ESROCOS and ScOSA

ESROCOS in Context of DLR's Reconfigurable High-performance Platform for Space Missions (ScOSA)

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DLR

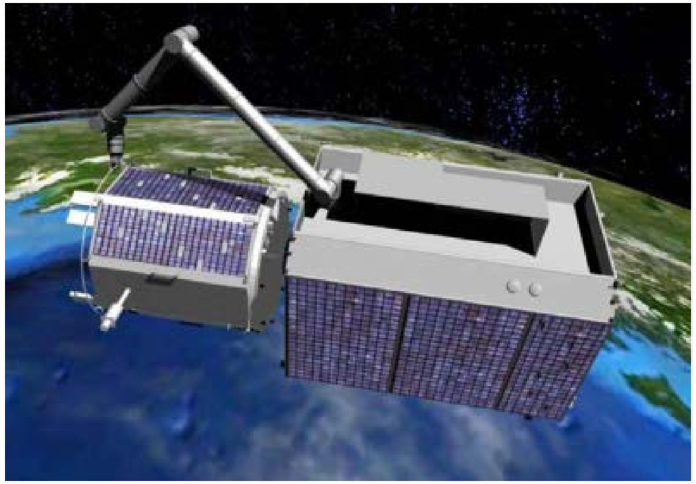
Reconfigurable Distributed Onboard Systems
Motivation

Missing On-board Computing Power

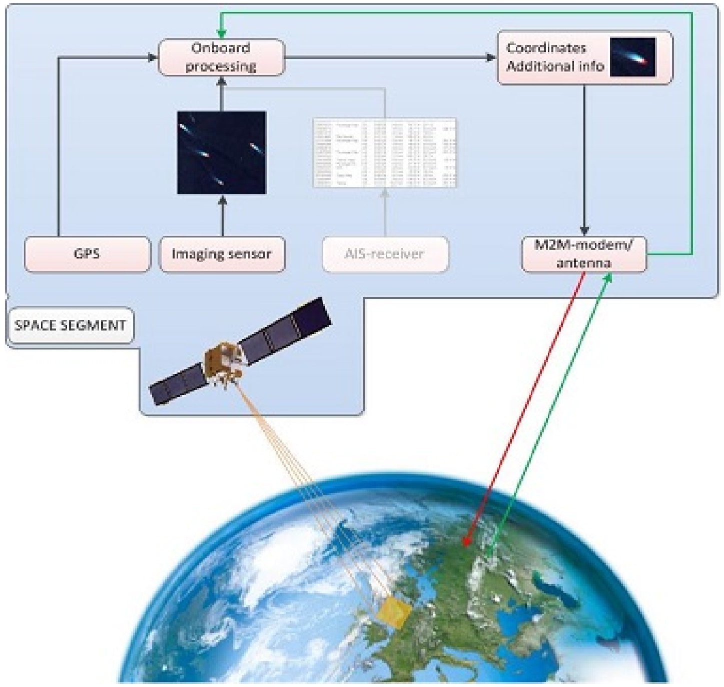
- Number of space-qualified processors and FPGAs is low
- Increasing requirements for more computing power in the areas:
  - Earth observations
  - Robotics
  - Navigation
  - …

Redundancy Concepts Often Limited to Subsystems

- Each computing unit has usually its dedicated redundant counterpart
- Standby systems can not take over tasks of computers in other subsystems



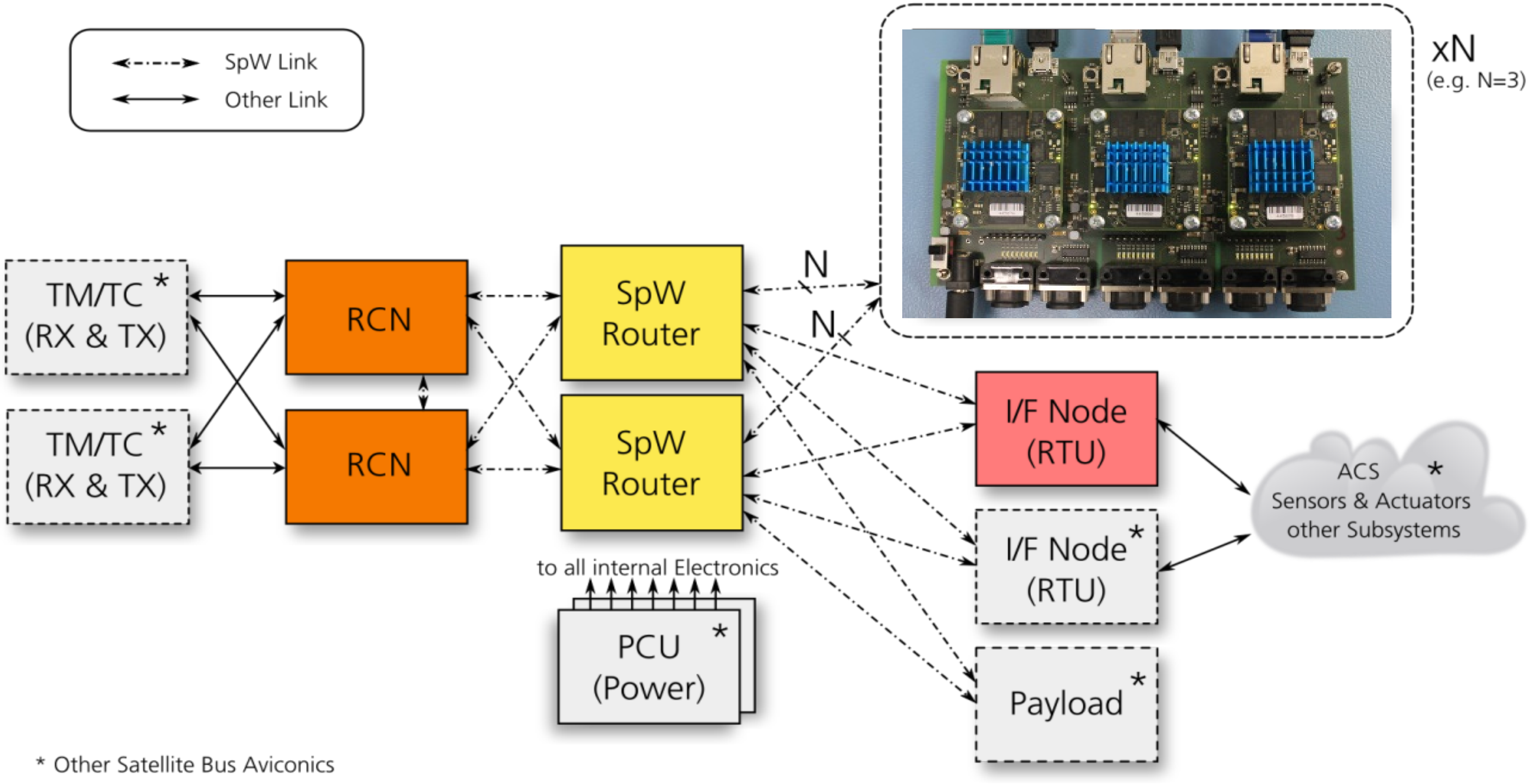
DEOS (On-Orbit Servicing) (Credit: DLR – RM)



On-Board Ship Detection(Credit: DLR – RB)

ESROCOS and ScOSA

Scalable On-board Computing for Space Avionics (ScOSA)



RCN: Reliable Computer Node
HPN: High Performance Node
I/F Node: Interface Node
SpW: SpaceWire
RTU: Remote Terminal Unit
PCU: Power Converter Unit
TM/TC: Telemetry/Telecommand
ACS: Attitude Control System

ESROCOS and ScOSA
ScOSA Features

Scalability

- Heterogeneous Architectures (CPU, FPGA, DSP)
- Combination of COTS and radiation tolerant hardware
- Reconfiguration for new mission phase

Resource Utilization

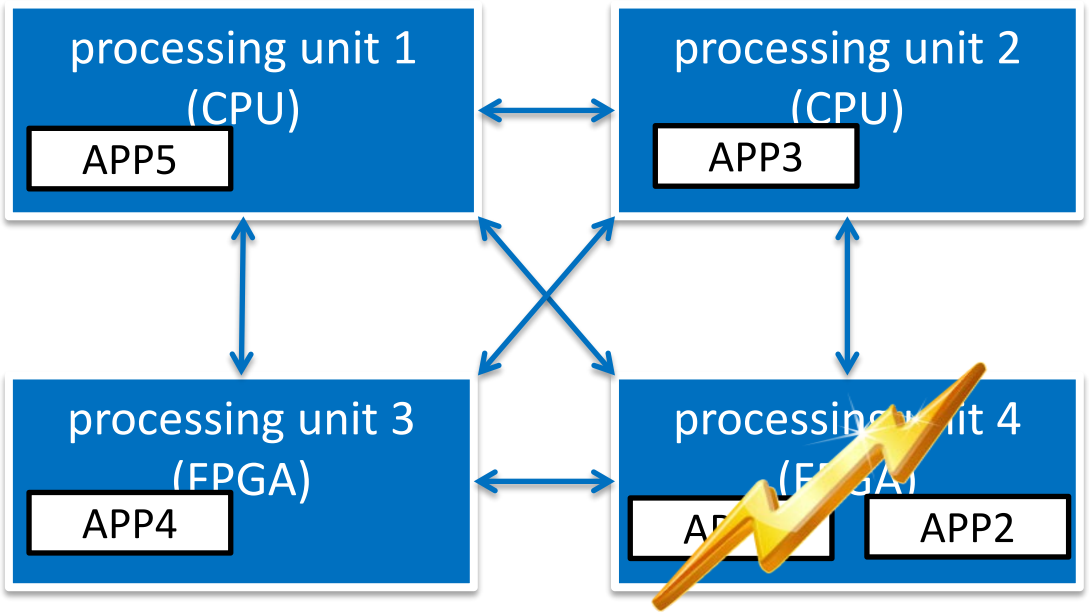
- Using all available computing resources
- Reintegrate recovered nodes into network

Network Protocol (SpaceWire-IPC)

- Reliable Messaging
- IPC among tasks on different nodes

Fault tolerance

- Distributed FDIR subsystem on data, task, node and system level



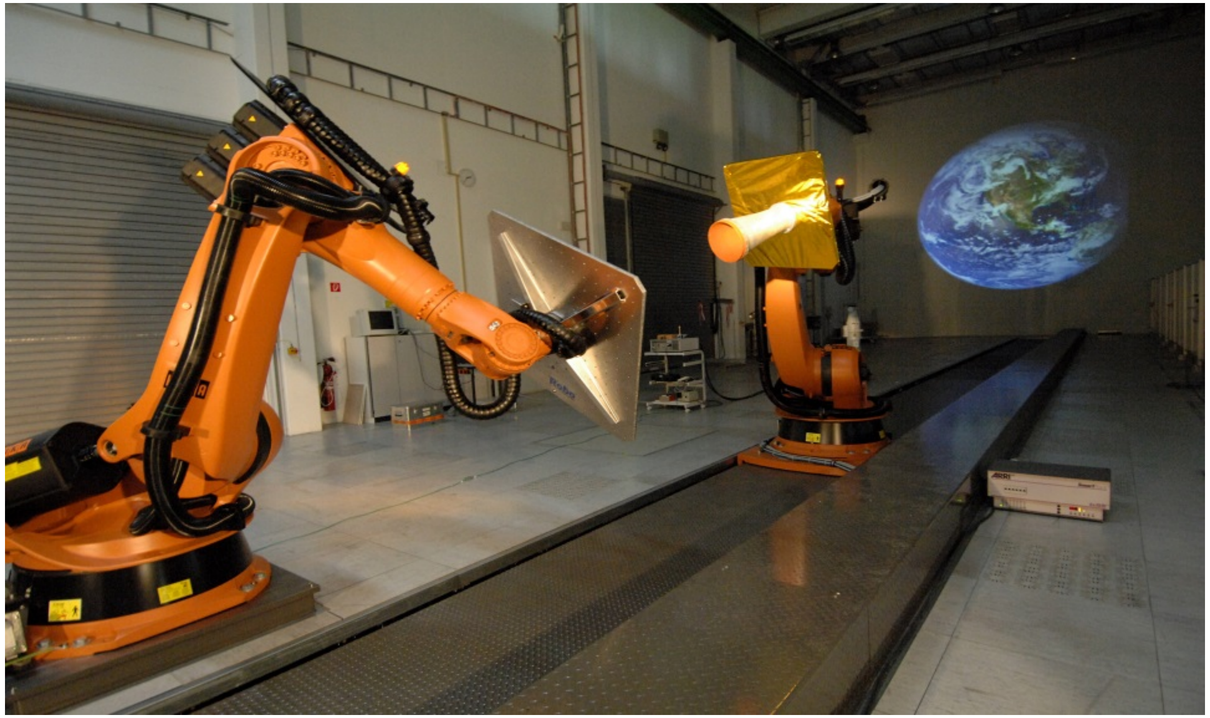
Criticality	Software Mechanisms	Hardware Mechanisms	cause
Level 4 Safe Mode	Safe Mode SW Configurations	Safe Mode HW Configurations	• Hardware alarms • Multiple level 2 or 3 failures
Level 2 & 3 Node & System Control	• Monitoring (D,I) • Reconfiguration (R) • Reintegration (R) • HealthManager (D)	• N/A	• Subsystem failure • FDIR equipment failure
Level 1 Task	• SystemAlert (I) • PlausabilityCheck (D) • Checkpointing (R)	• N/A	• Unit failure • subsystem performance degradation
Level 0 Data	• Soft Error Mitigation Means (D,I,R)	• Hardware Mitigation Means (D,I,R)	• Failures with no effect on the performance: Bit flip etc.

ScOSA Demonstrator: Rendezvous Navigation
DLR Institute Space Operations and Astronaut Training

- Hardware-in-the-Loop Simulation using the European Proximity Operations Simulator 2.0 (EPOS)

- CCD Camera as Rendezvous Sensor mounted on one robot, target satellite on another

- On-board Software (Soft Real-Time):
    - Image Processing
    - Navigation Filter
    - Guidance
    - Controller



EPOS (Credit: DLR Institute Space Operations and Astronaut Training)

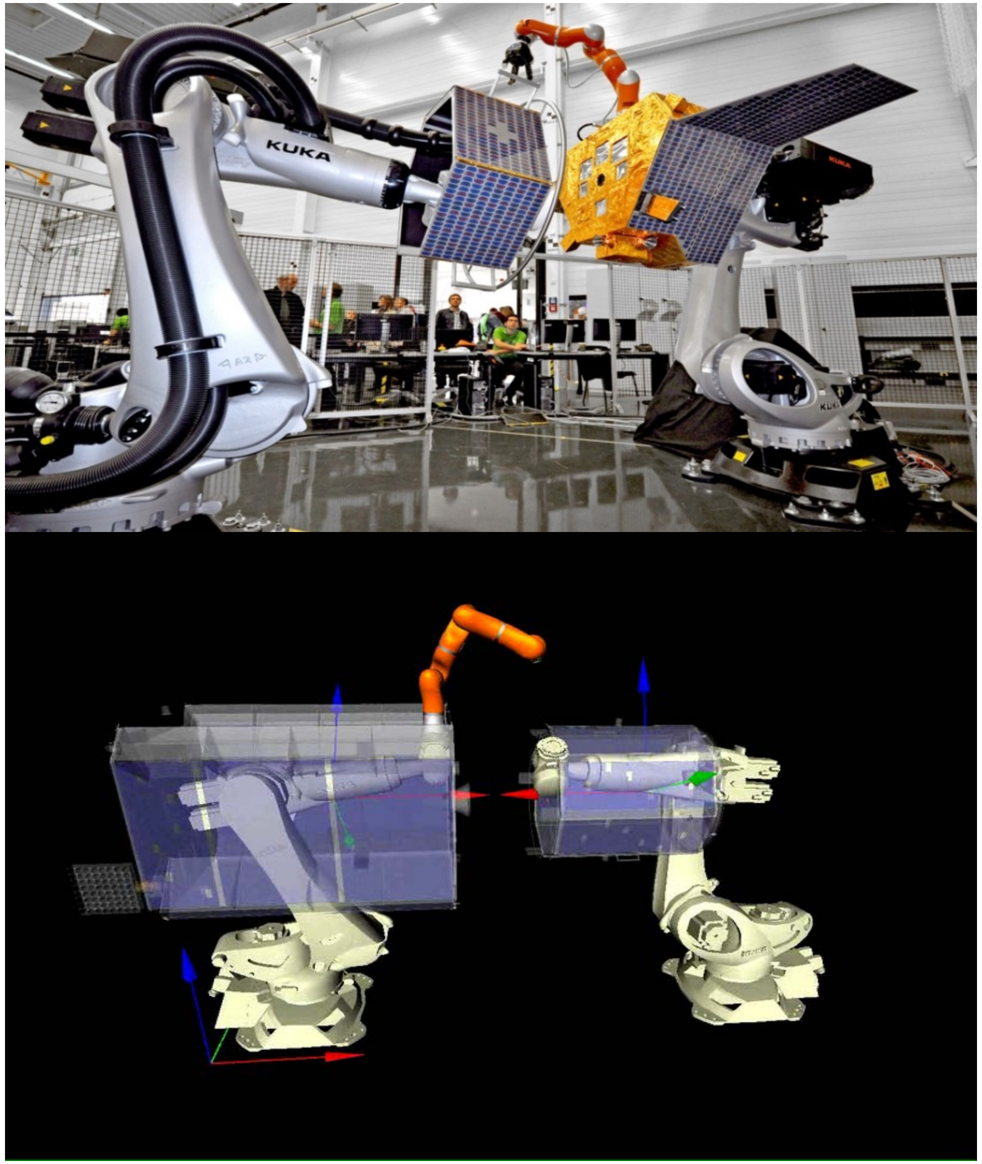
ScOSA Demonstrator: On Orbit Servicing
DLR Institute Robotics and Mechatronics Center

Deployment of tasks on three different HPNs because of computing performance demands:

- Task management
    - Supervisor
    - Flow control
    - Task decomposition

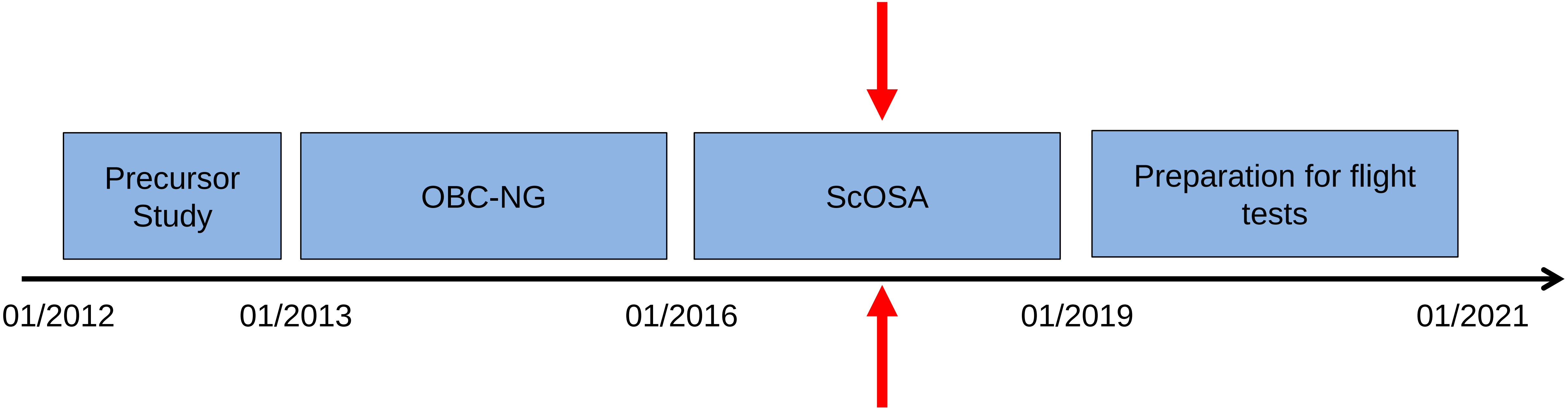
- Core control functions
    - Kinematics, dynamics
    - Impedance control
    - Interpolator

- Visual tracking with path planning



OOS-SIM (Credit: DLR Institute Robotics and Mechatronics Center)

ScOSA Project Timeline



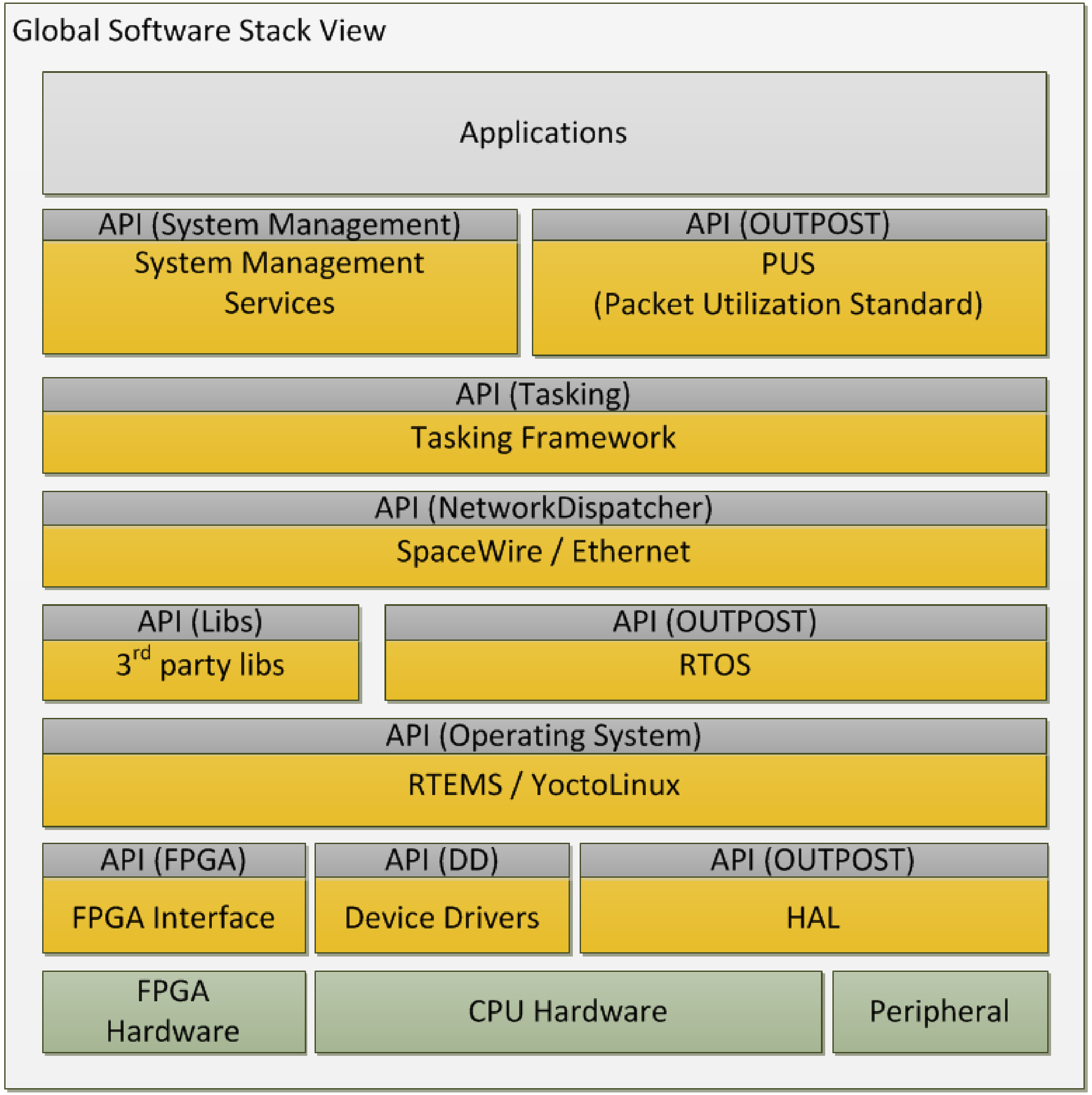
Publications:

D. Lüdtke *et al.*, "OBC-NG: Towards a reconfigurable on-board computing architecture for spacecraft," *2014 IEEE Aerospace Conference*, Big Sky, MT, 2014, pp. 1-13.

T. Peng, B. Weps, K. Höflinger, K. Borchers, D. Lüdtke and A. Gerndt, "A new SpaceWire protocol for reconfigurable distributed on-board computers: SpaceWire networks and protocols, long paper," *2016 International SpaceWire Conference (SpaceWire)*, Yokohama, 2016, pp. 1-8.

ScOSA Software Stack

- Used Hardware: FPGAs, ASICs, SoCs
- Used OSs: YoctoLinux and RTEMS
- Multi-OS capable system
- Reliable Process Communication Network protocol (SW-IPC) and RMAP
- Supports Spacewire and Ethernet (EtherCat)
- Tasking framework as algorithm scheduler and communication manager
- System management and PUS services
- Application developer friendly API

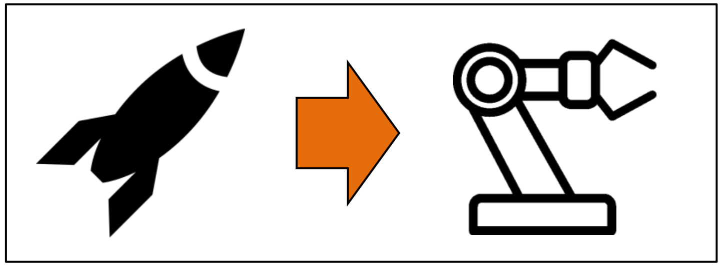


DLR

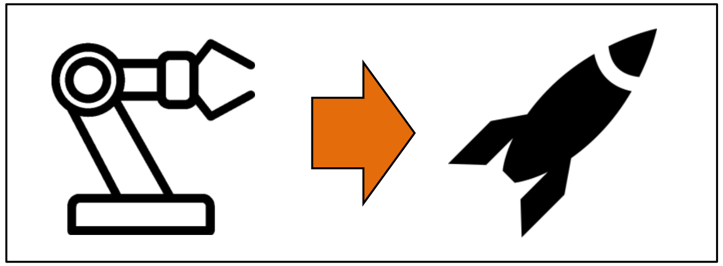
ESROCOS and ScOSA System Combination

- Domain Transfer Direction

ScOSA



ESROCOS

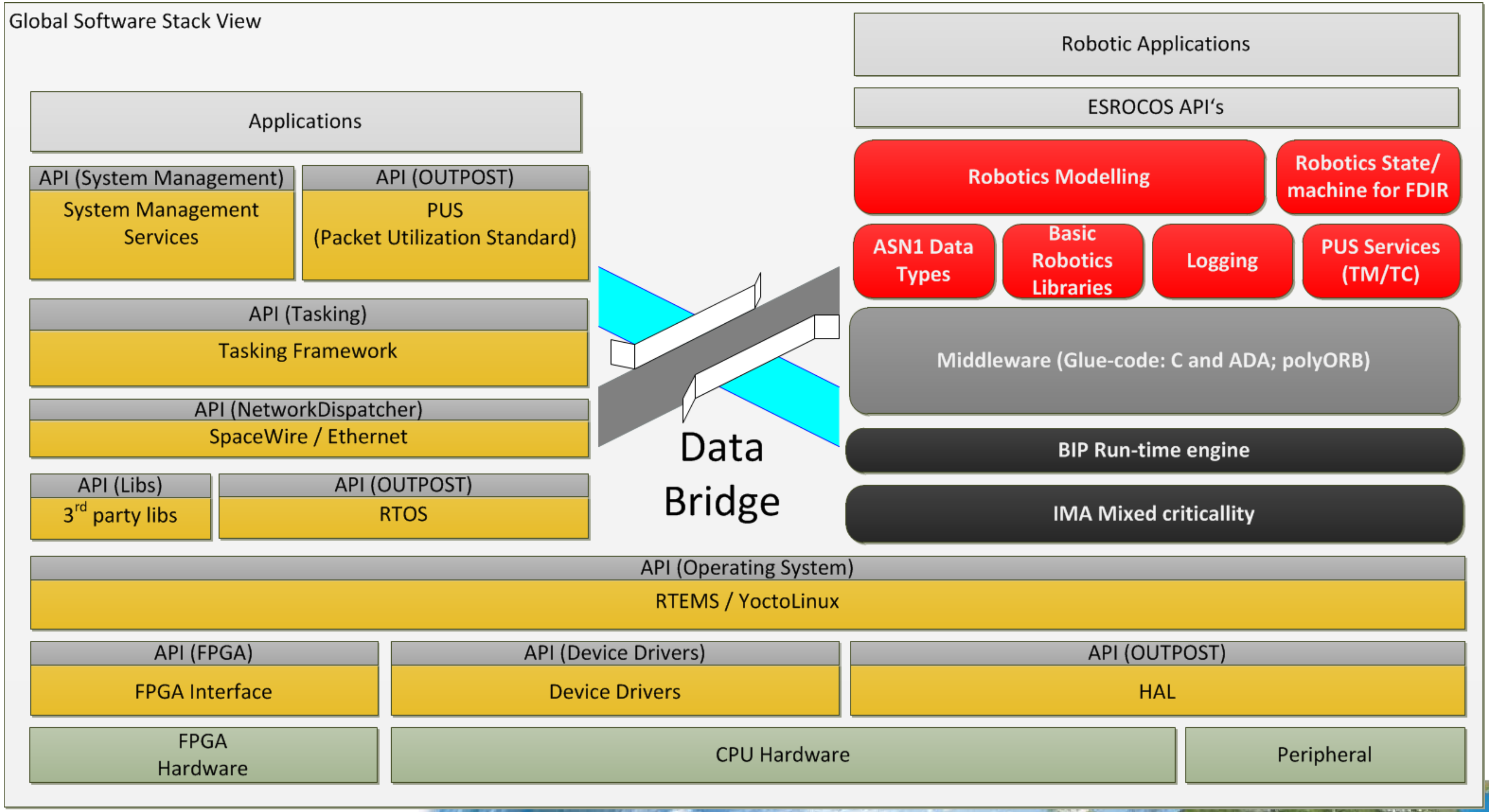


- ScOSA is not a pure robotic project, but of interest is:
  - Integration of ESROCOS robotic toolchain into ScOSA
  - Integration with emerging technologies, like TASTE
  - Integration with mixed criticality hypervisor
  - …

Credit: Robotic Manipulator: http://icons8.com, no changes made
Credit: Rocket: https://www.iconfinder.com/icons/298861/rocket_icon ,no changes made

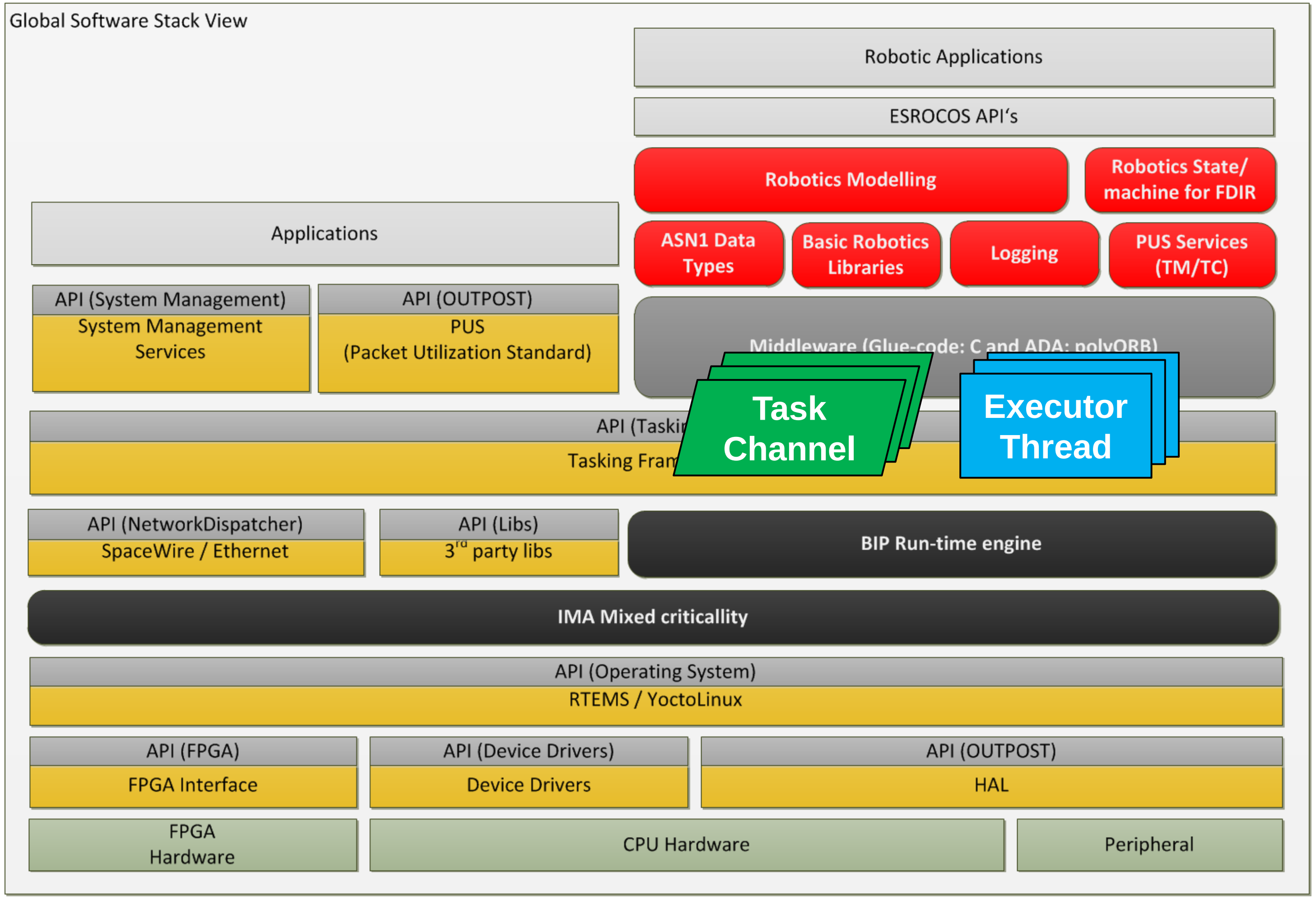
ESROCOS and ScOSA Software Stack

Naive integration



ESROCOS and ScOSA Software Stack

A more practical integration



ESROCOS and ScOSA
Conclusions

- Good integratability of ESROCS and SCOSA due to equivalent baseline technology
- ScOSA has similar demonstrator use cases as ESROCOS
- Provision of demanded computing performance for robotics application developers
- ScOSA is intended to become partially open-source, like ESROCOS