CONTROL SW FOR SPACE APPLICATIONS ACTIVITIES AT OATO

Sebastiano Ligori

Donata Bonino

Leonardo Corcione

Vito Capobianco

TEchnologies for Telescopes and Instrument control Software

THE TEAM

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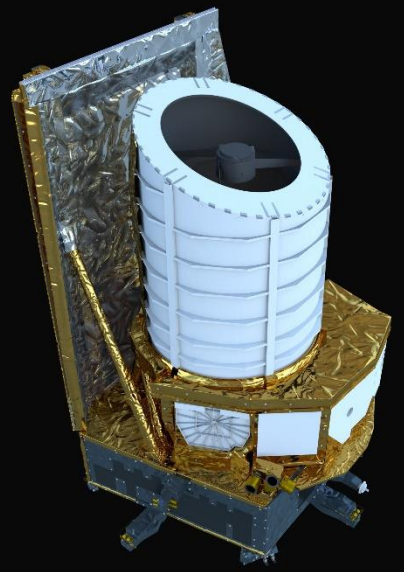
- Leonardo Corcione
  - Experience in instrument building, electronics design, detector operations
  - Examples: Photopolarimeter for Leoncito National Observatory (Argentina), GAIA, TNG, FINITO (prototype Fringe tracker for the VLT Interferometer), PRIMA (Fringe tracker for the VLT Interferometer), AMICA (Mid-IR camera for Antarctica), TIRCAM (Mid-IR Camera for TIRGO), TC-MIRC (two channel near- and mid-IR Camera for TIRGO)
- Sebastiano Ligori
  - Experience in instrument building, IR detector operations
  - Examples: MIDI (Mid-IR Instrument for the VLT Interferometer, Pyramir (IR Pyramid wavefront sensor), TC-MIRC

THE TEAM

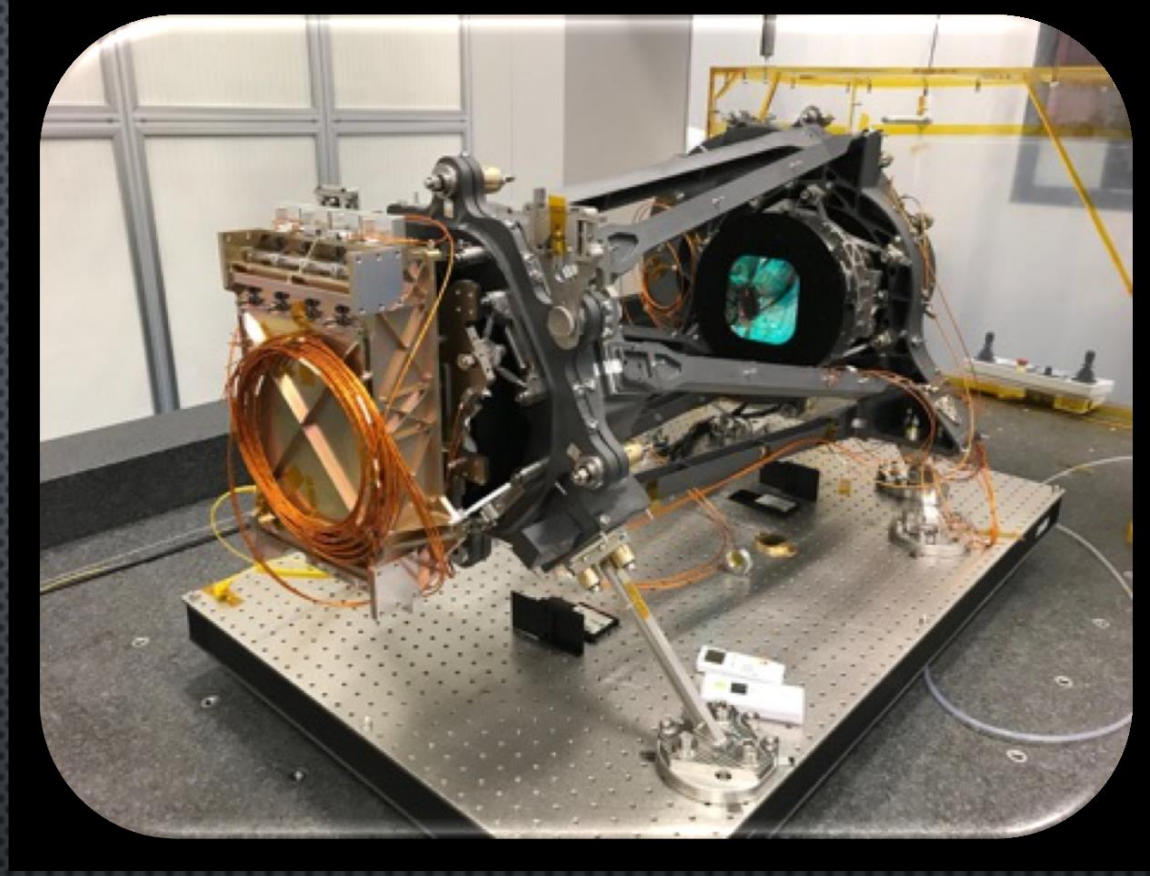
- Donata Bonino (assegnista di ricerca)
  - Ph.D. in Mathematics; previous experience of data analysis for FINITO and PRIMA, GAIA
- Vito Capobianco (CTER TD)
  - Experience in C, C++ coding for industrial applications

THE PROJECTS: EUCLID



- 1.2 m telescope in L2
- 2 instrument: VIS (36 4k x 4k CCDs imager, see A. Di Giorgio talk); NISP (Near-IR spectro-photometer, details in following slides)
- Main scientific goal: mapping extragalactic sky, getting spectro-z and photo-z information and weak lensing information from imaging in order to probe the structure of the universe, comparing with competing models for the origin of the dark matter and dark energy contribution

EUCLID NISP



- Focal plane populated with 16 Hawaii2-RG detectors (the largest IR Focal plane on a space mission)
- Two wheels to select Broad band filters or Grisms (motion compensated by a counter wheel operated by the Spacecraft)
- Autonomous operations must be ensured for up to 72 hours
- Telemetry constraints imply the images must be processed and compressed on board before being stored on the Spacecraft mass memory unit (MMU) and sent to Earth during visibility periods

NISP WARM ELECTRONICS

- The Italian contribution (by ASI through contracts with industry and academic institutions) to the NISP instrument comprises the Data Processing Unit (HW by OHB Italia, Application SW by INAF, see E. Medinaceli's talk), the Grism Wheel Assembly (by OHB Italia), and the Instrument Control Unit Application SW (the ICU HW is provided by Spain)
- Our team participated (with the "staff" component) to the early phases of the project, contributing to the design of the warm electronics, including the harness (a major source of concern in this kind of applications) and is responsible for the realization of the ICU Application SW

NISP: A DISTRIBUTED PROJECT

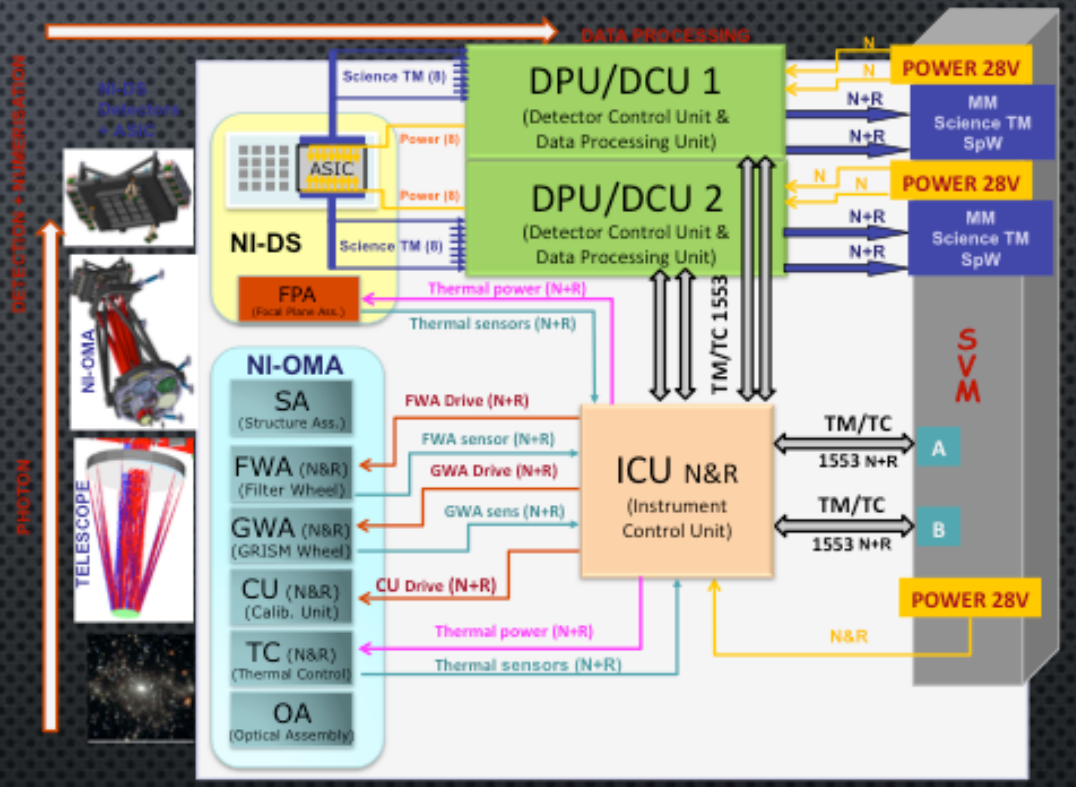
- This is common to many big projects, NISP is particularly fragmented
- The ICU SW must work on a computer built by Spanish industry, controlling a Calibration unit made by Germany, moving wheels built by Spain and Italy with motors built by France… exchange of information is critical (and it didn't always work perfectly!)
- The collaboration in Italy includes INAF OAPD, INAF OAS, INFN Padova, Bologna, Genova… and this only for the NISP part
- Very difficult, but the way to go (more integration between INAF structures, more synergies with INFN)

THE NISP INSTRUMENT CONTROL UNIT

- The ICU is produced by CRISA (Airbus), Spain, and is based on a radiation hardened LEON2 Sparc V8 processor, with EDAC protection
- Very small EEPROM size (2 MB) and RAM size (7 MB usable); the code must not handle big amount of data (in charge to the DPU) but it has in any case to be very efficient
- The application SW uses an open source real time operating system for embedded applications (RTEMS), which has been tailored and qualified for space applications (more in V. Capobianco's talk)
- A big effort has been made to learn and apply the relevant standards for this kind of applications (in particular ECSS docs, discussed in A. Balestra's talk)
- Product assurance is a very sensitive topic for ESA: luckily we had a big help on this from N. Auricchio (who will discuss this in her talk)
- Unit tests and functional tests required additional resources. We found these in the fruitful collaboration with INFN teams in Genoa and Bologna

THE NISP INSTRUMENT CONTROL UNIT

- CONTROLS THE NISP SUBSYSTEMS (WHEELS, CALIBRATION UNIT, THERMAL CONTROL)
- DISTRIBUTES TELECOMMANDS TO THE DPU
- SYNCHRONIZES WITH THE SPACECRAFT ON BOARD TIME, DISTRIBUTES IT TO THE DPU
- MONITORS THE STATUS OF THE SUBSYSTEMS INCLUDING DPU
- COLLECTS HK FROM THE SUBSYSTEMS INCLUDING DPU
- SENDS PERIODIC TELEMETRY AND EVENT PACKETS
- IMPLEMENTS SYSTEM LEVEL FAILURE DETECTION, ISOLATION, AND RECOVERY ALGORITHMS
- THE SYSTEM BEHAVIOR MUST BE COMPLETELY DETERMINISTIC (THE SEQUENCE OF TELECOMMANDS IS EXECUTED AS A TIMELINE FOR UP TO 72 HOURS)



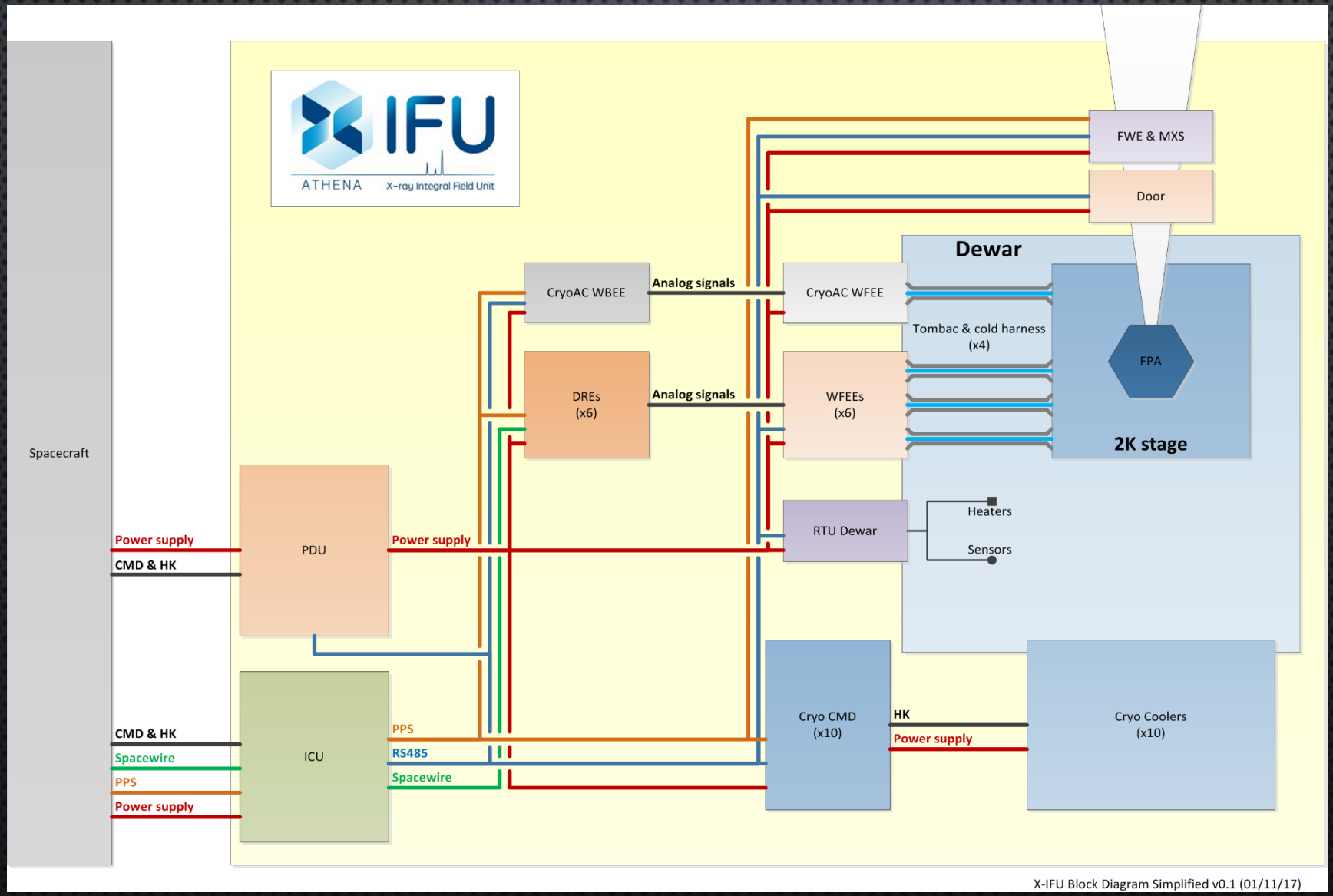
ICU ASW STATUS

- The ICU ASW has completed the Qualification and Acceptance Review; currently the NISP QAR started
- The ASW has been handled to the industries (Thales and Airbus) which will use it on different NISP models (including the Flight equipment) in the next test phase
- Launch is foreseen in 2022

THE FUTURE: ATHENA X-IFU

- Our team is involved in the realization of the ICU SW for the X-IFU on the Athena mission
- Athena is an X-ray telescope (energy range of 0.2-12keV), a Large ESA mission scheduled for launch in the "early 2030s" time frame
- Part of the "Cosmic vision" program "the hot and energetic universe"
- The X-IFU is one of the two intruments and it is an Integral Field Unit, based on an array of cryogenically cooled Transition edge sensors (TES)
- The Instrument Control Unit will be based on the NISP heritage, but will be more complex and will need a more performant HW
- The X-IFU collaboration include several INAF institutes, the work on the ICU is mainly done, in this phase, by INAF OAS and INAF OATo
- We expect to have in 2021 the Instrument Preliminary Requirements Review, SPC adoption in 2022

X-IFU BLOCK DIAGRAM



THE FUTURE THAT WILL NOT COME: SPICA

- The Spica mission is a cryogenic cooled telescope for mid- to far-IR observations. The diameter of 1.8 m and its cold temperature make it extremely sensitive
- Scientific goals span from extragalactic astronomy to exoplanet atmosphere studies
- It was about to enter the selection phases but ESA and JAXA recently decided to cancel it for budget reasons. The process that lead to this decision is obscure (at least to me and about 300 other scientists who wrote a letter to Nature) but the message is clear.

MULTI CORE PROCESSORS FOR SPACE APPLICATIONS

- In the context of the Spica study phase we acquired and used a quad-core LEON4 development board by OCE
- Multiprocessing for space applications could be very interesting, also to optimize performances and power consumption
- Two approaches have been explored:
  - 4 different instances of SW dealing each with a different set of capabilities, and communicating via dedicated memory areas
  - a single instance of RTEMS with the different tasks assigned dynamically to the different cores
- This experience will likely be transferred to the X-IFU project

FINAL CONSIDERATIONS IN RANDOM ORDER

- Distributed projects are now normal
- Remote working has demonstrated (forced by the current emergency) to be a manageable possibility for day to day work
- On the other hand, lab work can't be done remotely and localized teams are more efficient for clearly defined work packages
- We must leverage the expertise in the different INAF structures (That is why the Tetis initiative and other similar ones are important)
- Too much of this expertise is lost if we cannot manage to offer stable positions to our younger (but not so young) colleagues