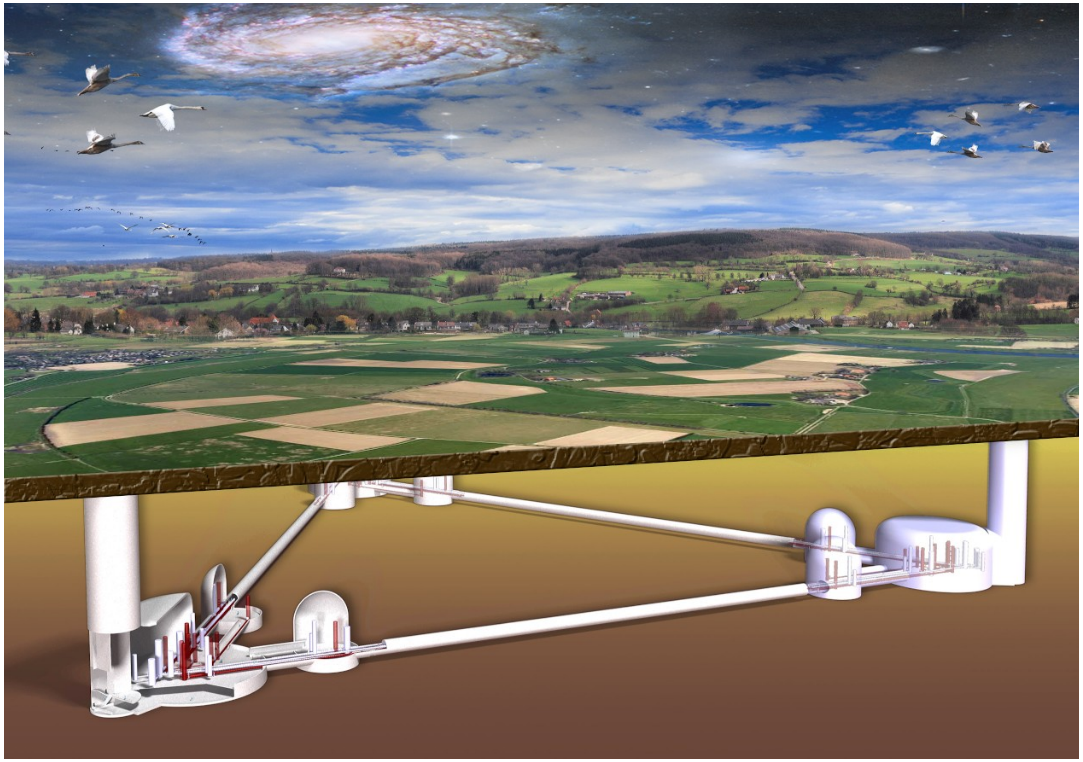
# Online computing for ET



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Einstein Telescope

EIB kick-off meeting
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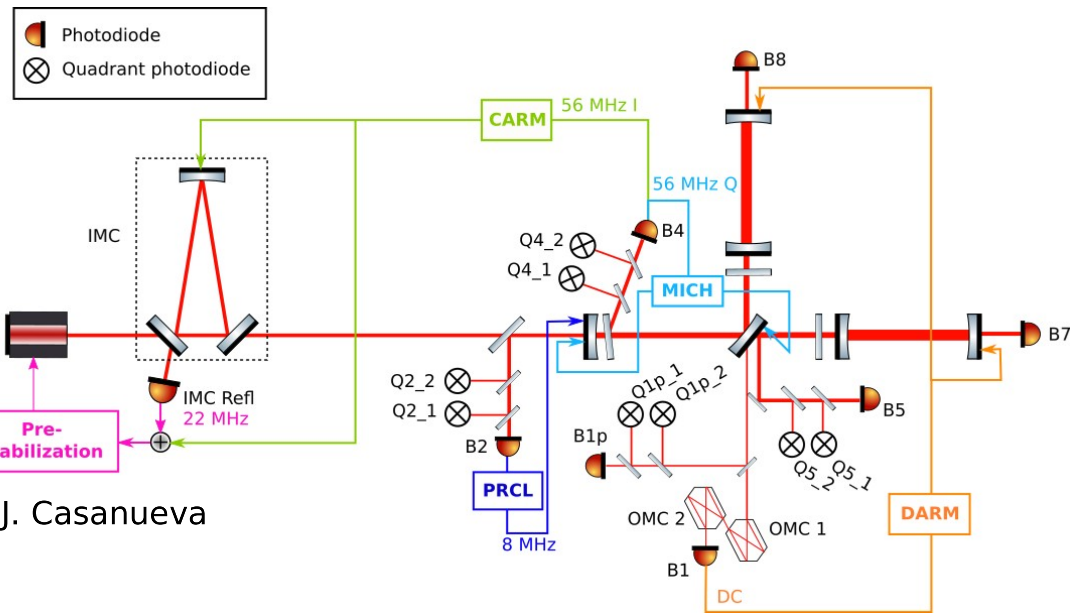
# Outline

- Overview of various types of online computing needed to control and operate a GW interferometer
- Explain Data Acquisition (DAQ) chain
- First attempt at defining what is in scope for DAQ/control WP and what for the EIB

- Disclaimer: I am not an expert on computing or data analysis, but have interacted with all software needed to run the Virgo interferometer

# Instrument control

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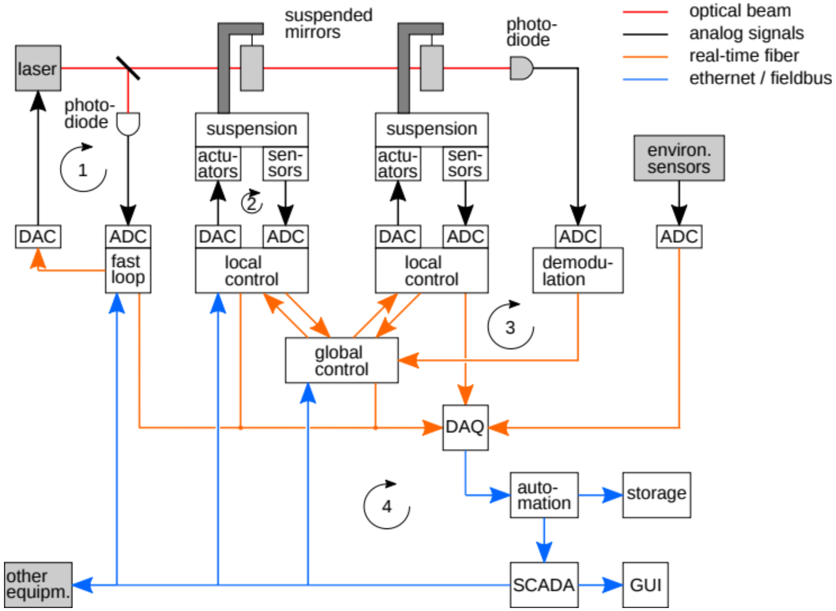
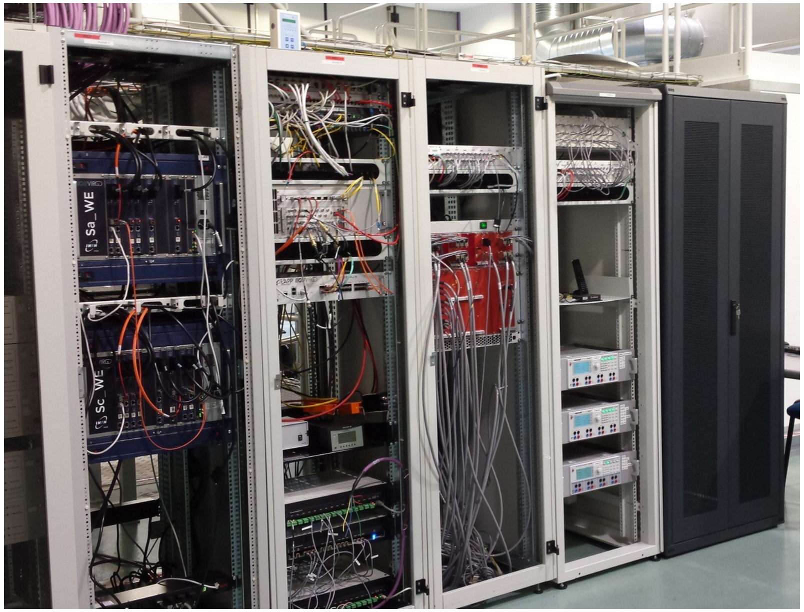
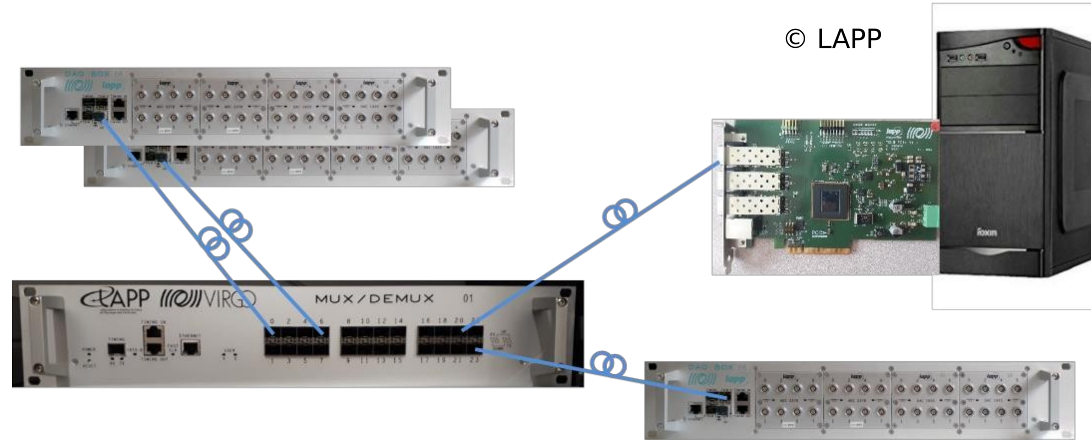



- Control system is an integral part of a GW interferometer: keep mirrors quiet and cavities on resonance
- Various levels of control:
    1) very fast analog/digital loops (~MHz)
    2) fast local control of suspensions (~10 kHz)
    3) fast global control of whole interferometer (~10 kHz)
    4) slow automation: lock acquisition (~1 Hz)
    5) ‘human-in-the-loop’ monitoring and operation (minutes)
- Hard real time, distributed, hierarchical control
- All signals from control system and environmental monitoring recorded by data-acquisition (DAQ) chain

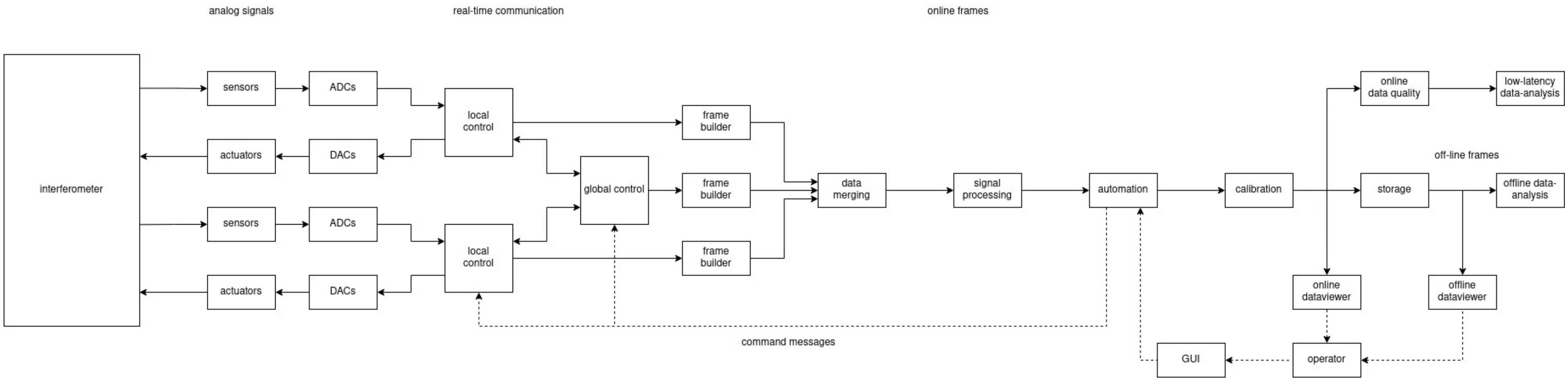
# Control hardware





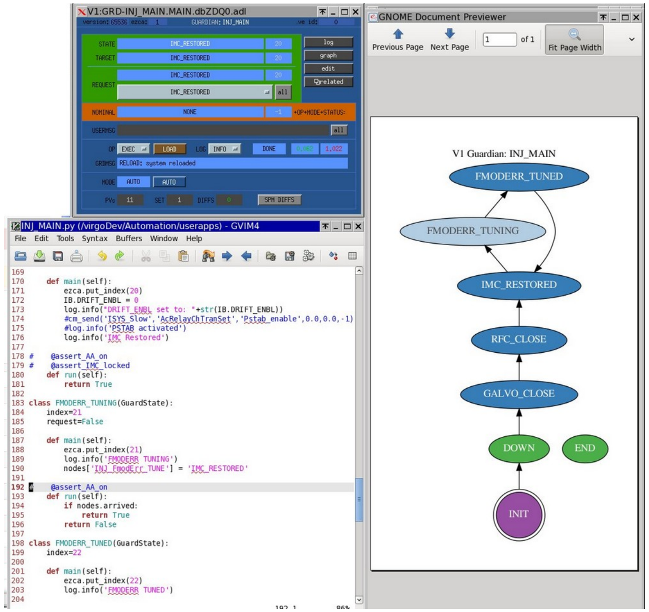

- Historic progression of control electronics: analog -> barely working custom digital -> comfortable custom digital -> off-the-shelf
- Current generation: hard real-time digital control consisting of ADCs, DACs, DAQ-boxes and controllers (real-time Linux PCs, DSPs). Typical sample frequency 10-20 kHz, control algorithm programmed by end-user in Simulink or similar
- Distributed system, sensors and actuators separated by kilometers: need real-time fiber communication
  LIGO uses ‘Reflected Memory’ by Dolphin, Virgo uses home built fiber system (TOLM), maybe >10 Gbit Ethernet in future?
- Fastest loops are mostly analog, but some recent examples of digital loops at ~1 MHz
  More flexible, might go completely digital in future

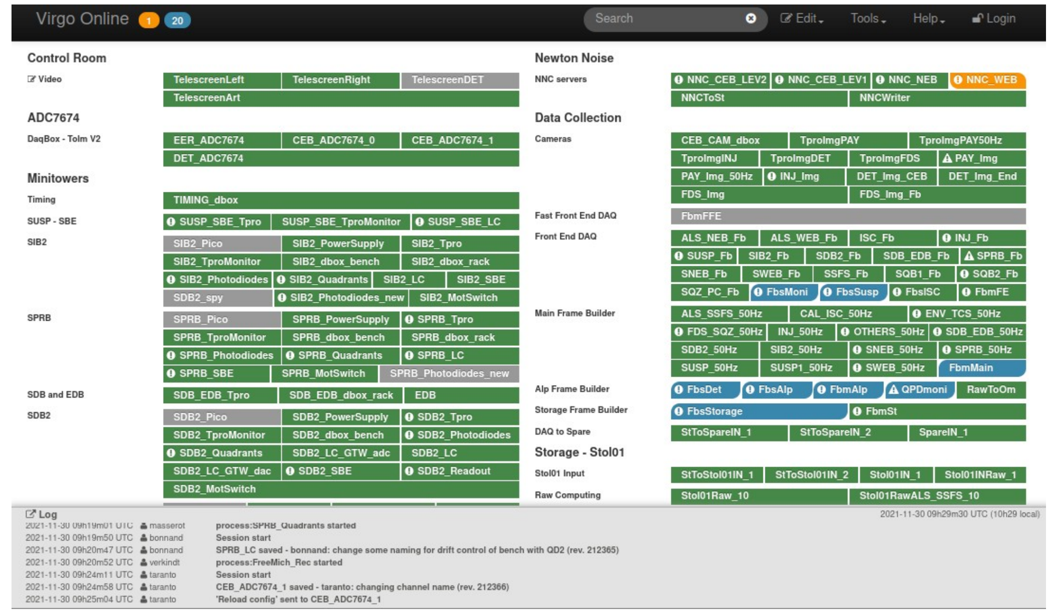
# DAQ chain




- '*frame builders*' which collect the data of the fast real-time processes in 1-sec chunks of data
- merging of various data streams
- additional signal processing (decimation, image processing, ...)
- automation nodes
- forward frames to storage machines and low-latency pipelines
- provide data viewers, GUIs for human interaction with the interferometer
- data flux relatively modest compared to e.g. CERN, but we care about latency

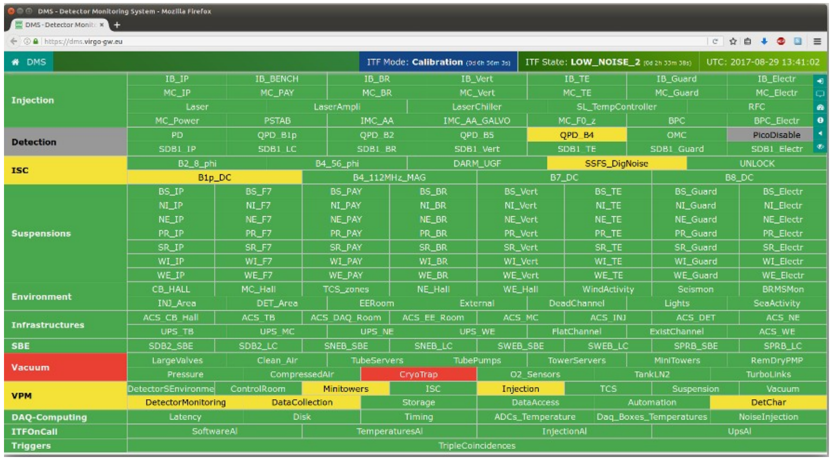
# Automation



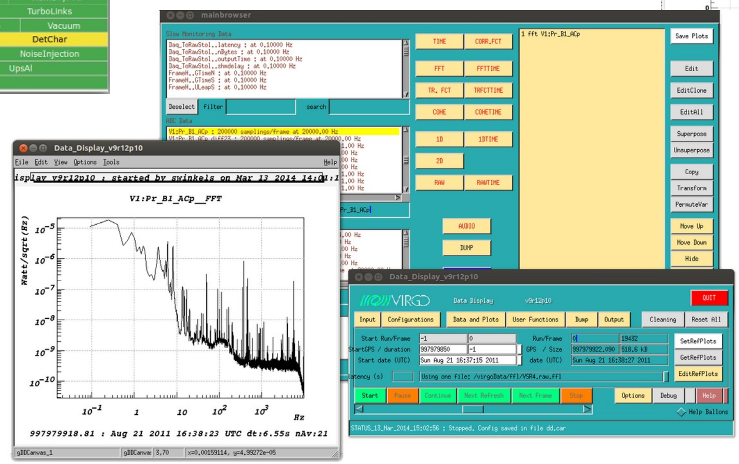




- Automation processes are embedded in the DAQ chain, so they have access to all data (with a latency of a few frames). Responsible for sequencing lock acquisition, various slow loops, basic safety checks
- Currently Python-based hierarchical set of state machines: Guardian/Metatron, see arXiv:1604.01456
- Needs a SCADA-like framework/communication protocol to change parameters of the fast processes (change gains/offsets/change filters, switch on loops): EPICS, TANGO, Cm, ...
- Process monitoring: Virgo Process Monitoring (VPM)

# Monitoring








- GUIs, data viewers for live monitoring of instrument status
- Web-pages with predefined plots for monitoring on scales of hours to days
- Supervising process to check that thousands of parameters are at their expected values, send alarm messages via mails/SMS when something breaks at night: Detector Monitoring System (DMS)

# In scope for DAQ/control WP

- Exact boundaries TBD, but roughly “all specialized computing hardware and software that directly interfaces with the experimental hardware”: DAQ front ends, data collection, monitoring, data visualization
- Interface with hardware subsystems: monitor/provide analog and digital signals from sensors and actuators, provide computing for their control loops
- Interface with EIB: infrastructure (hardware, software, network), data storage
- Estimate total data flux from front ends to storage input
- Choose the hardware architecture for the real-time detector control and data acquisition:
  - general purpose front-ends with ADCs, DACs
    (as far as they are not built into the sensors/actuators)
  - fast ADCs for digital demodulation
  - low phase noise timing distribution
  - real-time communication network (TOLM, reflective memory, ...)
  - fast computing for controls (real-time PC, DSP, FPGA, ...)
- Provide the software tools/architecture for the detector slow control
- Provide the software tools/architecture for the data acquisition pipeline

# In scope for EIB

- Provide general purpose computing hardware for running the DAQ chain and slow controls
- Integrate the hardware for the real-time control in the general computing environment
- Provide hardware for control room and other needs of the commissioners (user management ...)
- Provide network hardware (fibers, patch-panels, ...) and management (DHCP, HTTP, ...) used by all experimental devices
- Install and maintain operating systems for DAQ system machines
- Long term storage, distribution and backup of data
- Design the data flow and architecture for online alert generation system
- All off-line computing

# Grey areas

- Shared between EIB/DAQ
  - chose frameworks for low-latency frame distribution (Fd like)
  - chose protocol for inter-process communication (Cm/TANGO/EPICS like)
  - define file format for data exchange (gwf, hdf5, ...)
  - common package management?
- Done by other subsystems
  - provide space, power, cooling for underground control hardware (Infrastructure)
  - software for online data quality (Detector Characterization)
  - software for online/offline data analysis (Data analysis)
  - hardware/software for safety critical systems (laser interlocks, PLCs for vacuum system ...). Best if this is provided by the corresponding subsystem, but all status data should be provided read-only to the DAQ system

# Scaling up from Virgo to ET

- No major technological breakthroughs needed to control ET, could be evolution of current hardware
  - data flux might increase by order of magnitude: 4 TB/day now, but we will have multiple interferometers that are more complex
  - would like ADCs, DACs with a bit less noise
  - slightly faster digital loops (replace some more analog loops)
  - slightly better timing: lower phase noise
  - upgrade software to state-of-the-art
- Go more from custom built hardware and software to off-the-shelve where possible

# the end...