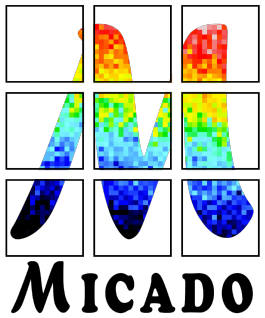
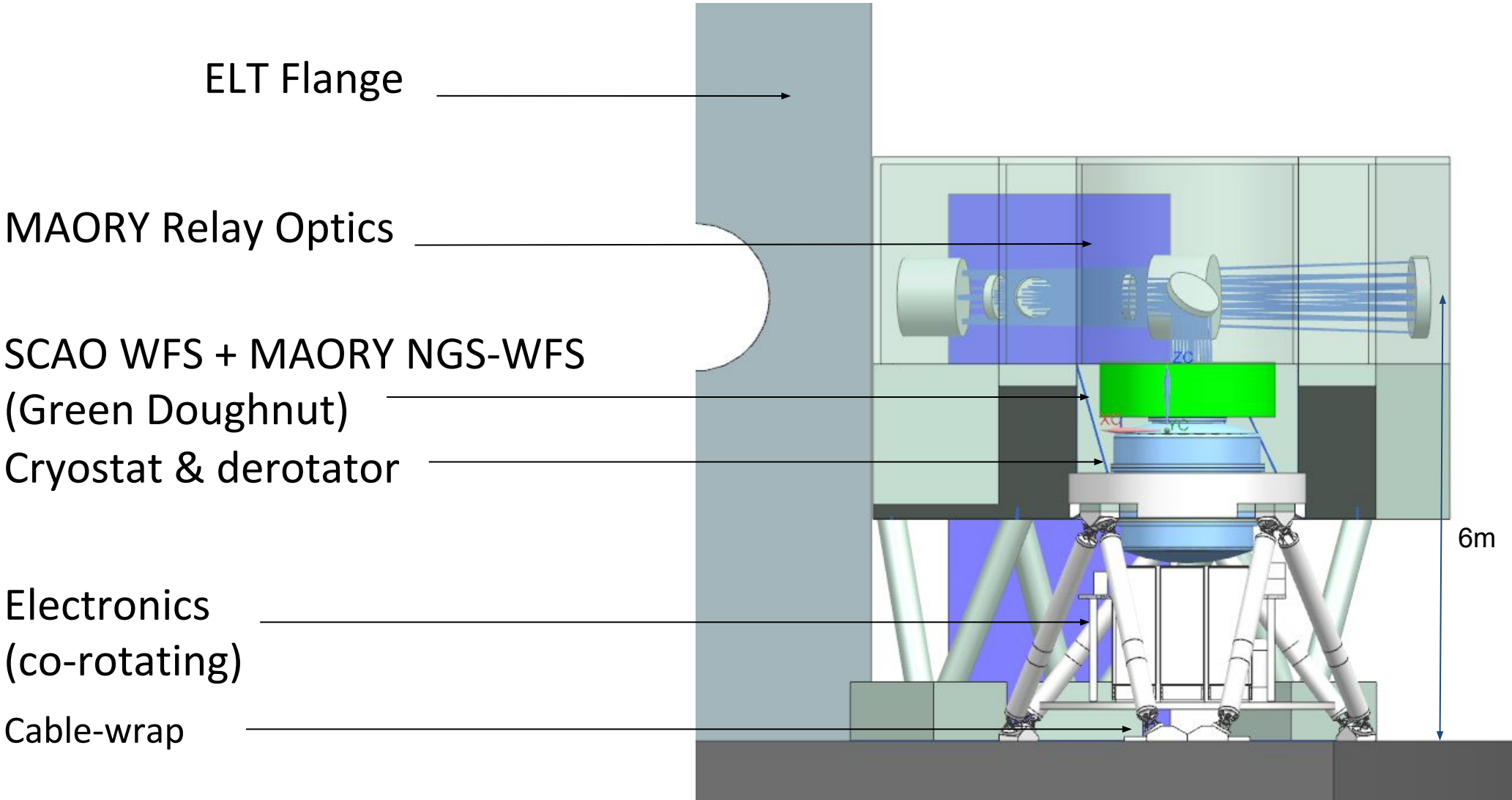


Status of the MICADO SCAO RTC

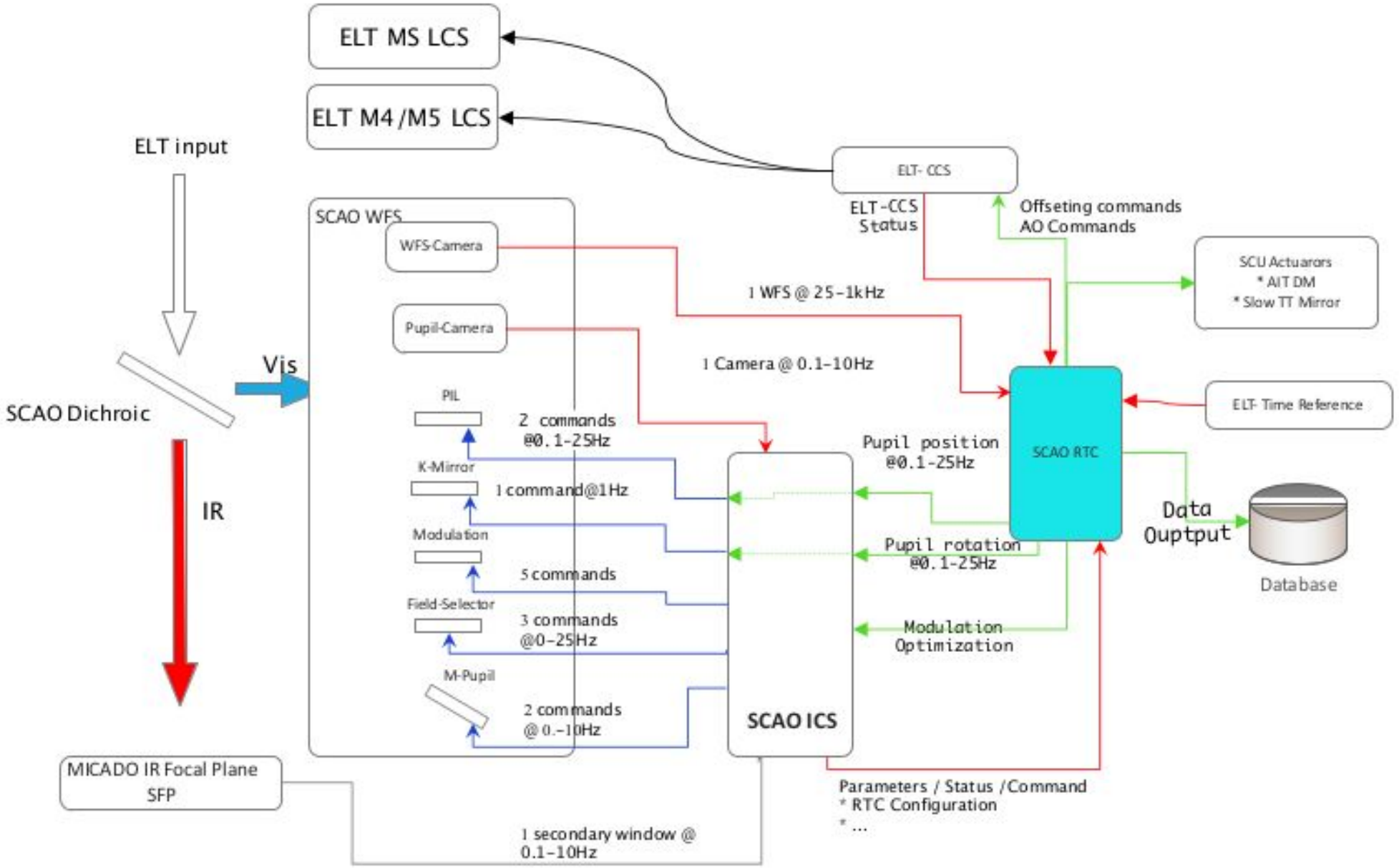
Arnaud Sevin & al.

Global overview of MICADO

MICADO (Infra-Red Camera with multiple observation modes: imaging, zoom, spectrometry and Coronagraphy) located on the Nasmyth Platform with MAORY (MCAO facility).



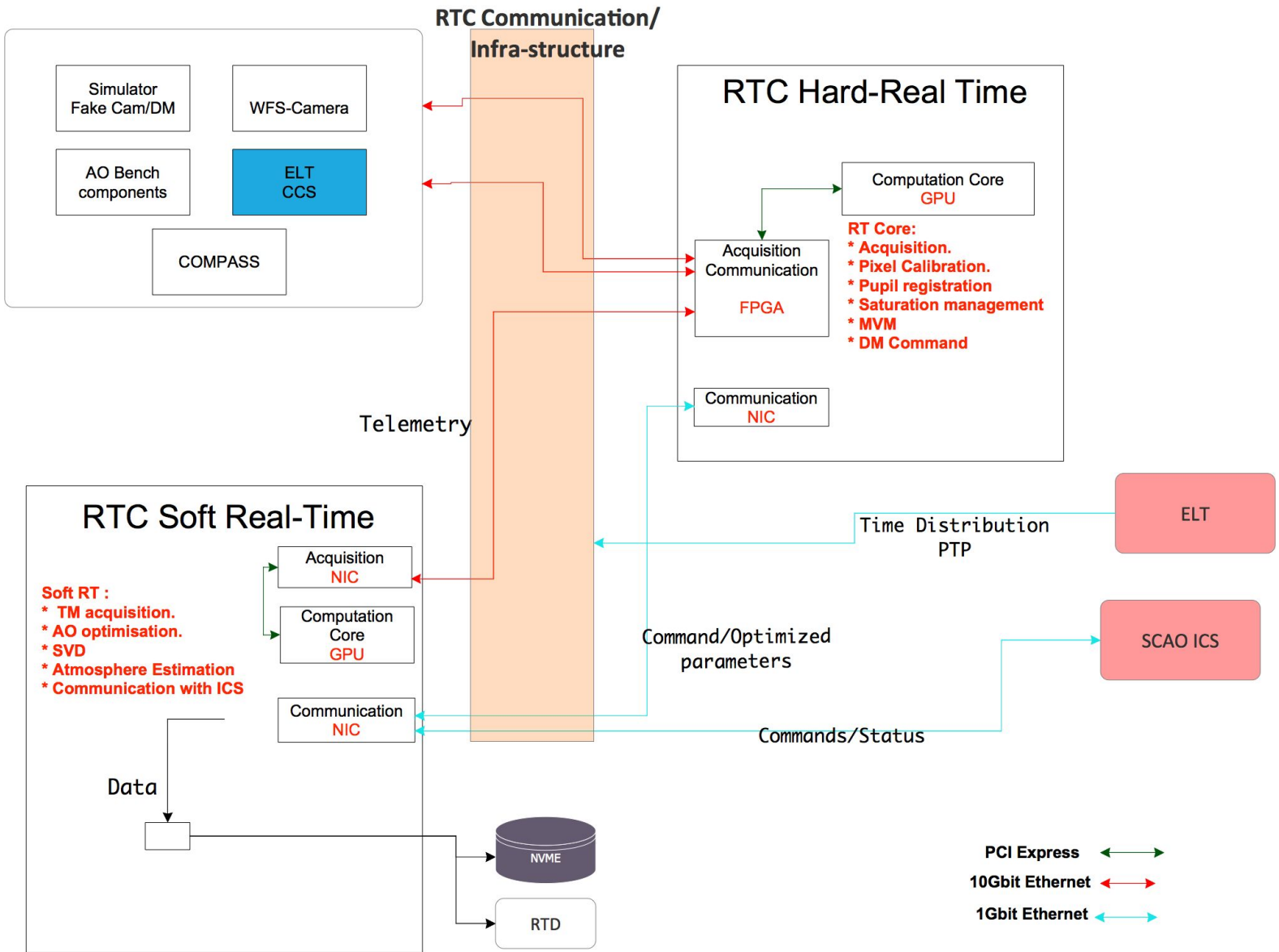
RTC subsystem overview



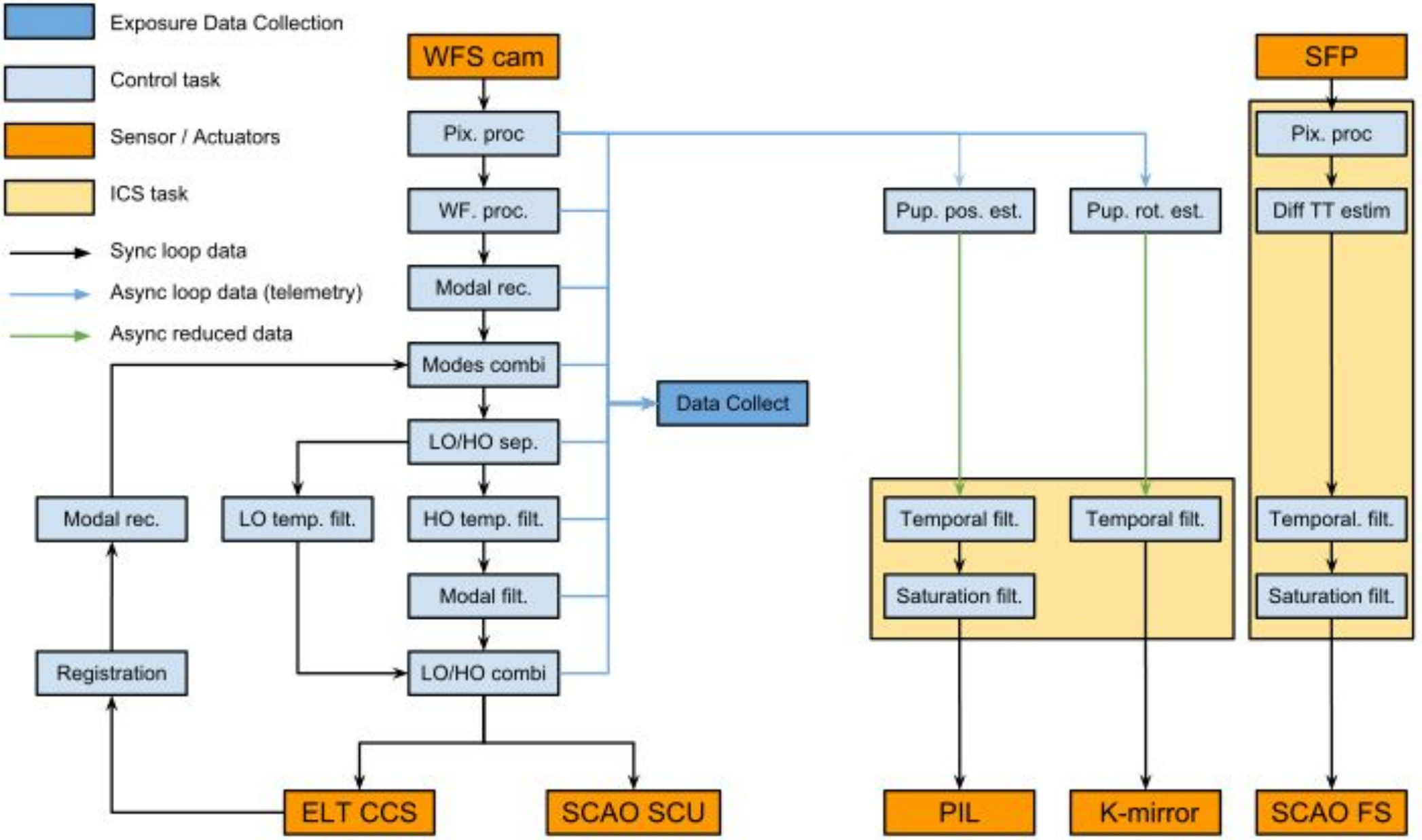
RTC General architecture

The architecture is composed by modules:

- HRTC module
- RTC I/O interface
- Supervision module
- Simulator module
- General SW stack



RTC Functional breakdown



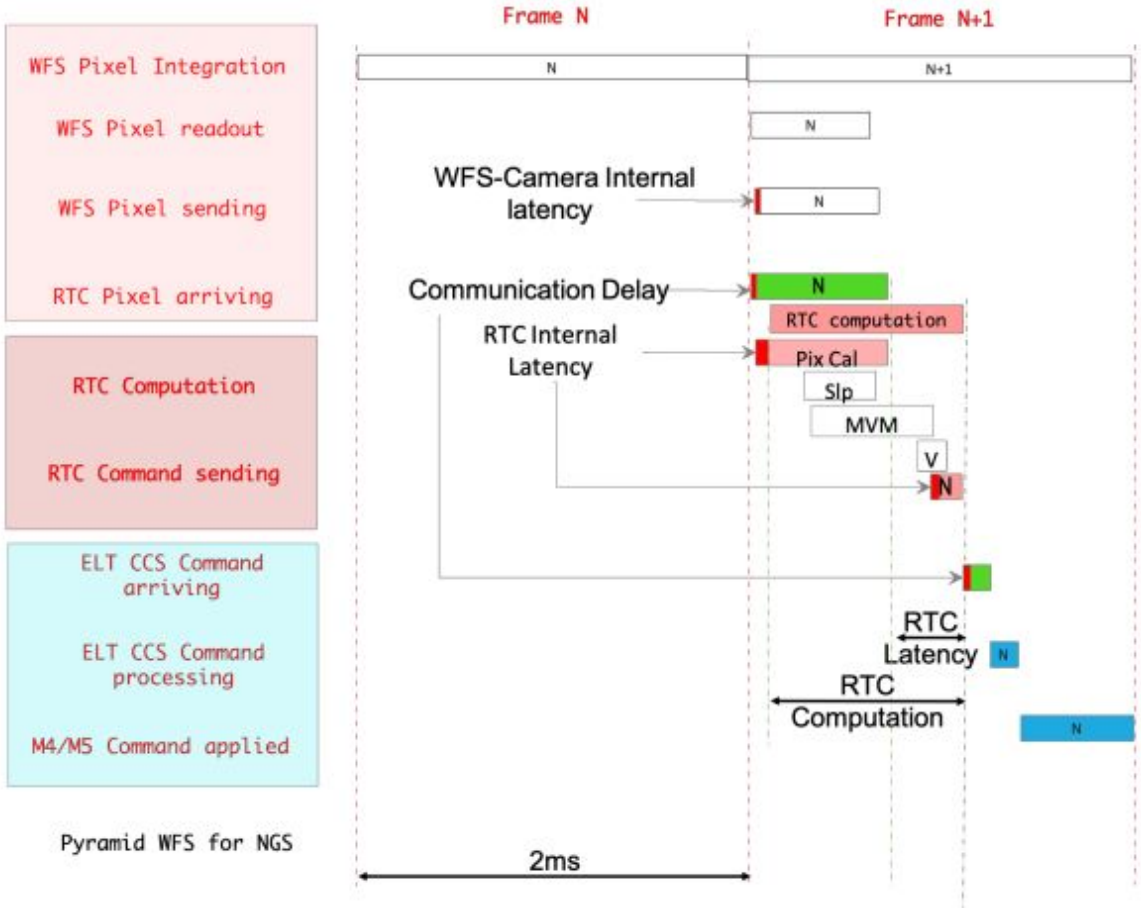
RTC in few numbers

- MICADO-MAORY SCAO baseline
  - Framerate: 500Hz with a goal @ 1kHz
  - 1 Pyramid WFS:
    - 240x240 pixels @500Hz ~500Mb/s
    - 92x92 ssp, around **~24k measurements (full pixels approach)**
  - ELT CCS: **~5.4k commands**
    - **Sequential control: “direct access to M4/M5”**
    - **Cascade control: “residual phase correction”**

- Baseline: linear control with matrix-vector multiply.

- Command matrix for a least-square controler ~3.6Gb ↔ 460Mo

RTC Performance assessment

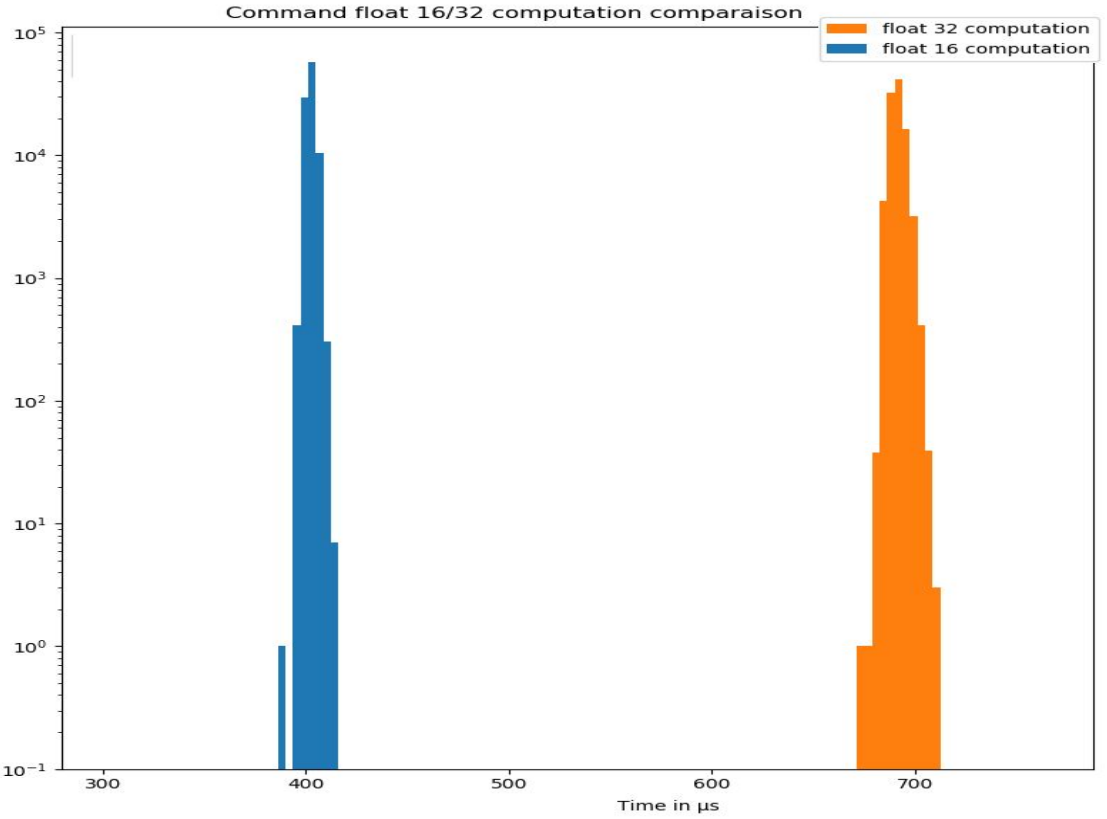


- Timing diagram:
  - Based on CCD220 readout schema.
  - Includes all the components with foreseen Latency.
  - Overlap: slopes computations during frame transfer and also (partial) MVM during slopes comp.
- Req on the global latency is 2 frames, i.e. 4000µs
- From the timing diagram:
  - sequential: 3648us + RTC_latency = 4000us
  - cascaded: 3898us + RTC_latency = 4000us
- Which yields:
  - sequential: RTC_latency <= 352us → **RTC_computation <= 1117us (with overlaps)**
  - cascaded: RTC_latency <= 102us → **RTC_computation <= 867us (with overlaps)**

RTC Performance assessment

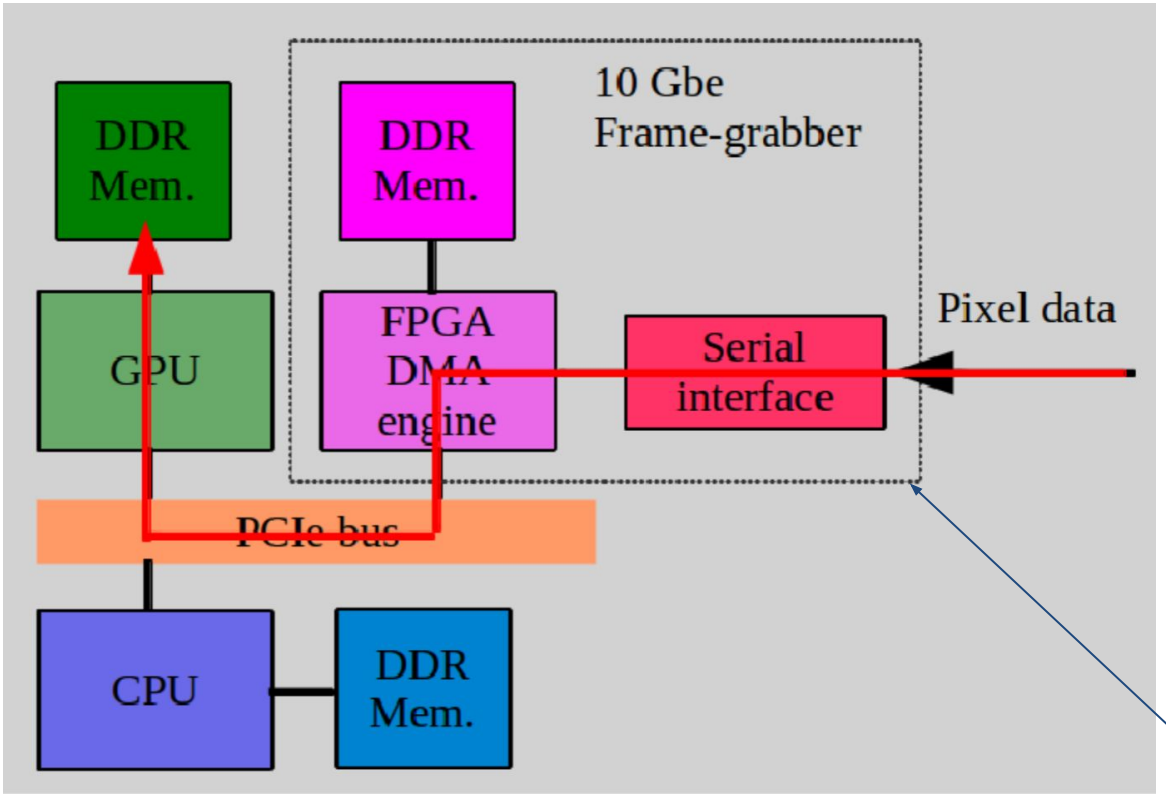
- Hard real-time subsystem:
  - ~24k measurements (full pixels approach) x ~5.4k commands
  - MVM Performance requirements: Need 240 MFLOP per frame with minimal RTC_computation gives 276 GFLOP/s
  - Determinism: 10% jitter over a 500 FPS frame rate so max peak to peak jitter of 200µs is required
- HRTC pipeline performance FP16 vs FP32 timing measured on 10^5 iterations:
  - Requirements:
    - sequential: RTC_computation <= 1117us
    - cascaded: RTC_computation <= 867us
  - Measured on GPU V100:
    - **~700µs in FP32 → 370 GFLOP/s**
    - **~400µs in FP16 → 600 GFLOP/s**
    - **Jitter = 52 µs**

FP16 seems to be enough TBC.

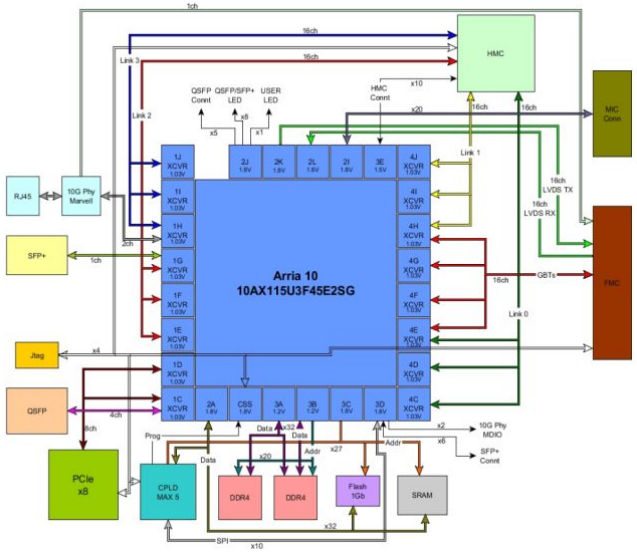


HRTC I/O interface

- Need for tailored data acquisition process to feed the GPU with pixel data



COTS component done and tested by µGate



- Cf Julien BERNARD presentation yesterday

RTC Supervision module (1/3)

- Supervision module: optimization of hard-real time parameters
  - Main powerful task: regular control matrix update
  - Singular Value Decomposition Performance: 750 GFLOP (but also memory-bound)
  - Addressed with a standard HPC cluster

- Performance monitor
  - Loop performance
    - Strehl
    - Latency
  - RT display

RTC Supervision module (2/3)

- Optimizer
  - Pupil registration tasks:
    - measurements based on flux (M1 position)
    - measurements based on slopes+voltages (M4 position)
    - measurements of pupil rotations
    - send the measurements to the ICS.
  - Command garbage collection
  - Command matrix computation & optimization (for mis-registration)
  - Reference slopes:
    - NCPA optical gains
    - Reference slopes rotation
  - Optimal modulation amplitude
  - Background follower
  - Modal gains:
    - PWFS modal optical gains
  - Temporal parameters:
    - Modes
    - Vibration
    - Windshake
  - Pupil guiding parameters (shift and rotation)
  - Disturbances generation

RTC Supervision module (3/3)

- Calibration
  - Dark / background / flat measurement.
  - Interaction matrix
  - Orientation, geometry
  - Noise
  - NCPA / Reference slopes
  - Turbulence estimation (seeing, outer scale, wind speed)
  - M4 pupil (spiders, reflectivity, missing segments, island effect, low wind effect)
  - Flux from guide source
  - Latency (HW and RTC)

Development Plan

Many steps in different environments.

2018-2019: The GF RTC prototype with simulators.
2018-2019: The GF RTC prototype with real Camera (EVT2000 10Gbit-Ethernet) and DM (ALPAO) on AO bench.

2020-2021: MICADO RTC Prototype with OCAM and DM (ALPAO) on AO bench and on-sky experiment (expected by end of 2021).

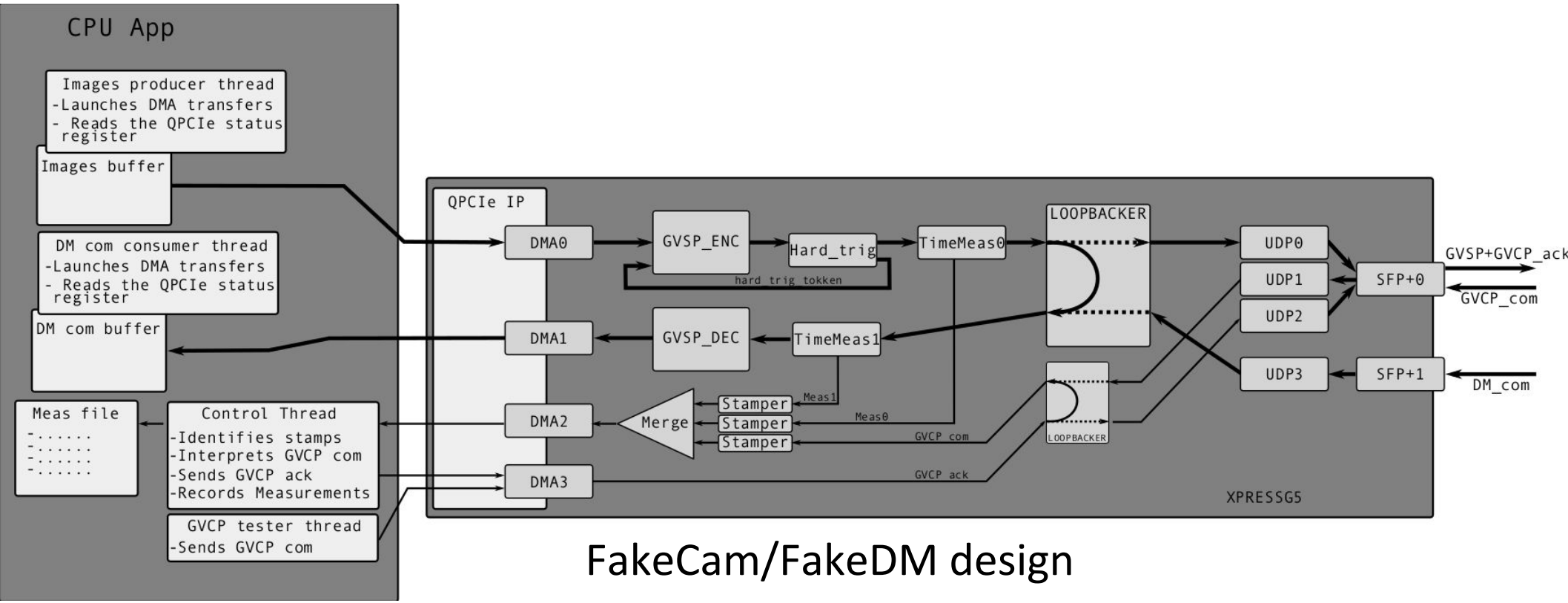
2022: MICADO RTC Prototype dealing with ELT IF (ALICE WFS-Camera, ELT CCS Simulator) and SCAO ICS (control software).

2023-2024: Building the MICADO RTC with a new DM to control (CILAS). SCAO and Instrument AIT with first version of RTC.

2024-2025: Instrument integration with final version of RTC, PAE and first-light at ELT.

RTC Simulator module

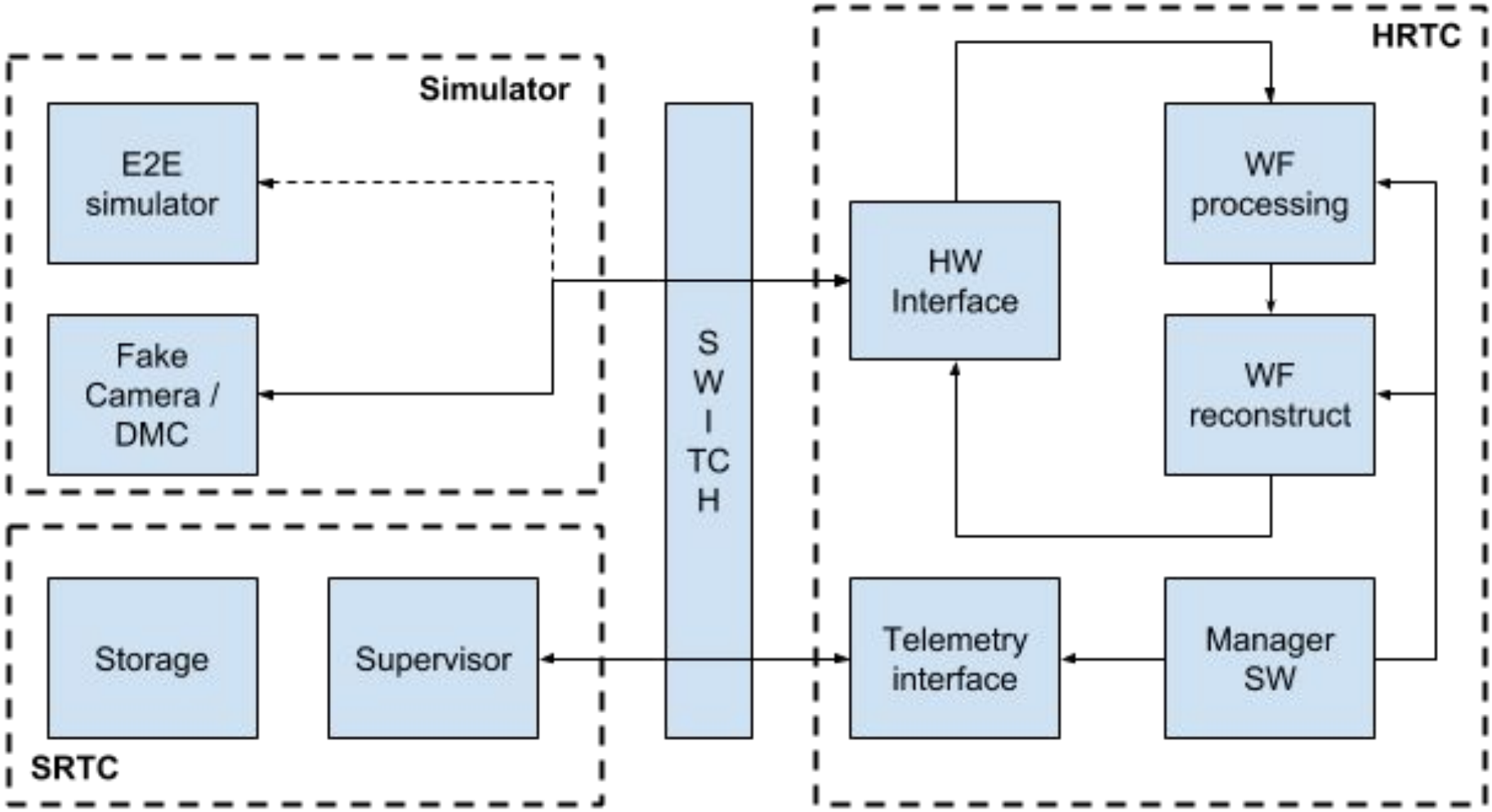
- Simulator module can be used with 2 modes:
  - Coupled with E2E simulator to perform long-term tests
  - Sending precomputed frames at full framerate using a FakeCam and receiving using a FakeDM in a FPGA design. This design is capable to perform an accurate measure of the overall latency.



FakeCam/FakeDM design

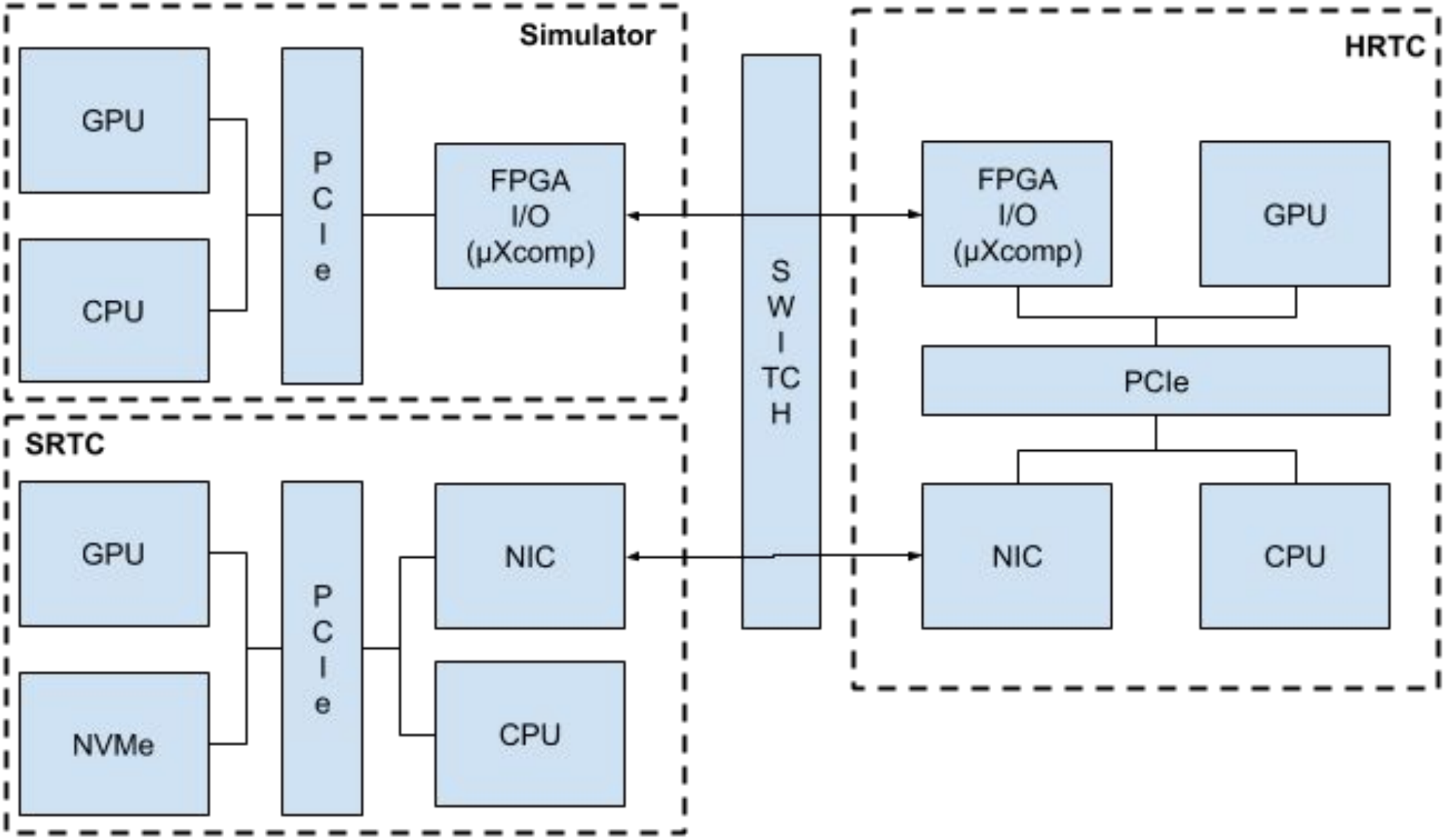
RTC Prototype SW architecture

- Validate the full concept, including the 3 modules:
  - A simulator server
  - A HRTC module receiving / publishing real-time data streams
  - A SRTC module able to perform basic supervision and storage tasks



RTC Prototype HW architecture

- Validate the full concept, including the 3 modules



ESO inputs

- ESO will define a RTC toolkit for instrument consortia
- ESO publishes a call for tenders on RTC prototyping for ELT-CCS (output end of this year?)
- Need to take into account E-ELT specificities : e.g. M4 control, handover between telescope control system and AO system …
- Instrument calibration issues : limited daytime slots for instrument calibration may impose efficient strategies with strong computing constraints
- WFS-Camera and CCS Interfaces.

Instrument inputs

- Definition of the AO Algorithms and Telemetry.
- Specific Camera and DM Interfaces.
- ICS Interfaces.

Conclusions

- MICADO Preliminary Design Phase in progress
- RTC Prototype under test.
- Concerns about the ESO development plan schedule vs. MICADO & MAORY FDR
- LESIA is leading the RTC for the MICADO-MAORY SCAO mode
- LESIA is proposing to build this RTC with foreseen international collaborations (CACAO framework) and industrial subcontracting.