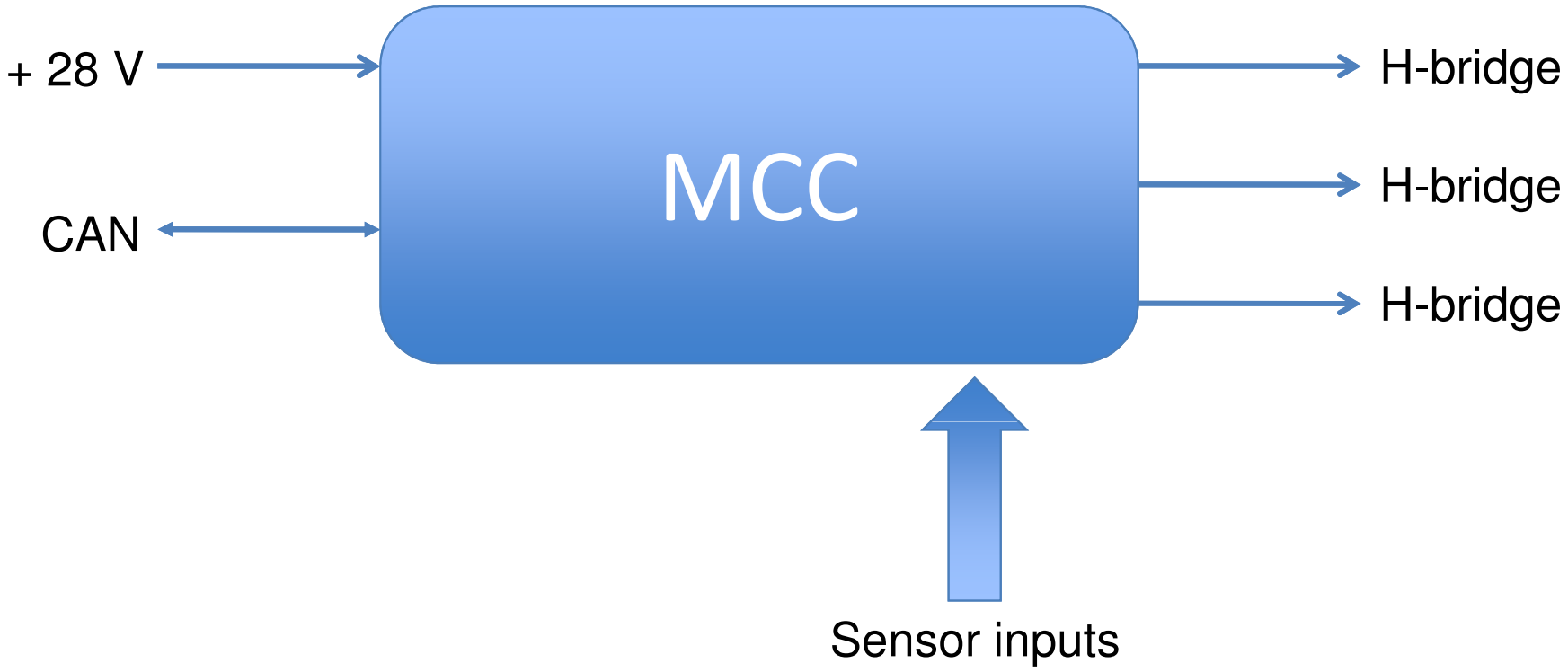
- ESA TRP started in 2008, ÅAC Microtec AB prime
- Miniaturzed Motion Control module for Cold Space environment
- Storage -120 ℃ to 70 ℃
- Operational -55 ℃ to 70 ℃
- Close cooperation with ExoMars team
- ~ 700 requirements (Selex Galileo/Astrium)

- Based on ÅAC packaging technology
- Distributed operation with only +28 V and CAN interface,
  – Software controlled (32-bit processor)
  – Current control loop >= 10 kHz

- Use of Nano-D connectors (space qualified by ESA)

- Modularized design for individual parts to be reused for other purposes

MCC operation overview

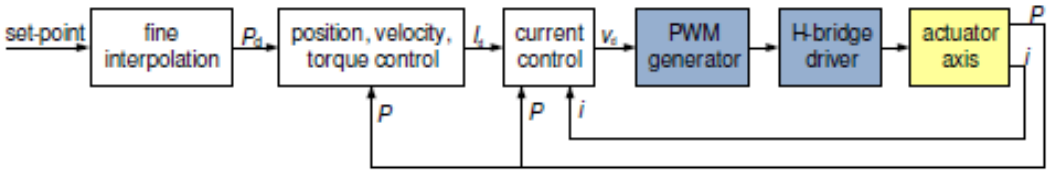


MCC supported sensors and motors

- 3 Brushed or 1 brushless motor operation in triple modes:
  - Position
  - Velocity
  - Torque

- Maxon (Brushed), RE13, RE20, RE25
- Maxon (Brushless), EC22, EC40, EC60

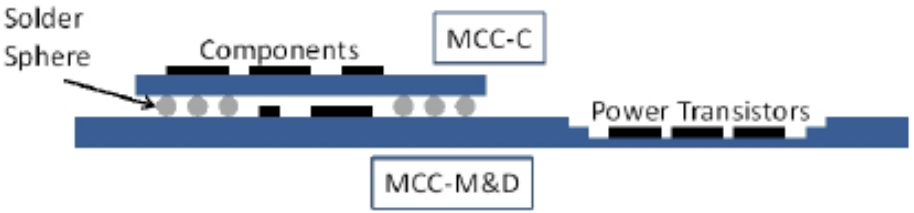
- A wide range of sensor inputs

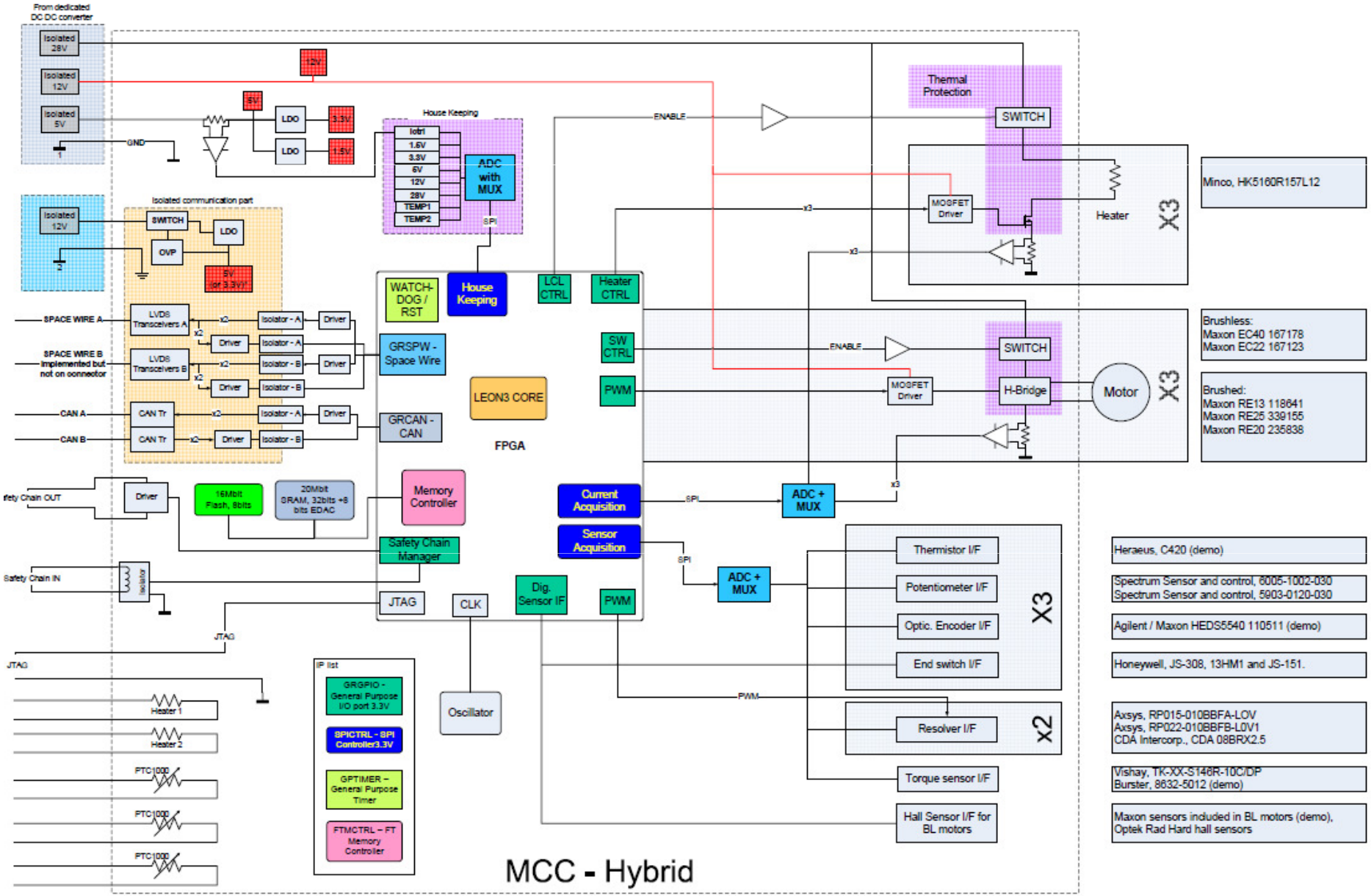


- Current loop frequency 10 kHz
- Outer loop frequency 1 kHz
- PWM frequency settable 20-100 kHz

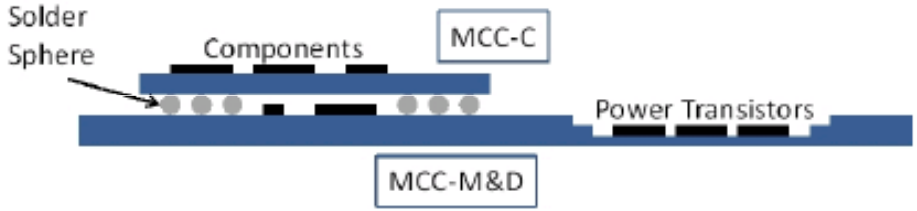
Sensor	Number of interfaces	Data	Description of accepted device
Resolver	2 (synchronized)	Axis position	Single pole, 4kHz
Strain Gage	1	Axis torque	350 to 1 kohm Wheatstone bridge
Digital encoder	3	Axis position counter	3 open-collector signals
Potentiometer	3	Axis position	5 to 10 kohm potentiometer
Thermistor	3	Motor temperature	PT1000
Hall sensor	1	Axis position	3open-collector signals
End switches	6	Position	3x2 switches referenced to ground

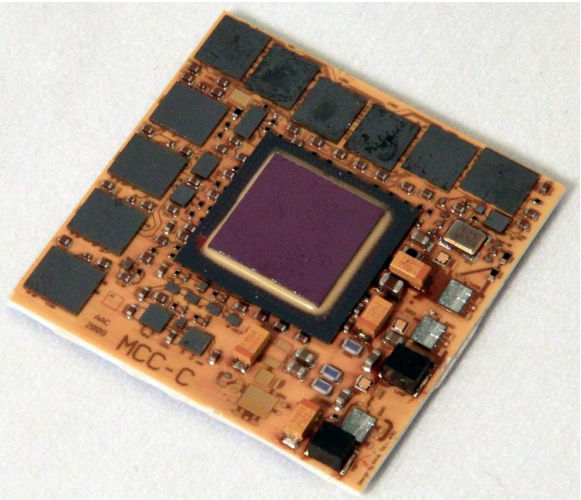
MCC Block diagram



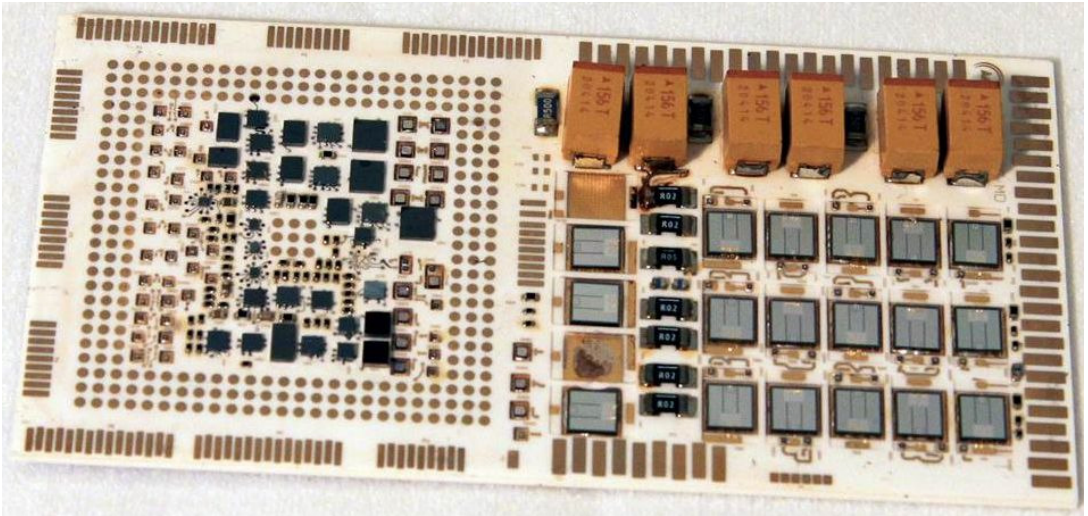


Hybridization and silicon interposer technology



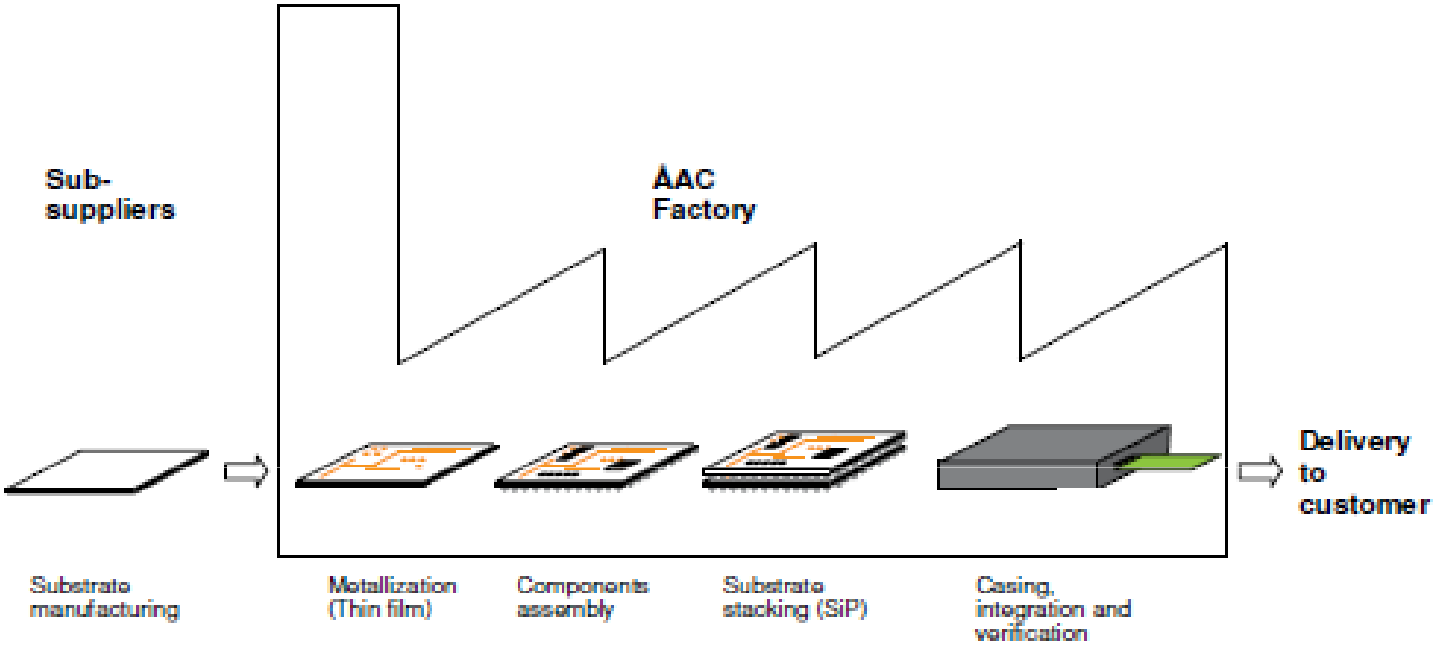


Digital part (MCC-C)



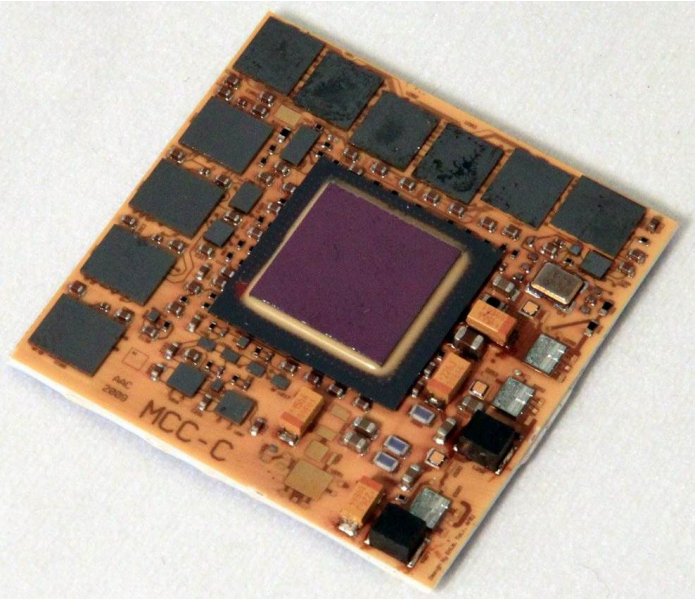
Analog part (MCC-MD)

Assembly flow



MCC-C

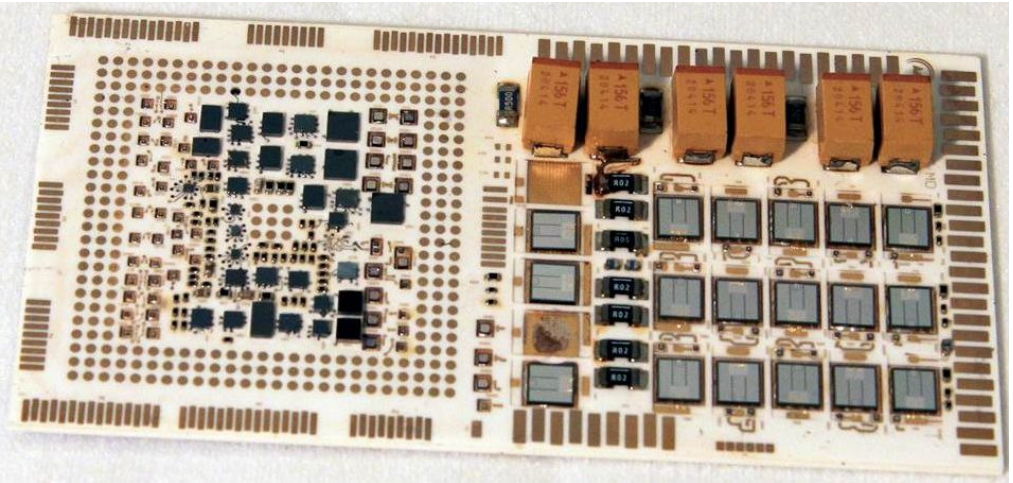
- ÅAC XiVIA® Thru-silicon-Via (TSV) interposer technology
- MicroSemi/ACTEL ProAsic A3P3000E FPGA
  - LEON3-FT (Gaisler) or OpenRISC 1200-FT (ÅAC)
  - Processor clock 25 MHz
  - Scheduler from CSEM
  - Direct memory mapping (no RTEMS drivers)
  - PWM IP
  - Redundant, isolated CAN 2.0
  - SpaceWire (optional)
  - Alternative, RTL control loop



- 2 MB of SRAM
- 16 Mbit of Flash
- Galvanic isolation of communication
- ADC, 12 bit, 500 kHz
- CAN phy, 3.3 V
- Linear power regulation
- 34 x 34 x 3 mm3

MCC-MD

- 3 H-bridges (28 V @ 5 A)
  – 3 Brushed or 1 Brushless
  – 4 quadrant mode (<= 150 W)
- Motor heater (<= 90 W)
- Isolated temperature measurement
- EMI filtering
- 80 x 40 x 6 mm3

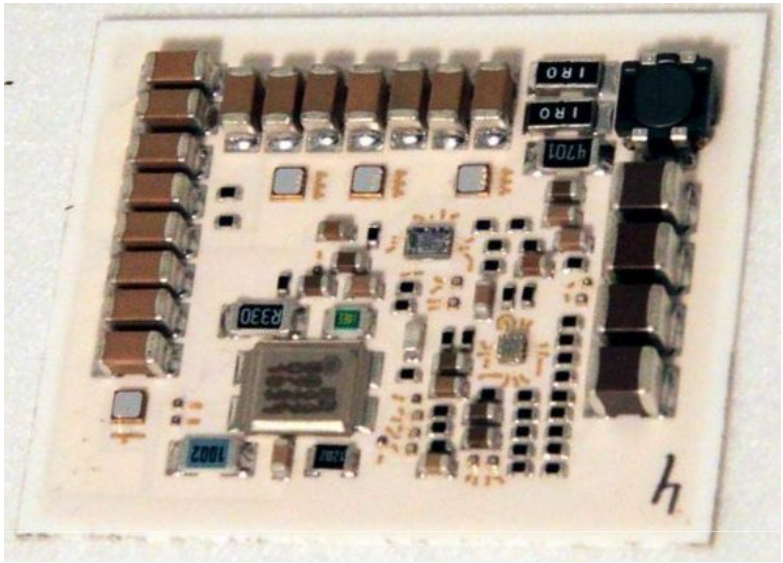


MCC-Power Supply Unit (PSU)

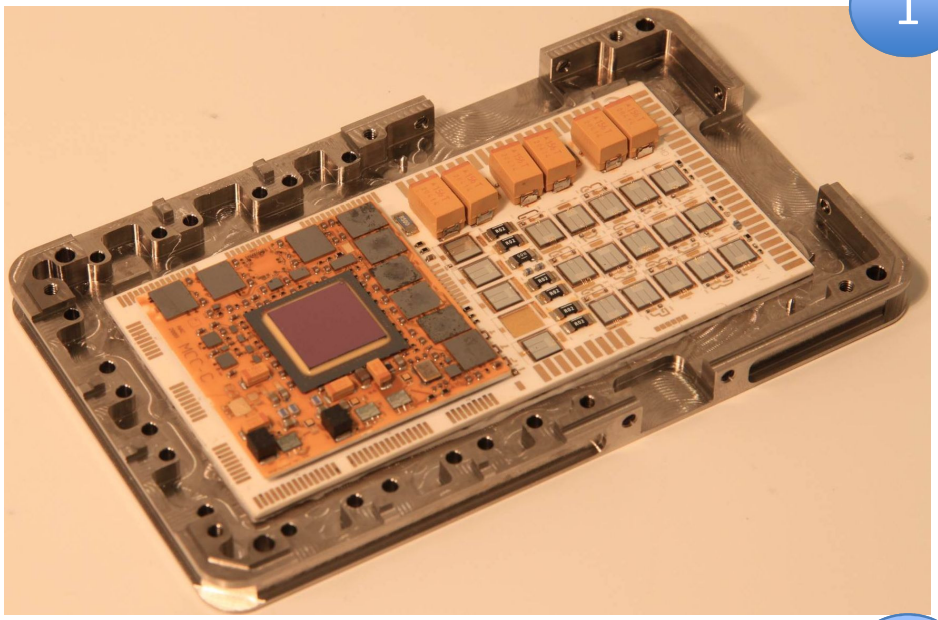
- Self resonant fly-back architecture (Designed in cooperation with ESA.

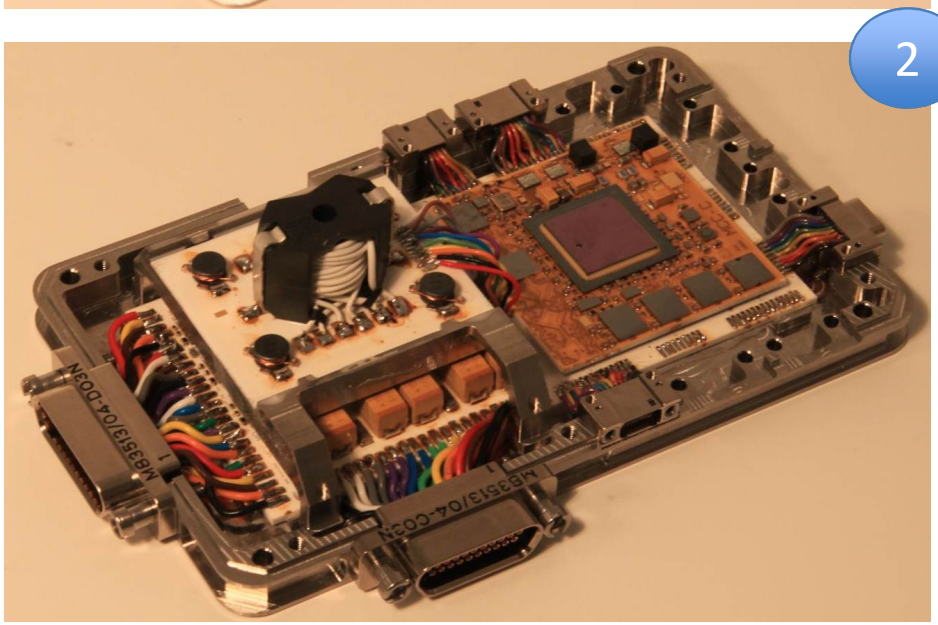
- +28 V input

- +12 V output
- - 12 V output
- 7 V output
- 5 V output

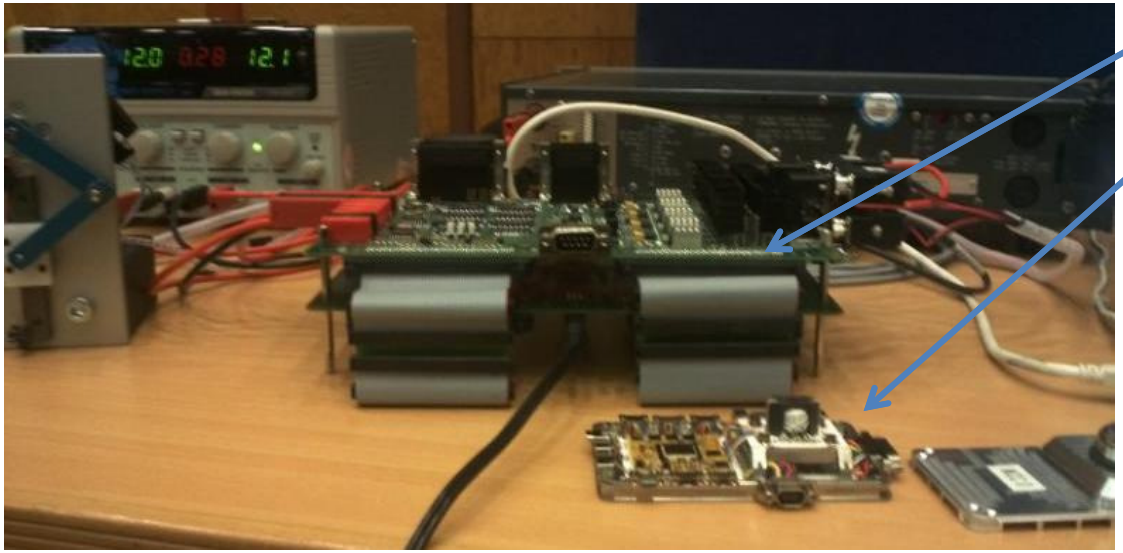


MCC Casing



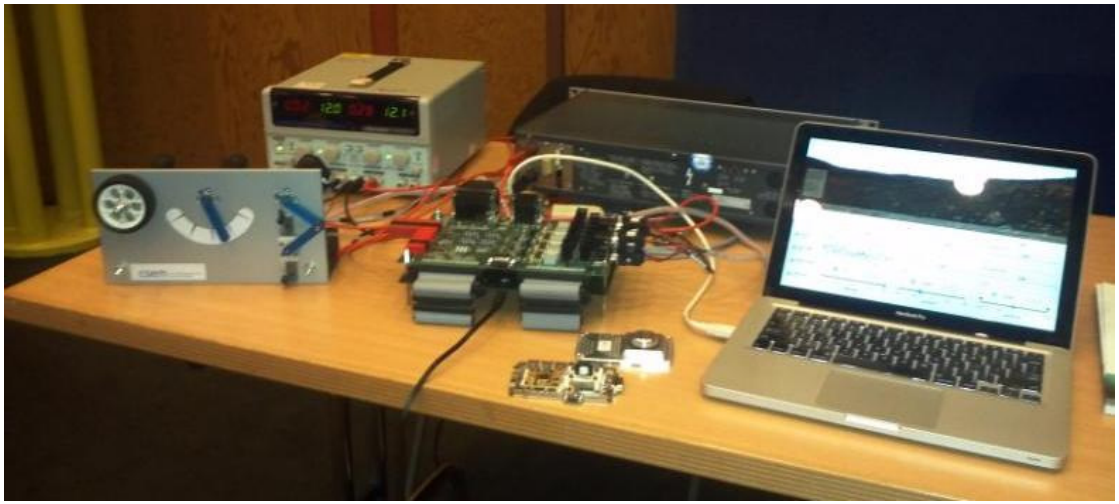


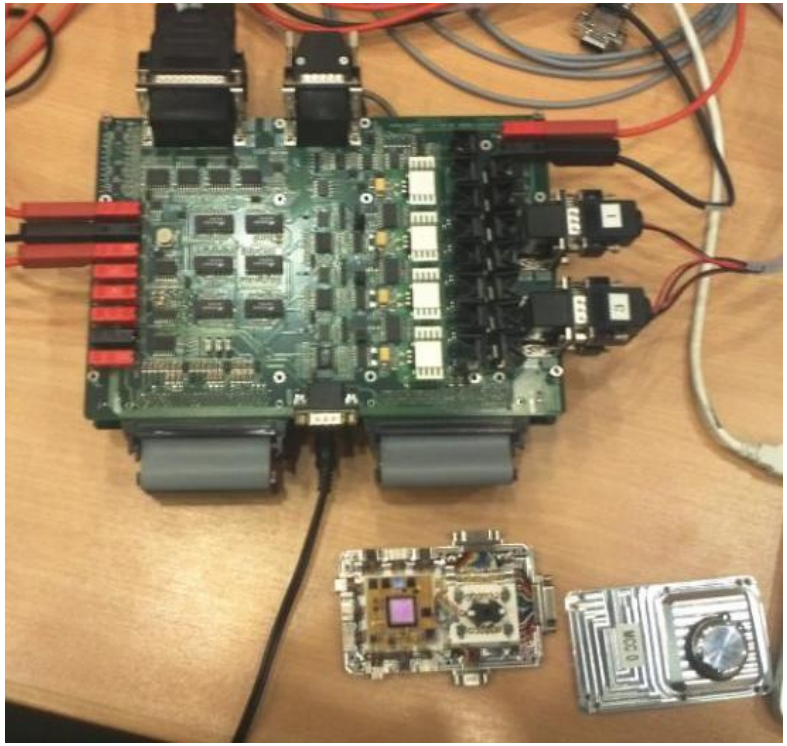
See the MCC in action, Visit the exihibition in ”Einstein”



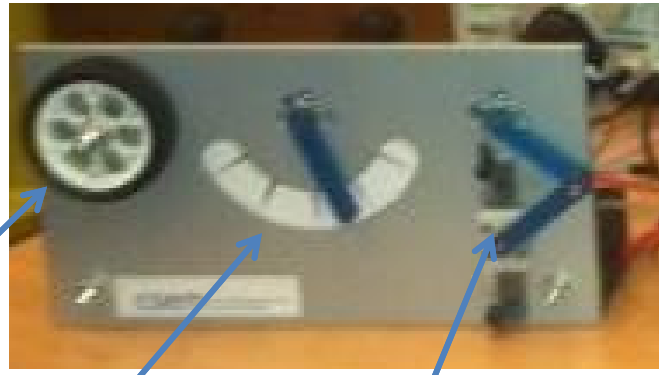
MCC breadboard

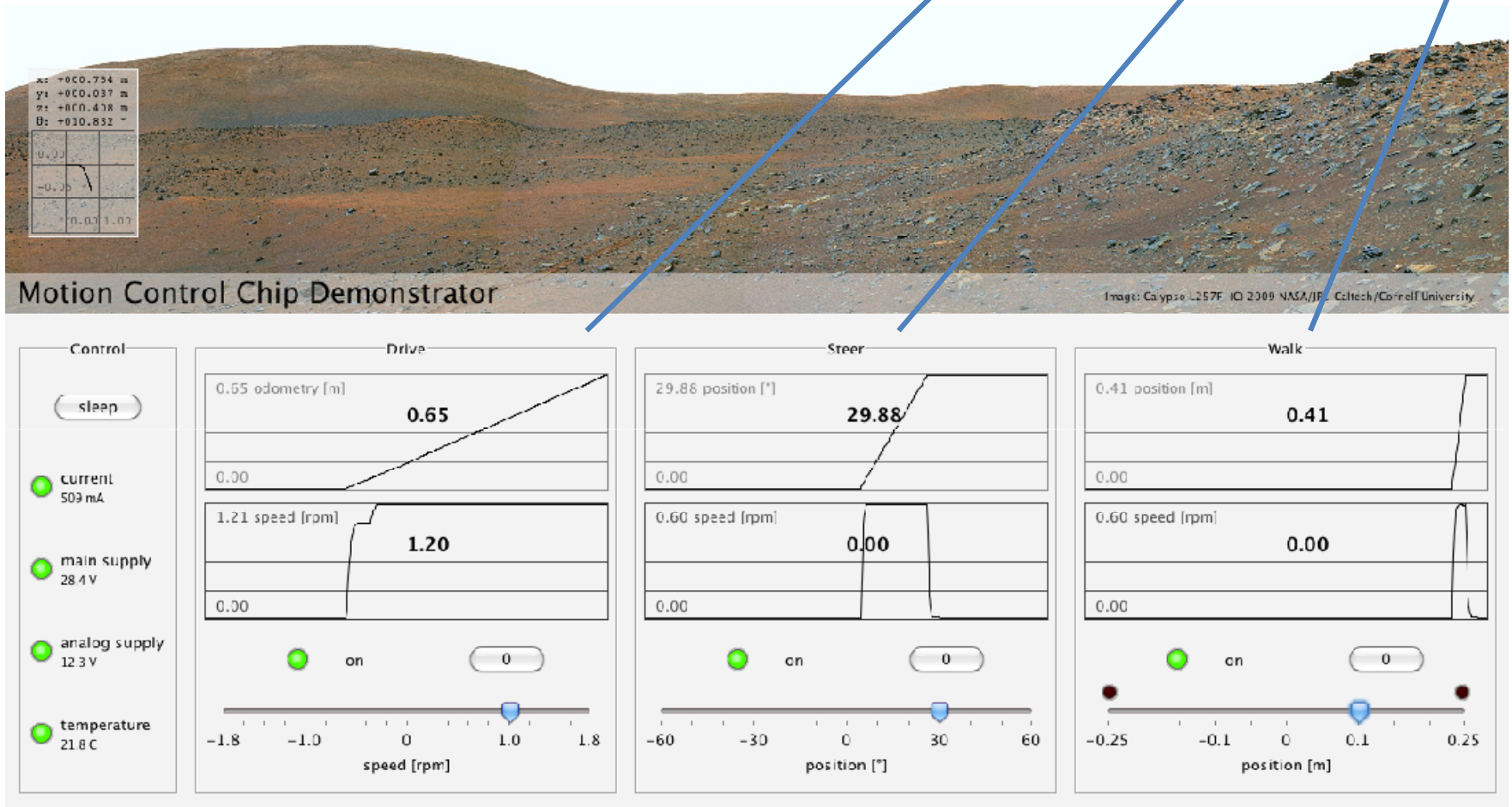
MCC



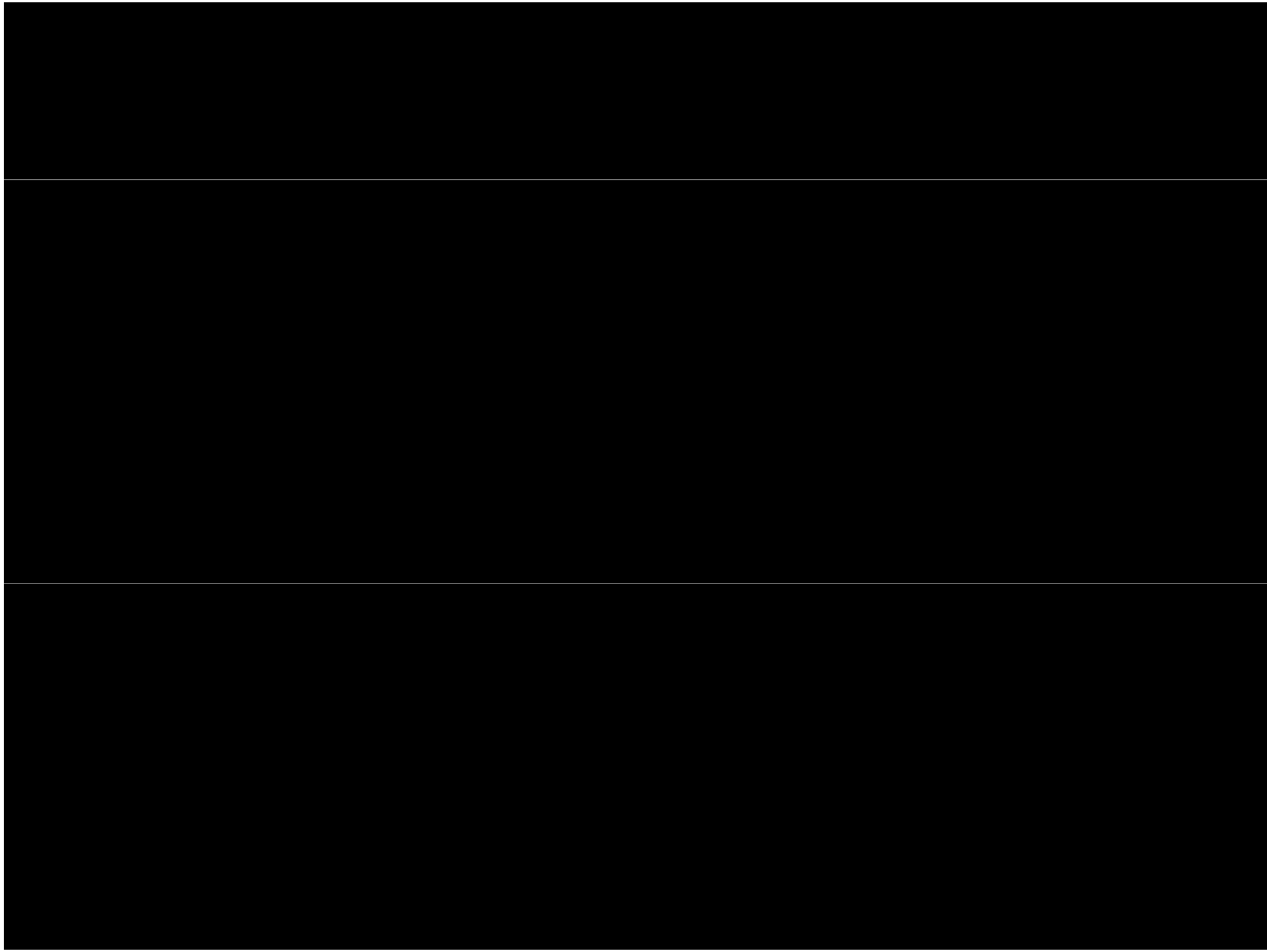


Control software environment (CSEM)





Movie showing operation of MCC



Results and current status

- 6 MCC units manufactured
- Challenges with process flow of ADC, SRAM, and Flash
- Electrically partially verified

- Power figures (more than half is lost in linear regulation):
  – Standby power 4 W,
  – Running 3 brushed motors simultaneously in torque and position mode 9 W.
- Weight:
  – Electronics 30 grams
  – Casing and connectors: 270 grams
  – Total: 300 grams

- Next step is TRR and following testing (DLR)

- The MCC needs another iteration to mature. But the result so far is really encouraging and promising

Acknowledgments

- European Space Agency, TRP program
- Dr. Johan Köhler
- Olivíer Mourra
- Long term commitment of Swedish National Space Board (SNSB)
- Partners below

- For more information, go to
- http://www.aacmicrotec.com