Bologna, 22-24/06/2022 – Forum della Ricerca Sperimentale e Tecnologica in INAF

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

IAPS ISTITUTO DI ASTROFISICA
E PLANETOLOGIA SPAZIALI

Attività HW&SW Strumentale (Monitoring & Control) @IAPS

Anna Maria Di Giorgio e Emanuele Galli

in rappresentanza di tutto il personale IAPS coinvolto nelle attività

SW controllo strumentazione @IAPS
Il Team

Anna Maria Di Giorgio – Management progetti + progettazione sistemi SW + AIV

Emanuele Galli – Team leader tecnico + Ingegneria del SW (progettazione, sviluppo e testing)

Giovanni Giusi – Definizione requisiti SW + DOORs + Supporto AIV

Maria Farina – PA SW + sistemi TM/TC + documentazione

Scige J. Liu – sviluppo e integrazione HW/SW + Supporto AIV

Andrea Russi – sviluppo e integrazione HW/SW + FPGA + AIV

Silvia Tofani – documentazione + Supporto AIV

Fabrizio De Angelis – Supporto AIV + web applications

SW controllo strumentazione @IAPS
Progetti

Passati (missioni concluse):

- Missione ESA Herschel – responsabilità italiana fornitura sistemi controllo dei 3 strumenti al piano focale: Supporto ASI per gestione e controllo HW prodotto da industria + produzione SW controllo 3 strumenti di payload + partecipazione IDTs

Presenti (missioni approvate):

- Missione ESA Euclid (lancio 2023) – Responsabilità italiana fornitura sistema controllo Strumento VIS + partecipazione IDT
- Missione ESA PLATO (lancio 2026) - Produzione SW controllo per Instrument Control Unit di payload + PA SW
- Missione ESA ARIEL (lancio 2028) - Produzione SW controllo per Instrument Control Unit Strumento AIRS + PA SW
- Missione cinese CSES (Lancio 2023) – Definizione requisiti e Interfacce. Progettazione e sviluppo SW controllo Strumento EFD per il modello EM. Validazione del SW-FM sviluppato dall'industria

SW controllo strumentazione @IAPS
Le competenze

Processori:
- DSP21020
- SCS 750 – PowerPC
- SPARC – V8
- LEON 3 (+ dual core) →LEON 4 (quad core)
- ARM Cortex A9

Sistemi operative (RTOS):
- VxWorks
- RTEMS
- Virtuoso
- FreeRTOS

Interfacce:
- MIL1553 STD - B
- SpaceWire
- CAN bus
- RS422

Protocolli:
- RMAP
- Protocollo proprietario su SpaceWire
- Packet Utilization Standard ESA

Algoritmi:
- Compressione lossless (extended Rice)
- Pre-processing custom

Standards:
- ECSS SW system engineering/QA/Manag.

SW controllo strumentazione @IAPS Tools

Definizione e tracking requisiti:

- IBM DOORS

Progettazione e sviluppo SW:

- IBM Rational Rhapsody suite
- Tornado/VxWorks development environment
- GRMON debug monitor

FPGA:

- ACTEL A3P1000
- XILINX Spartan e Virtex

Test tools:

- IBM Rational Test tool
- Parasoft C++ Test
- Vectorcast

Gestione sistemi TM/TC:

- SCOS2000
- IDEHAS (TAS-I)

Controllo configurazione:

- GitHub

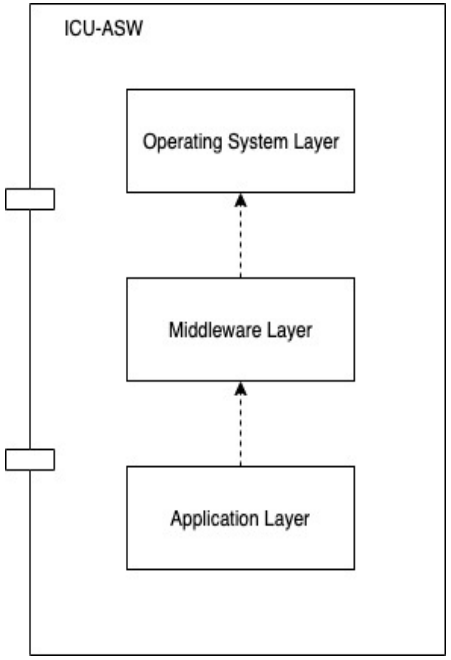
Tracking problemi:

- Redmine
- GitHub
- ECLIPSE NCTS/eRID/AIM

Document Management:

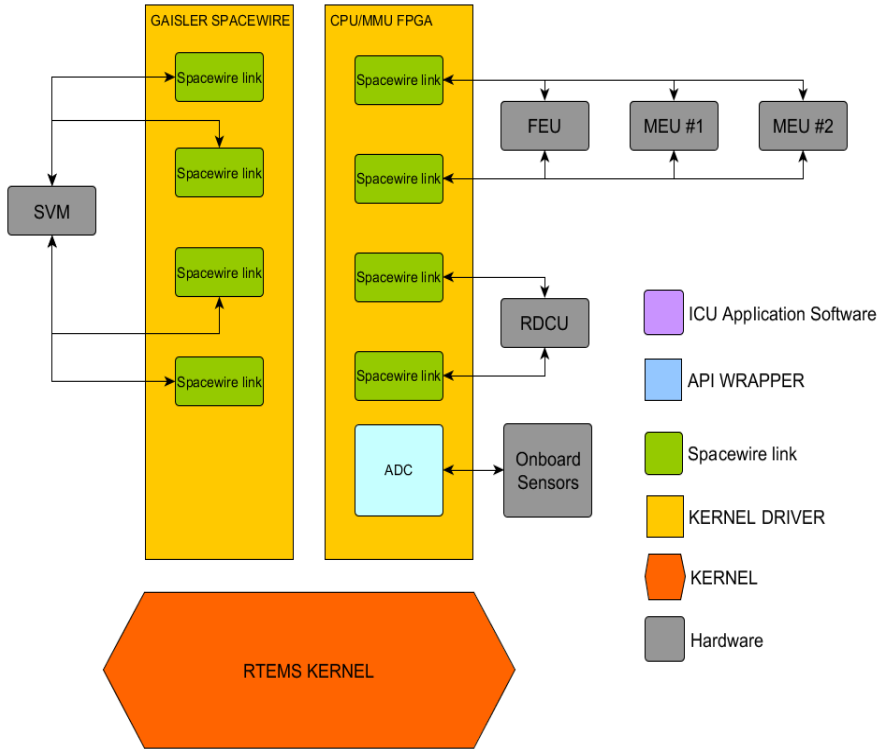
- ECLIPSE DCCM

SW Layers - RTOS

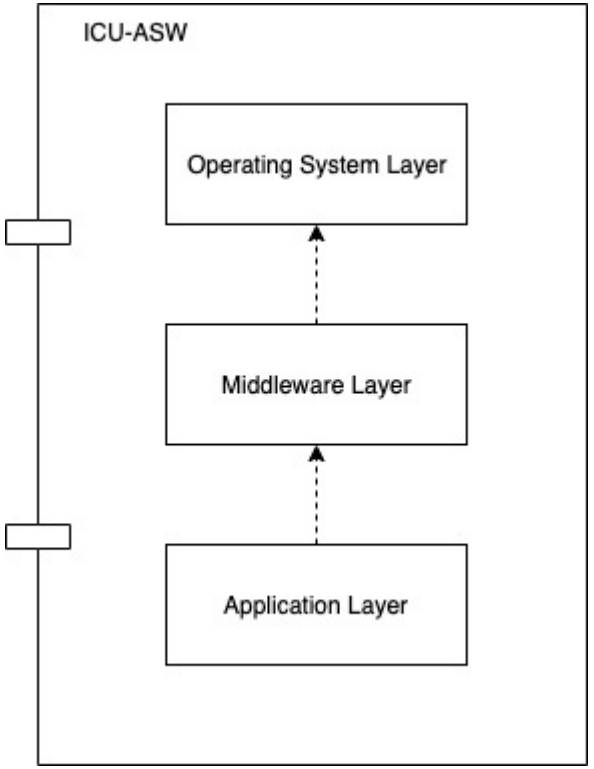


Operating System Layer:

- *RTOS*: it includes all the library of the adopted Real Time Operating System
- *Processor BSP*: it includes the library for the management of the processor
- *DPU boards HW BSP*:
  - GPIO component: it is in charge of management GPIOs on the ICU board.
  - EDAC component: it allows to manage the EDAC on the ICU SRAM volatile memory
  - FPGA component: it is in charge of the communication on Spacewire links (PUS or RMAP), and to handle the HW watchdog
  - NVM component: to store and load data on the NVM non-volatile memory
  - ADC component: to read housekeeping



SW Layers - Middleware



Middleware Layer (sviluppato in IAPS per RTEMS):

OS Adapter: a generic interface to access inter process communication interface in order to be independent from the underlying operating system layer:

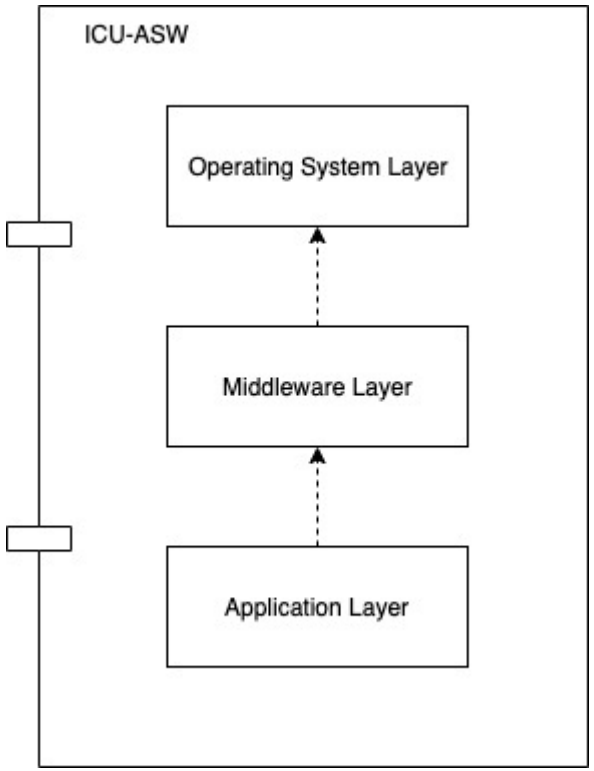
- Task Interface: provides the interface to create/start/suspend and destroy real time processes
- Mutex Interface: provides the interface to the mutual exclusion OS functionality
- Semaphore Interface: provides the interface to create counting semaphores.
- Timer clock Interface: provides the interface to get the current time clock
- Event Interface: provides the interface to exchange signals among tasks
- Message Queue Interface: provides the interface to exchange data among tasks

SafetyMicroCframework (smxf): it is the component of the IBM Rational Rhapsody tool and provides all modules to build an event-driven and time-driven Real Time application:

- Event: it is the component to implement the event-drive semantics and functionality
- Event Queue: queue of events accessed by the producer and consumer of events
- Timed Action: periodic actions that occurs at specific timeouts
- Reactive Task: a task that can process events and timeouts

The smxf uses the OS_Adapter component to create reactive tasks that are OS tasks that exchange events and timeouts by means of the OS message queue, events and to manage timed events

SW layers – Application layer



Communication Layer:

- SVM component: handles the PUS TC/TM (high and low priority) communication with the S/C (CDMU and MMU)
- DPS component: handles the payload internal communications

Application Layer:

- Data Pool component: to store and retrieve stored Housekeepings and ICU ASW params.
- PUS services: provides the implementation of all foreseen PUS services
- Unit Controller component: it is in charge of the execution of telecommands and the management of operational modes
- Housekeeping component: to read HK (from all payload subsystems), to generate the relative Telemetries and to check limits
- Event Action component: to manage actions activated by external events
- Science Data Handling component: to handle the scientific data coming from focal plane detectors, to packetize scientific data and to generate the relative PUS TM
- Memory component: to process PUS Memory service
- FDIR component: to handle the HW watchdog and to provide the set of functions to execute an FDIR when an error is detected
- Idle component: to put the CPU in idle and to SCRUB the CPU memory

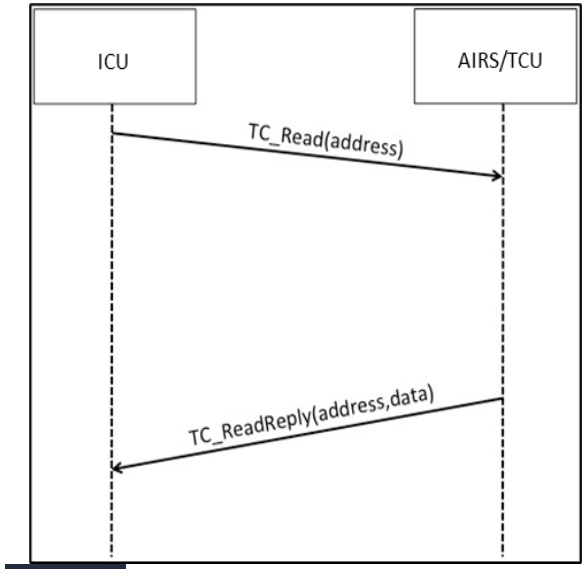
Link SpaceWire: il protocollo IAPS

Similarly to RMAP, two types of commands are defined: **write commands** and **read commands**

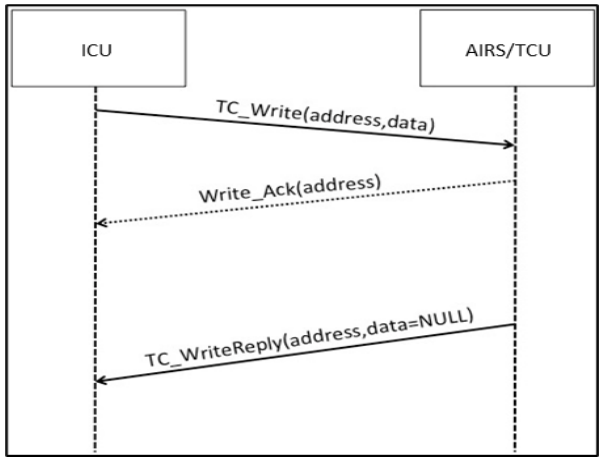
General command structure

Byte 0	Byte 1	Byte 2	Byte 3
Destination Address	Protocol ID	Source Logical Address	PaketType, Ack, Err
Transaction ID		Data Length	
Command Id | Address	Transaction Sequence Counter		
Cargo			
Footer			

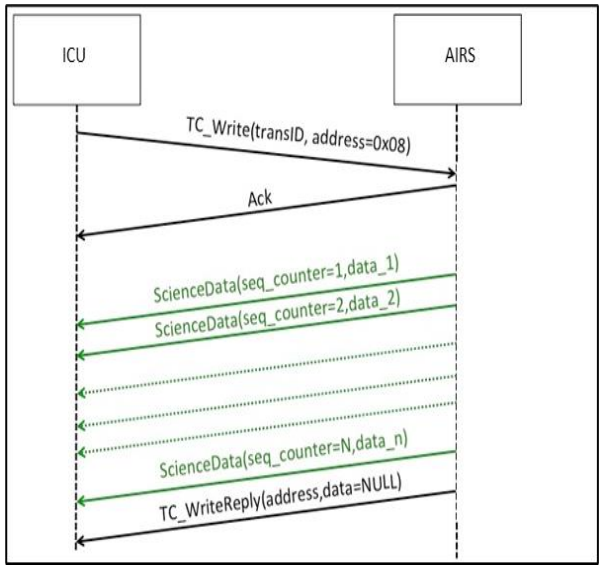
Read commands



Each time an error is detected by the SpaceWire controller due to errors on the links (e.g. parity error), then the full transaction is considered as not successfully executed.



Write commands



Acknowledge Packets

Byte 0	Byte 1	Byte 2	Byte 3
Destination Address	0x02	Source Logical Address	0xA[3..0]
Transaction ID		Data Length (0x0000)	
Address/Command Id	Transaction Sequence Counter (0x000001)		
Footer			

Reply Packets

Byte 0	Byte 1	Byte 2	Byte 3
Destination Address	0x02	Source Address	Packet Type 0x8[3..0]
Transaction ID		Data Length - from 0 to (2^{16} -1)	
Address/Command Id	Transaction Sequence Counter - From 1 to (2^{24} -1)		
Reply Data			
Footer			

Science Data Packets

Byte 0	Byte 1	Byte 2	Byte 3
Destination Addr (0x01)	0x02	Source Address (0x11)	0xC0
Transaction ID		Data Length	
Address/Cmd ID (0x08)		Sequence Counter	
Science data			
CRC-16 MSB	CRC-16 LSB	EOP	

SW controllo strumentazione @IAPS Considerazioni

- *SW controllo in strumentazione astronomica spaziale è una componente chiave per il corretto funzionamento dello strumento per l'intera vita della missione:*

  → Il responsabile dello sviluppo fa parte del System Team di strumento/payload e partecipa alla definizione dei modi operativi, del commanding, del data processing e delle funzionalità FDIR

  → segue standard di progettazione, realizzazione e testing analoghi a quelli stabiliti per le componenti HW (in particolare attività AIV molto pesante)

  → permette di acquisire una conoscenza approfondita del funzionamento e delle performances degli strumenti di payload e fornisce le competenze per supportare gli astronomi nell'utilizzo ottimale degli strumenti

  → Attività di formazione specifiche necessarie in aggiunta al "training on the job"

- *La partecipazione alle missioni ESA ha permesso di consolidare il team, che però è ancora sottodimensionato rispetto alle necessità derivanti dalla sovrapposizione delle attività sui vari progetti*

  → Coordinamento con altri teams in INAF + necessità (ormai strutturale) di personale a contratto.

- *Molte competenze in comune con SW controllo per strumentazione terrestre:*

  → Importante attività di individuazione sinergie - TETIS

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

IAPS ISTITUTO DI ASTROFISICA
E PLANETOLOGIA SPAZIALI

Grazie per l’attenzione!