Robotic Demands on On-Board Data Processing

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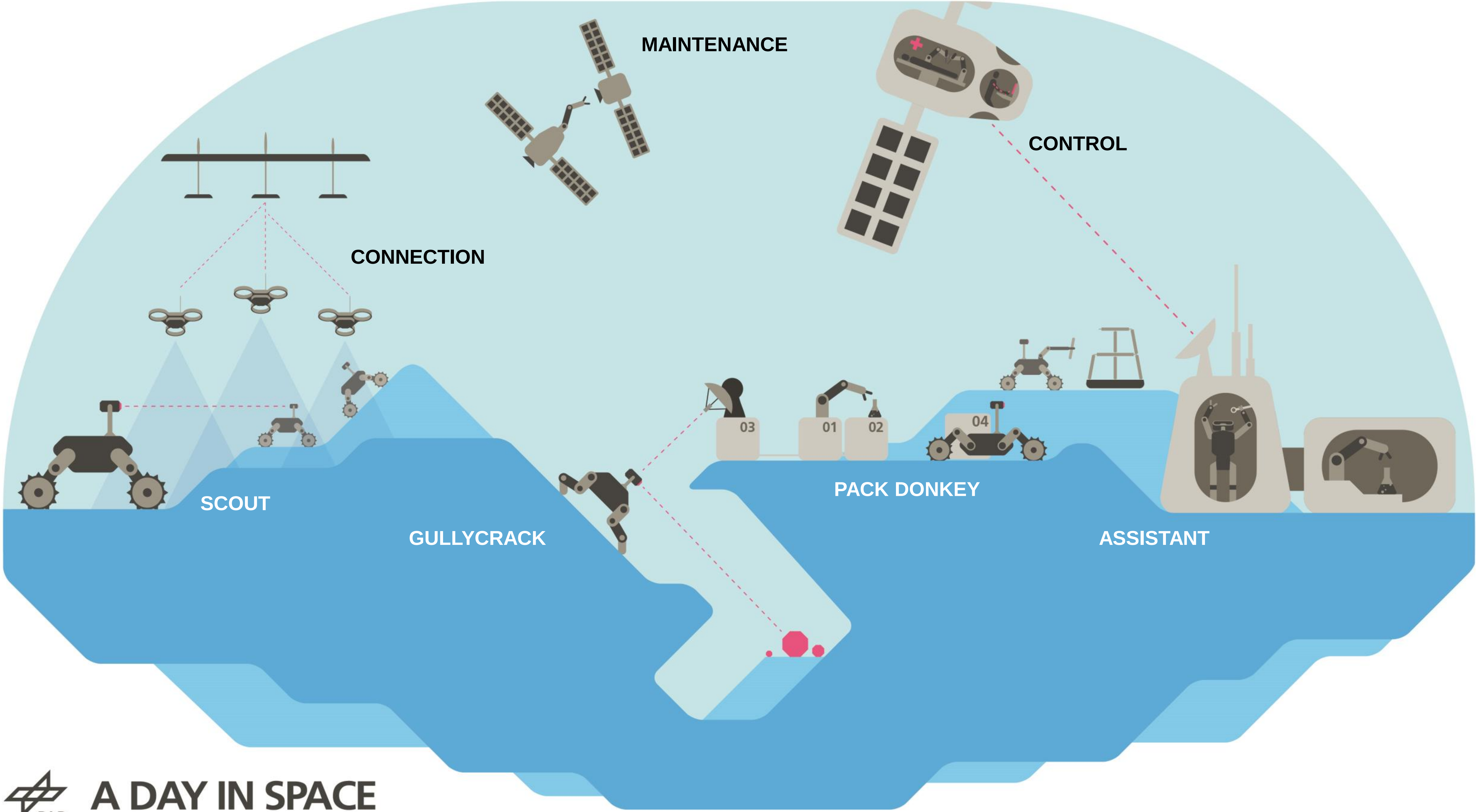
DLR

Introduction

1. RMC’s contributions to future space missions
2. CAESAR - Compliant Assistance and Exploration SpAce Robot
3. Architecture of a robotic system using the example of CAESAR
4. On-board data processing requirements for space robotics



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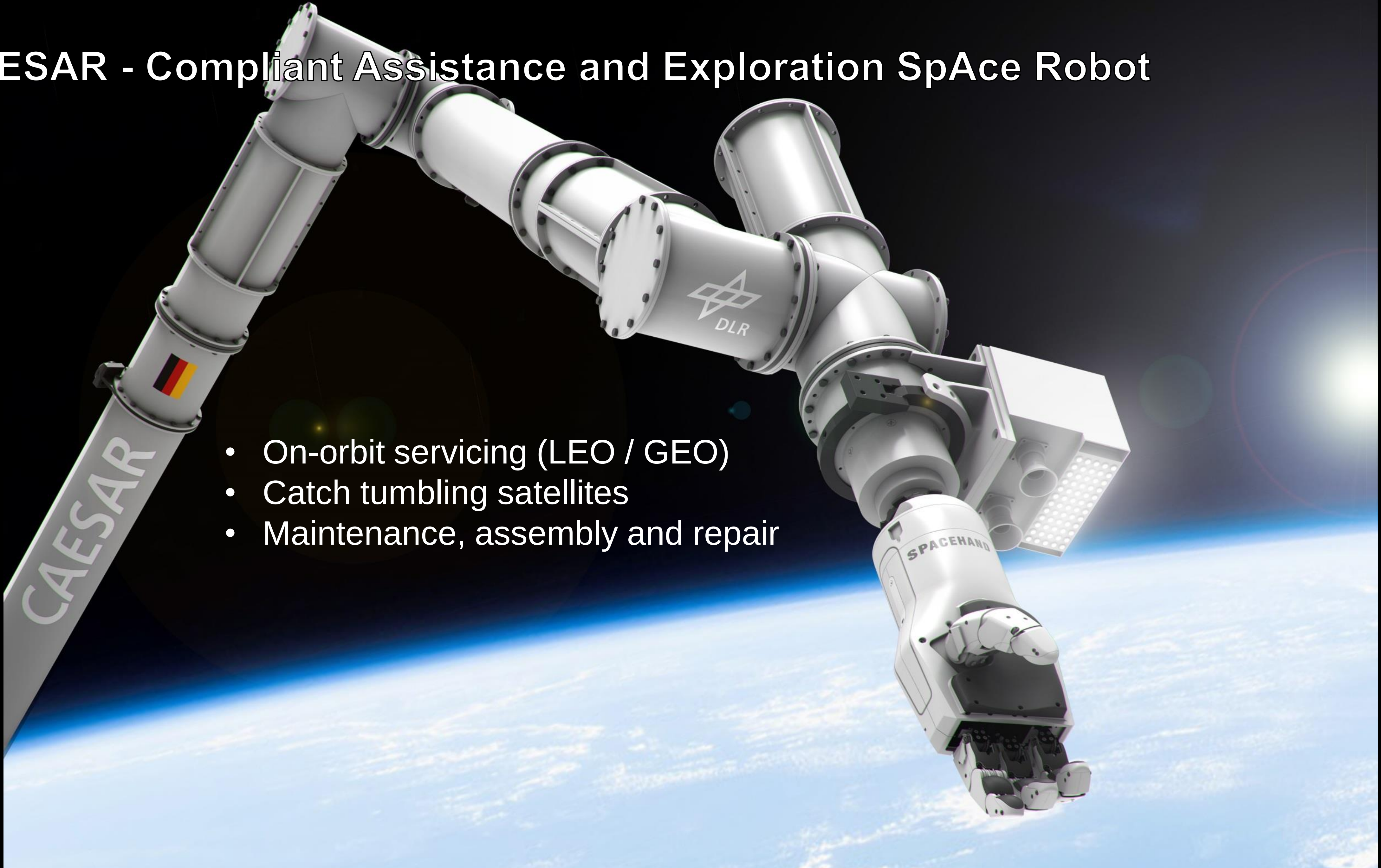
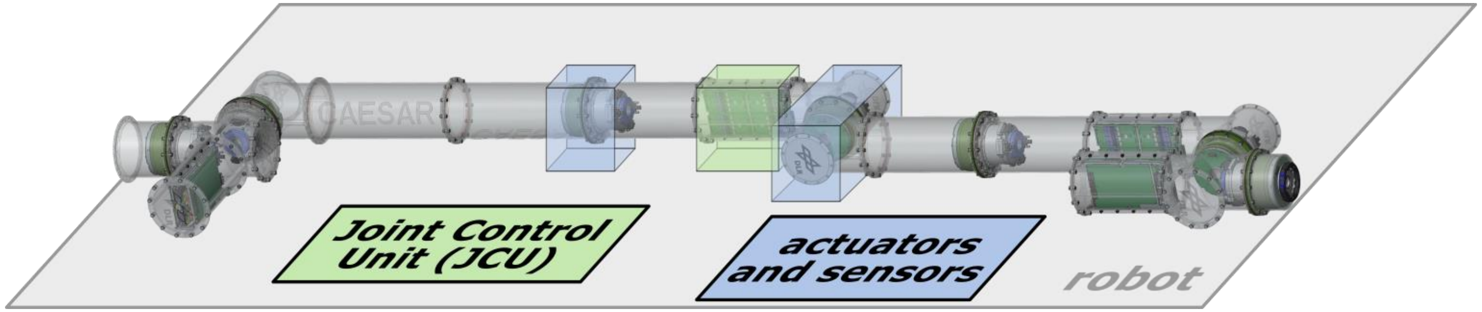
A DAY IN SPACE

CAESAR - Compliant Assistance and Exploration SpAce Robot



- On-orbit servicing (LEO / GEO)
- Catch tumbling satellites
- Maintenance, assembly and repair

Architecture of a Robotic System Using the Example of CAESAR



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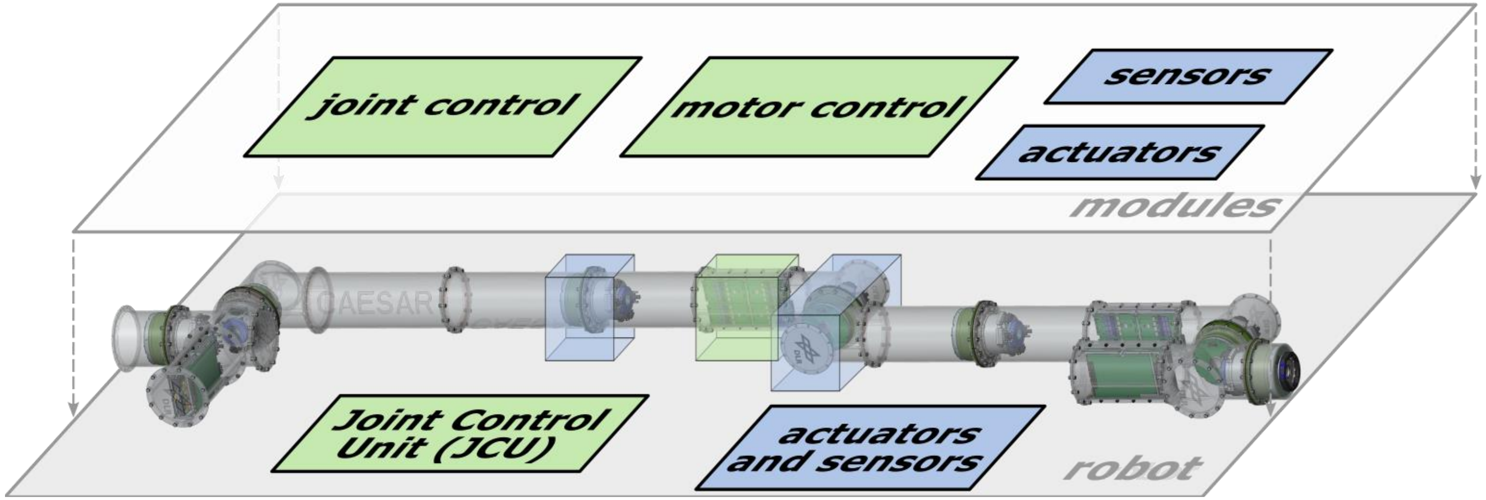

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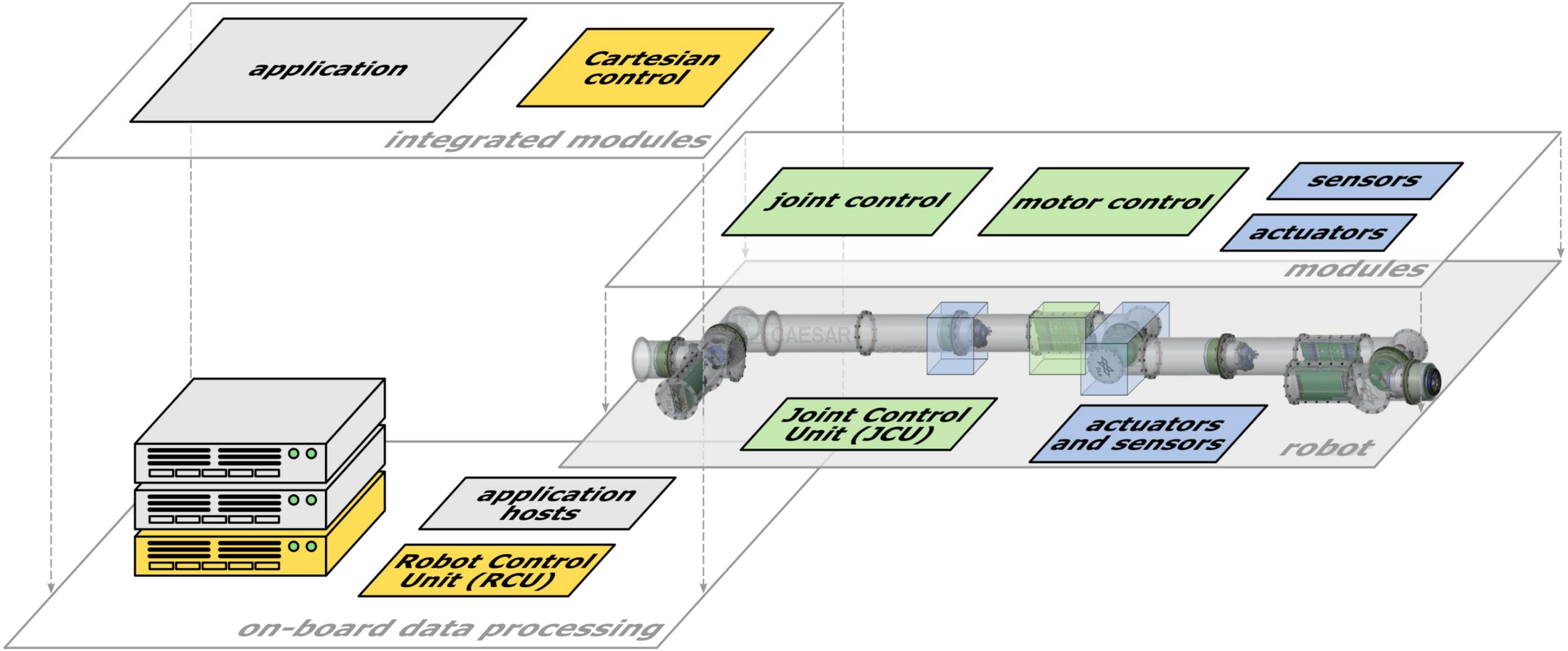

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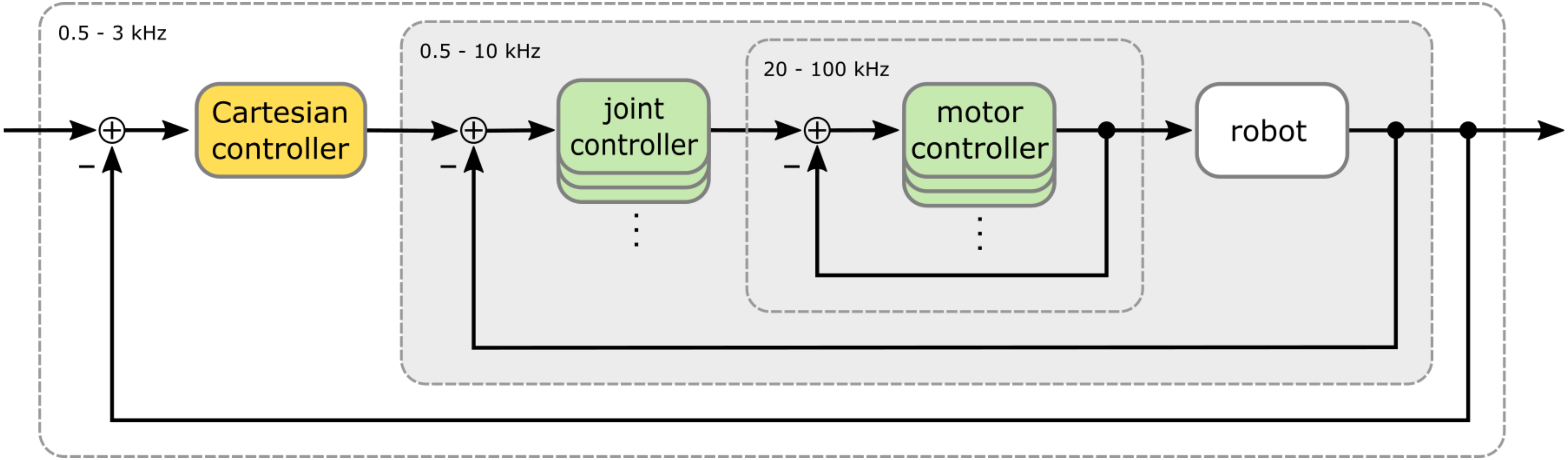
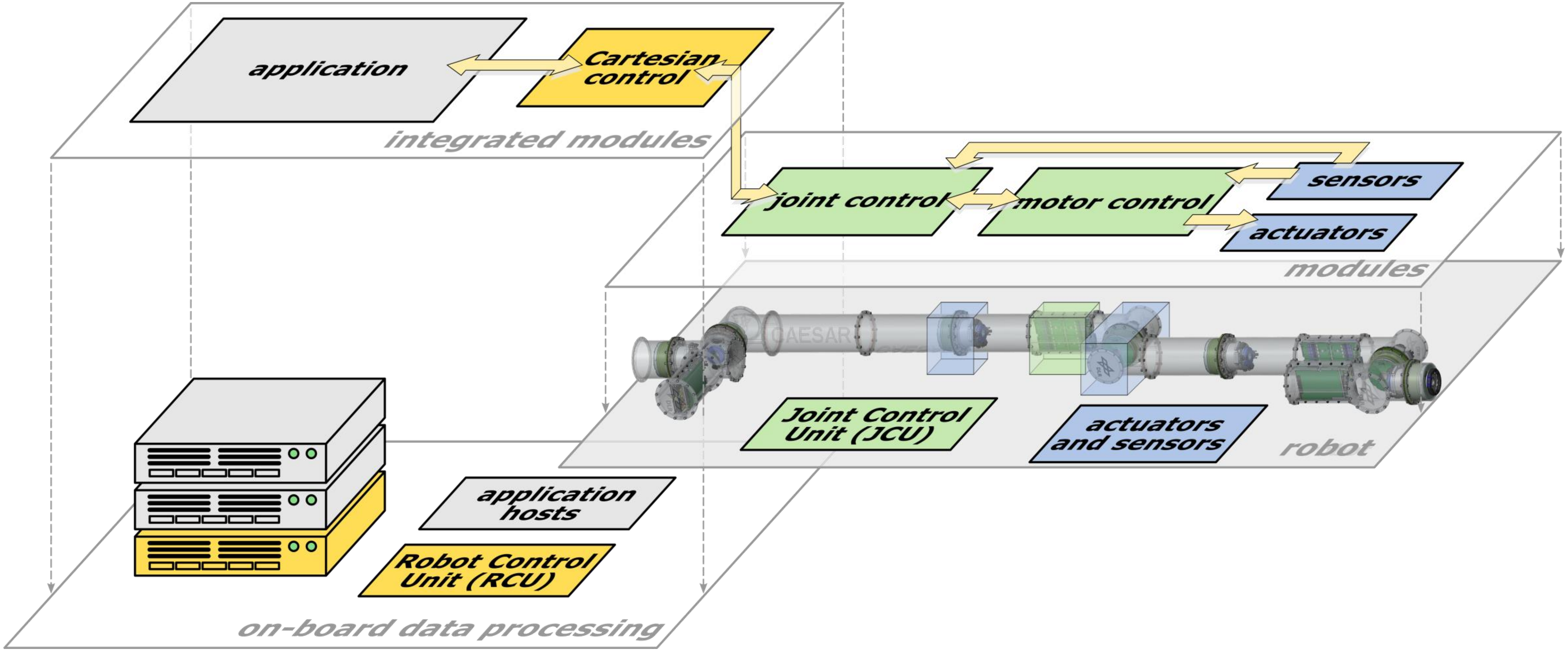


• Cartesian controller:	desired state of robot → joint positions or torques
• Joint controller:	joint positions or torques → motor positions or torques
• Motor controller:	motor positions or torques → motor currents

Architecture of a Robotic System Using the Example of CAESAR



Architecture of a Robotic System Using the Example of CAESAR

Robot Control Unit (RCU)

- Performs Cartesian control
- Provides interfaces to application hosts
- Handles communication with robot and other low level tasks
- Communication has to be deterministic
- Has to fulfil hard real-time requirements
- RCU tasks should be physically separated from other high priority tasks
- Minimal example: ARM Cortex A9 @ 600 MHz for 500 Hz Cartesian control loop of DLR’s Light-Weight Robot III [5]

application host

- Required computing power depends on application, used algorithm, etc.
- May require considerably more calculation power than the RCU

Examples for demanding applications:

- On-line motion and grasp planning
- Artificial Intelligence and machine learning
  - Life long calibration of robotic systems
  - Increase autonomy: not only “independence from human intervention”, but also “the capability to decide between different courses of action based on the current goals”

Requirements

- Control requirements [1,2]
    - Strict real-time to guarantee determinism of control loop frequencies
    - Minimal communication latency (RCU needs to be relatively close to the robot)
- Communication requirements [1-4]
    - Deterministic communication to guarantee data delivery in a certain time
    - Data integrity: CRC and encryption
    - Synchronisation
    - Transport layer implementation due to large amount of network participants [2]
- Computation requirements for Robot Control Unit (RCU):
    - ScOSA: RCU for LWR III on ARM Cortex-A9 @600 MHz / 500Hz control loop [5]
- Computation requirements for Applications
    - While the timing requirements may be not as strict as for the RCU, even more computing power may be required. Examples:
        - On-line motion and grasp planning
        - Artificial Intelligence and machine learning

References

[1] Hirzinger, G. und Sporer, N. und Albu-Schäffer, A. und Hähnle, M. und Krenn, R. und Pascucci, A. und Schedl, M. (2002) DLR's torque-controlled light weight robot III - are we reaching the technological limits now? In: Proceedings ICRA 2002, Seiten 1710-1716. IEEE International Conference on Robotics and Automation ICRA, Washington D.C., USA, May 2002.

[2] Hagn, Ulrich und Nickl, Matthias und Jörg, Stephan und Passig, Georg und Bahls, Thomas und Nothhelfer, Alexander und Hacker, Franz und Le-Tien, Luc und Albu-Schäffer, Alin und Konietschke, Rainer und Grebenstein, Markus und Warpup, Rebecca und Haslinger, Robert und Frommberger, Mirko und Hirzinger, Gerd (2008) The DLR MIRO: A versatile lightweight robot for surgical applications. Industrial Robot, 35 (4), 324 -336. EMERALD GROUP PUBLISHING LIMITED. DOI: 10.1108/01439910810876427 https://doi.org/10.1108/01439910810876427 ISSN 0143-991X

[3] Jörg, Stefan und Nickl, Mathias und Nothhelfer, Alexander und Bahls, Thomas und Hirzinger, Gerd (2011) The Computing and Communication Architecture of the DLR Hand Arm System. In: Proccedings IEEE/RSJ International Conference on Intelligent Robots and Systems, Seiten 1055-1062. IEEE. IEEE/RSJ International Conference on Intelligent Robots and Systems, 25.-30. Sep 2011, San Francisco. ISBN 978-1-61284-455-8

[4] Nickl, Mathias und Jörg, Stefan und Bahls, Thomas und Nothhelfer, Alexander und Strasser, Stefan (2011) SpaceWire, A Backbone For Humanoid Robotic Systems. In: Proceedings of the 4th International SpaceWire Conference, Seiten 356-359. Space Technology Centre, University of Dundee. International SpaceWire Conference, 8-10 Nov 2011, San Antonio, TX, USA. ISBN 978 0 9557196 3 9

[5] Treudler, Carl Johann und Benninghoff, Heike und Borchers, Kai und Brunner, Bernhard und Cremer, Jan und Dumke, Michael und Gärtner, Thomas und Höflinger, Kilian Johann und Lüdtke, Daniel und Peng, Ting und Risse, Eicke-Alexander und Schwenk, Kurt und Stelzer, Martin und Ulmer, Moritz und Vellas, Simon und Westerdorff, Karsten (2018) ScOSA - Scalable On-Board Computing for Space Avionics. In: Proceedings of the International Astronautical Congress, IAC. IAC 2018, 1.-5.Okt 2018, Deutschland, Bremen.