Fusion Technologies

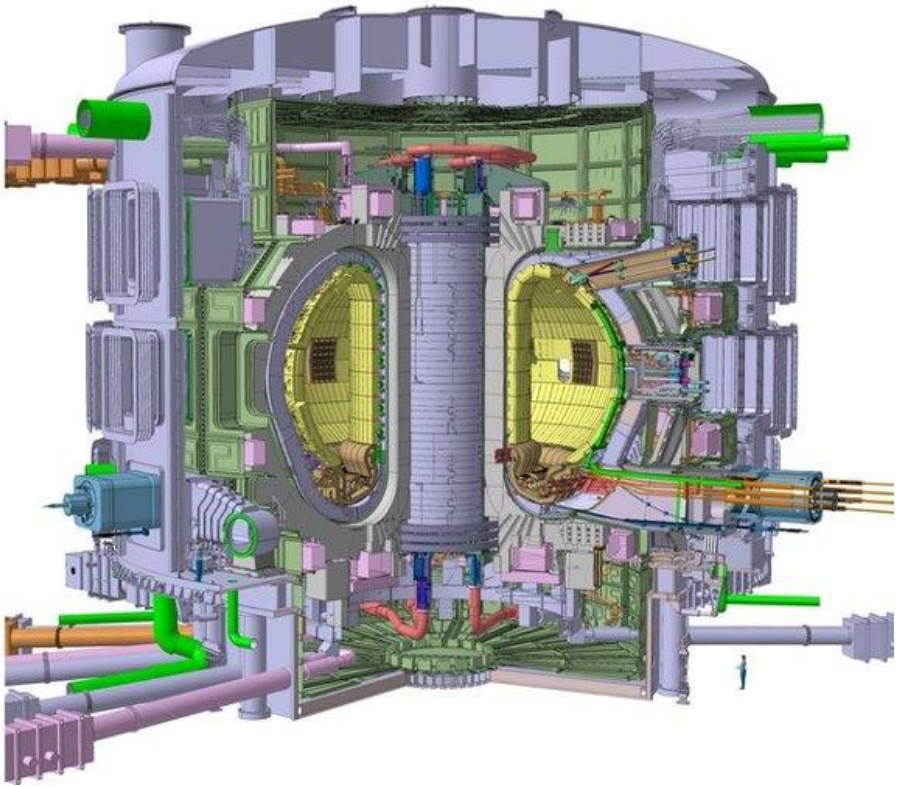
IT, control, data acquisition

J. Decker

Special thanks to :
B. Duval, C. Galperti, SPC IT team

Introduction : fusion experiments

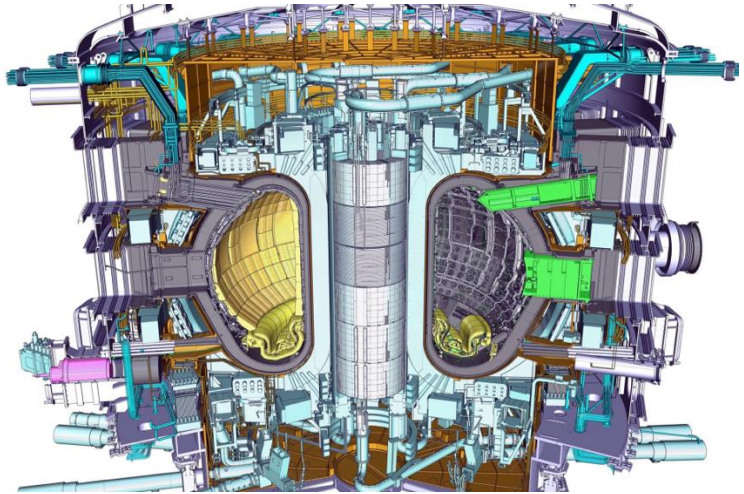
- Fusion experiments are complex interconnected systems
- A fusion plant requires safety protocols and 24/24 monitoring
- Magnetic fusion experiments operation mode is cyclic



Introduction : Fusion and IT

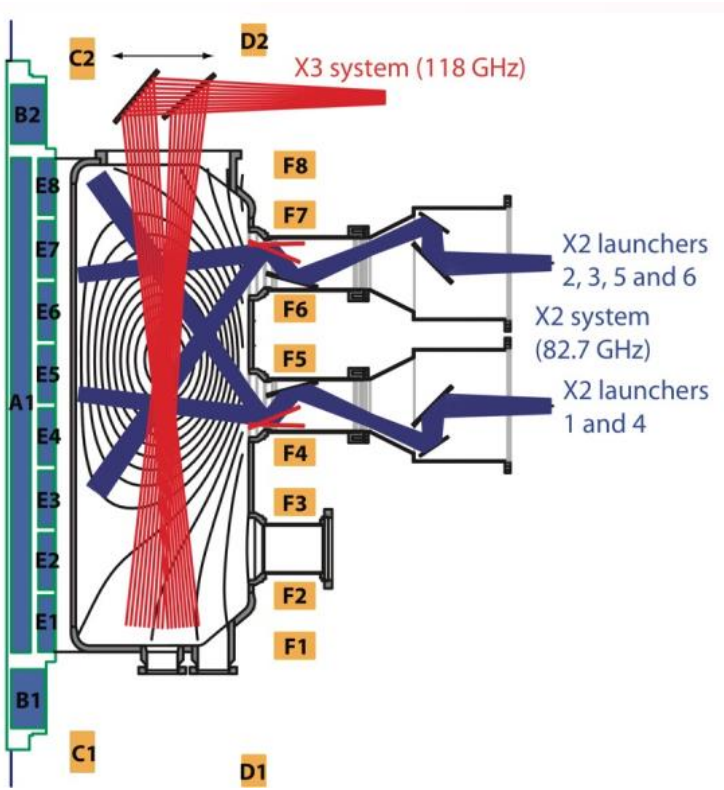
- **Fusion experiments are digital systems**
  - Computers control (nearly) everything
  - Almost all measurements are voltages, currents, or (especially recently) images.

- **IT is central to all fusion activities**
  - Diagnostics
  - Actuators (heating, fueling, shaping, ...)
  - Real-time control
  - Data analysis
  - Theory



Example : actuators on TCV

- **Building a new diagnostic or actuator always requires advanced IT developments**
  - Identify control variables and integrate in TCVCS (TCV control system)
  - Write drivers for equipment I/O
  - Program state machine and synchronization
  - Prepare structures for acquiring data
  - Setup signal digitization
  - Convert raw signals to physical quantities
  - Integrate in post-shot analysis



General remarks

- Fusion experiments mix **hardware and software, physics and engineering**
  -> **IT must integrate this diversity**
  - Hardware and software development are part of the research effort

- This talk focuses on TCV
  - 30 years of history, a remarkable mix of old and new technology

- Despite dozens of fusion research plants worldwide, there has been surprisingly little effort towards common IT solutions

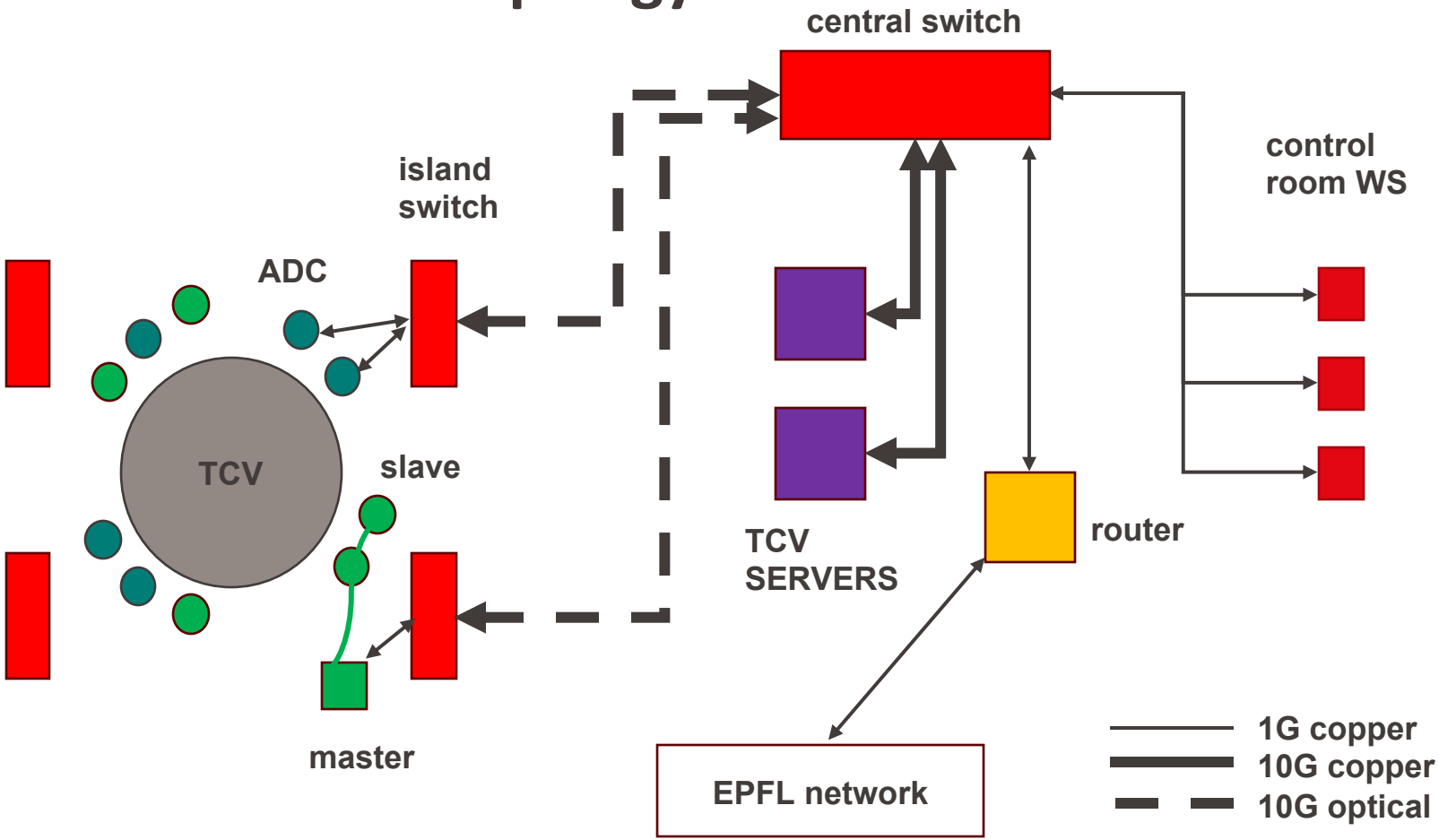
- Control and data acquisition are increasingly intertwined
  - We need to save control data (for analysis, ML, and future shots)
  - We need to control data acquisition (setup, timing, …)

Outline

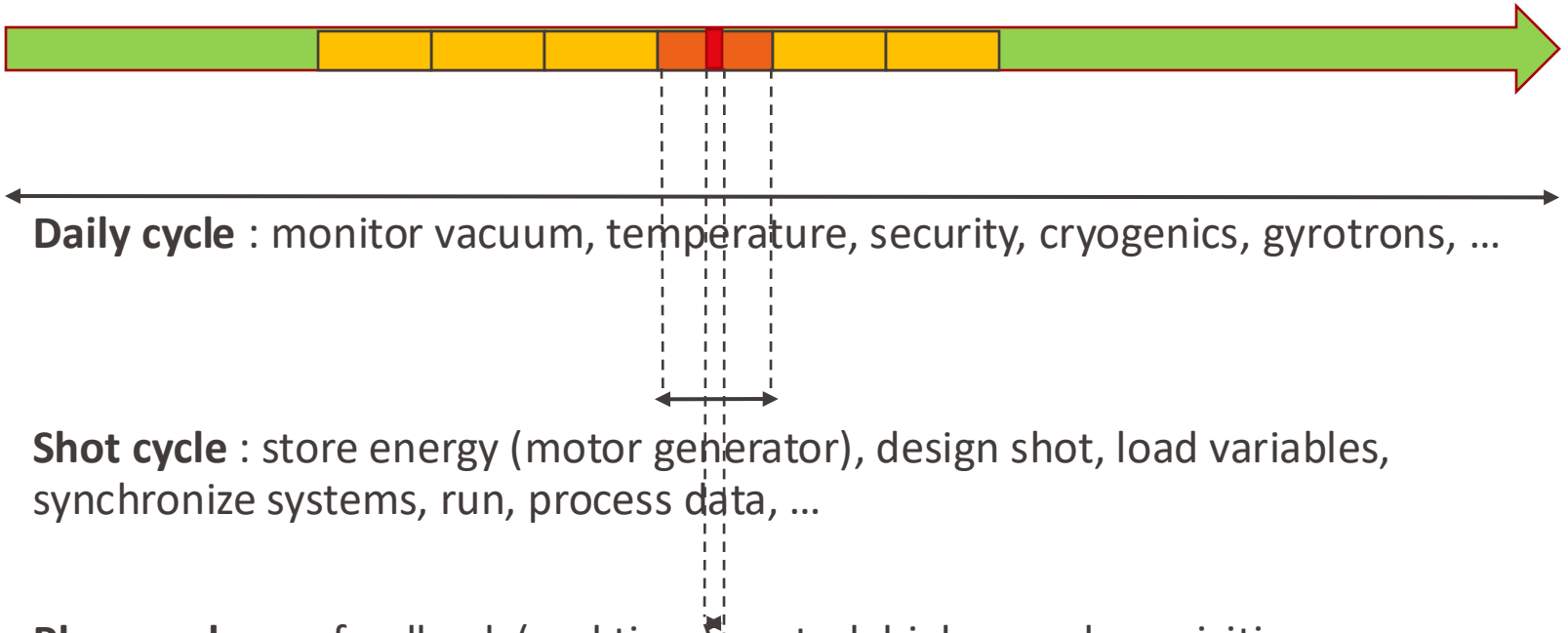
- First Part
  - Fusion experiment timeline
  - Plant and plasma control
  - Real time control
  - Digitization & acquisition

- Second Part
  - Data processing
  - Data organization, data access, outreach
  - Data storage and backup
  - Fusion IT environment

TCV Network topology



Fusion IT timeline



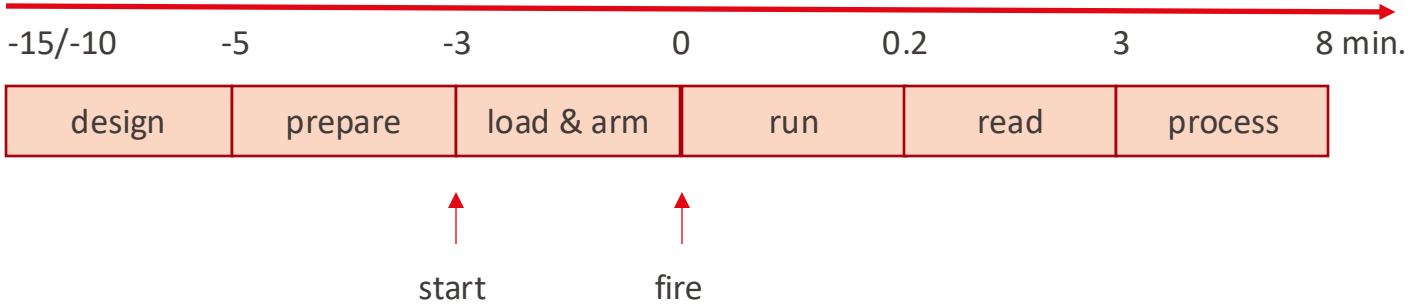
Daily cycle : monitor vacuum, temperature, security, cryogenics, gyrotrons, …

Shot cycle : store energy (motor generator), design shot, load variables, synchronize systems, run, process data, …

Plasma phase : feedback (real time) control, high-speed acquisition

TCV shot cycle

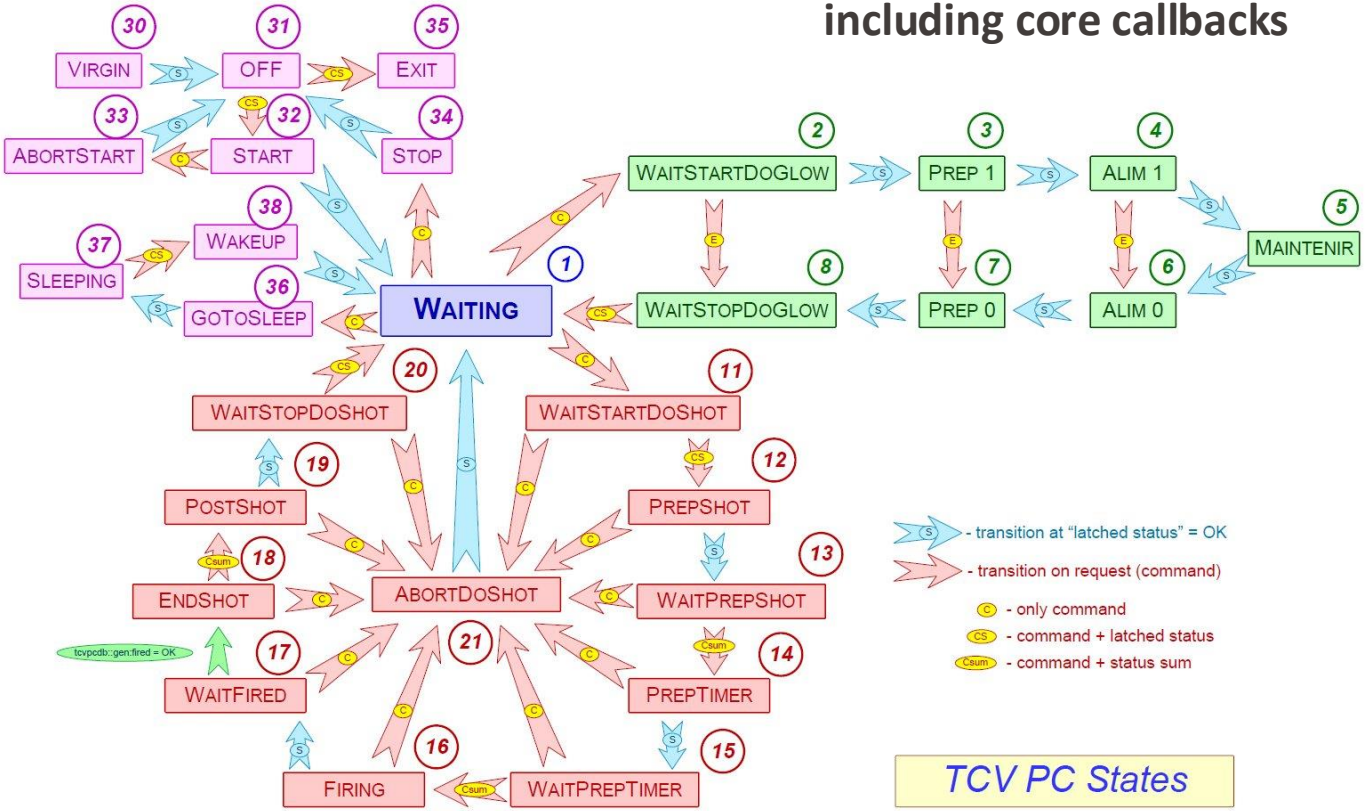
- Fusion experiments are based on shot cycles



- **design** (session leader) : plasma evolution, heating selection, diagnostics
- **prepare** (pdj, ddj) : control waveforms, equilibrium prediction, timing, gains
- **load & arm** (IT) : setup acquisition, load control variables into systems
- **run** (pilot) : plasma discharge, feed-forward and feedback (real-time) control
- **read** (IT) : transfer data from digitizers to server
- **process** (IT + physicists) : analysis chain to calculate physical quantities

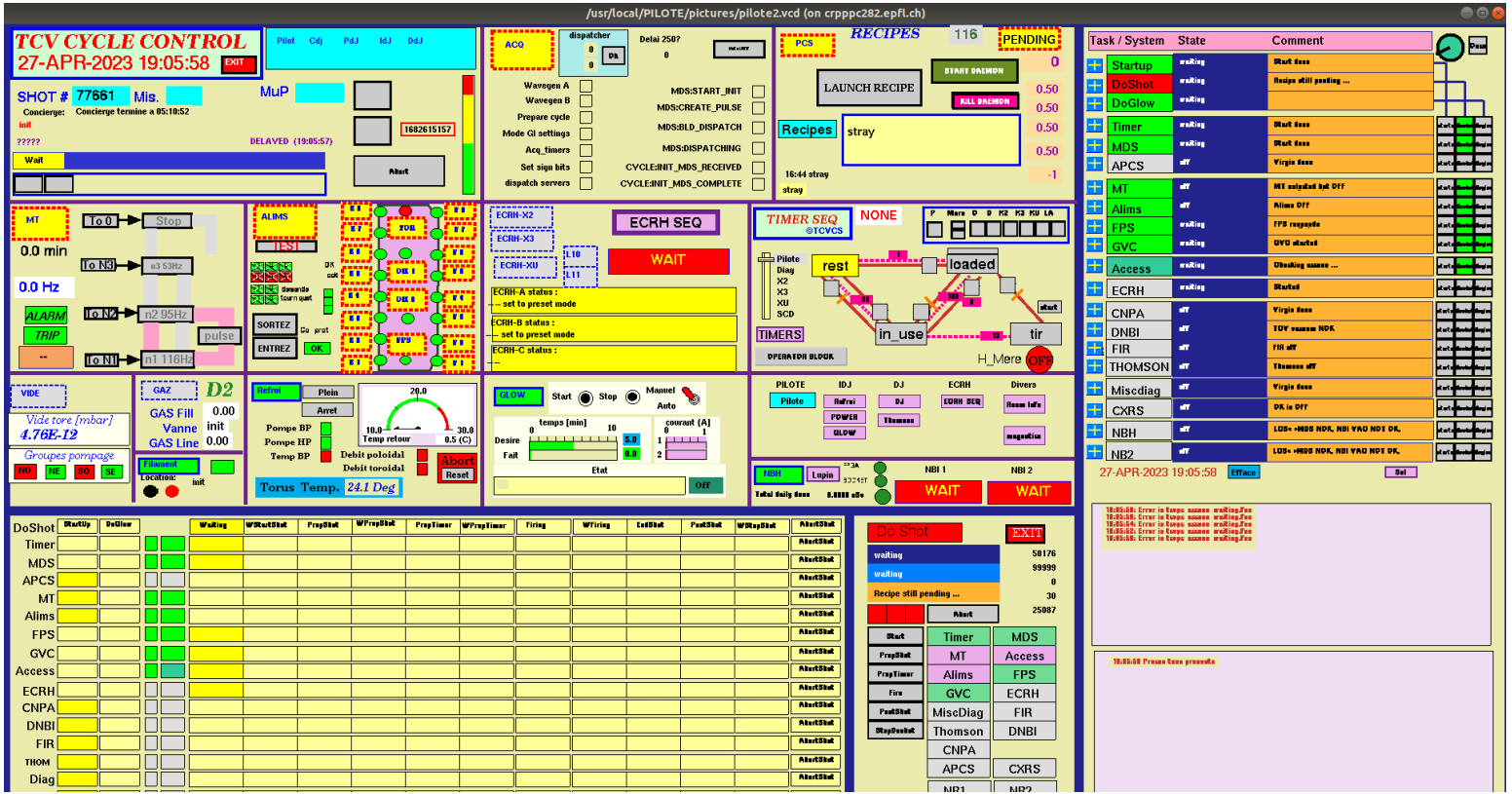
Plant control

TCVPC is the TCV experiment state machine including core callbacks



Plant & shot control

- Pilot main interface



Control framework

- **TCV live database : VISTA CONTROL SYSTEMS**
- Two main channel type :
  - **IN**put : updated upon read or periodically
  - **OUT**put : callback upon update, includes use of “event”
- Multiple servers with remote access
- Multiple databases
- Permissions per channel or per database
- Tools :
  - **Vdraw** : control GUI
  - **Valarm** : graphical and sound alarm
  - **Vscript** : simple sequential language for “daemon”
  - **Vlogger** : storage of selected channels
  - **Vtrend** : graphical tool for visualizing logged data

VISTA databases

- Example of out channels : TS gains
- Handler (callback) : C or fortran

- Access control : example

/vsys/crpppc282/db/TCV_PROTECTDB.access

```
DEFAULT: tcv_root=adefmnrwx,
\default=erx, tcv_idj=werx,
\ech_oper=werx, \tcv_oper=werx

GAS_OPER_ACCESS:   tcv_root=adefmnr
wx, \default=erx, tcv_idj=werx,
\tcv_oper=werx, gas_oper=werx
```

Note : channel-based access rights enabled

```
! sparam1   : i2c server IP adress
! hparam1   : i2c server port
! value     : initial value
! handler   : callback function
! automatic : automatically write or read upon
channel access

DEFINE CRPPSRV23_I2C
•     sparam1 '10.27.128.209'
•     hparam1 50000
•     value   0
•     handler_c i2c_handler
•     ch_v3_function_style
•     automatic


! hfunction : i2c handler function selection
! lowlim 0  : low limit
! hilim 7   : high limit

DEFINE SETHFGAIN_I2C
•     integer out
•     hfunction 1512
•     lowlim 0 hilim 7


! hparam2   : i2c channel
! hparam3   : i2c address

$thomson:hf_gain:ch_060   SETHFGAIN_I2C   CRPPSRV2
3_I2C   hparam2 49   hparam3 40
```

Control framework

- **Alternative control framework :**

  EPICS

  - selected by ITER
  - used at SPC (gyrotron test bed)
  - Multiple compatible protocols
  - Requires I/O drivers

Hardware Support: by Bus

Database updated 15 March 2023 at 10:53 CDT

The following table contains a list of I/O devices for which EPICS device and/or driver support has been written, sorted by the primary I/O bus type. The table is also available sorted by Manufacturer, by Contact Name, or by Link name (you can also click on any active column title to switch views).

The related Soft Support database is available here.

To sumbit a new entry to this list for your Hardware Support module, use this form. Email corrections or questions about this page to Andrew Johnson.

Contact email addresses have had an anti-spam filter applied. To mail anyone from the mailto: links below you will have to replace the strings "-AT-", "-DOT-" and "-DASH-" in the email address with an "@", "." or "-" character respectively.

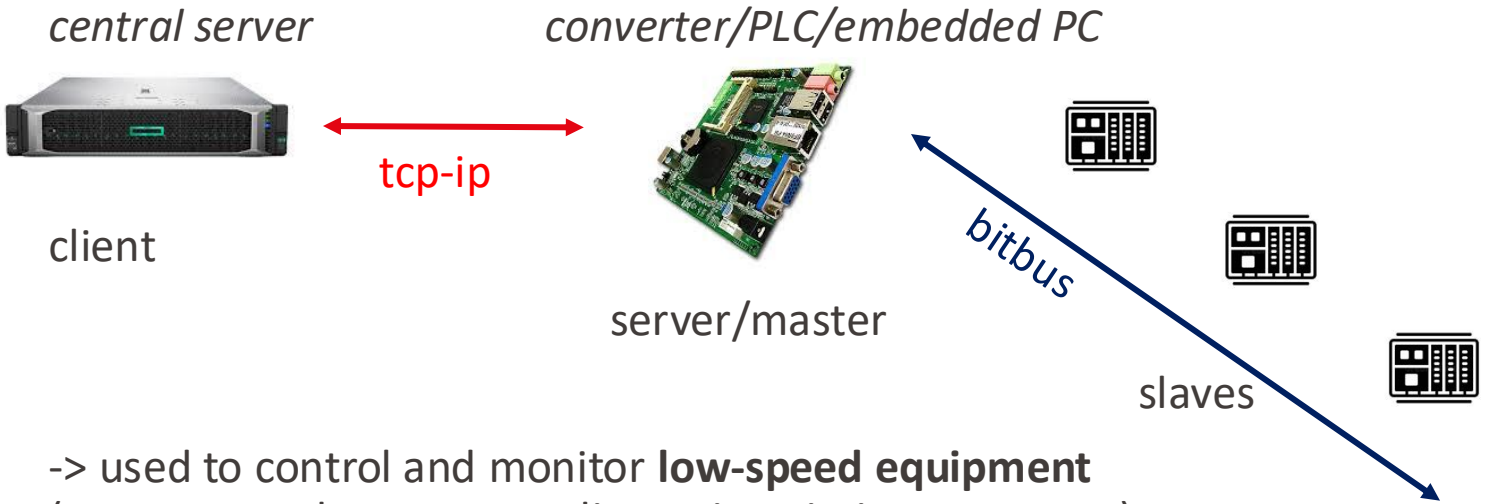
Contents

- AB1746/1747
- AB1771
- AB1794
- ARM IOC (Linux)
- CAMAC
- CAN
- CAN (iCS2)
- cPCI (devLib2)
- CPCI/PXI
- EPP
- EtherCAT
- Ethernet
- Ethernet (Asyn)
- Ethernet (HTTP)
- Ethernet (Modbus)
- Ethernet (Streams)
- Ethernet SNMP
- Ethernet, USB, Firewire
- Ethernet-CAMAC (Asyn)
- Ethernet-GPIB
- Ethernet-GPIB (Asyn)
- Ethernet-Modicon
- Ethernet/NIM
- Firewire
- Firewire (Asyn)
- GPIB
- GPIB (Asyn)
- GPIB (Streams)
- Group3
- I2C (Asyn)
- IEEE1394 (Asyn)
- IOC (Asyn)
- IOC-Arduino (Streams)
- IOC-BPM
- IOC-CAN (iCS2)
- IOC-CPCI (Linux)
- IOC-DSO
- IOC-IPAC (VxWorks)
- IOC-PC/104 (Linux)
- IOC-RS-232 (RTEMS)
- IOC-Stepper (RTEMS)
- IPAC
- IPAC (Asyn)
- IPAC-CAN (devLib)
- IPAC-GPIB (Asyn)
- IPAC-RS-232 (RTEMS)
- IPAC-RS-232 (VxWorks)
- ISA-IPAC (vxWorks)
- Linux
- Modbus (Asyn)
- Modbus TCP
- Modbus/TCP (Linux)
- Modbus/TCP (vxWorks)
- PC/104 (Linux)
- PCI
- PCI (Linux)
- PCI, USB, GigE
- PCI-VME (Linux)
- PCI/CameraLink
- PCIe-IPAC
- PMC (devLib2)
- PXI
- RS-232
- RS-232 (Asyn)
- RS-232 (Linux)
- RS-232 (ornlSerial)
- RS-232 (RTEMS)
- RS-232 (Streams)
- RS-232-ABDF1
- RS-422
- RS-422 (Streams)
- RS-485
- RS-485 (Streams)
- RS232 (Streams)
- RS485 (stream)
- Streams
- TTL (streams)
- TTL (Streams)
- UEI Proprietary
- USB
- USB (Asyn on Windows)
- USB (Asyn)
- USB (Streams)
- USB, GigE, CameraLink
- USB, PCI, CameraLink
- VME
- VME (Asyn)
- VME (devLib)
- VME (devLib2)
- VME (Linux)
- VME-AB1771
- VME-Bitbus
- VME-CAMAC
- VME-ControlNet
- VME-GPIB
- VME-Group3
- VME-IPAC (devLib)
- VME-PC104 (Linux)
- VME-VXI
- VME64x-IPAC
- VXI
- VXI (RTEMS via VXIGPIB)

TCV control

- **TCV uses a combination of central and distributed control systems**

- **Central systems** : device control from central computer via slave/master protocol (ex : BITBUS, RS232, MODBUS, I2C…)

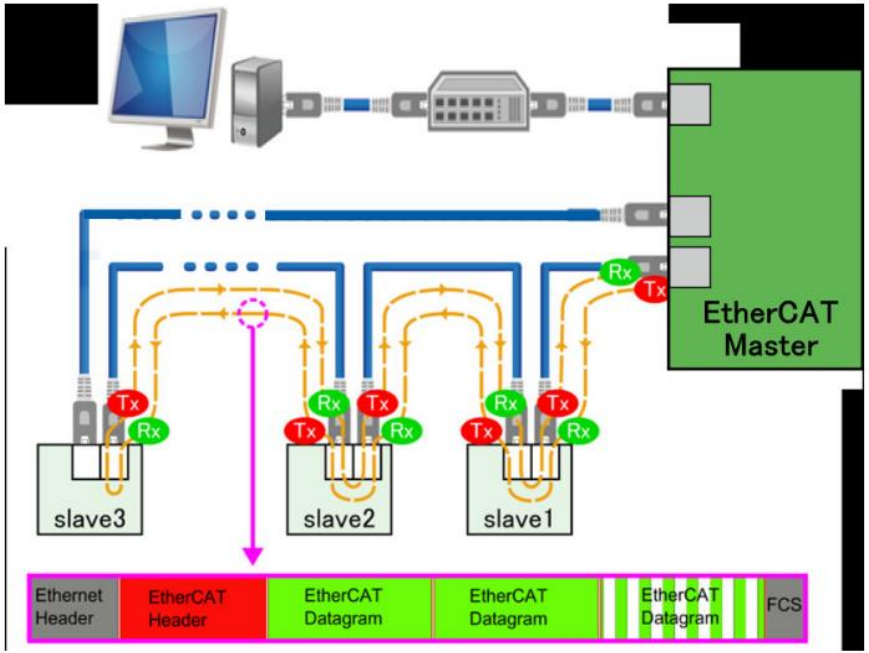


-> used to control and monitor **low-speed equipment** (pump control, power supplies, gains, timing setup, etc)

Modern bus : Ethercat

EtherCAT (Ethernet for Automation and Control Technology)

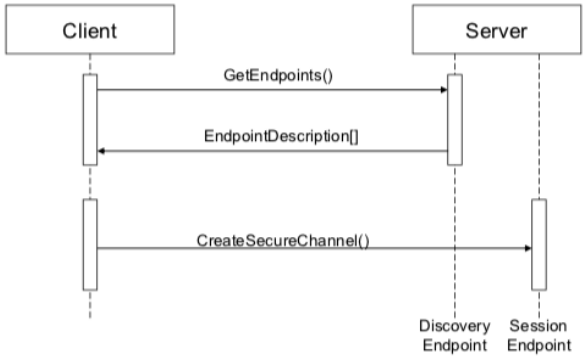
- Ethernet based control fieldbus.
- short data update times (> 50 µs)
- low communication jitter (≤ 1 µs)
- reduced hardware costs.

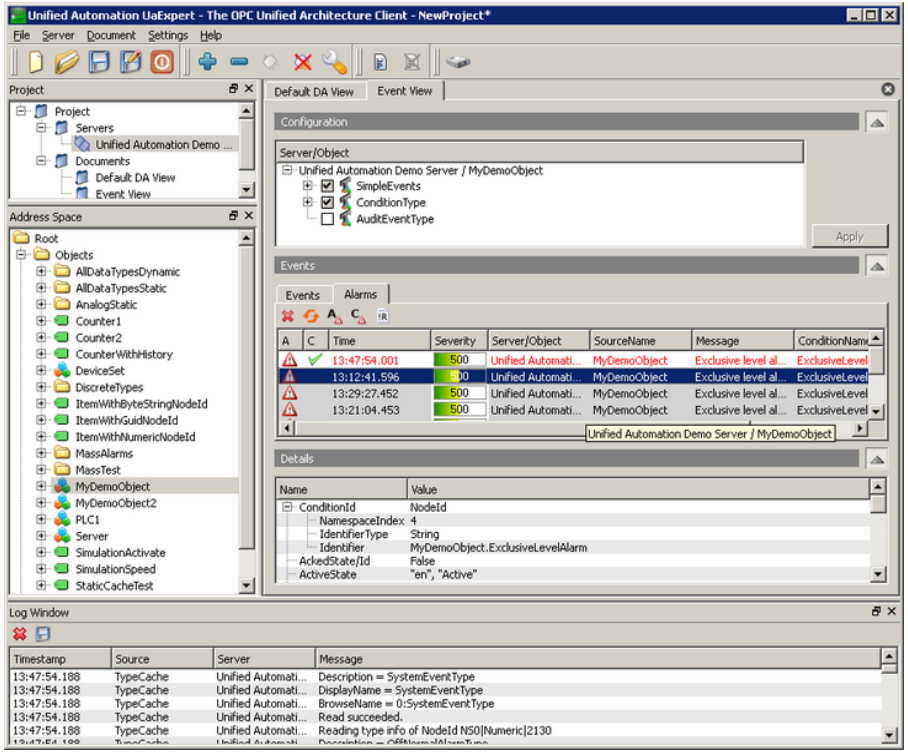


TCV control

Distributed (decentralized) control : autonomous subsystems with own state machine

- **Independent subsystem control PC**
  (i.e. **labview** CODAC with NI PLCs)
- **Advanced control protocols** (**OPC-UA**)
  - Control channel list exposed by server
  - Secured communication
  - Self-describing variables (objects)





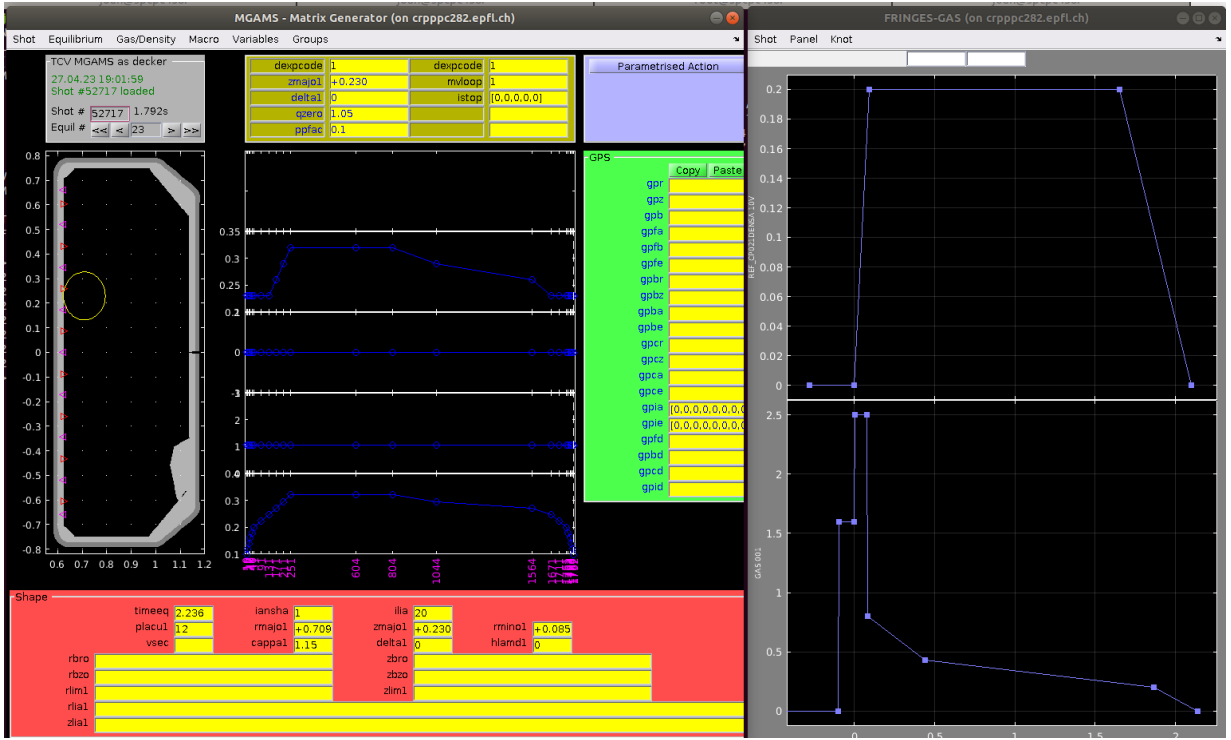
Plasma control

- Control a (limited) series of **actuators** through a combination of :
  - Feed-forward control waveforms
  - Feedback control by processing (real time) observations

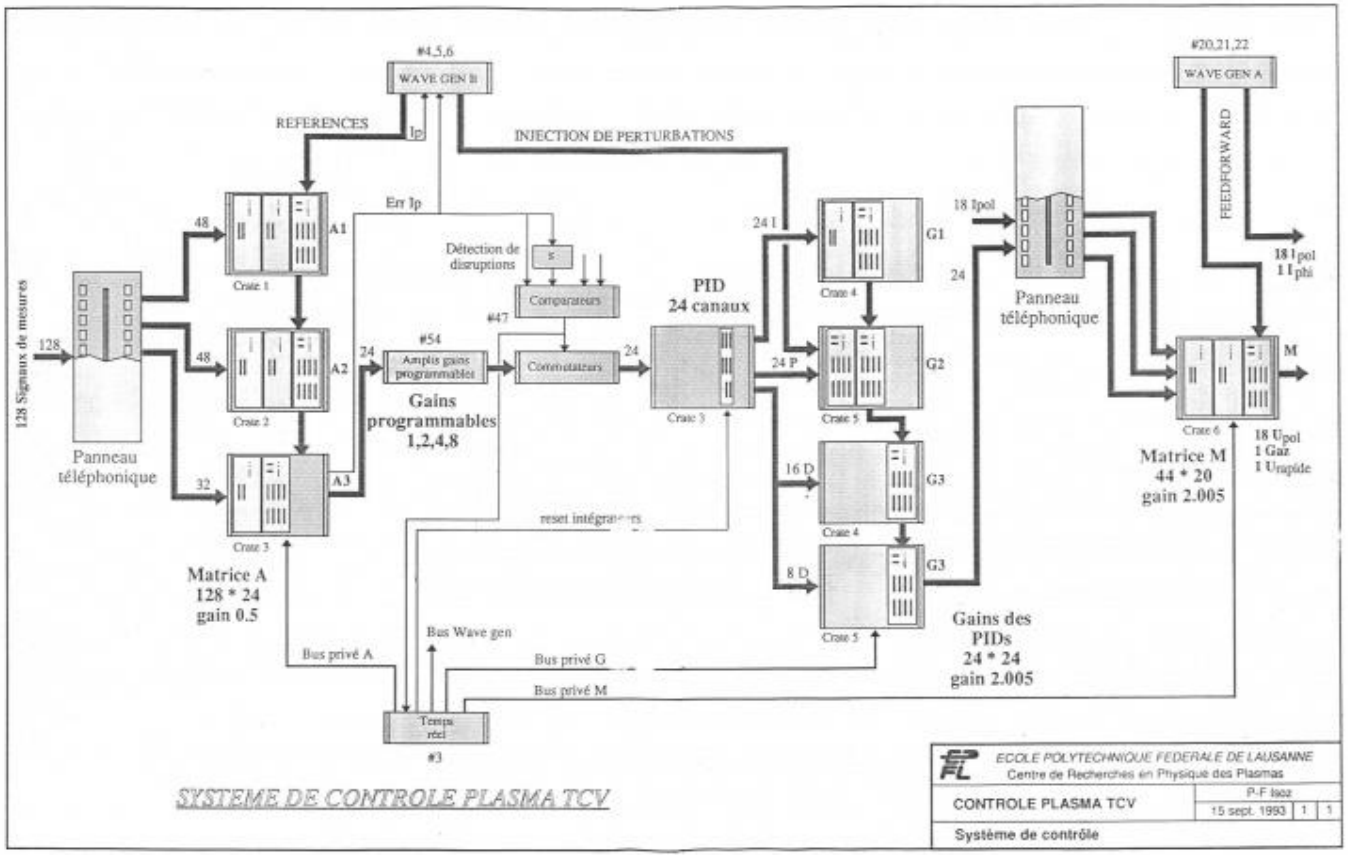
- TCV may use thousands of observables to control a limited number of actuators:
  - Toroidal and OH coils (Bt and Ip)
  - Poloidal coils (plasma shaping)
  - Gyrotrons (EC heating and current drive)
  - Neutral beam injection systems (NBH and DNBI)
  - Fueling systems (gas valves + MGI)

Shot design

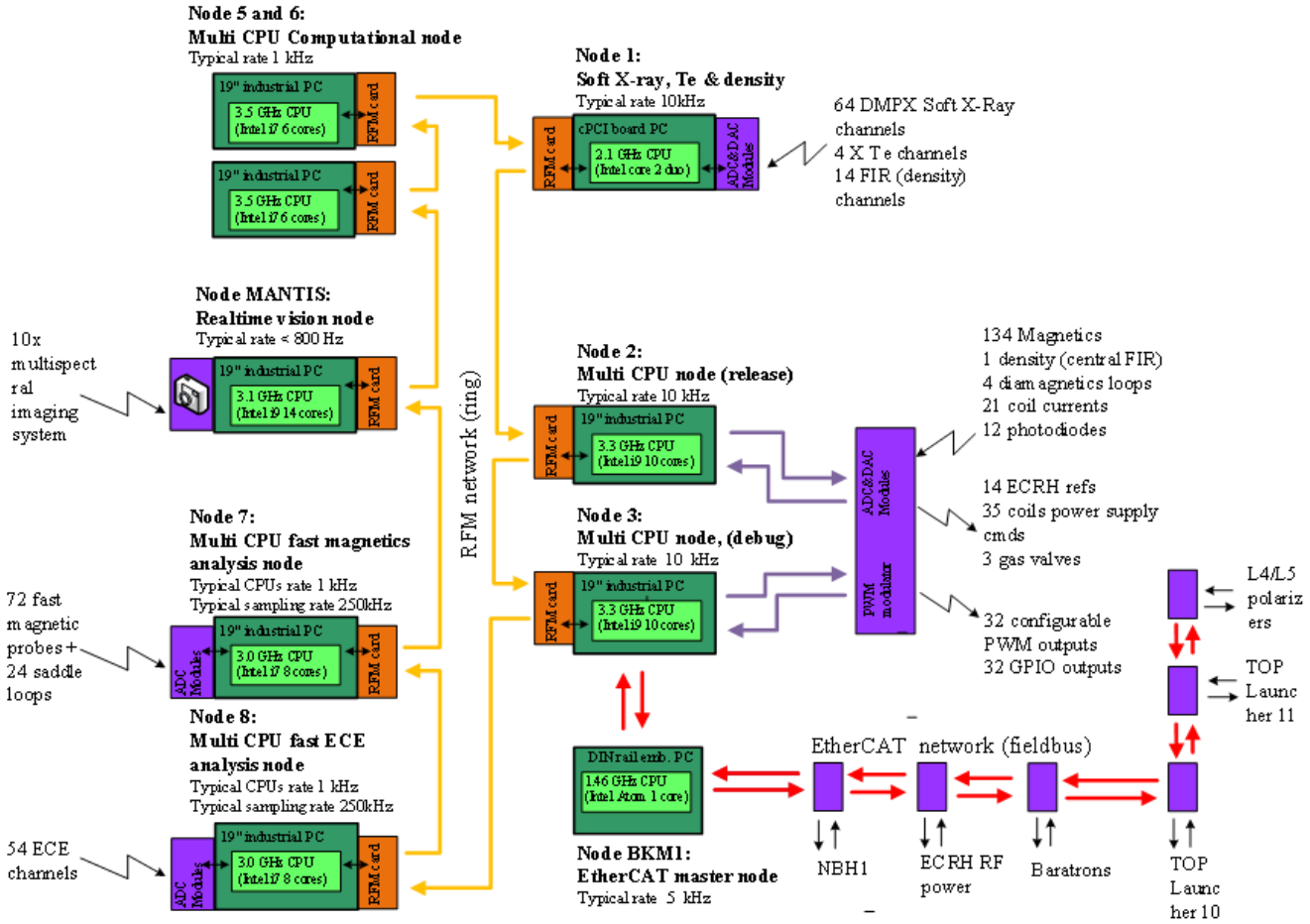
- **Shot design interface : mgams**
- Secondary systems : echcs, nbhcs, fueling, etc



Analog real-time control

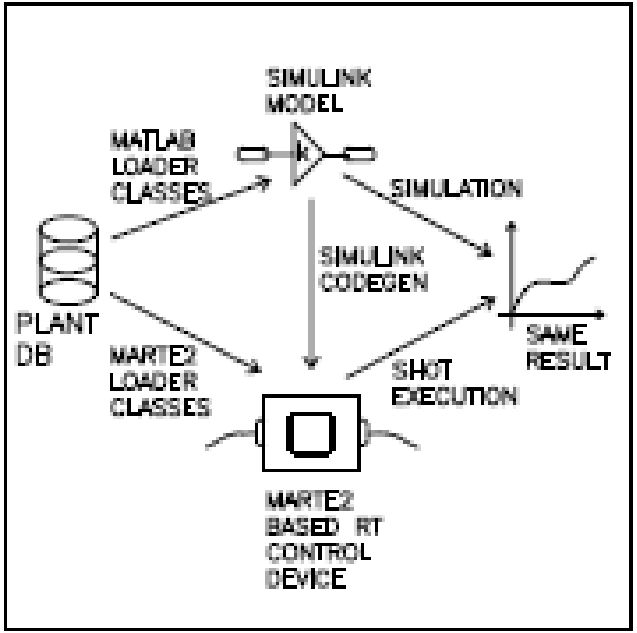


Digital real-time control



Real time control : recent developments

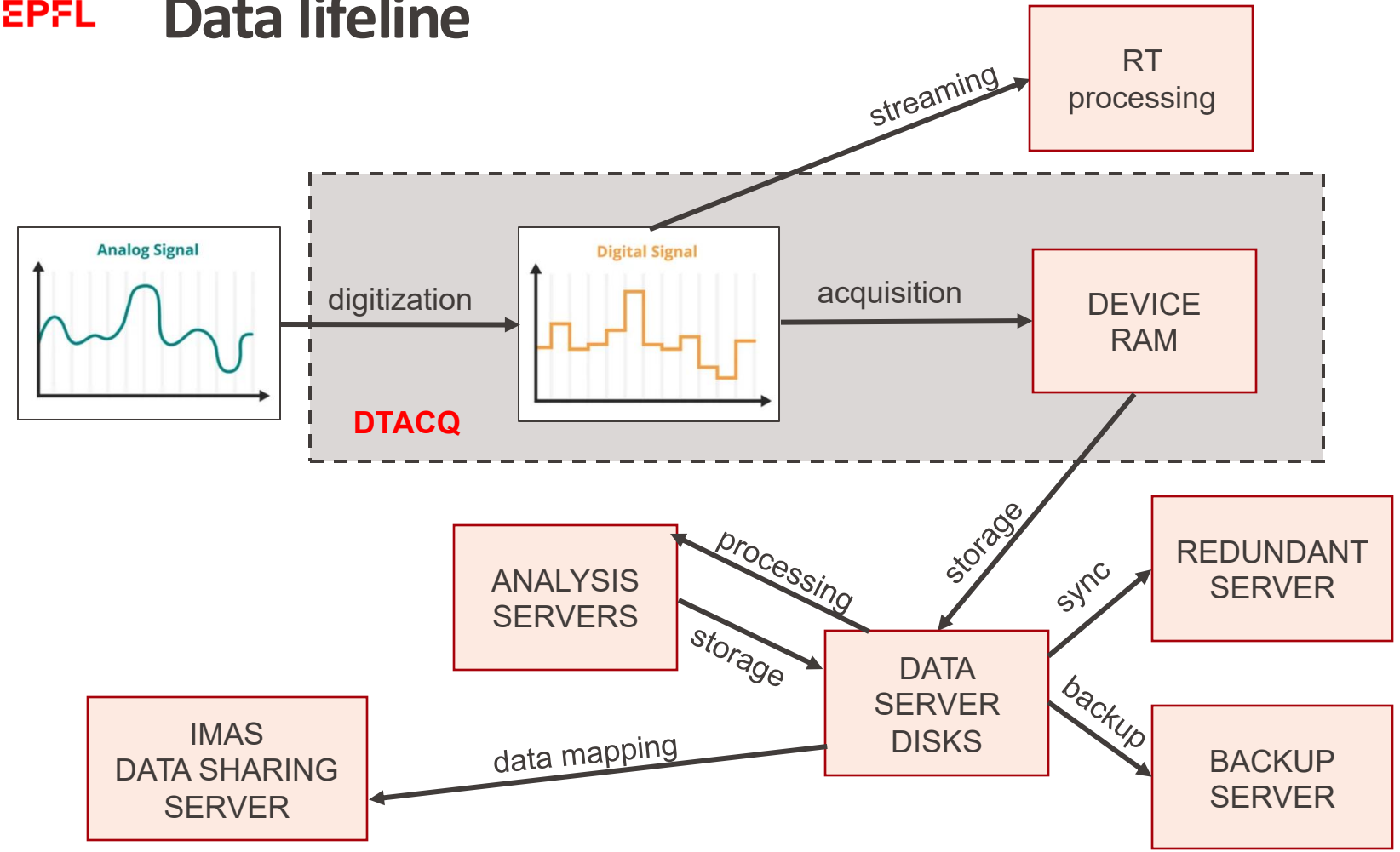
- Increasingly complex control algorithms
  - Equilibrium reconstruction (shaping)
    -> real time **liuqe**
  - ECRH beam tracing
    -> real time **torbeam**
  - Transport and current diffusion
    -> real time **RAPTOR**



- Global platform for RT simulation and compilation using MATLAB/Simulink
- Global RT execution platform using MARTe2
- Deployment of AI-ML techniques

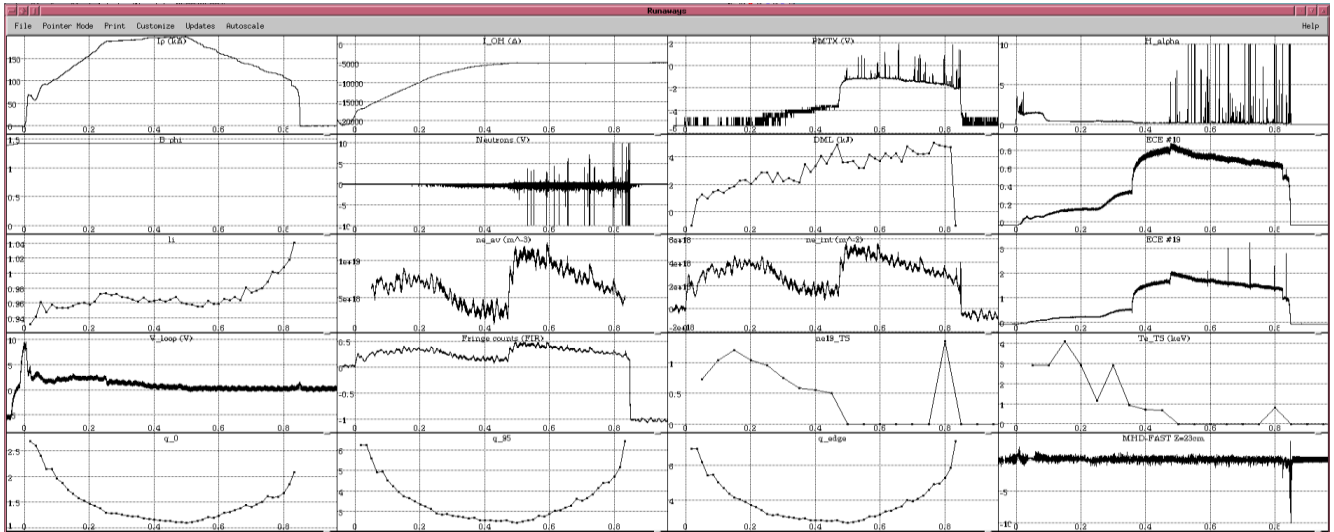
  -> complex events on very short timescales (disruption mitigation and avoidance)

Data lifeline



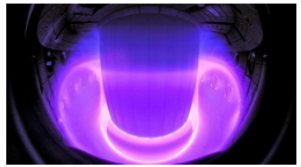
Timing and synchronisation

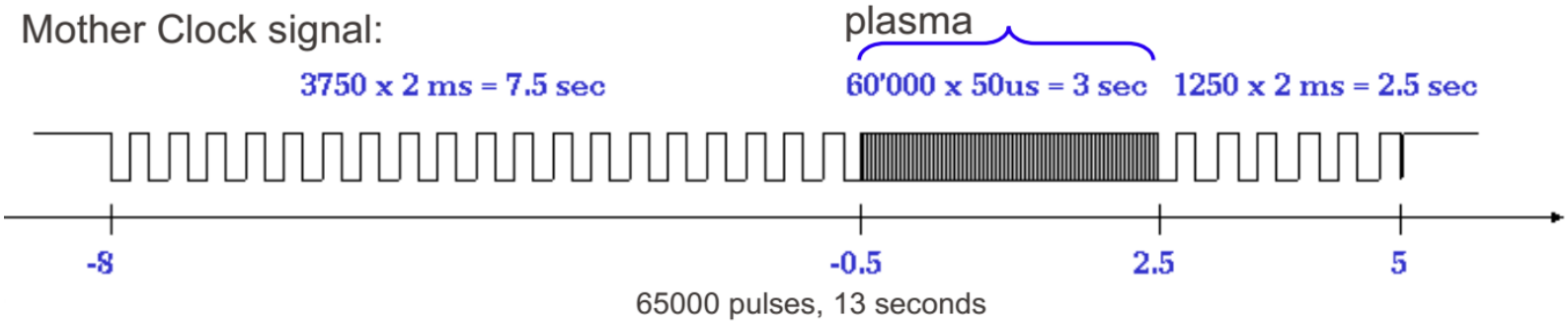
- Causal analysis is essential in experimental plasma physics
- Tools dedicated to multi-signal time evolution comparison (i.e. dwscope, jScope)
- Ideally, synchronization precision must at least match acquisition rate
- For a long time, TCV sync precision was less than one microsecond
  (but better for signals acquired on the same ACQ unit)
- Better synchronization enables cross-correlation analysis from different diags



TCV legacy timing system

- Main time source = “Mother Clock” (MC):
  - Bitbus slave generates mother clock signal and 1 MHz
  - 65000 clock ticks limited by 16 bit counter on MC signal
  - Slow (2 ms) period before and after the plasma phase
  - Fast (50 us) period for refined timing during plasma phase





Courtesy of E. Carletti

White Rabbit Synchronisation

- Excellent precision : < 1 ns !
- Fiber = no need for isolation

- D-TACQs (ACQ2106) shipped with WR
- Trigger times are programmed at endpoint level
- Inter-operable with legacy system
  - 1MHz can be generated locally = synchro

Acquisition cycle

- Program acquisition modules (mdsplus Init action)
  - Model tree (enable actions, set # of samples and frequency)
  - Setup timers (WR or legacy)
- Arm acquisition modules
- Trig -> Run
- After shot, either :
  - Push data from dtacq
  - Send event for pulling data from central servers
  - Wait for postshot phase and pull from (mdsplus Store Action)
- Recent feature : share acquisition with RT systems
  - Instead of splitting signals, combine streaming and writing into RAM
  - Still some work to do… magnetic signals acquired 4 times...

Digitization

Magnetic Fusion **acquisition rate** examples

- <1 Hz : monitoring
- 20-60 Hz : pulsed lasers (thomson scattering)
- 1 kHz : diags with large integration period
- 1 MHz : diags with short integration period
- 10 MHz : pulse shape processing
- 10 GHz : pulse reflectometry

-> different acquisition technologies required

Corresponding **synchronization technology**

- 1 – 10 ms precision : NTP (network time protocol, synchronisation)
- 1 µs : TCV MHz clock and legacy trig system
- 0.1 – 1 µs : PTP (precision time protocol, synchronisation + syntonisation)
- < 1 ns : White Rabbit (CERN), uses dedicated network hardware

Digitization

- **Constraints**
  - Capture relevant time evolution
  - Relevant amplitude variations
  - Avoid saturation : gain controls (DDJ)

- **Digitization specifications**
  - Rate
  - Duration
  - Resolution
  - Dynamic range
  - Differential or not
  - Connectors
  - Streaming capabilities ?

CAMAC

DTACQ

Ultrafast Acquisition Modules

Title: SPC Fast Acq Catalogue
Date: 23/08/2024
Author: L. Simons

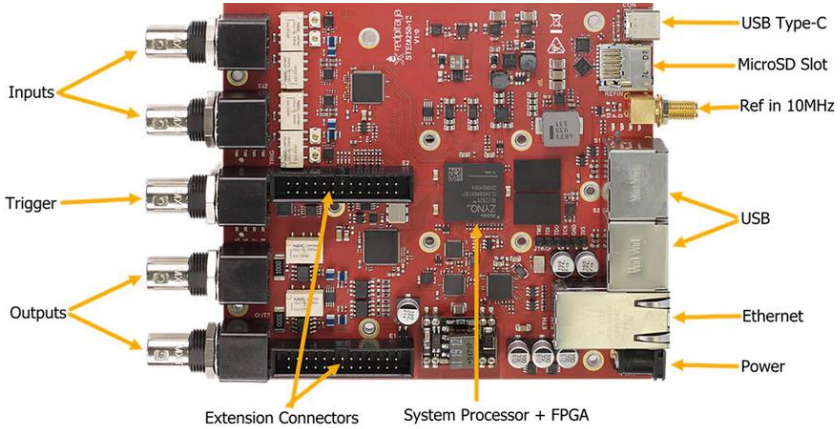
Type	Company	Model Name	Stand Alone?	Max Chans	BW [MHz]	Acq rate [MHz]	Prec [bits]	Acq Time [s]	Sum of Price
ADC	**Acqiris**	Acqiris SA248P	n	1	2500	8000	14	0,500	- €
	Acquisys	ATS9364	n	2	1000	3000	12	0,171	- €
	CAEN	CAEN2730	y/n	32	250	500	14	0,156	- €
	D-tacq	ACQ482ELF	y	16	40	80	14	0,500	- €
	GUZIK	GUZIK ADP7000 series 10-bit	n	4	6500	16000	10	1,600	100 000,00 €
		VR8042	n	2	4000	10000	12	2,570	35 000,00 €
	Keysight	M5200A	n	4	2000	4800	12	1,200	- €
	NI	NI-5186	n	2	5000	6250	8	0,080	- €
		NI-9775	n	4	13,9	20	14	0,105	4 310,00 €
		PXIe-4481	n	6	10	1,25	24	0,000	14 100,00 €
	Red Pitaya	SIGNALlab 250-12 v1.2a	y	2	60	250	12	0,700	2 367,97 €
	Spectrum Instrumentation	M4x.22xx	n	4	1250	1250	8	0,800	- €
		M5i.33xx	n	2	4700	5000	12	0,400	- €
	Teledyne	ADQ14	y/n	4	1200	2000	14	0,537	- €
		ADQ30	y/n	1	1000	1000	12	4,295	- €
		ADQ32	y/n	2	1000	2500	12	0,859	9 260,00 €
		ADQ33	y/n	2	1000	1000	12	2,147	5 960,00 €
		ADQ35	y/n	2	2500	5000	12	0,429	13 750,00 €
		ADQ36	y/n	4	2500	2500	12	0,429	- €
		ADQ7/DC	y/n	2	3000	5000	14	0,200	20 690,00 €
	Vitrek	EON Express	n	2	1750	3000	12	1,333	16 750,00 €
Osc				36	5500	7437,5	23	0,635	68 970,76 €
PHA				3	50	162,5	26	0,000	11 965,00 €

Courtesy of L. Simons

Examples of ultrafast Acquisition Modules

RED PITAYA 250-12

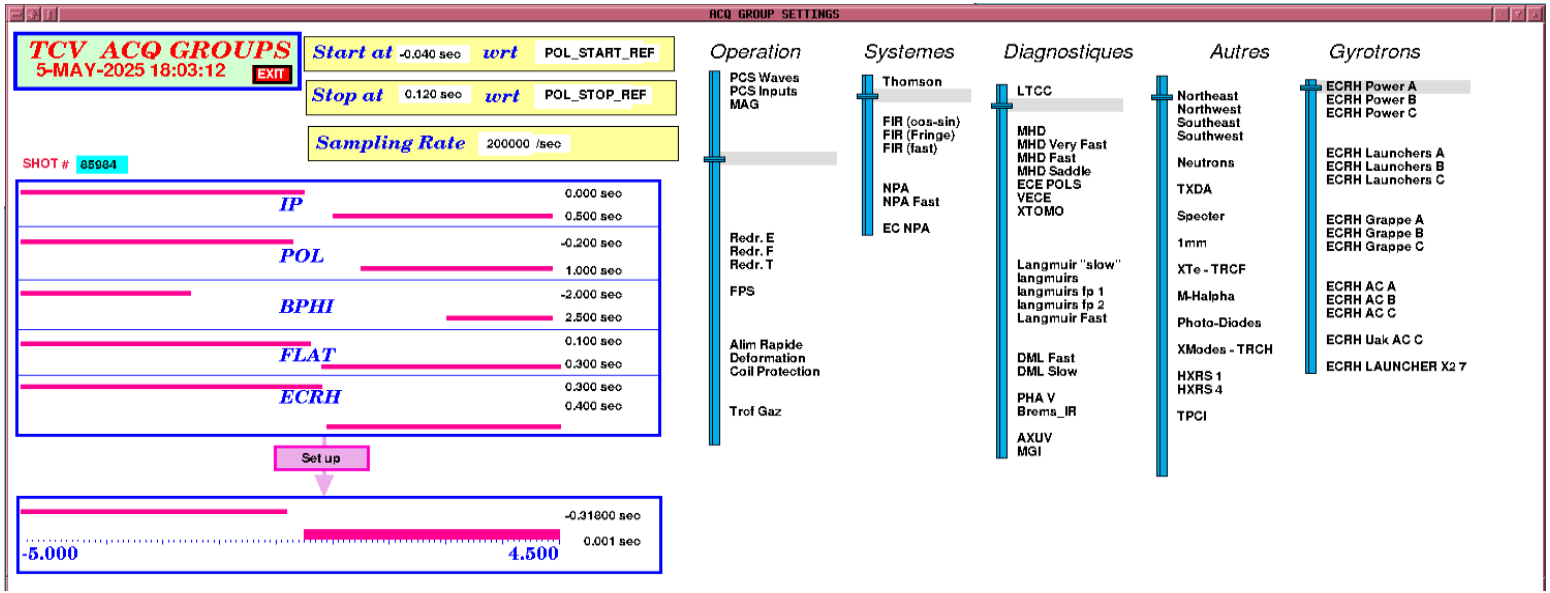
BOARD LAYOUT



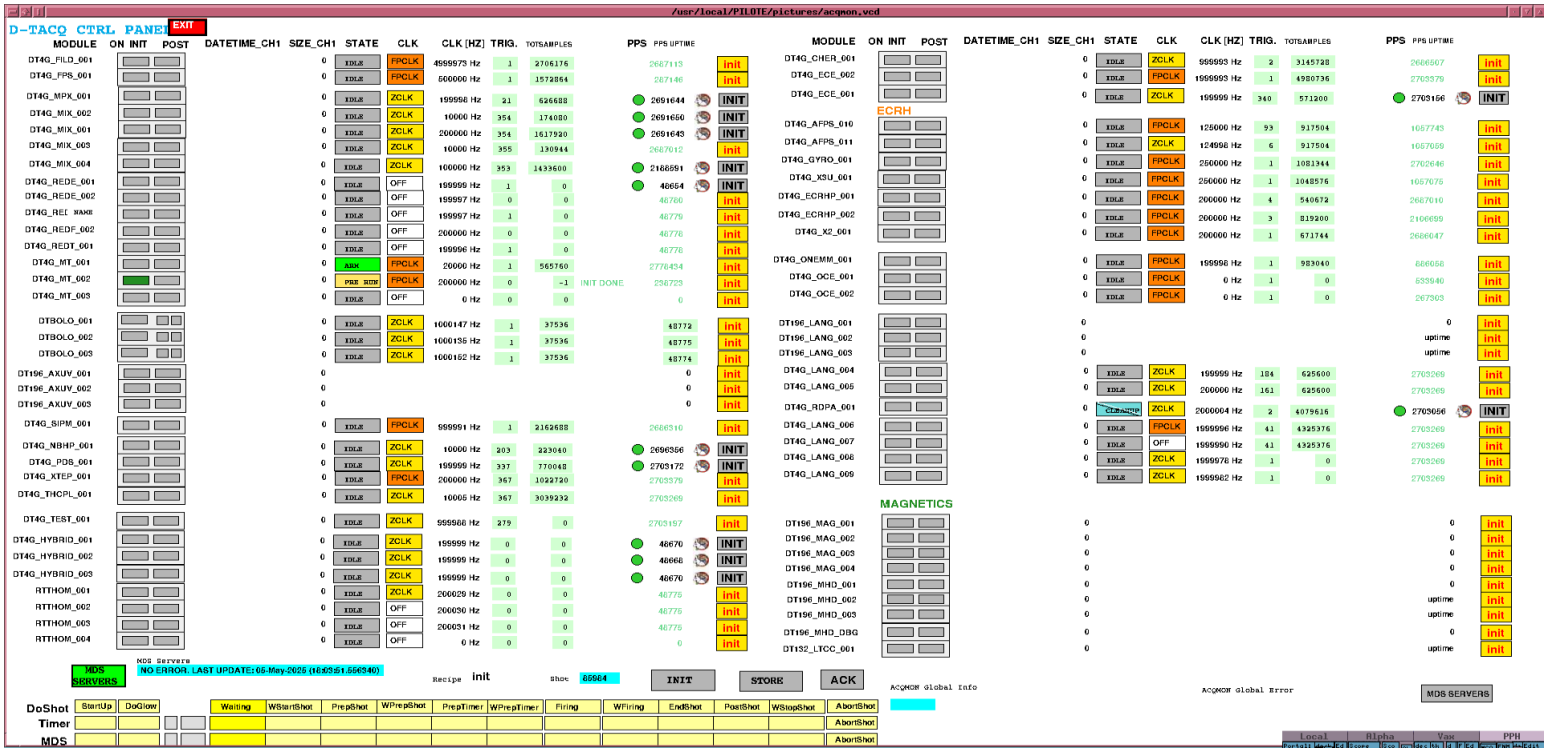
TELEDYNE ADQ35

Acquisition timers programming

- The number of acquired samples might be limited by board RAM
  - Compromise between sampling rate and acquisition window duration
- Acquiring useless data is detrimental (storage, I/O, backup, etc)
  - Acquire only relevant diagnostics during relevant shot phases
- Acquisition windows and sampling rate can be set in ACQ GROUPS or directly in VISTA



Monitoring of data acquisition



Resist the temptation…

… to acquire **everything** for **as long as possible** at the **highest possible rate**, and keep it **forever**

- Imagine 50’000 channels, acquired on 16 bit resolution, for 10s, at 1MHz

-> this is **1 TB of data for one shot ! 40 TB in one day**…

  - Can the network carry all this data between shots?
  - Can we hold the data in one place?
  - Can we process this data between shots?
  - Can we back up the data overnight?

- Examples **good practices** :
  - train of pulses -> keep peak amplitude and timestamp?
  - Oscillating signals -> FFT and keep strongest/most meaningful features?
- FPGAs can help (process data between digitization and acquisition)
- Electronicians can help : pre-ACQ treatment of analog signals

End of first part

Outline

- First Part
  - Fusion experiment timeline
  - Plant and plasma control
  - Real time control
  - Digitization & acquisition

- **Second Part**
  - **Mdsplus : data storage and organization**
  - **Data processing**
  - **Data access, outreach**
  - **Storage and backup**
  - **Fusion IT environment**

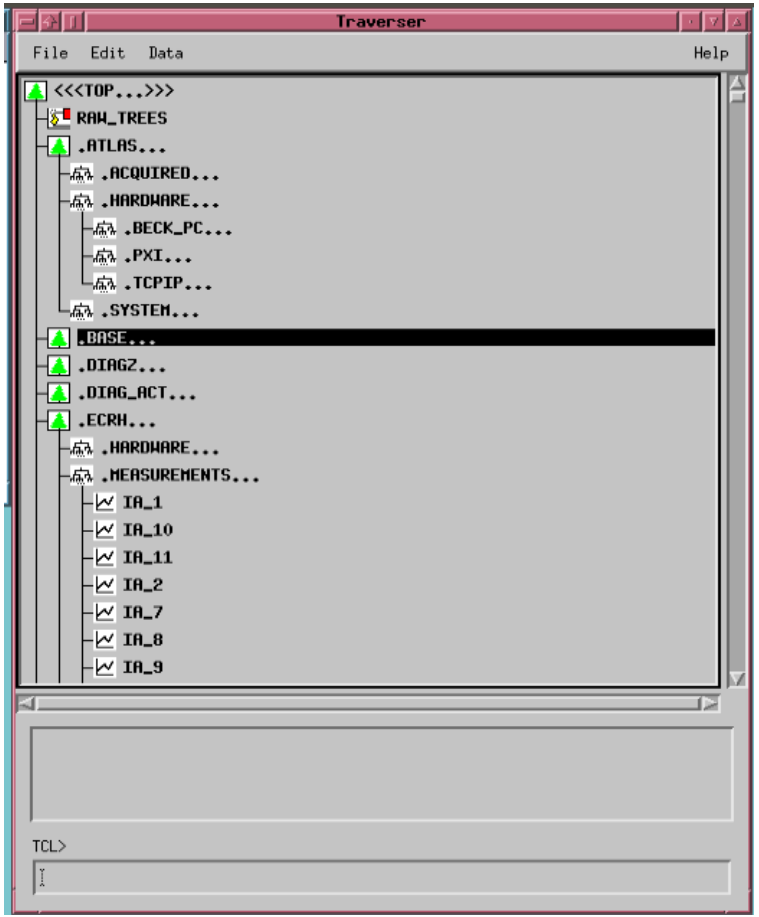
Data storage : mdsplus

- Large number of time traces (signals) with different timestamps
- Shot-based acquisition

- **MDSPlus** : data storage in shot-based files
- Intrinsic language : TCL/TDI
- Built-in objects (signals, data with units)
- Built-in basic data processing
- On the fly data compression

- Video storage poses different challenges

-> favor single frame or full movie access?

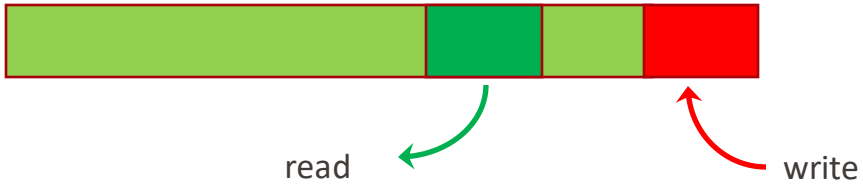


Remote control and data access

- **Challenge** : let authorized people in, keep everyone else out
- One powerful protocol : **SSH** (Secure SHell)
  - Ensures both authentication and encryption
  - Tunable based on hosts, users, groups, etc.
  - Passwordless key-pair authentication
  - X11 forwarding
  - Tunneling, proxy jumping
  - Command execution, filtering
- Several virtual desktop systems (NX, VNC) use ssh (x2go, nomachine, thinlinc, …)
- **MDSPlus remote data access** is based on a IP protocol : **mdsip**
  - Possibility to use in thin or thick client
  - Can be encapsulated in SSH

Monitoring

- Read and store parameters beyond shot cycle. Ex : vessel pressure
- Heterogeneous data sources
- Data storage : shot -> day
- Solutions :
  - Vista Vtrend
  - MDSplus segmented data

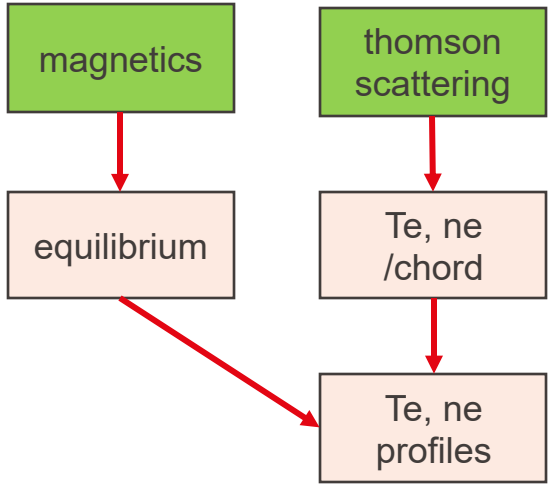


- Note : future experiments will combine high-frequency acquisition (physics does not slow down) with long durations… how will they manage? Who knows….

Data processing chain

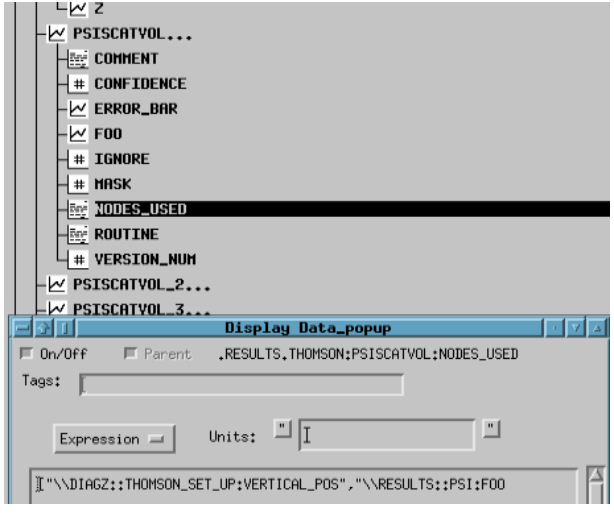
- Data analyses are interdependent
- One analysis can depend upon a number of raw data samples and anterior analyses

  → analysis chain
- Enforcing consistent causality means updates must be followed downsteam



- TCV solutions : **anasrv**
  - calculations upon request
  - calculation of upstream nodes if missing
  - recalculation of downstream node if outdated

- Thinking of a forward solution



Data provenance and metadata

- **Provenance** is metadata tracking the analysis chain to a given dataset with the possibility to reconstruct the dataset identically
- **Essential provenance metadata** includes :
  - Electronic treatment tunable parameters (gains)
  - Acquisition setup parameters (timing, precision, calibration, conversion)
  - Raw and processed data chain of dependences
  - Analysis codes versions
  - Analysis codes tunable parameters

- Metadata also include :
  - Data physical description
  - Data samples for **shot searchi**ng, grouping, etc
    -> average, min/max, steps, ramps, coarse timegrid….

How many different TCV data subsampling systems do we have at SPC?

Data versioning

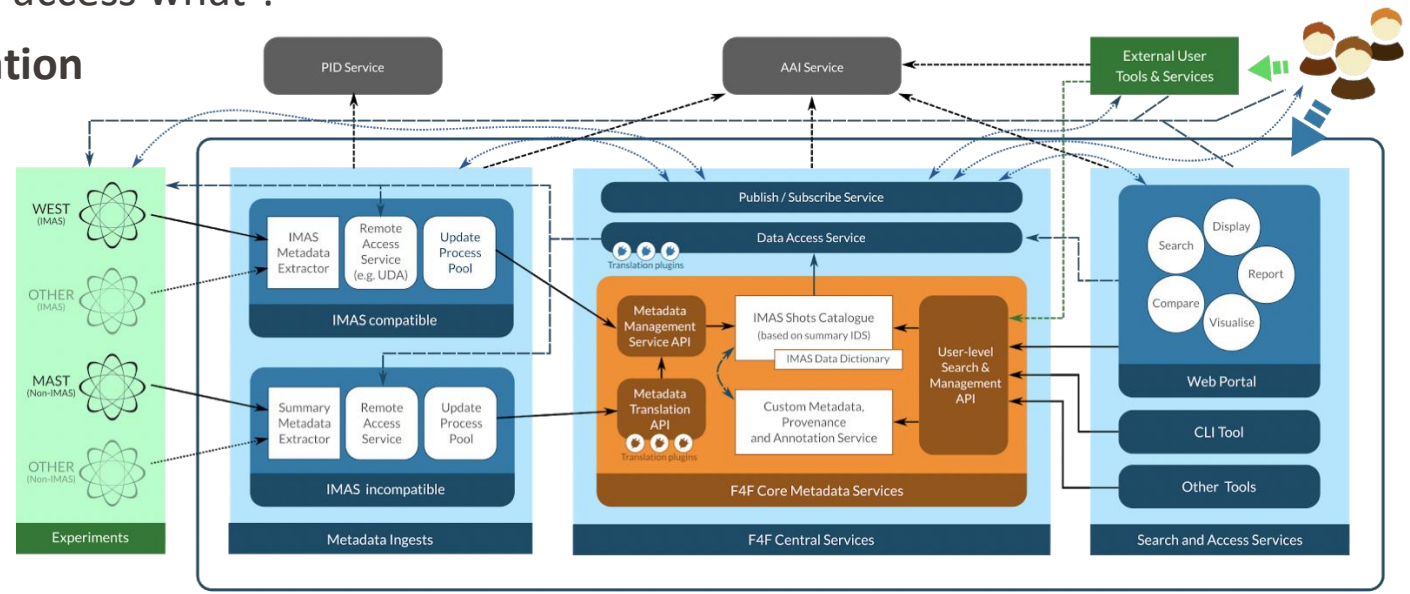
- TCV : trial indices, derived trees
- Essential when carrying out multiple shot analyses
- Must decide on default version (standard, latest, intelligent)
- Capacity to browse among versions -> annotations
- Complexity increases exponentially with the number of interdependent analyses

-> So far, a satisfactory global data versioning system is still missing at TCV

Data sharing - openscience

- Public funding imposes open data
- Delay to protect original work
- Meaningful data sharing is quite complex
- A&A : who can access what ?
- **Data identification & definition**
  - Dictionary
  - Metadata
  - Ingestion
  - Format
  - Search
  - Access

FAIR4FUSION
-> Eurofusion DMP

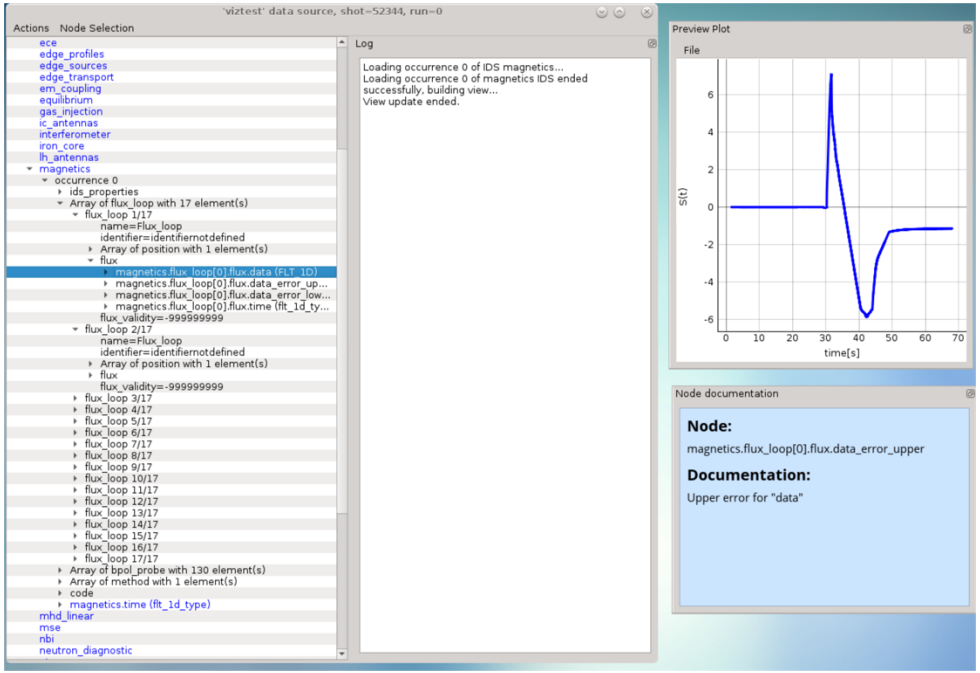


Data structuration – linking theory and experiment

- **Integrated Modelling and Analysis suite (IMAS)**
  - Interconnected software for ITER modelling
  - Modular selection of components

- **Interface Data Structures (IDSs)**
  - Organised as tree structures
  - Describe both experimental and modelling data
  - Work for any device
  - Describe plant systems and physics object
  - Self-describing objects
  - Information on provenance

IMASViz



IMAS data model

Heating systems

Diagnostics

IMAS Data Model 3.34.0

amns_data	disruption	iron_core	reflectometer_profile
barometry	distribution_sources	langmuir_probes	refractometer
bolometer	distributions	lh_antennas	sawteeth
bremsstrahlung_visible	divertors	magnetics	soft_x_rays
calorimetry	ec_launchers	mhd	spectrometer_mass
camera_ir	ece	mhd_linear	spectrometer_uv
camera_visible	edge_profiles	mse	spectrometer_visible
charge_exchange	edge_sources	nbi	spectrometer_x_ray_crystal
coils_non_axisymmetric	edge_transport	neutron_diagnostic	summary
controllers	em_coupling	ntms	temporary
core_instant_changes	equilibrium	pellets	thomson_scattering
core_profiles	gas_injection	pf_active	tf
core_sources	gas_pumping	pf_passive	transport_solver_numerics
core_transport	gyrokinetics	polarimeter	turbulence
cyrostat	hard_x_rays	pulse_schedule	wall
dataset_description	ic_antennas	radiation	waves
dataset_fair	interferometer	real_time_data	workflow

- The tokamak WEST has selected IMAS for experimental data storage organisation

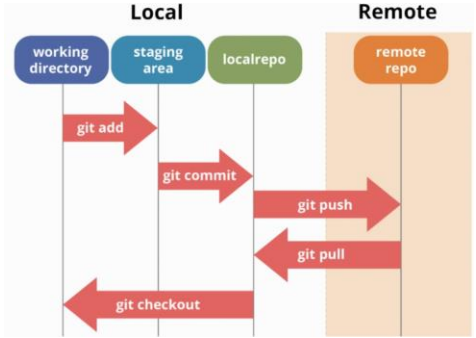
FAIR principles of data management

- **Findable** : capacity to search through datasets with meaningful criterias/filters
- **Accessible** : A&A solution, API
- **Interoperable** : Data definition, format
- **Reproducible** : provenance, versioning

- Are we there yet…?
  - Findable? Logbook, alma database, IMAS summary IDS
  - Accessible? Remote access servers, LDAP A&A
  - Interoperable? Eurofusion DMP effort (IMAS) (3 years from now)
  - Reproducible? Not systematically

Code development and versioning

- Simultaneous code development by several people (and even several teams) can be a strong accelerator, but requires organisation and discipline
- An essential requirement is **code versioning**
  - centralised systems : CVS, SVN
  - distributed systems : GIT (gitlab, github)



- **Verification, moderation, merging, and documentation of large codes are essential tasks** that :
  - Require a significant effort
  - Fall on people with a deep understanding of the code (core developer)
  - Are generally not provisioned by labs nor rewarded by the community

IT security

- SPC servers are attacked constantly
- When one protection fails, attack rates explodes
- Password strength matters

Number of Characters	Numbers Only	Lowercase Letters	Upper and Lowercase Letters	Numbers, Upper and Lowercase Letters	Numbers, Upper and Lowercase Letters, Symbols
4	Instantly	Instantly	Instantly	Instantly	Instantly
5	Instantly	Instantly	Instantly	Instantly	Instantly
6	Instantly	Instantly	Instantly	Instantly	Instantly
7	Instantly	Instantly	2 secs	7 secs	31 secs
8	Instantly	Instantly	2 mins	7 mins	39 mins
9	Instantly	10 secs	1 hour	7 hours	2 days
10	Instantly	4 mins	3 days	3 weeks	5 months
11	Instantly	2 hours	5 months	3 years	34 years
12	2 secs	2 days	24 years	200 years	3k years
13	19 secs	2 months	1k years	12k years	202k years
14	3 mins	4 years	64k years	750k years	16m years
15	32 mins	100 years	3m years	46m years	1bn years
16	5 hours	3k years	173m years	3bn years	92bn years
17	2 days	69k years	9bn years	179bn years	7tn years
18	3 weeks	2m years	467bn years	11tn years	438tn years

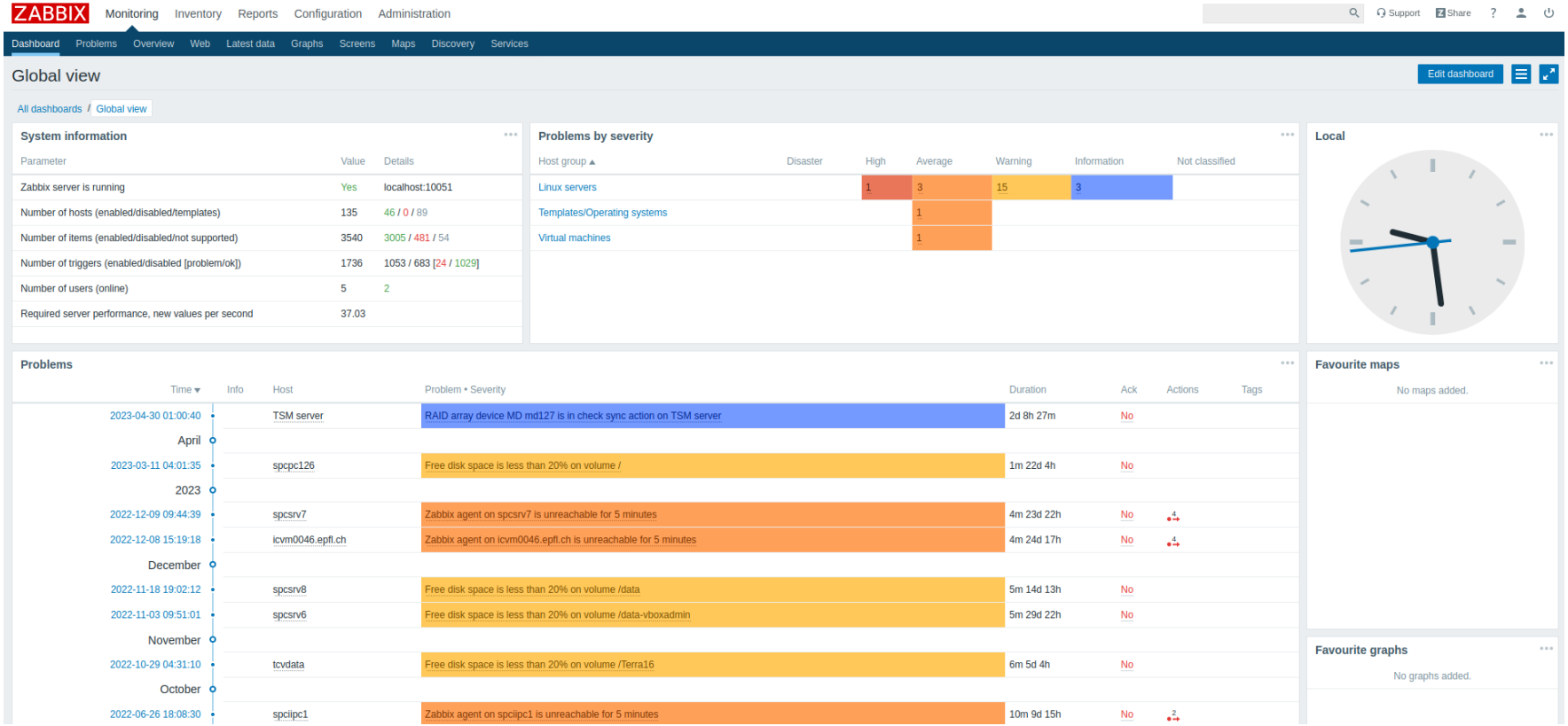
TIME IT TAKES A HACKER TO BRUTE FORCE YOUR PASSWORD IN 2022

- 2FA is effective
- Some essentials
  - Set up firewall
  - Enable selinux
  - No root access with password (use SSH key pairs or su from user account)
  - Enable fail2ban (delay or block following unsuccessful attempts)

Server administration

- OS selection : **rocky linux** (centOS, fedora, …). Compromise stability vs update
- Filesystems : ext4, **xfs**, zfs
- Partitioning : **GPT** : boot (EFI), space management (/home, /var/log)
- Storage arrangement : RAID 0/10 (speed), RAID 5/6 (volume)
- Invest in **RAM** : Swapping kills performance, FS caching is a powerfull feature
- Software : **minimalist approach** (faster, less maintenance, reduced risk of conflict)
- Redundancy of power supplies, network interfaces (bonding)
- Use UPS (Uninterrupted Power Suply)
- ILO/IDRAC : onboard chip accessible if server is down. Hardware survey, console
- Monitoring : **Zabbix** , Nagios
- Backup

Zabbix IT park monitoring



Data storage technologies

technology	speed	capacity	CHF/ TB
SD	25 MB/s	< 0.25 TB	200
USB 3.0	80 MB/s	< 4 TB	50
HDD	150 MB/s	< 20 TB	15
SATA SSD	500 MB/s	< 4 TB	50
NVMe SSD	2000 MB/s	< 4 TB	50

Compare with network speed :

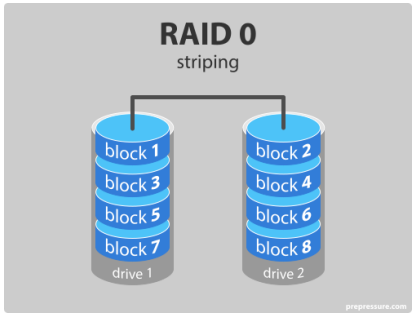
- 100 Mbs : 11 MB/s
- 1 Gbs : 110 MB/s
- 10 Gbs : 1100 MB/s

- Fastest storage at TCV (SPR diag) : 4 x raid0 NVMe : 8GB/s (~RAM speed)

Data storage arrangements

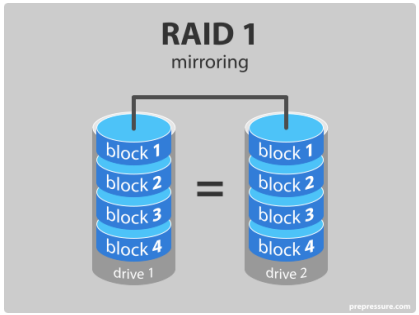
RAID array
Redundant Array of Independent Disks

RAID0 : stripping



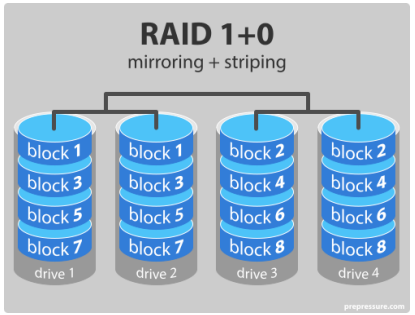
Fast but risky

RAID1 : mirror



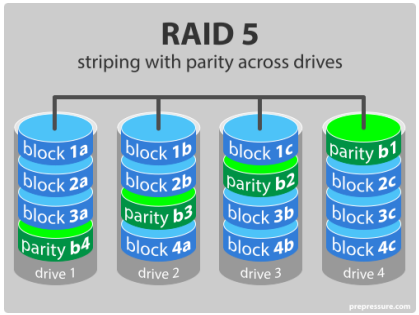
Safe but slow

RAID10 : combine



Fast and safe but expensive

RAID5 : parity



Fast (read) and safe

Data backup

- **To not back up data is an act of carelessness or… faith** ?
- Important (and/or voluminous) data should be backed up **at least twice**
  - If possible, **in different buildings**
  - If possible, using different technology
- Different backup types
  - Copies – archives – differential – incremental
  - **System restorable** or not (DRM protection)
  - Drive, partition, file backups
  - Redundant systems (**replication**)
- Some remarks :
  - **Restore operations must be tested** (including bootable full system restores)
  - If the main drive is encrypted by malware, will the backup be impacted ?
  - **Think of all possibilities**

Backup solutions used at TCV

- **IBM spectrum protect**
  - Secure (the client asks the server what to do, the server cannot access the client)
  - Multi platform incremental backup
  - Monitoring, alerts, …
  - Replication : seamless synchronization with second server
  - Deduplication : mark identical binary data blocks and save space
  - Strategies : number of versions kept, delay to keep outdated objects

- **Rsync** : an amazing tool (coming out of a Ph.D. thesis) : copies, backups, etc

- Atempo Lina : official EPFL solution

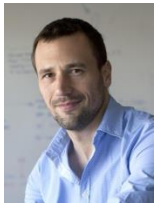
For more information

- **SPC wiki**
  https://spcwiki.epfl.ch/
- **Redmine** knowledge base (ticketing system)
  https://spcsrv18.epfl.ch/redmine/
- EPFL **Gitlab**
  https://gitlab.epfl.ch/
- **SPC user web pages**
  https://crppwww.epfl.ch/~<username>/
  https://crpplocal.epfl.ch/~<username>/

- IAEA meeting on Control, Data Acquisition and Remote Participation (every two years)

SPC IT team

Christos Paraskevopoulos


Joan Decker

Pierre Etienne

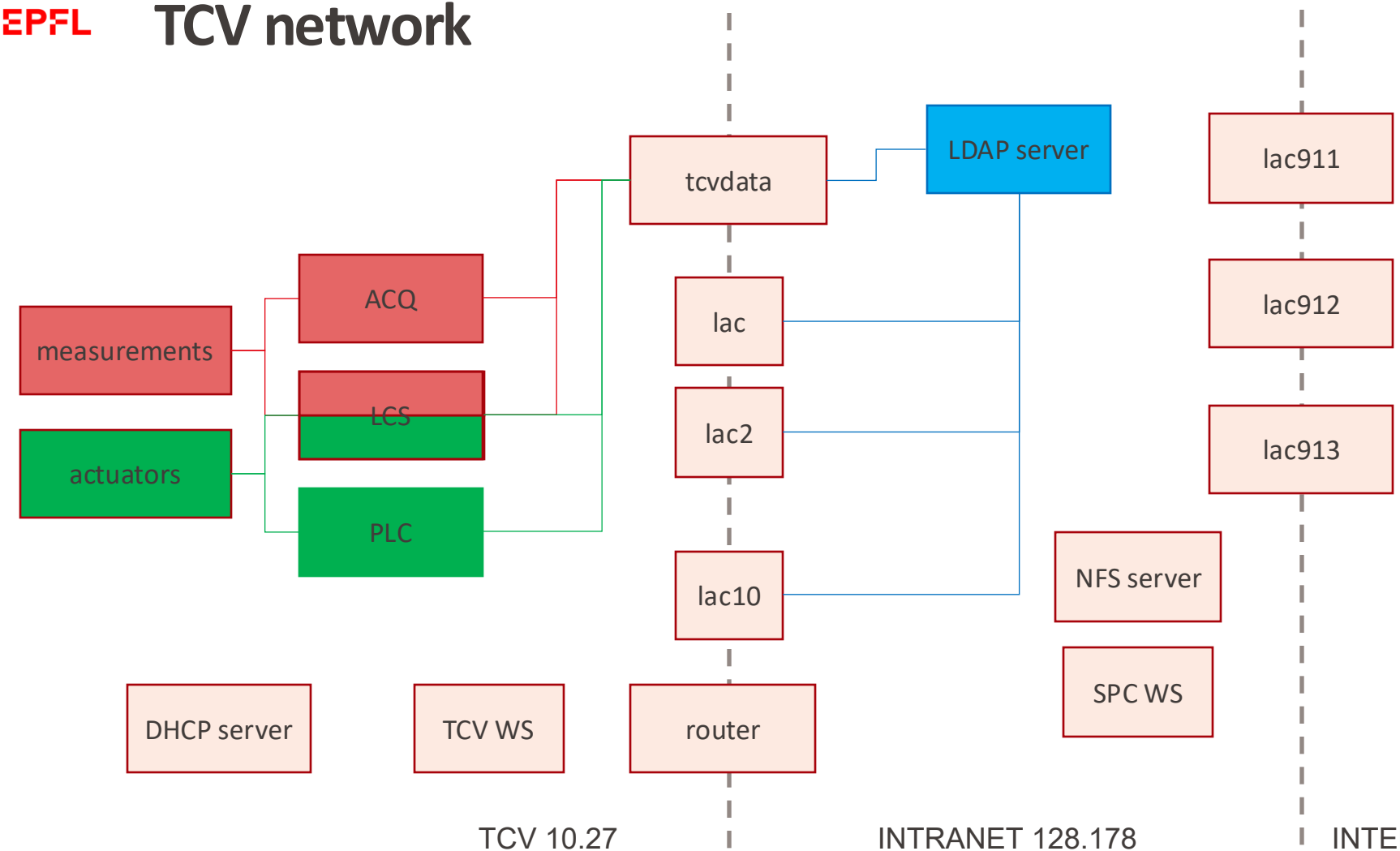
Mateusz Gospdarczyk

Luke Simons

Cenk Yildiz

Questions?

TCV network


tcvdata
LDAP server
lac911
ACQ
lac
lac912
measurements
LCS
lac2
lac913
actuators
PLC
lac10
NFS server
SPC WS
DHCP server
TCV WS
router
TCV 10.27
INTRANET 128.178
INTERNET

Virtual machines and containers