Control Software at OATo: from stratosphere to space

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ONGOING PROJECTS… not exaustive!

CORMAG (Hemera)

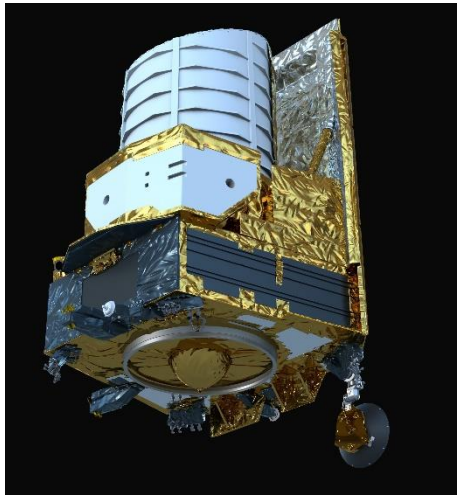
2022 2023 ? 2024 2029 2035

EUCLID

ARIEL

Athena

EUCLID: our experience



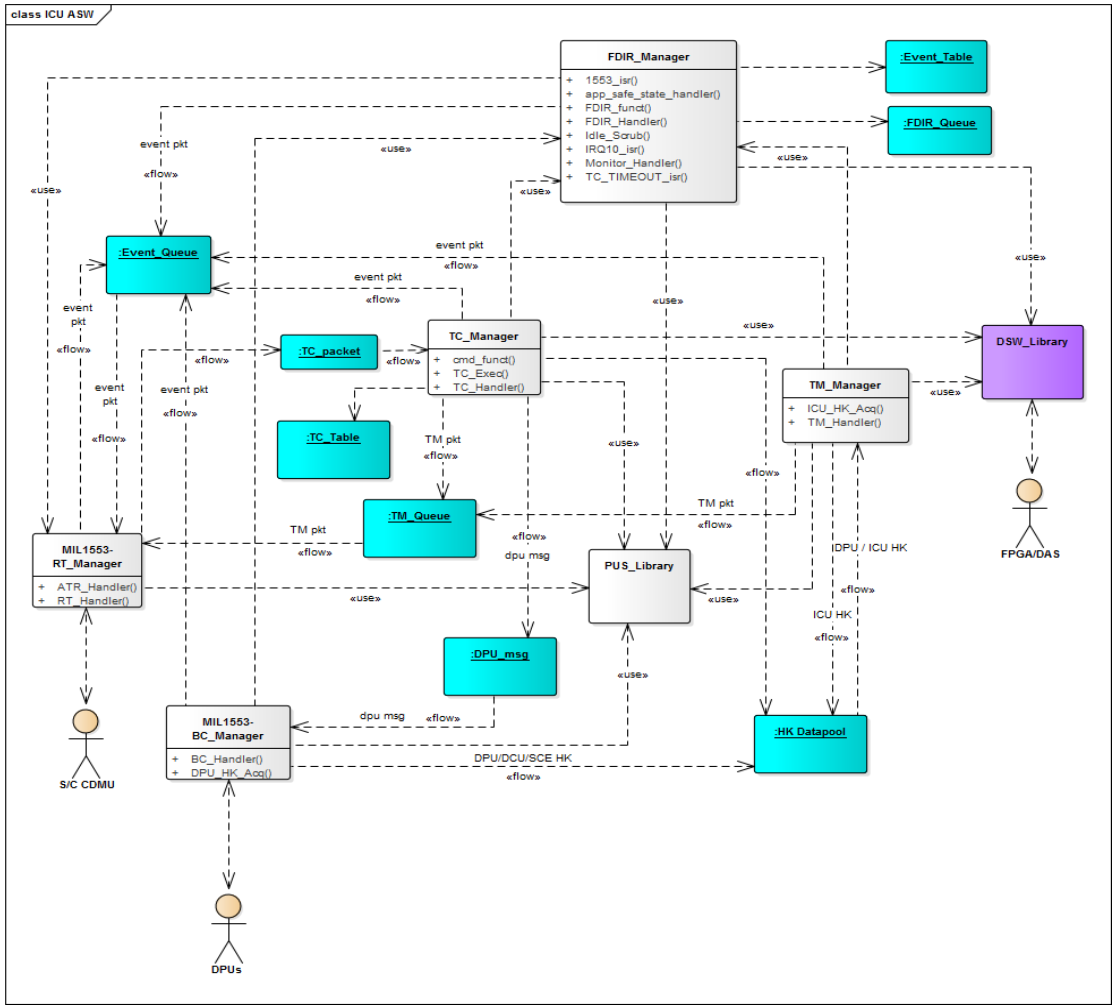
- Launch window from July 2023 from Cape Canaveral with a SpaceX Falcon 9 launcher
- Two instruments: VIS (Visible Instrument) and NISP (Near Infrared Spectro-Photometer)
- Mainly involved on the ASW of the Instrument Control Unit (ICU) of NISP

The ICU ASW:
… is based on a SPARCv8 LEON2-FT CPU processor
… real Time OS: RTEMS 4.8 (space qualified) on Debian 5.0
… interfaces with subsystems and SpaceCraft on MIL-BUS 1553 and SPI
… scientific data processing and transmission handled autonomously by DPUs (Data Processing Unit)

EUCLID: our experience

- Modelled using UML 2.0 Language

Within other tasks, the ICU ASW …
… Exchanges TMs and TCs with SpaceCraft (S/C)
… Communicates with the DPUs
… Commands subsystems
… Monitors status of all subsystems and acquire TMs
… Synchronizes time with the S/C
… Distributes time to DPUs
… Handles FDIRs

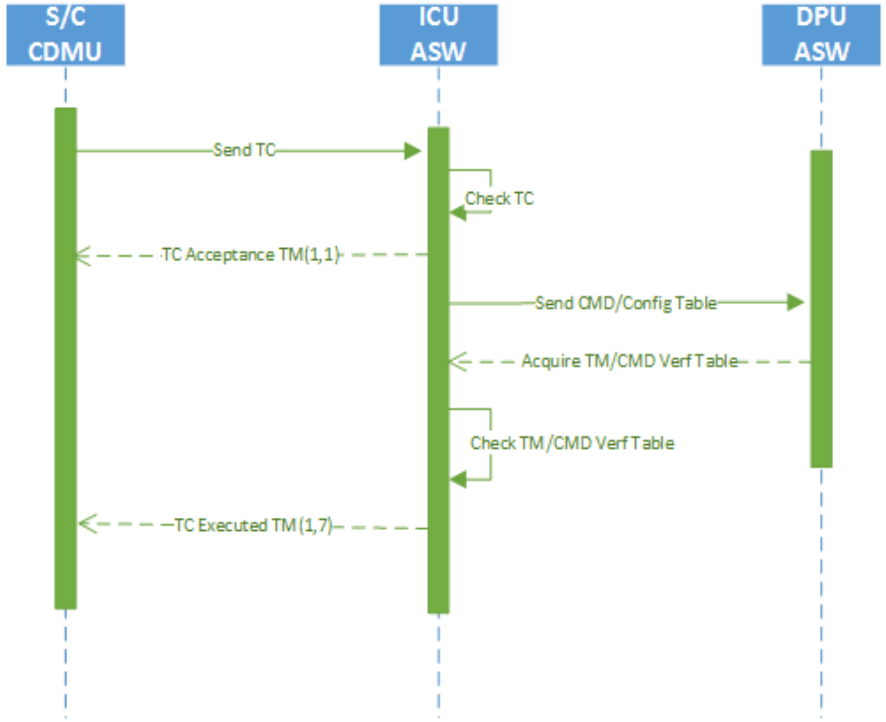


EUCLID: our experience

Communication on MILBUS 1553 and TM and TC are handled following ECSS protocols
PUS Services implemented:

- ✓ PUS 1: TC aknowledge
- ✓ 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

… while communication with DPUs follows a dedicated protocol:



EUCLID: our experience

- Requirements management: custom-made database (INFN-Bo)

Requirement_ID	TechSpec_ID	TestCase_ID	TProc_ID
NI-ICU-ASW-D-1002	TS-NI-ICU-ASW-CMD-460	NITC-380	FT13
NI-ICU-ASW-D-1002	TS-NI-ICU-ASW-CMD-460	NITC-380	FT17
NI-ICU-ASW-D-1002	TS-NI-ICU-ASW-CMD-440		
NI-ICU-ASW-D-1036			
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-070	FDIR-040	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-130	FDIR-100	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-080	FDIR-050	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-020	FDIR-010	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-030	FDIR-010	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-040	FDIR-015	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-150	FDIR-120	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-160	FDIR-130	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-140	FDIR-110	FT12
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-050	FDIR-020	None
NI-ICU-ASW-D-1044	TS-NI-ICU-ASW-FDIR-140	FDIR-110	FT11

- Unit tests: Unity and Cmock, managed with Ceedling (Throw The Switch)
(in collaboration with INFN-Genova)

```
[----------] Global test environment tear-down.
[==========] 639 tests from 273 test cases ran.
[  PASSED  ] 636 tests.
[  FAILED  ] 0 tests.
[  IGNORED ] 3 tests, listed below:
[  IGNORED ] test__rtems_configuration__asw_task_idle.c.test_TESTDESCRIPTION__asw_task_idle
[  IGNORED ] test__PUS_Service_8_1_fwa_gwa__asw_PUS_8_1_8_8_hs_check.c.test_hs_center_check_15__asw_PUS_8_1_8_8_hs_check
[  IGNORED ] test__PUS_Service_8_1_fwa_gwa__asw_deploy_FDL.c.test_branches__asw_deploy_FDL

 0 FAILED TESTS
```

What's next: Athena

- X-ray telescope (0.2 – 12 keV) of the Cosmic Vision *The hot and energetic Universe* program
- Two instruments: X-IFU - high-spectral resolution imaging
  WFI – medium resolution spectrograph

- Status of X-IFU: System Requirement Review in June 2022,
  … but at the same time ESA requested for cost and mass reduction of the whole mission
  … results of the new design and science redefinition expected in spring 2023

OA-Torino and OAS-Bologna involved in the X-IFU Instrument Control Unit (ICU)

… The proposed board: SPARCv8 LEON3 CPU processor, multicore
… The proposed real Time OS: RTEMS 6 (space qualified) compatible with multiprocessing
… Interfaces with subsystems and SpaceCraft on Spacewire

What's next: Athena

Exchange of TM and TC with SpaceCraft will be handled following ECSS protocols

PUS Services requested:

- ✓ PUS 1: TC aknowledge
- ✓ PUS 2: Device access
- ✓ PUS 3: TM report definition and report
- ✓ PUS 5: Event generation
- ✓ PUS 6: Memory management
- ✓ PUS 9: Time management
- ✓ PUS 12: On-board monitoring
- ✓ PUS 17: Test Service
- ✓ PUS 18: OBCP
- ✓ PUS 19: Event-action
- ✓ PUS 20: On-board parameter management

New services required

Enrich our NISP library of PUS Services!

What's next: Athena

Some details are still to be defined, as:

- Communication protocol with subsystems
- Synchronization between ICU and subsystems

- Requirement management
- Software Design:

The team in OAS has previous experience in EUCLID NISP with Enterprise Architect

→ Foreseen usage also for Athena!

What’s next: Athena

Major innovations w.r.t EUCLID NISP ASW:

- OBCP requires a dedicated engine

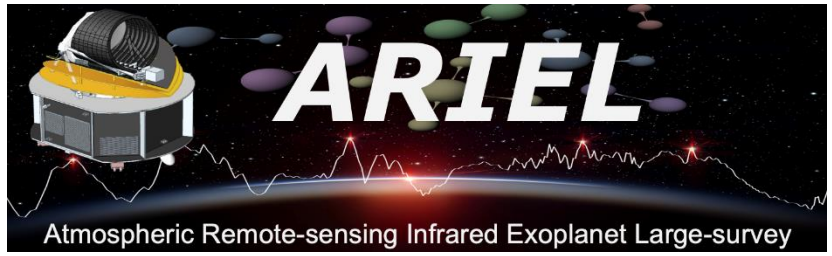
First tests done at OATo:

→ OBCP engine based on the Space qualified version of Micropython by George Robotics.
. Tested on a single-core board
. Modified and tested on multi-core boards

- Possibility of multiprocessing

→ Multiprocessing:
. tested both Asymmetrical and Symmetrical MP
. Tested on dual-core and quad-core boards

What's next: ARIEL



- M4 mission of the Cosmic Vision program for a chemical census of exoplanets
- Equipped with the Ariel InfraRed spectrometer (AIRS) and a combined spectro/photometric channel in the visible/NIR
- Launch foreseen in 2029

IAPS-Roma and now OA-To involved in the Instrument Control Unit (ICU) ASW

- The ICU manages the AIRS and the telescope control unit.
- Status of ICU: in 2022 passed the SRR (System Requirements Review)
  now under the PDR (Preliminary Design Review)

… The board: LEON3-FT CPU processor
… The proposed real Time OS: RTEMS

… w.r.t. NISP ICU and Athena ICU ASW, this ASW is in charge of the formatting and transmission of the Science Packet

What’s next: ARIEL

Exchange of TM and TC with S/C handled following ECSS protocols
PUS Services requested:

- ✓ PUS 1: TC aknowledge
- ✓ PUS 3: TM report definition and report
- ✓ PUS 5: Event generation
- ✓ PUS 6: Memory management
- ✓ PUS 9: Time management
- ✓ PUS 12: On-board monitoring
- ✓ PUS 17: Test Service
- ✓ PUS 18: OBCP (?)
- ✓ PUS 20: On-board parameter management
- ✓ Mission specific for science packet transfer

What’s next: ARIEL

- Requirements management and ASW design...

ESA management of the whole mission through MBSE, from interfaces to requirements, designs, mission performances, meetings…

ESA gives to partners the opportunity to join on the *shared project*

We are planning to work on the shared subsystem AIRS for requirements management and ASW design

Tool: Enterprise Architect

Temporal constraints: time is very tight!

What we are working for…

- Switch from a document-based approach (NISP) to a model-based approach for:

  - Requirement management
  - ASW design

- Set of tools able to adapt to different missions:

  - Adapt to different boards
  - Implement standard protocols, such as PUS libraries
  - Adapt to different RTOS

Examples from the community:

- IAPS Roma: used IBM Rhapsody as multi-functional tool

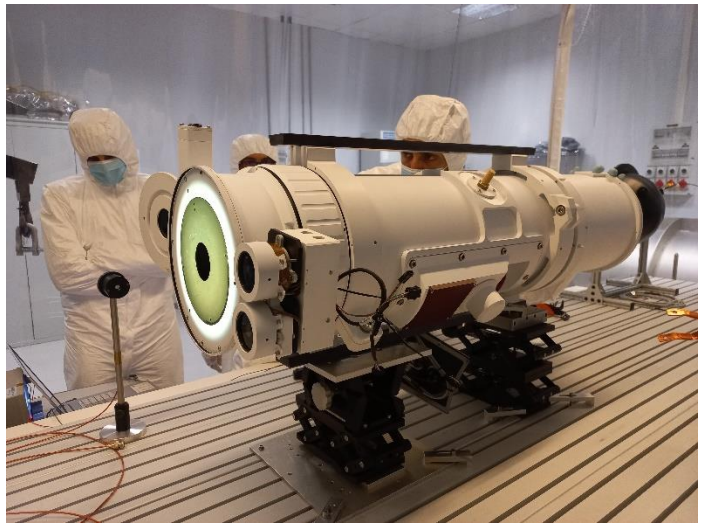
Evaluated /evaluating:

- LibPUS from CNES – a static implementation of PUS services

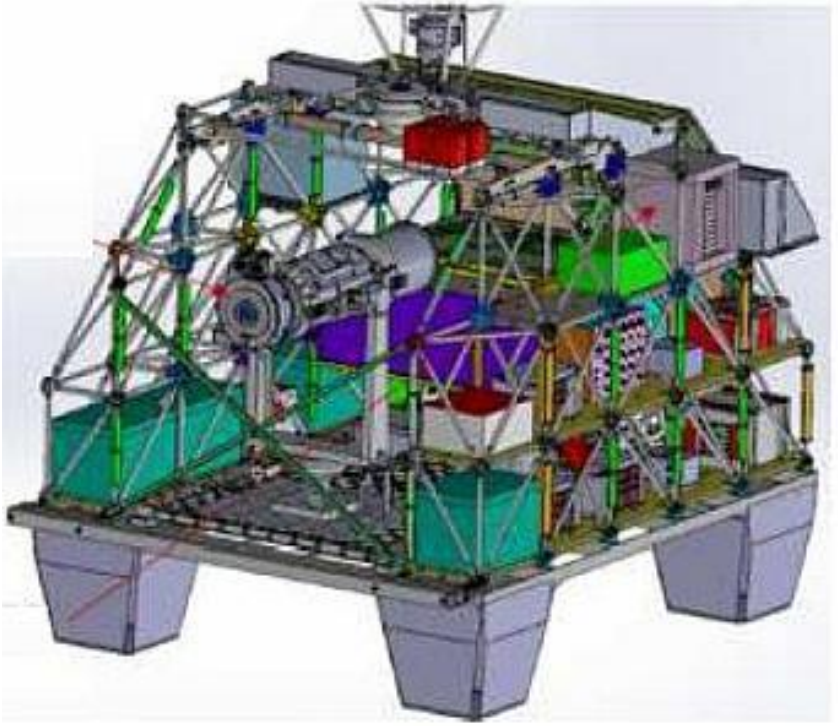
- CORDET (Wien University, presented in TETIS 1° workshop) Framework for SW development, but also to manage the design and configuration, specifications and requirements

- IAPS Roma: a huge effort done with past projects (Euclid, PLATO) in order to have a OS adapter between RTOS (RTEMS 4.8, VxWorks) and the ASW

… and back to Earth: CORMAG



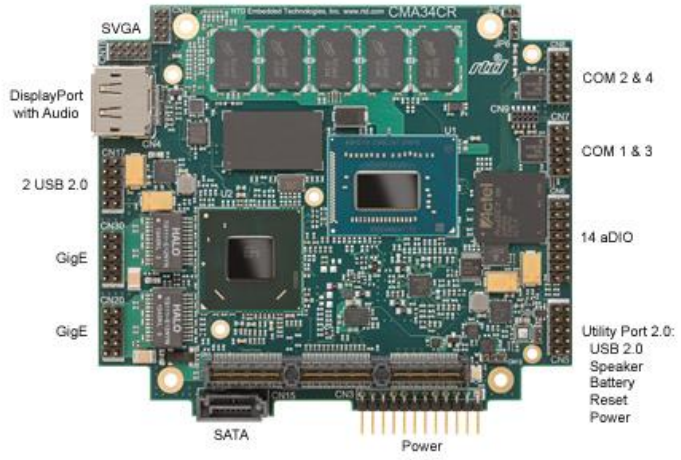
- Internally occulted coronagraph for the study of the topology of solar coronal magnetic fields
- Stratospheric-altitude (~ 35 km), 1-day duration
- active pointing and tracking of the sun
- remotely commanded by ground



First flight on 17/08/2022 from Timmins to ~ Pukaskwa Park, Ontario

Possible flight in August 2023

… and back to Earth



- Two CPUs, based on a Intel i7 processor, in a master/slave configuration:

CPU1) connection to Ground, control of all subsystems: filter, camera, heaters, energy supply
CPU2) dedicated to pointing and tracking

- Communications ground/on-board and master/slave CPUs: Ethernet with UDP protocol

- Software designed without RTOS
- Based on Debian 11 Bullseye distribution
- Use of libc6 libraries and POSIX services, like threads

… and back to Earth

- Communication protocols:

A simplified version of PUS protocol (no explicit subservices, only limited functionalities)

- ✓ TC aknowledge
- ✓ TM report definition and report
- ✓ Event generation
- ✓ User defined commands
- ✓ Test Service ground/on-board and between CPUs

- Drivers of hw components:

… one of the hardest thing to get and manage!

Conclusions

- Several projects with similarities, but also innovations: good for research!
- «Space working approach» applicable also to smaller projects
- Availability of tools that can do many things… but we need time to learn
- Need more people… not easy to find (not easy to compete with private companies)
- We shoud increase the sinergies between groups in INAF, and share expertise


Thank you!