

Space mission instruments Real-time control software: from requirements definition to flight version

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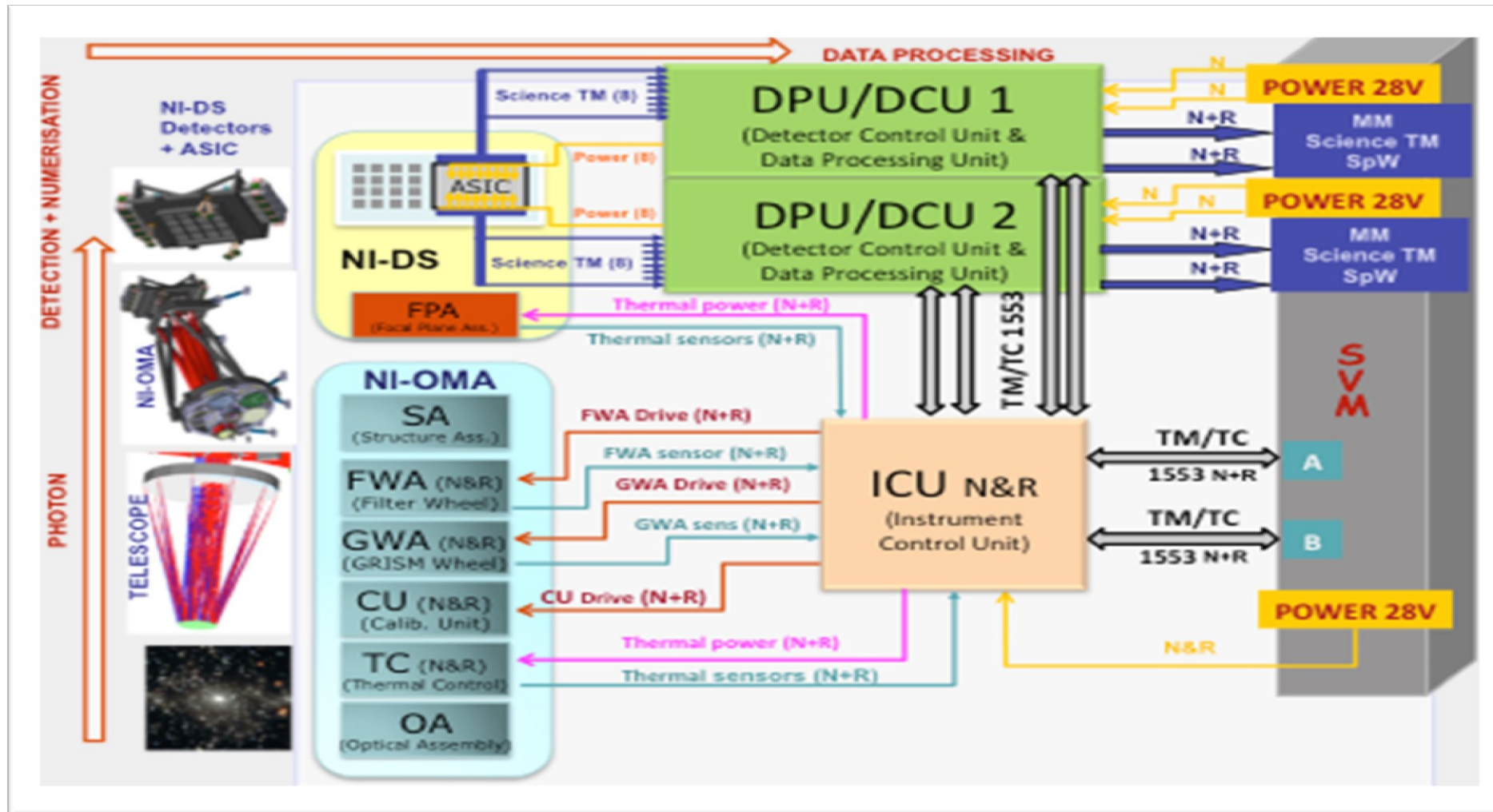


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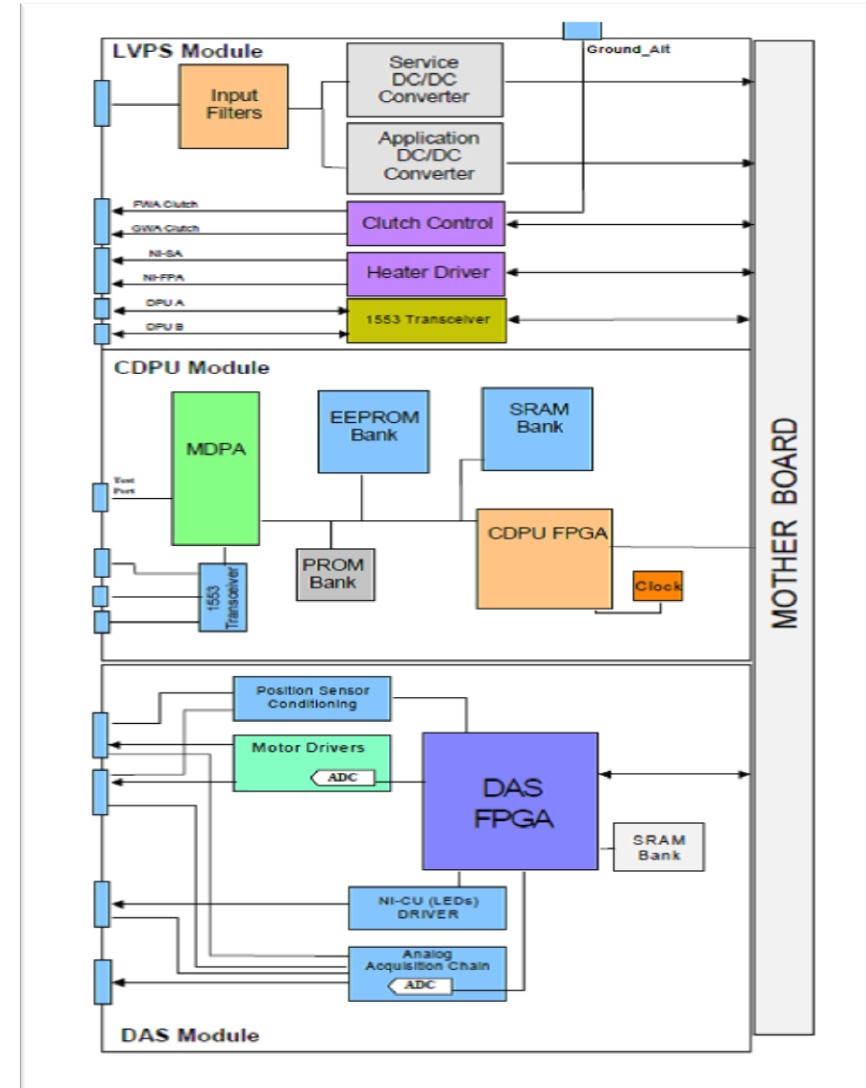


- Study of dark universe (dark energy and dark matter)
- ESA M2 mission placed in L2 orbit
- Mission lifetime will be about 6 years
- Telescope diameter is 1.2 meters
- 2 on-board instruments:
 - VISible imager
 - Near Infrared Spectro-Photometer



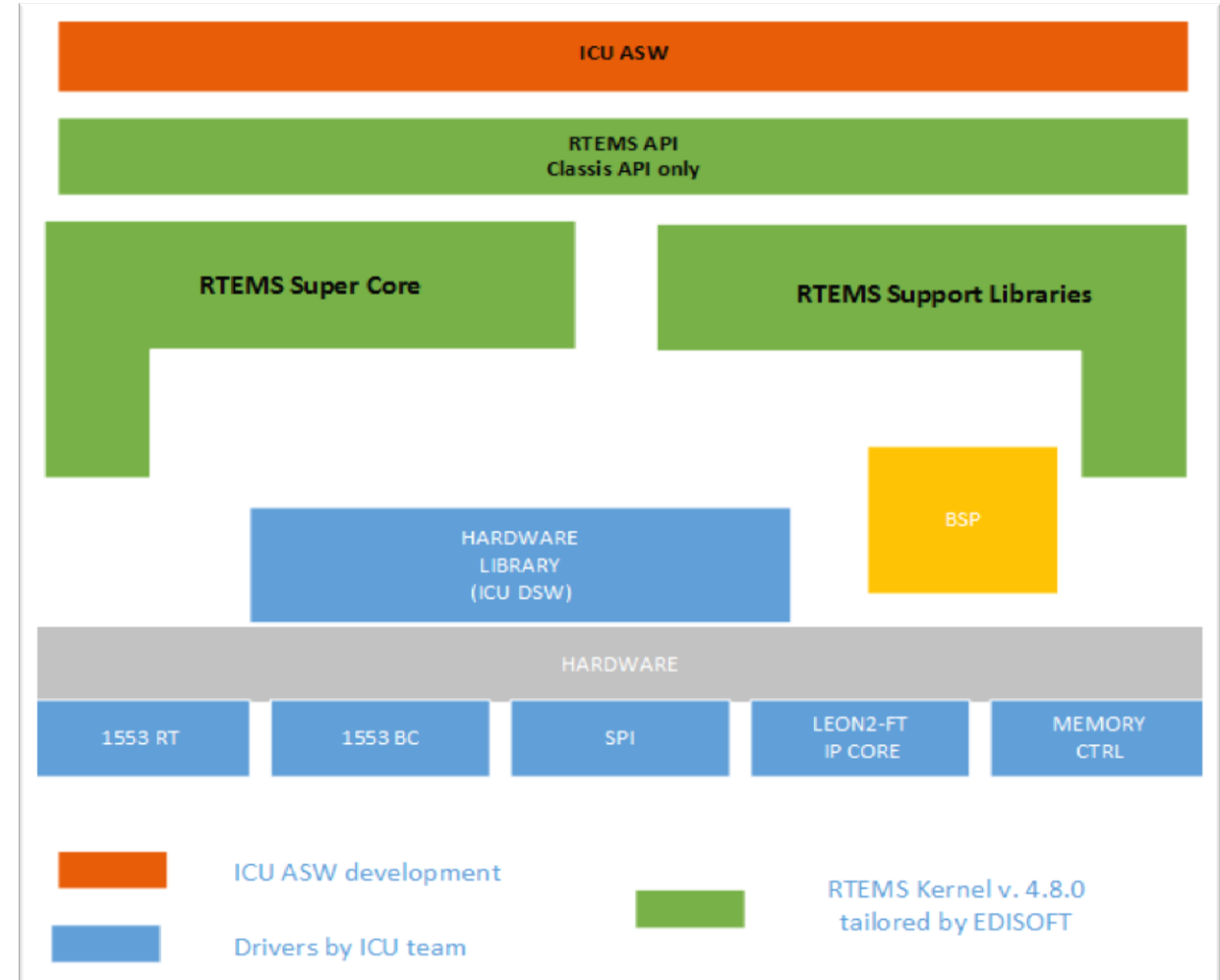
Schematic view of NISP

- SPARCv8 LEON2-FT CPU processor embedded on a MDPA ASIC
- CPU clock is 80MHz
- Composed of three modules connected on a backplane motherboard:
 - Low Voltage Power Supply
 - Central Data Processing Unit
 - Data Acquisition System
- Memories:
 - 64KB PROM
 - 4MB EEPROM (2 banks of 2MB)
 - 8MB SRAM with EDAC protection
- RTAX FPGA:
 - Extends MDPA functionalities (WatchDog, Reset, Clock, OBT)
 - Interface CDPU with DAS Module
- Interfaces:
 - 2 Mil-BUS 1553
 - 1 Spacewire
 - 1 SPI



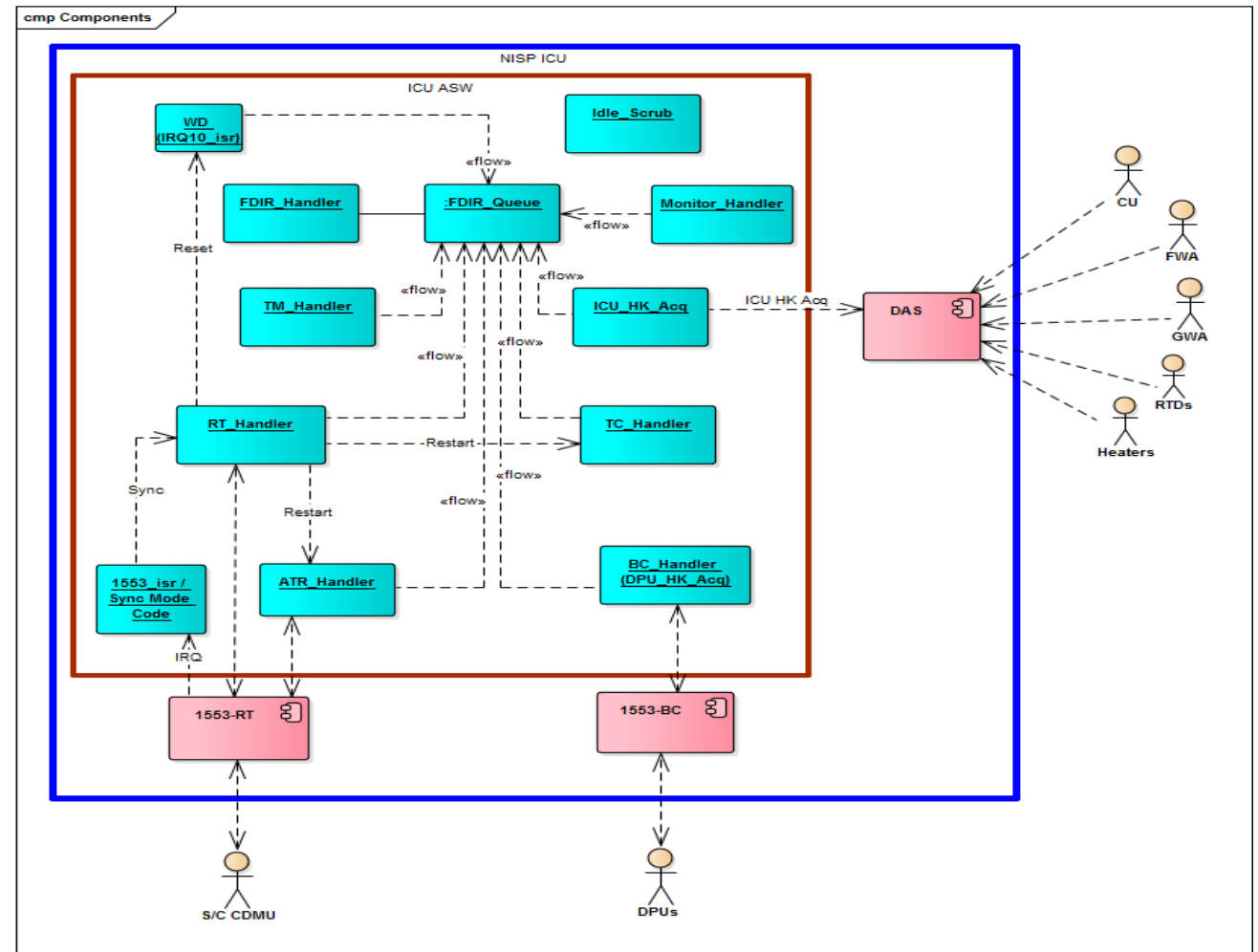
ICU HW Configuration

- RTEMS 4.8 Edisoft Space qualified libraries
- Written in C language
- Modelled using UML 2.0 Language
- GCC 4.2.1 Compiler
- OS: Debian 5.0
- Debugger: GRMON and GDB
- Framework Eclipse with plugins
- Versioning and Issues: GitLab
- Static Analysis: Parasoft C/C++ and BugDetective
- Unit test: Ceedling
- ICU DSW
- User-defined BSP based on Sparc Leon2



ICU ASW Executive Environment

- Handling communication with SpaceCraft
- Handling communication with DPUs
- TM acquisition of all NISP subsystems
- Time distribution and synchronization to DPUs
- Monitoring of health parameters and subsystems status
- RAM memory scrub
- Management of NISP operating modes
- FDIRs handling



ICU ASW basic runtime processes

Handling communication with SpaceCraft

- Implementing ECSS protocol for 1553 communication
- Implementing PUS standards for TC/TM packets exchange
- PUS Services implemented are:
 - PUS 1: TC acknowledge
 - PUS 3: TM report definition and report
 - PUS 5: Event generation
 - PUS 6: Memory management
 - PUS 8,1: User defined commands
 - PUS 9: Time management
 - PUS 17: Test Service
- Cyclic schedule based on $T=1s$
- Each second is divided in 60 Communication Frames (starting with a synch message)
- Drives ICU-ASW scheduler (synch messages reception are handled by an ISR that resume scheduler task)

Handling communication with DPUs

- Cyclic schedule based on $T=1s$
- Each second is divided in 60 Communication Frames (in order to have same slots and timing of Spacecraft interface)
- Manage 1553 messages schedule based on DPU SW status
- 1553 shedule are fixed apart CF corresponding to:
 - Telecommand slots
 - Memory load messages slots
- Schedule generation, transmission and retrieval are synchronized with spacecraft
- Data processing is not event driven, restarts after 25ms after conclusion of previous cycle

TM acquisition of all NISP subsystems

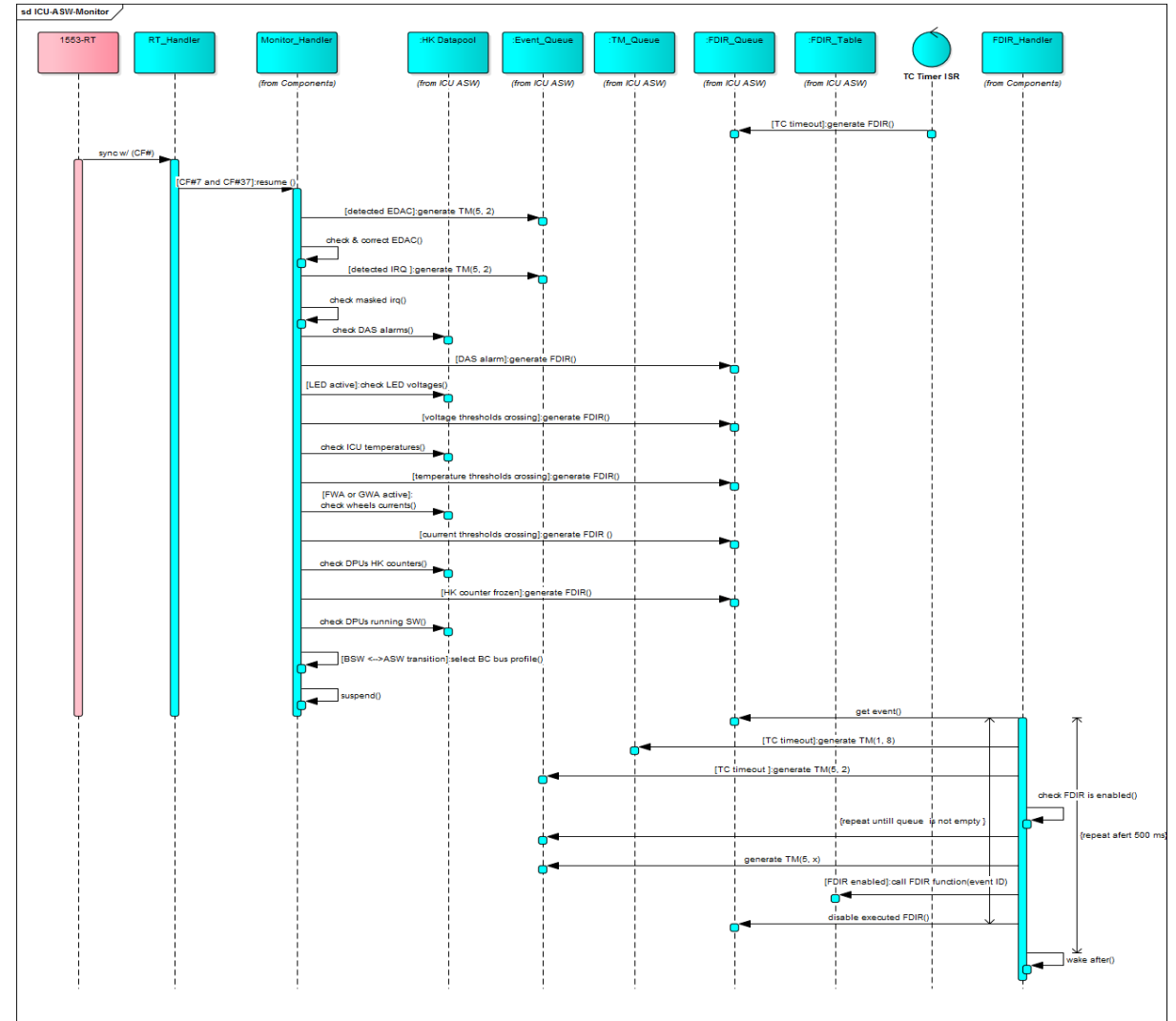
- Task driven by 1553 synch reception on Spacecraft 1553 interface
- Internal ICU HK acquisition cycle is 2Hz
 - On Analogic parameter a median on last 3 values is applied
 - Digital parameter are stored inside DB
- DPU HK acquisition cycle is 1Hz (based on 1553 schedule), data are stored inside DB

Time distribution and synchronization to DPUs

- Task driven by 1553 synch reception on Spacecraft 1553 interface
- ICU-ASW resynch OBT every second based on OBT packet received on S/C 1553
- ICU-ASW sent received OBT packet every second to DPU based on internal schedule

Monitoring of health parameters and subsystems status

- Task driven by 1553 synch reception on Spacecraft 1553 interface
- Monitor task frequency is 2Hz
- Based on settings and instrument status checks:
 - Wheel currents
 - LEDs voltages
 - ICU temperatures
 - ICU alarms
 - DPU SW status
 - Correctable EDAC error



High level view of HK monitoring and FDIR handling sequence

RAM memory scrub

- Performed by Idle task(lowest priority) accessing cyclically RAM area
- Error checked by Monitor task

Management of NISP operating modes

- Only autonomously transition to SAFE state is allowed
- A reboot is performed in case of RTEMS fatal error, Initialization failure or WD t2 expiration
- Any other transition must be commanded

FDIRs handling

- Handled by a dedicated task with highest priority
- Uses an RTEMS queue in order to enqueue errors to be processed
- Asynchronous task scheduled with a frequency of 2Hz

- 12 Tasks + Init task
 - All tasks are preemptive scheduled based to priority
 - Time slicing (10 ms) is used in order to avoid task endless loop
 - WD t1 and status on task restart/resume calls are used to check task correctness
- 4 Timers
- 13 Telemetry queues
- 1 FDIR event queue
- 85 Telecommands
- ~2000 HK Parameters
- Max TC data rate: 1 pkt/s (~1 KB)
- Max TM data rate: 2 pkt/s (~2 KB)
- ICU-ASW source size: ~370KB
- Current version 1.7 (passed QAR review)
- Next Release 1.8

- Limited memories resources
 - 7MB of RAM available for ICU-ASW (1MB is reserved for ICU BSW)
 - 2MB of EEPROM (store 2 identical copies of ASW and ancillary data)
- BSP and DSW interaction with OS
- Development environment portability
- Wheels movements synchronized with CMU
- OBT synchronization of DPUs
- Anomalies handling
- Up to 72 hours of autonomous operations

- ICU EBB model
- setup board (DAS board simulator)
- Ballard 1553 USB Interface
- Spacecraft simulator
- DPU simulator
- Mission Database libraries
- TSC software to execute test scripts
- Pulpo tool generating EEPROM file as expected by drivers



- 5 repositories
 - 3 repositories with Continuous Integration jobs:
 - ICU-ASW
 - Ancillary Data
 - Unit Tests
 - Generates reports containing modules status and coverage
 - Manual trigger
 - 2 repositories with no jobs:
 - Pulpo tool
 - MIB and Test sequencies

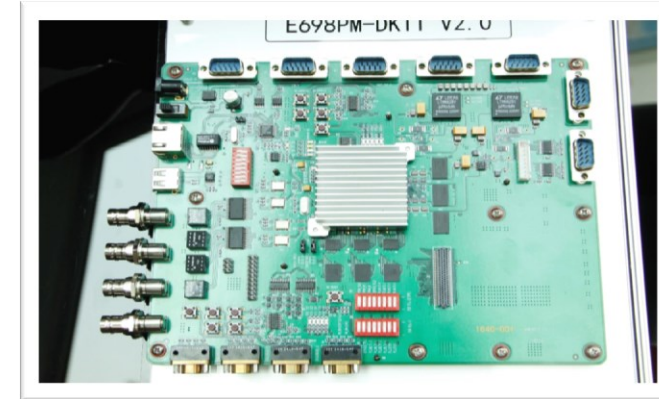
- Data contained are:
 - ICU-ASW source code
 - Scripts used during Continuous Integration process (7 jobs)
- Artifacts generated are:
 - ICU-ASW Executable to be loaded using Test port + GRMON
 - ICU-ASW memory map
 - ISO checksums to be compared with PUS 6,9 Service results
 - MISRA report + Static Analysis report (Parasoft + BugDetective)
 - Issues report
 - ICU-ASW Manual (HTML and RTF versions) based on doxygen comments
 - Executable to update EEPROM sections using Test port + GRMON
 - EEPROM data in s2k (used by MOC) format

- Data contained are:
 - Wheel profiles + LUTs table + FDL
 - ICU-ASW startup settings
 - Scripts used during Continuous Integration process (4 jobs)
- Artifacts generated are:
 - Executables to update EEPROM sections using Test port + GRMON
 - EEPROM data in s2k (used by MOC) format
 - ISO checksums to be compared with PUS 6,9 Service results
 - Full EEPROM map in s2k format (containing last ICU-ASW image pushed on branch master of ICU-ASW repository)
 - EEPROM Patches (comparing current EEPROM map against last tagged)
- Pipeline execution triggered also updating ICU-ASW repository (branch master)

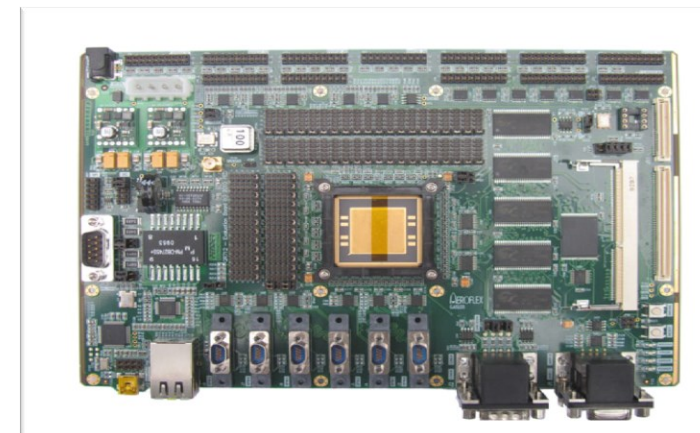
- New projects:
 - Athena
 - Spica ???

- Acquired new Hardware:
 - two multiprocessor boards:
 - OCE E698PM quad-core SPARCv8 LEON4
 - Gaisler GR712 dual core SPARCv8 LEON3
 - USB CAN bus interface
 - Spacewire router

- Current activities
 - Test task scheduling
 - SMP
 - ASMP
 - Compare performance between platforms
 - Operating Systems evaluation



OCE E698PM Board



Gaisler 712 Dev. Board