On-board Software Systems

Olaf Maibaum
German Aerospace Center
One DLR – Three Pillars

- Research Institution
  - Germany’s national research center for aeronautics and space
- Space Agency
  - Responsible for the forward planning and the implementation of the German space program by the German federal government
- Project Management Agency
  - Germany’s largest project-management agency
German Aerospace Center
Locations and Employees

- Locations
  - 16 Sites
  - 4 Offices

- Employees
  - Approx. 8000 employees across 33 institutes and facilities
DLR Simulation and Software Technology Organization

Director: Rolf Hempel

Intelligent and Distributed Systems
Andreas Schreiber (Cologne/Berlin)

Software for Space Systems and Interactive Visualization
Dr. Andreas Gerndt (Braunschweig)

High-Performance Computing
Dr. Achim Basermann (Cologne)

Sites: Cologne, Braunschweig, (Berlin)
DLR Simulation and Software Technology
Scientific Themes and Working Groups

- Intelligent and Distributed Systems
- Software for Space Systems and Interactive Visualization
- High-Performance Computing

Working Groups:
- Distributed Systems
- Software Engineering
- Data Science
- Modeling and Simulation
- Onboard Software Systems
- Scientific Visualization
- 3D Interaction
- Numerical Simulations
- Quantum Computing
Simulation and Software Technology
CROSS DRIVE – Collaborative Planet Exploration

Fig.: Terrain rendering on a multi pipe system

Fig.: Exploring the mars via VR glasses
Space Systems and Interactive Visualization
Group: Modeling and Simulation

• Dedicated Software to support Concurrent Engineering

• Model-based Systems Engineering
  • Different Views from One Single Point of Truth
  • Further Benefits
    • Sensitivity Analysis

• Covering whole Lifecycle
  • Closing Gaps between Phases

• (Concurrent) Model Checking

• More ...
Space Systems and Interactive Visualization
Group: Onboard Software Systems

Mission:
• Provide reliable real-time software for embedded space systems

Research Focus:
• Model-driven Software Development
• (Real-time) Execution Platforms
• Reconfigurable Distributed Onboard Systems
• Verification/Validation and Quality Assurance

Fig.: TET-1 and BIROS = FireBird
Our Use Cases

- New On-board Computer Architectures
  - OBC-NG
  - ScOSA
- Attitude (and Orbit) Control
  - BIRD
  - OOV-TET
  - BIROS
  - Eu:CROPIS
- Command & Data Handling
  - Eu:CROPIS
  - MAIUS
- (Optical) Navigation
  - SHEFEX
  - ATON
- Payload Software
  - MAIUS
MAIUS / QUANTUS
Payload Software / Experiment Control

Mission
• Bringing Bose-Einstein-Condensate and atom interferometers to space (Geodesy, Fundamental Physics)

Payload Control and Data Handling
• Software for on-board computer
• Experiment selection
• Tele-Command / Telemetry
• Hardware drivers

Images: QUANTUS Consortium
Autonomous Terrain-based Optical Navigation (ATON)

- Optical navigation for autonomous landing on celestial bodies
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
  - …

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
Reconfigurable Distributed Onboard Systems

Vision

Resource Utilization
Using all available computing resources

Redundancy
Migration of applications across subsystems

Reconfiguration
Software and hardware reconfiguration for different mission phases and error mitigation

Evaluation of COTS (Commercial Off-The-Shelf)
Reconfigurable Distributed Onboard Systems
Scalable On-board Computing for Space Avionics

Fault tolerance
• Reconfiguration due to failure

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
Reconfigurable Distributed Onboard Systems
Scalable On-board Computing for Space Avionics

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

* Other Satellite Bus Avionics

SpW Link
Other Link
(Real-time) Execution Platforms
Tasking Framework

- Event based execution framework
- Inspired by Petri Nets
- Start of computation tasks by
  - availability of data
  - time events
- Parallelization for
  - multi core
  - distributed systems
- Scheduler available for different platforms
  - Linux
  - RTEMS
  - Xilinx bare metal (ongoing)
OBC-NG: Task Reconfiguration

- Tasks running on one computing node:
OBC-NG: Task Reconfiguration

- Tasks running on two computing nodes:
Model-Driven Software Development (MDSD)

Overview

Graphical DSLs

Textual DSLs

Model

Documentation

Source Code

Unit-Tests
(Real-time) Execution Platforms
Experiment Control Platform

- Software framework to support autonomous execution of complex experiments
- Features:
  - Sequence player
  - Graph-based experiment control
- Use case: quantum optical experiments on a sounding rocket
Model-Driven Software Development (MDSD)
Example: Hardware Driver Description

- Textual DSL to describe behavior of hardware
  - Content presented with textual DSLs can be edited faster
- Textual DSL to describe how different hardware is physically organized
- DSL descriptions are transformed to C++ source code

- Now, hardware developers are able to provide also the software drivers!

Fig.: DSL for laser driver definition (MAIUS mission)
Questions?