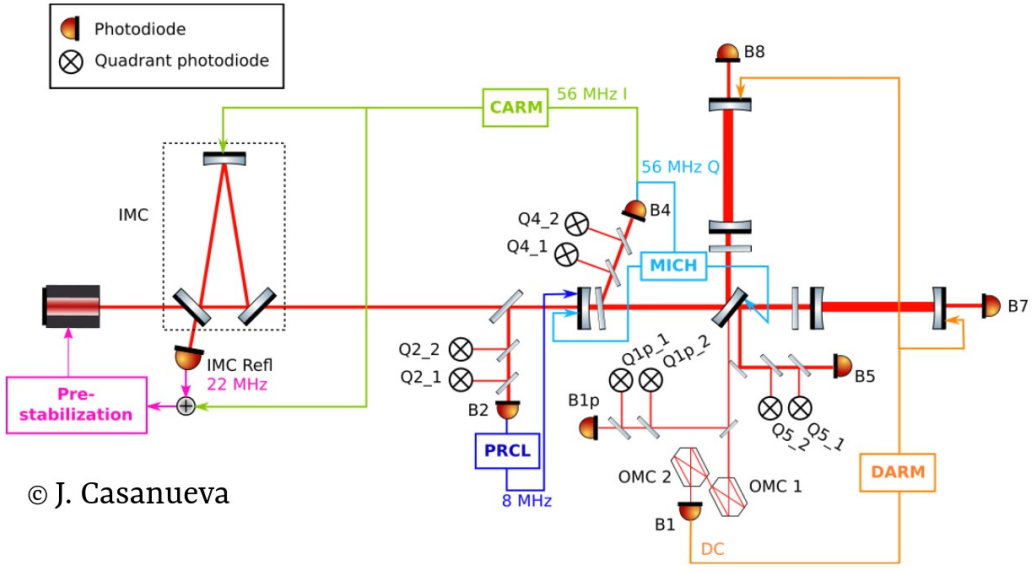
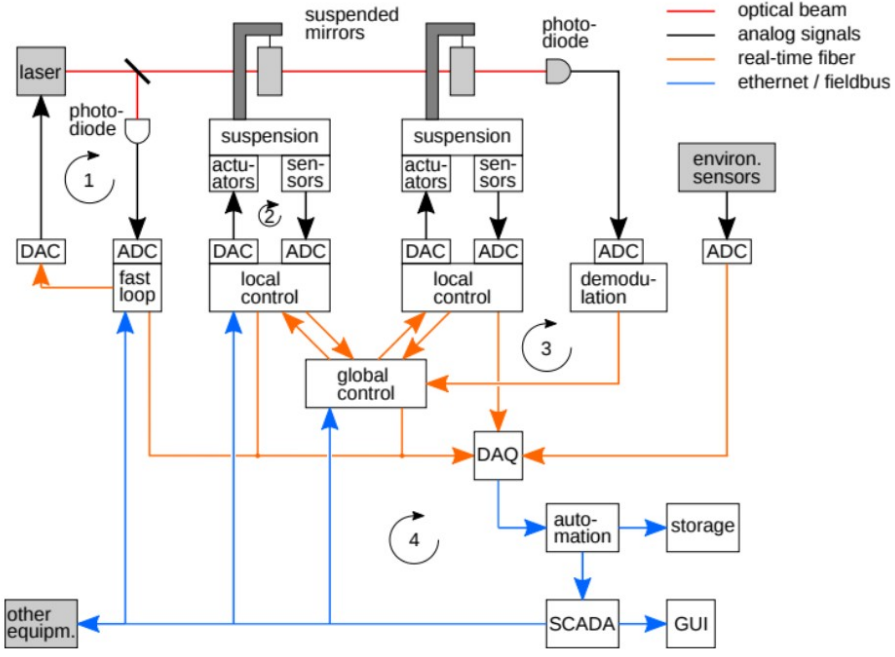
Quelques activités techniques Virgo/ET
Electronique/software pour contrôles temps-réel et acquisition des données

Avril 2024

Interferometer control and data collection





Control system is key part of GW interferometer:

keep mirrors quiet and cavities on resonance at picometer level

Various levels of control loops:

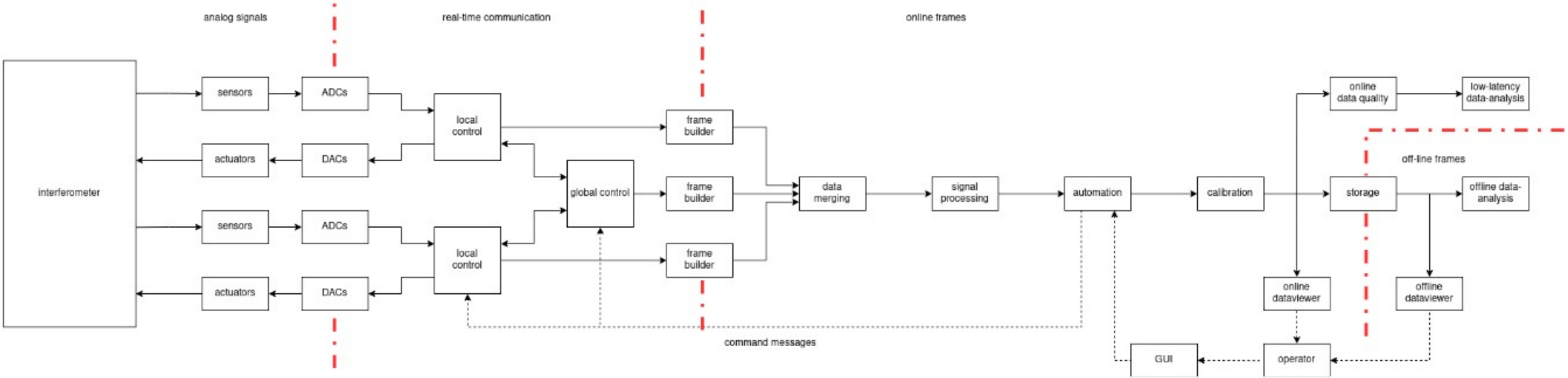
- vary fast analog/digital loops (100 kHz to 1 MHz)
- fast local control of suspension (~10 kHz)
- fast global control of whole interferometer (~10 kHz)
- slow automation: lock acquisition (~1 Hz)
- human in-the-loop monitoring and operation (minutes)

Timing synchronisation over kilometers + constraints on phase noise of clocks

Hard real-time, distributed, hierarchical control. Control bandwidth limited by sampling frequency/delays.

All signals from control system and environmental monitoring recorded by **data acquisition chain**

Collection chain from front-end to data storage



Analog signals of sensors/actuators converted to/from digital,
sent around for **digital real-time controls**

Fast signals **collected** by "frame builders" into chunks of data (0.1 to 1.0 s),
then merged with slow data

Slow automation : update parameters of fast processes based on data in frames

Optional signal processing (decimation, image processing, ...)

Data viewers, GUIs for human interaction with interferometer

Data **storage**
Calibrated strain signal sent to online and offline **data analysis**

Control hardware and software

Evolution going to more and more digital electronics and control loops

Key components:

- ADC/DAC
- computing units: FPGA/DSP/CPU… part of an electronic board, a crate or a remote PC
- real-time communication network
- timing network (timestamp + low-noise clocks)
- software : real-time software, data collection chain, automation, supervisory control, …

Not everywhere a single solution in Virgo

- for example specific real-time electronics used for the suspension (developed by Pisa group)

+ different configuration and control softwares

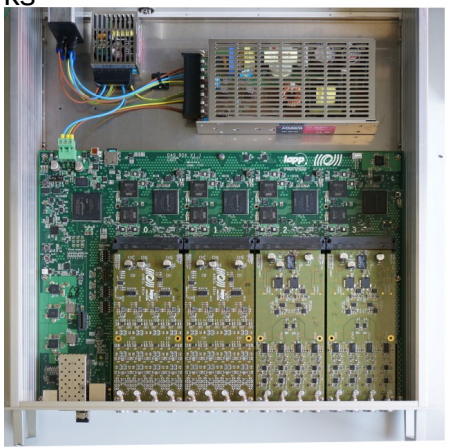
→ limit the number of experts on different solutions ; more difficult for users to acquire knowledge on different systems

Opportunity to start from scratch for E.T., applicable/testable in Virgo (or part of Virgo)

Real-time digital electronics/software developped at LAPP

DAQ-box with slots for 4 mezzanines

- mother board with DSPs for decimation, FPGAs, interface with data and timing networks
- analog front-end and ADC/DAC chips
- digital demodulation with on-board FPGAs
- fastDAC for some loops with UGF of ~10 kHz
- photodiode acquisition and control, camera control
- timing clock generation
- associated software/firmware for configuration and slow monitoring



Real-time PCs

- fast PC with real-time Linux
- PCIe board for timing and data network interfaces
- software for real-time I/O and synchro of real-time processes
- software for computing control loops and signal processing
- software for front-end data collection

MuxDemux boards as “switches” of real-time data network

TimingDistributionBoxes for timing distribution

- timing synchro over 2x3 km arms, at the ~100 ns level
- 100 MHz clock with low phase noise for digital demodulation
- on-going move to WhiteRabbit, in collaboration with Nikhef

Virgo slow monitoring and automation

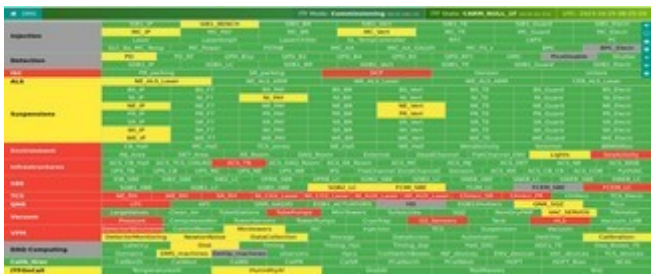
Automation

running on the DAQ server
1 Hz loop

Detector slow monitoring: some additional machines at EGO

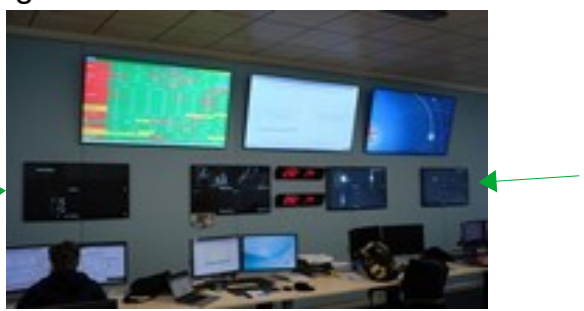
Cm nameserver
Virgo Process Monitoring server (VPM)
Detector Monitoring System server (DMS)
…

} GUIs Web interfaces for users

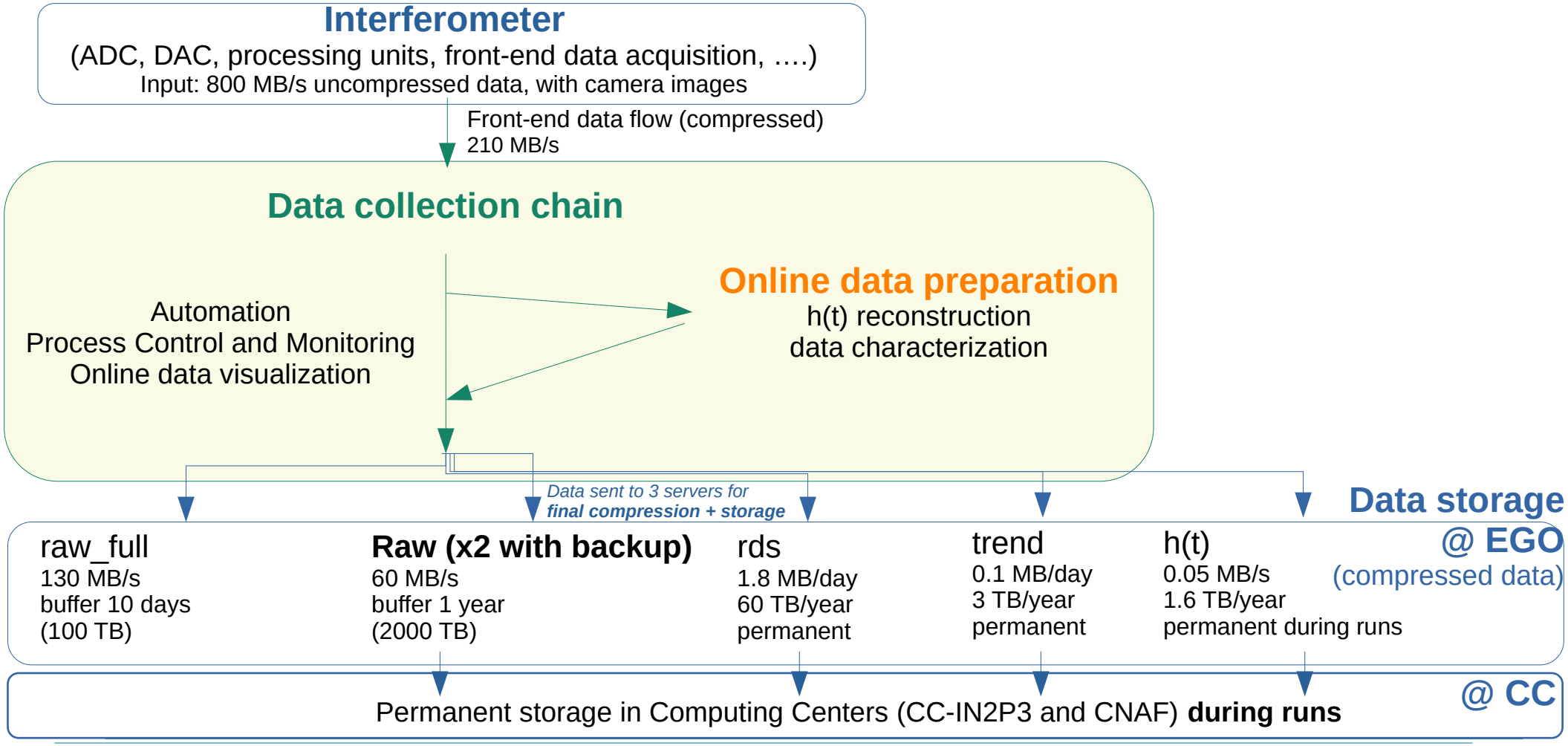


Camera image visualization in control room screens

2 vid machines, each with 16 CPU and 50 GB memory
4 screens for display
home-made software for display configuration



Virgo data collection : main data flows



Scaling up from Virgo to ET

No major technological breakthroughs needed to control ET, could be evolution of current hardware
Virgo will still be online for ~20 years, upgrades of current hardware will be needed

- data flux might increase by ~1 order of magnitude: Virgo produces 5 TB/day (1 “raw” flux), ET will have multiple interferometers that are more complex

- longer arms (3 km → 10 km, or more?): control strategy due to larger transmission delays?

- ADCs and DACs noise close to limiting for some critical sensors/actuators

- some faster digital loops (to replace some more analog loops)

- (slightly) better timing: lower phase noise (for digital demodulation)

- upgrade software/hardware to state-of-the-art

- make things more uniform/maintainable: don’t have multiple devices for the same job

Some possible activities… “DAQ” electronics and software

Investigations towards E.T. but applicable/testable on (a part of) Virgo

Fast digital control loops
- with unity gain frequency ~>100 kHz (for laser, injection, …)

Digital demodulation :
- on-going R&D at LAPP, based on demodulation computed on FPGA
- exploration of alternative solutions, for example computation on GPU

Network for real-time data
- explore solutions, future developments as WhiteRabbit 10 GB

Alternatives to real-time software (Tolm, Acl)
- use a friendly user-interface, matlab/simulink to design filters and configure controls
- on-going activity at LAPP about real-time kernel, with possible impact on real-time software

New tools for data visualisation
- web version ?

Control electronics for the suspensions (driven by Pisa)

Evolutions of data collection and data format

+ help in reviewing and completing the ET PBS

Any other topics of interest from IP2I?

Some possible activities… others

More directly useful for Virgo (within DETetection and CALibration sub-systems)

Participation to test and installation of ADC/DAC channels for O5 ?
- as a training

Calibration of photodiodes (absolute timing and frequency-dependent response)
- develop method on calibration test-bench
- installation on Virgo (EDB, SDB2 benches)

Fast-shutter for detection bench
- electro-mechanics and driving
- possibility that LAPP will work on it

Interface of real-time control and DAQ with EIB ?