



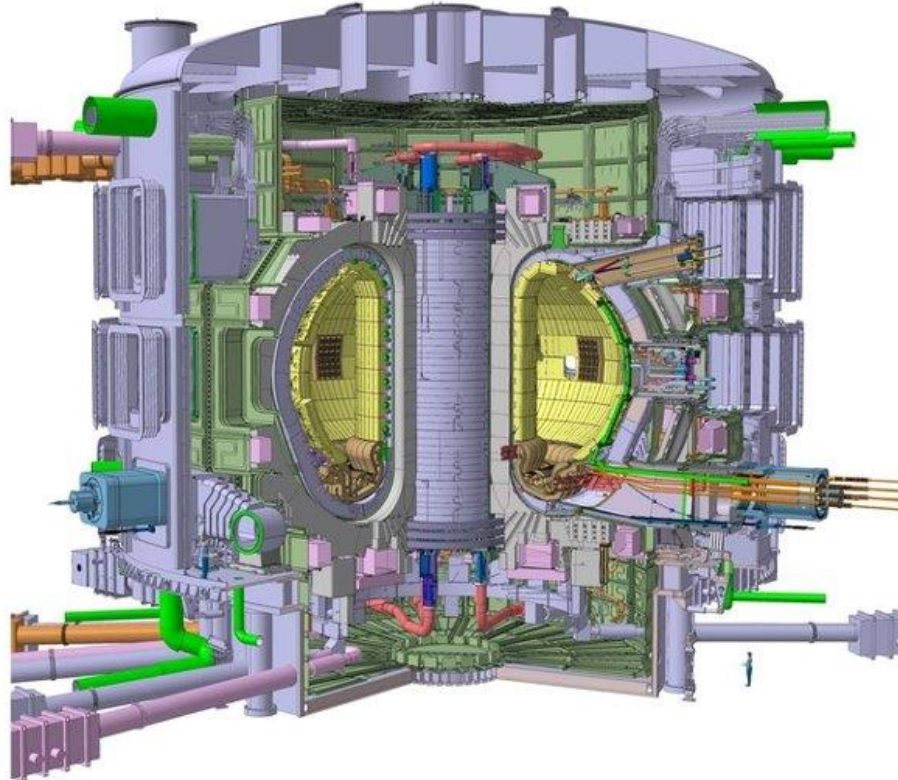
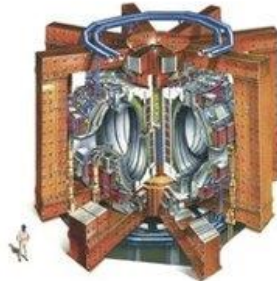
Fusion Technologies

IT, control, data acquisition

J. Decker

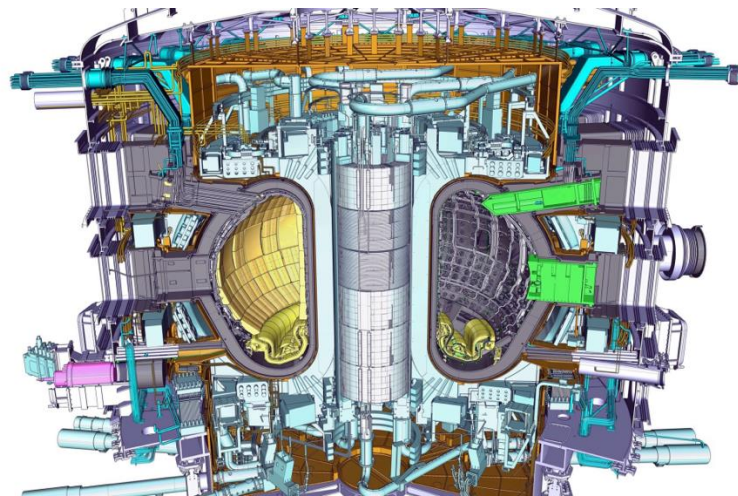
Special thanks to :
B. Duval, C. Galperti, SPC IT team

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

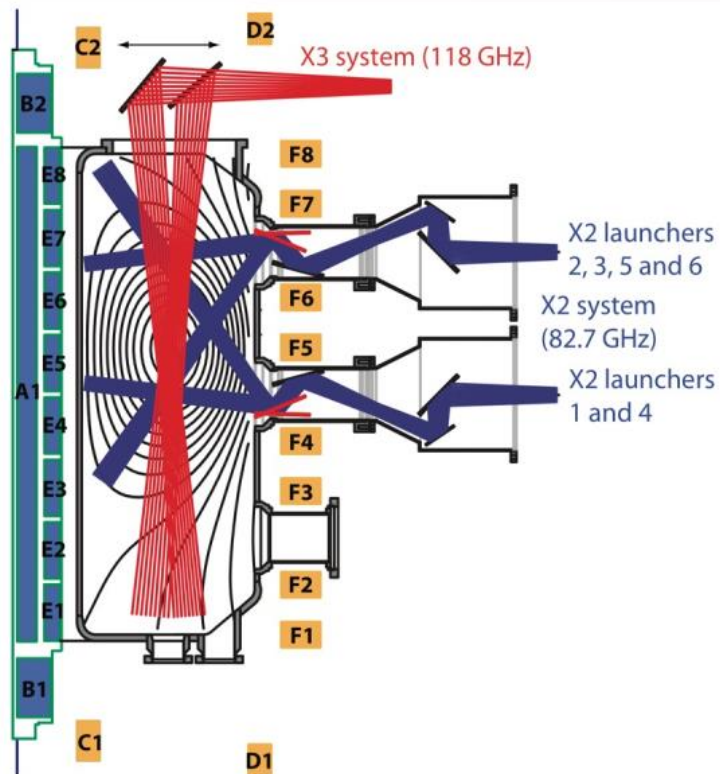


- **Fusion experiments are digital systems**
 - Computers control (nearly) everything
 - Almost all measurements are voltages, currents, or (especially recently) images.

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



- 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

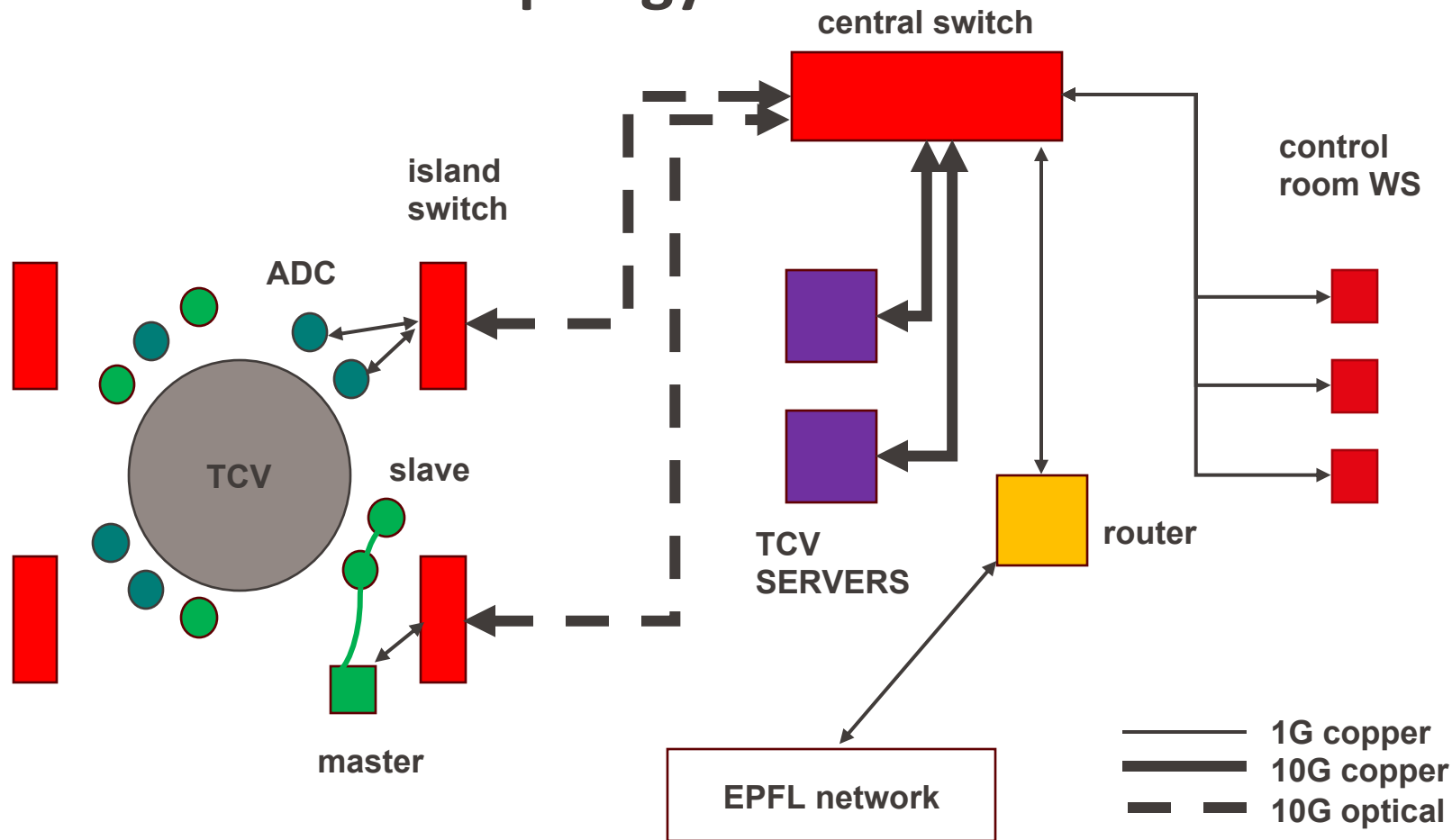


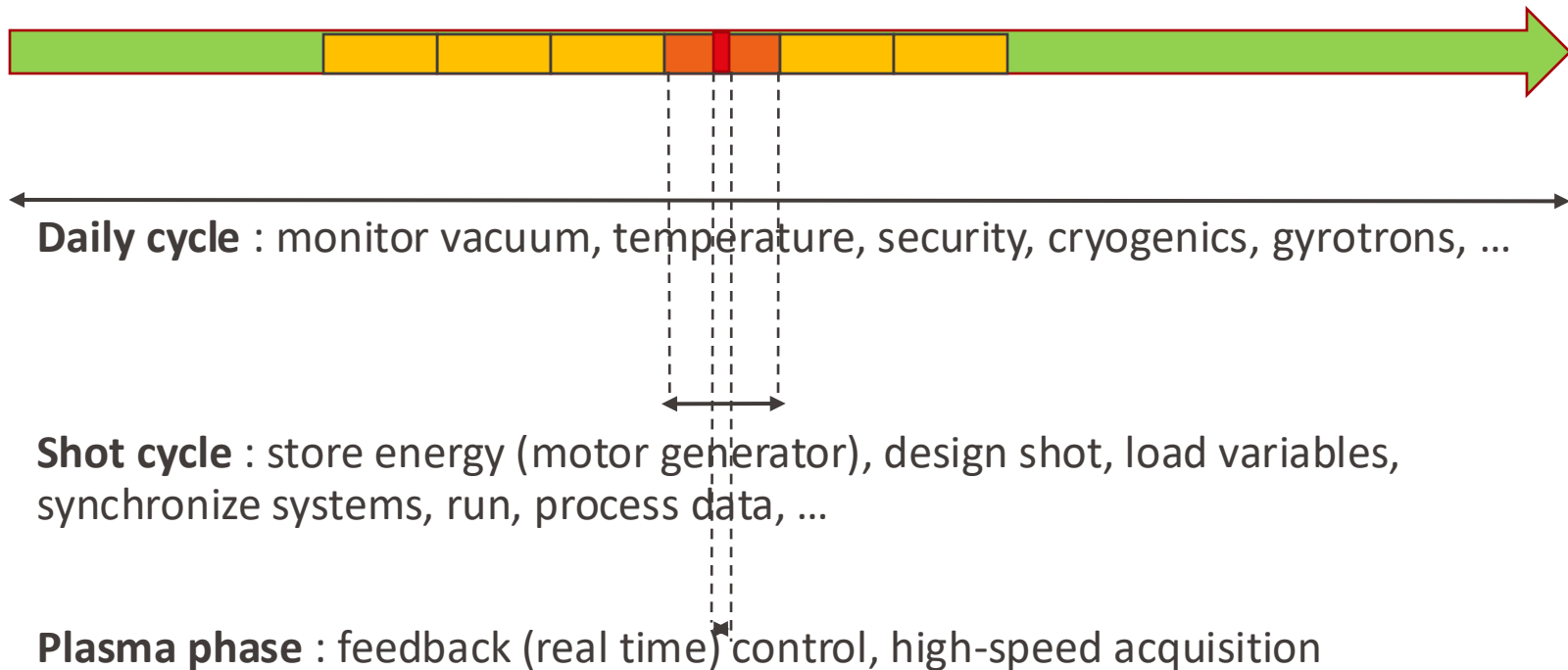
- Fusion experiments mix **hardware and software, physics and engineering**
 - > **IT must integrate this diversity**
 - Hardware and software development are part of the research effort
- This talk focuses on TCV
 - 30 years of history, a remarkable mix of old and new technology
- Despite dozens of 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, ...)

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

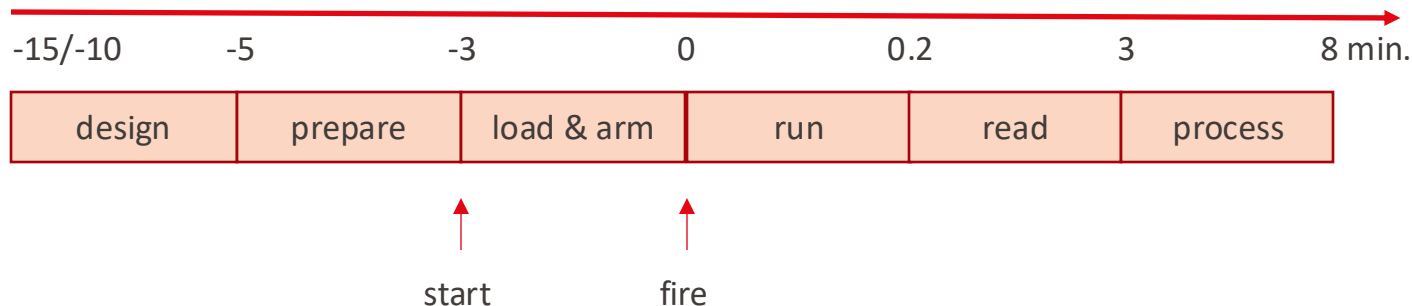
- Second Part
 - Data processing
 - Data organization, data access, outreach
 - Data storage and backup
 - Fusion IT environment

TCV Network topology



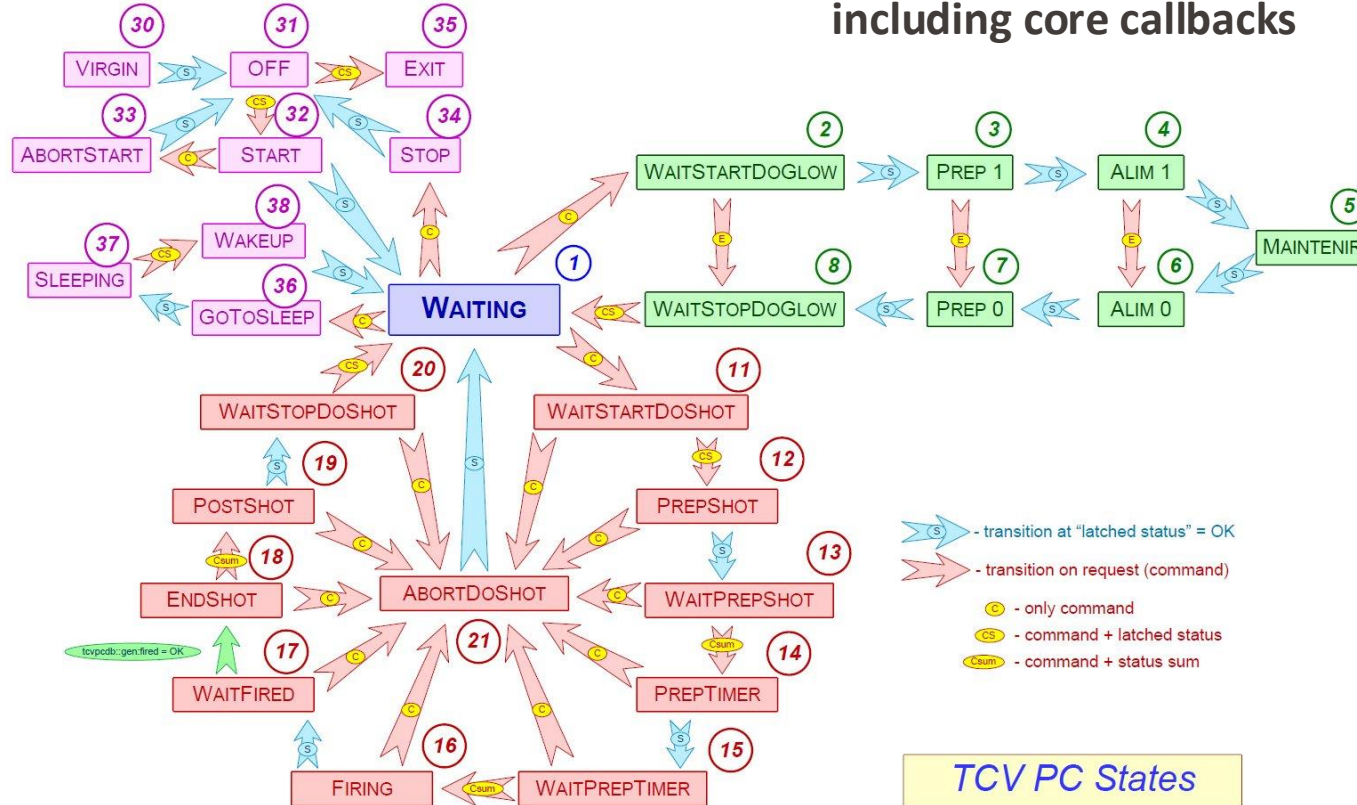


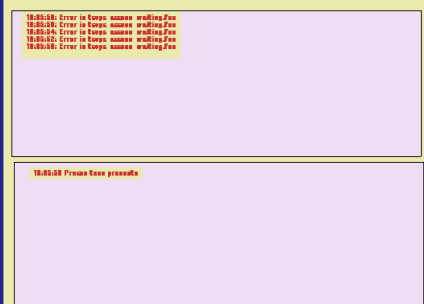
- Fusion experiments are based on shot cycles



- **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

TCVPC is the TCV experiment state machine including core callbacks





- **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
```

• Alternative control framework :

EPICS

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

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](#).

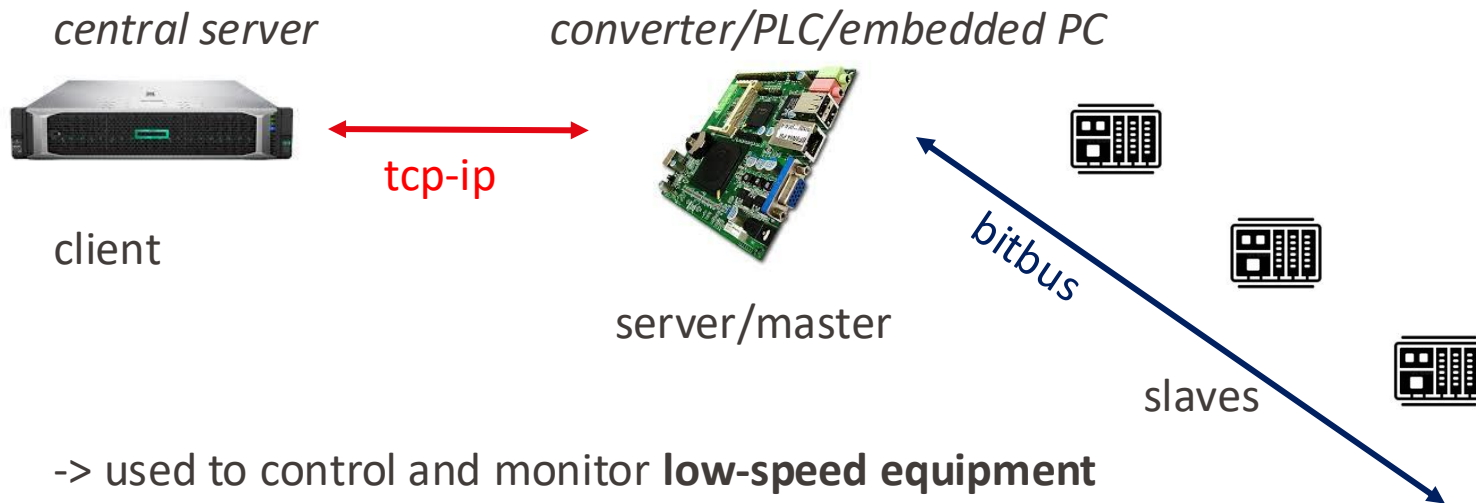
To submit a new entry to this list for your Hardware Support module, use [this form](#). Email corrections or questions about this page to [Andrew Johnson](#).

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

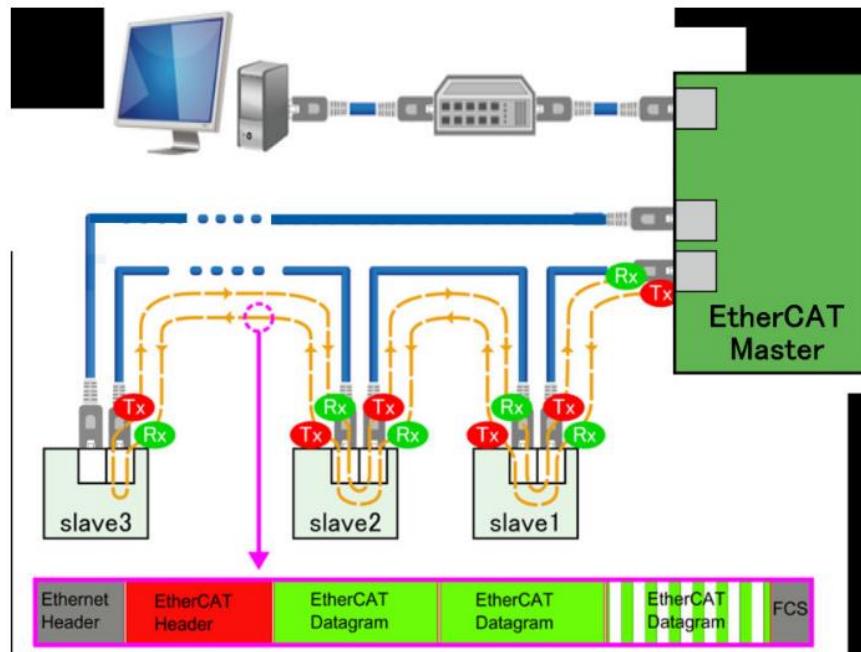
- TCV uses a combination of central and distributed control systems
- **Central systems** : device control from central computer via slave/master protocol (ex : BITBUS, RS232, MODBUS, I2C...)



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

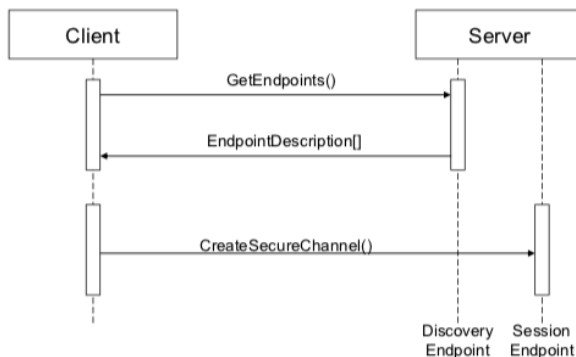
EtherCAT (Ethernet for Automation and Control Technology)

- Ethernet based control fieldbus.
- short data update times ($> 50 \mu\text{s}$)
- low communication jitter ($\leq 1 \mu\text{s}$)
- reduced hardware costs.



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)



The screenshot shows the **Unified Automation UaExpert - The OPC Unified Architecture Client - NewProject*** interface. The **Project** pane on the left shows a tree structure with **Servers**, **Documents**, and **Default DA View**. The **Address Space** pane shows a tree structure with **Root**, **Objects**, and various data types like **AllDataTypesDynamic**, **AllDataTypesStatic**, **AnalogStatic**, **Counter1**, **Counter2**, **CounterWithHistory**, **DeviceSet**, **DiscreteTypes**, **ItemWithByteStringNodeId**, **ItemWithGuidNodeId**, **ItemWithNumericNodeId**, **MassAlarms**, **MassTest**, **MyDemoObject**, **MyDemoObject2**, **PLC1**, **Server**, **SimulationActivate**, **SimulationSpeed**, and **StaticCacheTest**. The **Configuration** pane shows the **Server/Object** configuration for **Unified Automation Demo Server / MyDemoObject**, with checkboxes for **SimpleEvents**, **ConditionType**, and **AuditEventType**. The **Events** pane shows a table of events with columns for **Events**, **Alarms**, **Time**, **Severity**, **Server/Object**, **SourceName**, **Message**, and **ConditionName**. The **Details** pane shows the details for the selected event, including **Name**, **Value**, **ConditionId**, **NamespaceIndex**, **IdentifierType**, **Identifier**, **AckedState/Id**, and **ActiveState**. The **Log Window** at the bottom shows a table of log messages with columns for **Timestamp**, **Source**, **Server**, and **Message**.

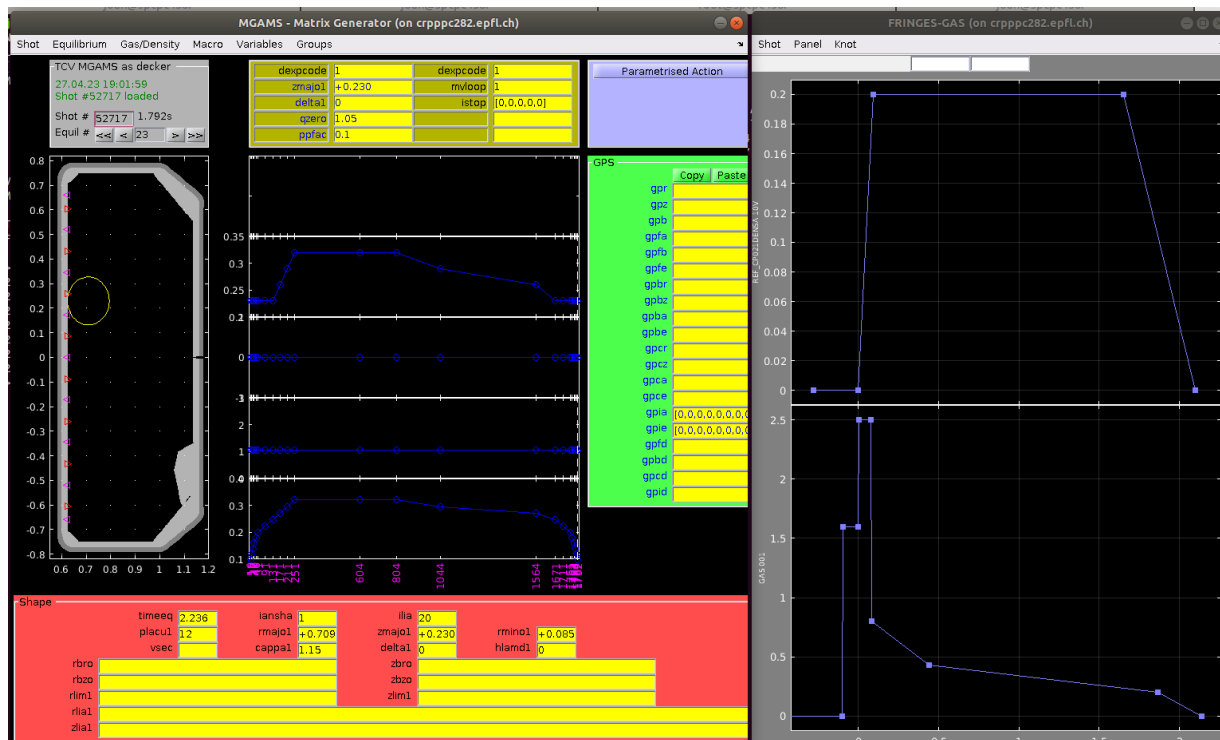
Events	Alarms	Time	Severity	Server/Object	SourceName	Message	ConditionName
✓	✓	13:47:54.001	500	Unified Automati...	MyDemoObject	Exclusive level al...	ExclusiveLevel
✓	✓	13:12:41.596	500	Unified Automati...	MyDemoObject	Exclusive level al...	ExclusiveLevel
✓	✓	13:29:27.452	500	Unified Automati...	MyDemoObject	Exclusive level al...	ExclusiveLevel
✓	✓	13:21:04.453	500	Unified Automati...	MyDemoObject	Exclusive level al...	ExclusiveLevel

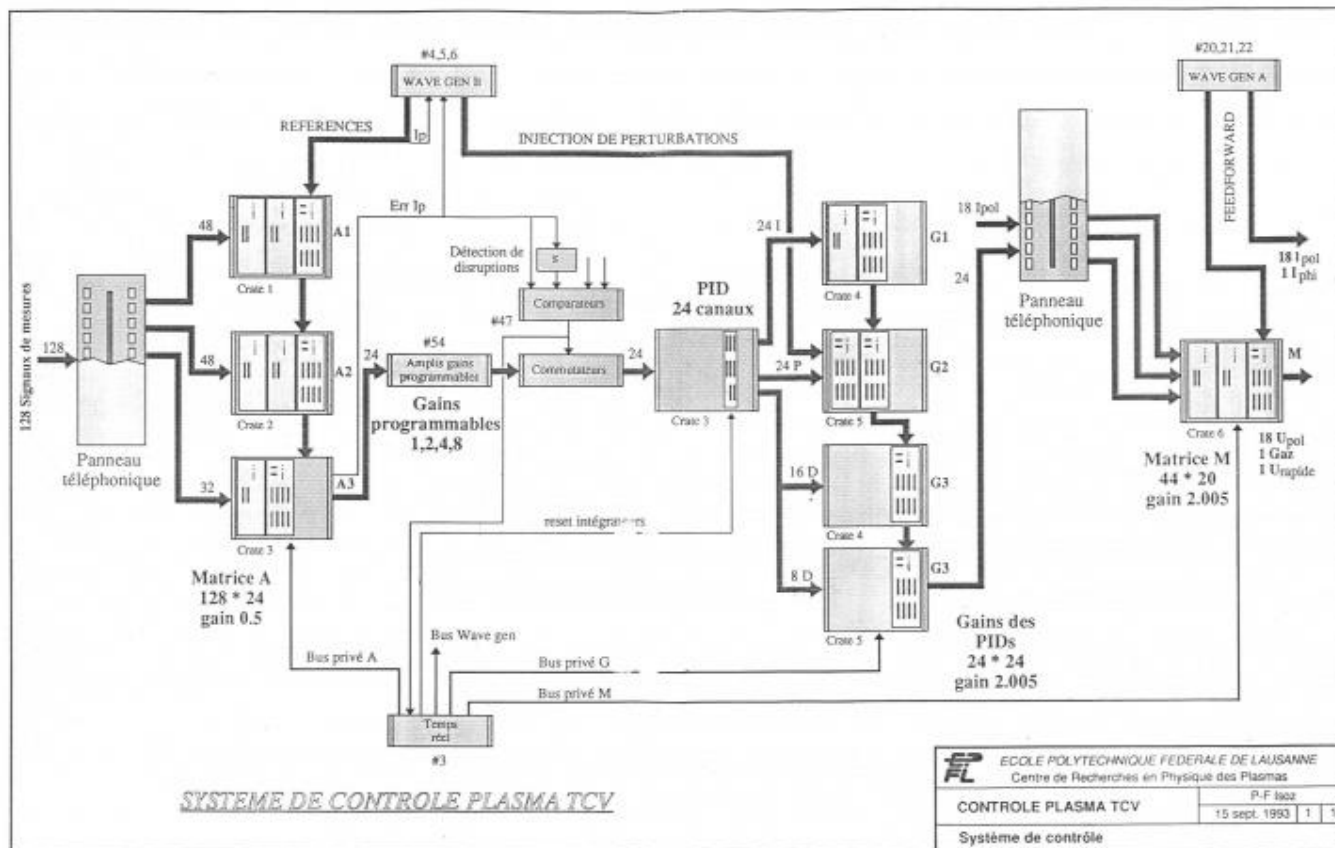
Name	Value
ConditionId	NodeId
NamespaceIndex	4
IdentifierType	String
Identifier	MyDemoObject.ExclusiveLevelAlarm
AckedState/Id	False
ActiveState	"en", "Active"

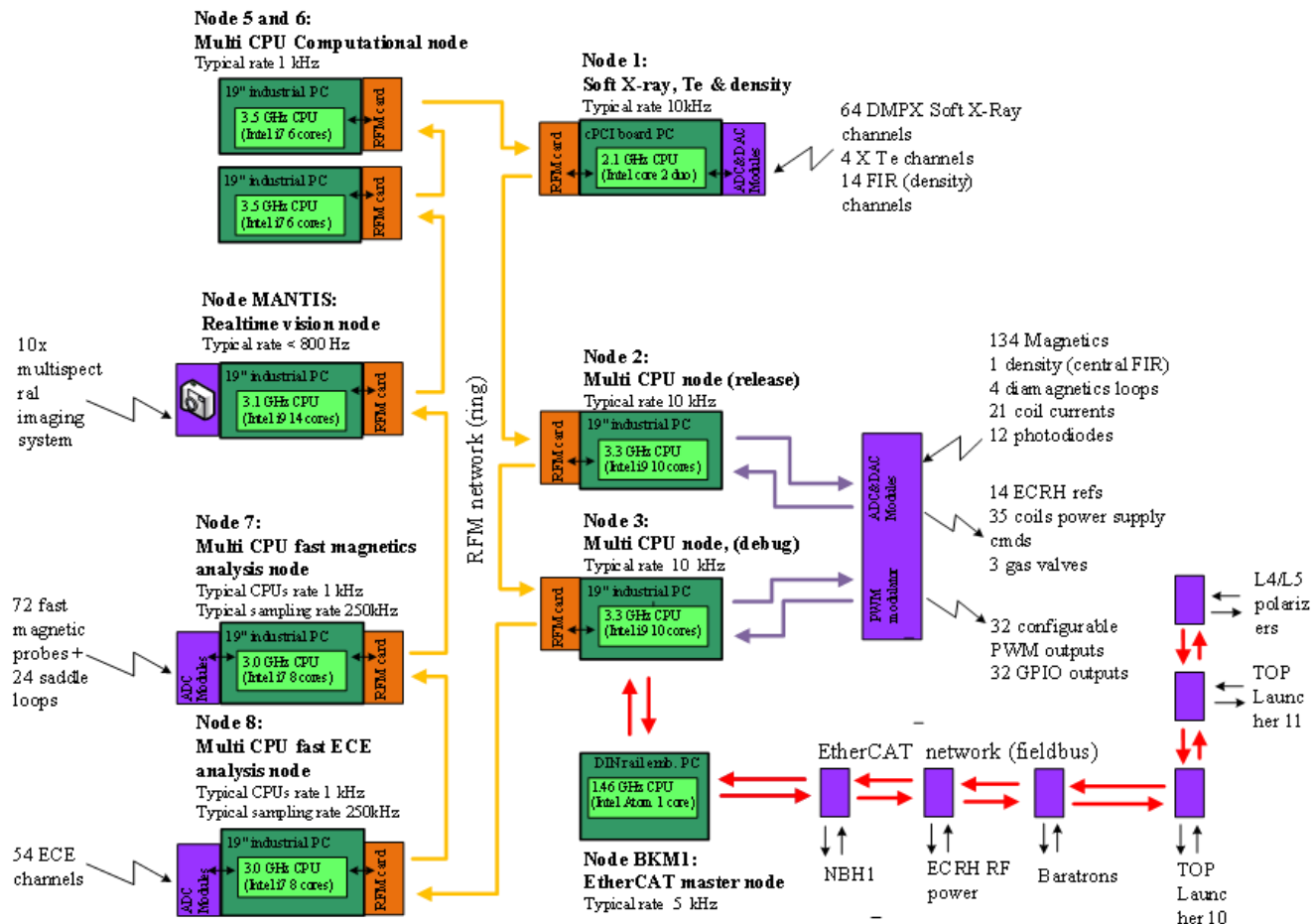
Timestamp	Source	Server	Message
13:47:54.188	TypeCache	Unified Automati...	Description = SystemEventType
13:47:54.188	TypeCache	Unified Automati...	DisplayName = SystemEventType
13:47:54.188	TypeCache	Unified Automati...	BrowseName = 0: SystemEventType
13:47:54.188	TypeCache	Unified Automati...	Read succeeded.
13:47:54.188	TypeCache	Unified Automati...	Reading type info of NodeId NS0[Numeric]2130

- 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)

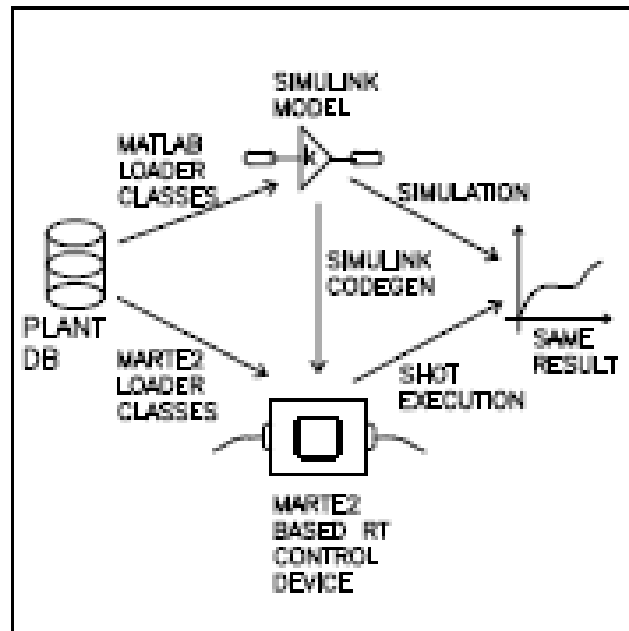
- Shot design interface : mgams
- Secondary systems : echcs, nbhcs, fueling, etc

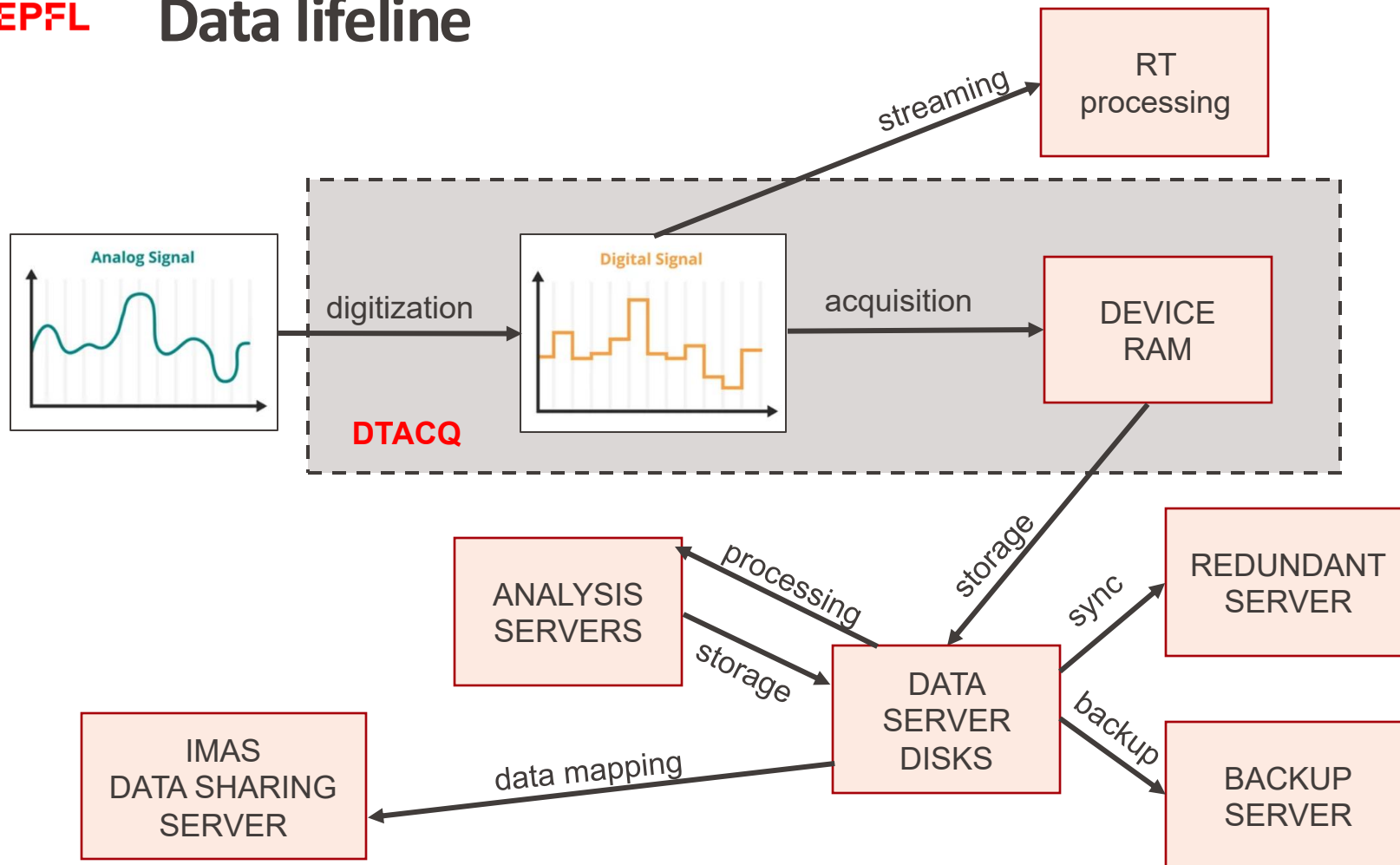




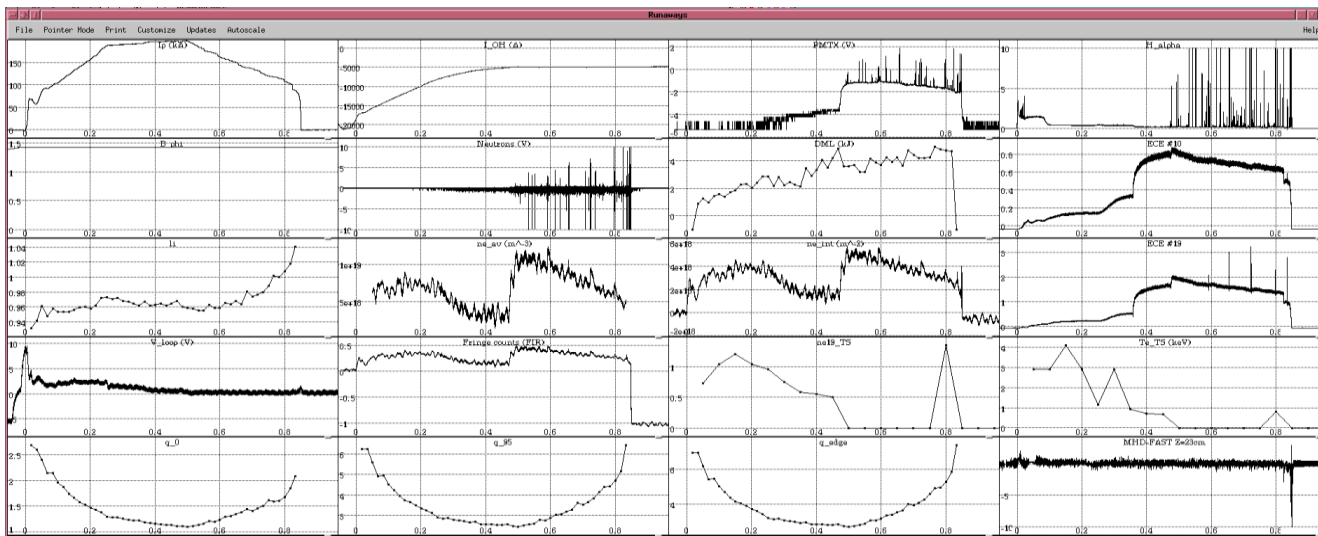


- Increasingly complex control algorithms
 - Equilibrium reconstruction (shaping)
 - > real time **liuqe**
 - ECRH beam tracing
 - > real time **torbeam**
 - Transport and current diffusion
 - > real time **RAPTOR**
- Global platform for RT simulation and compilation using MATLAB/Simulink
- Global RT execution platform using MARTe2
- Deployment of AI-ML techniques
 - > complex events on very short timescales (disruption mitigation and avoidance)

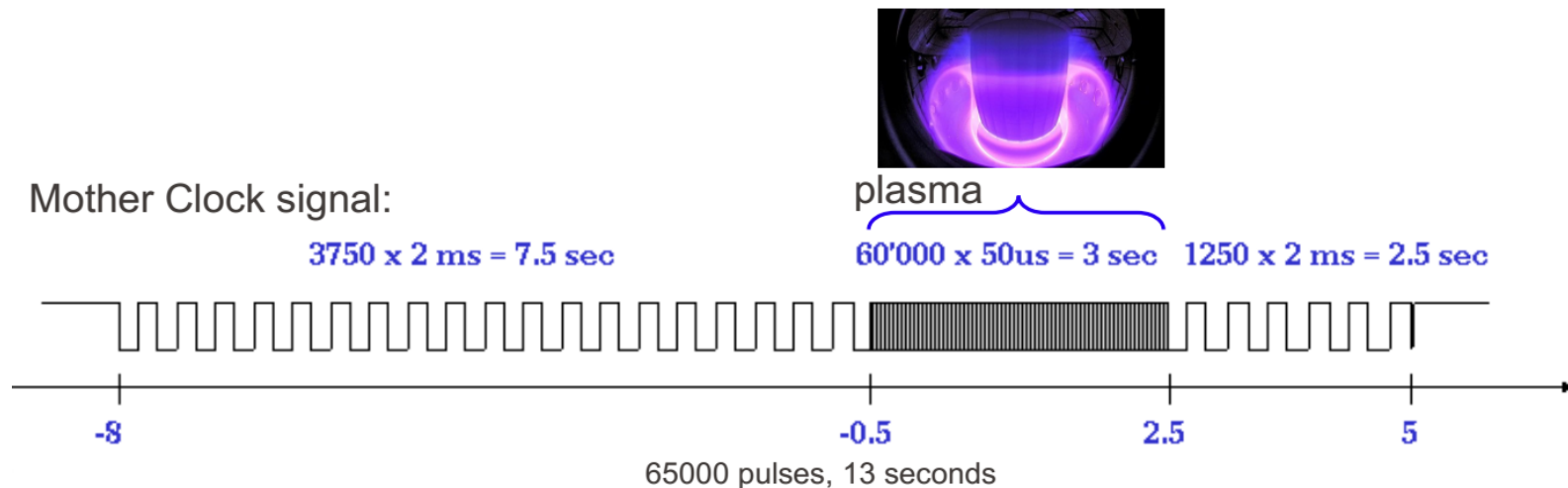




- Causal analysis is essential in experimental plasma physics
- Tools dedicated to multi-signal time evolution comparison (i.e. dwscope, jScope)
- Ideally, synchronization precision must at least match acquisition rate
- For a long time, TCV sync precision was less than one microsecond (but better for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



- 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 μ s) period for refined timing during plasma phase



- 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

- 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...

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

- **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



Title: SPC Fast Acq Catalogue

Date: 23/08/2024

Author: L. Simons

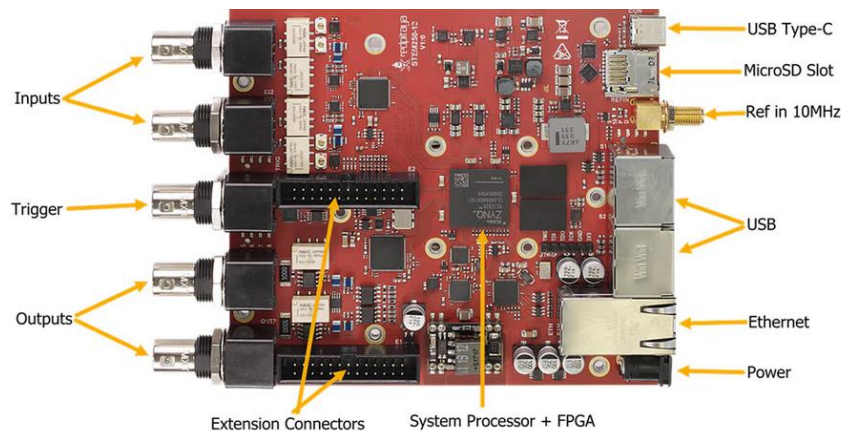
Type	Company	Model Name	Stand Alone?	Max Chans	BW [MHz]	Acq rate [MHz]	Prec [bits]	Acq Time [s]	Sum of Price
ADC	Acqiris	Acqiris SA248P	n	1	2500	8000	14	0,500	- €
	Acquisys	ATS9364	n	2	1000	3000	12	0,171	- €
	CAEN	CAEN2730	y/n	32	250	500	14	0,156	- €
	D-tacq	ACQ482ELF	y	16	40	80	14	0,500	- €
	GUZIK	GUZIK 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

RED PITAYA 250-12



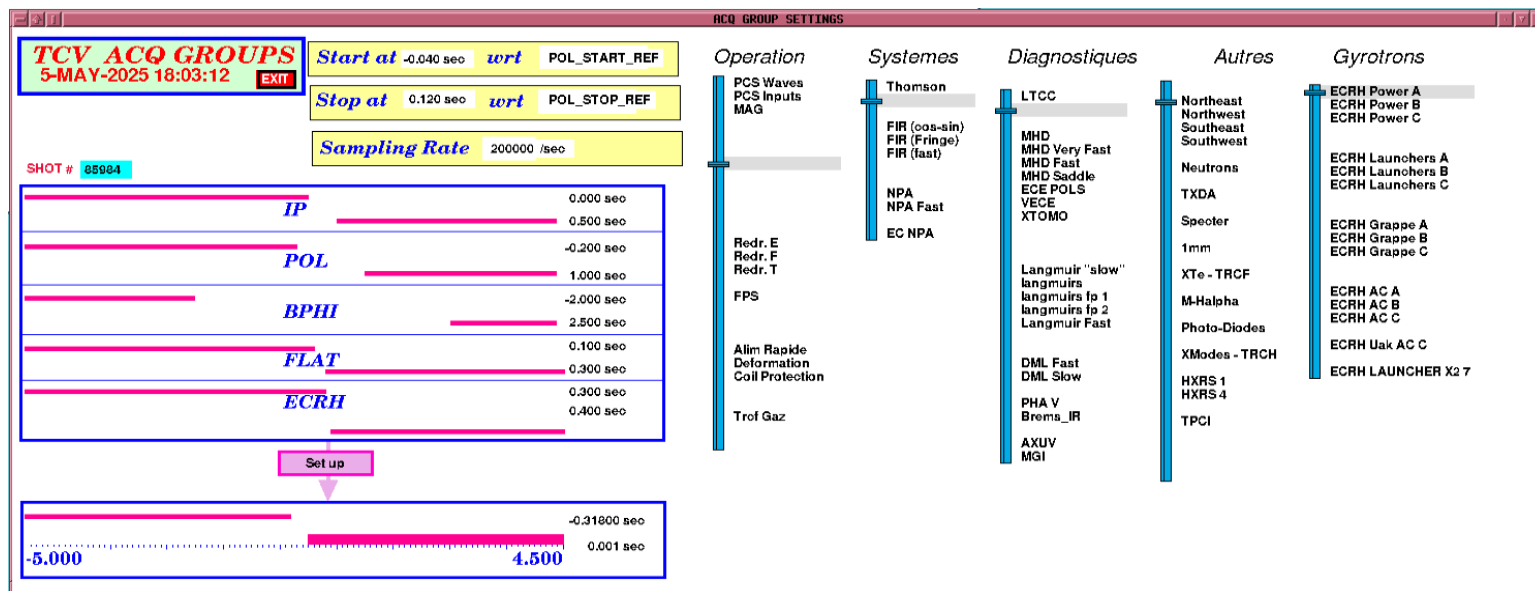
BOARD LAYOUT



TELEDYNE ADQ35



- 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



Local/PILOT/pictures/acqmon_vcd

D-TACQ CTRL PANEL **EXIT**

MODULE	ON	INIT	POST	DATETIME_CH1	SIZE_CH1	STATE	CLK	CLK [HZ]	TRIG.	TOTSAMPLES	PPS	PPS UPTIME
DT4Q_FILD_001				0	EDLR	PPCLK	4555579 Hz	1	2765176		2687113	init
DT4Q_FPS_001				0	EDLR	PPCLK	560000 Hz	1	1572854		267146	init
DT4Q_MPX_001				0	EDLR	ZCLK	155556 Hz	21	626688		2691644	init
DT4Q_MIA_002				0	EDLR	ZCLK	10000 Hz	354	174080		2691660	INIT
DT4Q_MIA_001				0	EDLR	ZCLK	200000 Hz	354	1617920		2691643	INIT
DT4Q_MIA_003				0	EDLR	ZCLK	10000 Hz	355	130944		2667012	init
DT4Q_MIA_004				0	EDLR	ZCLK	100000 Hz	353	1433600		2166591	init
DT4Q_REDE_001				0	EDLR	OFF	155559 Hz	1	0		40664	INIT
DT4Q_REDE_002				0	EDLR	OFF	155557 Hz	0	0		40760	init
DT4Q_REF_NAME				0	EDLR	OFF	155557 Hz	1	0		40779	init
DT4Q_REDF_002				0	EDLR	OFF	200000 Hz	0	0		40778	init
DT4Q_REDT_001				0	EDLR	OFF	155556 Hz	1	0		40778	init
DT4Q_MT_001				0	ADLR	PPCLK	20000 Hz	1	565760		2776454	init
DT4Q_MT_002				0	PPR STOP	PPCLK	200000 Hz	0	-1	INIT DONE	2367253	init
DT4Q_MT_003				0	EDLR	OFF	0 Hz	0	0		0	init
DTBOLO_001				0	EDLR	ZCLK	1000147 Hz	1	37536		48772	init
DTBOLO_002				0	EDLR	ZCLK	1000136 Hz	1	37536		48775	init
DTBOLO_003				0	EDLR	ZCLK	1000162 Hz	1	37536		48774	init
DT196_AXUV_001				0							0	init
DT196_AXUV_002				0							0	init
DT196_AXUV_003				0							0	init
DT4Q_SIPM_001				0	EDLR	PPCLK	555551 Hz	1	2162688		2686310	init
DT4Q_NBHP_001				0	EDLR	ZCLK	10000 Hz	203	223040		2696366	INIT
DT4Q_PDB_001				0	EDLR	ZCLK	155556 Hz	337	770048		2703172	INIT
DT4Q_XTEP_001				0	EDLR	PPCLK	200000 Hz	367	1022720		2763579	init
DT4Q_THCP_001				0	EDLR	ZCLK	10000 Hz	367	3039232		2763269	init
DT4Q_TEST_001				0	EDLR	ZCLK	555568 Hz	279	0		2763197	init
DT4Q_HYBRID_001				0	EDLR	ZCLK	155559 Hz	0	0		48670	INIT
DT4Q_HYBRID_002				0	EDLR	ZCLK	155559 Hz	0	0		48666	INIT
DT4Q_HYBRID_003				0	EDLR	ZCLK	155559 Hz	0	0		48670	init
RTTHOM_001				0	EDLR	ZCLK	200029 Hz	0	0		48775	init
RTTHOM_002				0	EDLR	OFF	200030 Hz	0	0		48775	init
RTTHOM_003				0	EDLR	OFF	200031 Hz	0	0		48775	init
RTTHOM_004				0	EDLR	OFF	0 Hz	0	0		0	init
DT4Q_OHER_001				0	EDLR	ZCLK	555553 Hz	2	3145728		2664507	init
DT4Q_ECE_002				0	EDLR	PPCLK	1555553 Hz	1	4580136		2763379	init
DT4Q_ECE_001				0	EDLR	ZCLK	155559 Hz	340	571200		2763196	INIT
DT4Q_APS_010				0	EDLR	PPCLK	125000 Hz	93	937504		1657743	init
DT4Q_APS_011				0	EDLR	ZCLK	125000 Hz	6	937504		1657699	init
DT4Q_GYNO_001				0	EDLR	PPCLK	250000 Hz	1	108344		2762646	init
DT4Q_XSU_001				0	EDLR	PPCLK	200000 Hz	1	1048576		1657676	init
DT4Q_ECRHP_001				0	EDLR	PPCLK	200000 Hz	4	540672		2667610	init
DT4Q_ECRHP_002				0	EDLR	PPCLK	200000 Hz	3	819200		2106959	init
DT4Q_X2_001				0	EDLR	PPCLK	200000 Hz	1	671744		2666047	init
DT4Q_ONEMP_001				0	EDLR	PPCLK	155558 Hz	1	983040		666056	init
DT4Q_OCE_001				0	EDLR	PPCLK	0 Hz	1	0		655940	init
DT4Q_OCE_002				0	EDLR	PPCLK	0 Hz	1	0		267303	init
DT196_LANG_001				0							0	init
DT196_LANG_002				0							0	init
DT196_LANG_003				0							0	init
DT4Q_LANG_004				0	EDLR	ZCLK	155555 Hz	184	625600		2763269	init
DT4Q_LANG_005				0	EDLR	ZCLK	200000 Hz	161	625600		2763269	init
DT4Q_R0PA_001				0	EDLR	ZCLK	2000004 Hz	2	4075616		2763656	INIT
DT4Q_LANG_006				0	EDLR	PPCLK	1555596 Hz	41	4325376		2763269	init
DT4Q_LANG_007				0	EDLR	OFF	1555596 Hz	41	4325376		2763269	init
DT4Q_LANG_008				0	EDLR	ZCLK	1555576 Hz	1	0		2763269	init
DT4Q_LANG_009				0	EDLR	ZCLK	1555582 Hz	1	0		2763269	init
DT196_MAG_001				0							0	init
DT196_MAG_002				0							0	init
DT196_MAG_003				0							0	init
DT196_MAG_004				0							0	init
DT196_MHD_001				0							0	init
DT196_MHD_002				0							0	init
DT196_MHD_003				0							0	init
DT196_MHD_DBG				0							0	init
DT196_LTCC_001				0							0	init

MOD SERVERS **NO ERROR, LAST UPDATE: 65-May-2025 16:28:51.658340**

Recipe **init** shot **65864** **INIT** **STORE** **ACK**

Acqmon global info **MOD SERVERS**

DoShot	StartUp	DoGlow	Waiting	WSartShot	PrepShot	WPrepShot	PrepTimer	WPrepTimer	Firing	WFiring	EndShot	PostShot	WSupShot	AbortShot
Timer														AbortShot
MDS														AbortShot

Local Alpha Vpp PPH
Port01 Beam-22 Beam-23 Beam-24 Beam-25 Beam-26 Beam-27 Beam-28 Beam-29 Beam-30 Beam-31 Beam-32 Beam-33 Beam-34 Beam-35 Beam-36 Beam-37 Beam-38 Beam-39 Beam-40 Beam-41 Beam-42 Beam-43 Beam-44 Beam-45 Beam-46 Beam-47 Beam-48 Beam-49 Beam-50 Beam-51 Beam-52 Beam-53 Beam-54 Beam-55 Beam-56 Beam-57 Beam-58 Beam-59 Beam-60 Beam-61 Beam-62 Beam-63 Beam-64 Beam-65 Beam-66 Beam-67 Beam-68 Beam-69 Beam-70 Beam-71 Beam-72 Beam-73 Beam-74 Beam-75 Beam-76 Beam-77 Beam-78 Beam-79 Beam-80 Beam-81 Beam-82 Beam-83 Beam-84 Beam-85 Beam-86 Beam-87 Beam-88 Beam-89 Beam-90 Beam-91 Beam-92 Beam-93 Beam-94 Beam-95 Beam-96 Beam-97 Beam-98 Beam-99 Beam-100 Beam-101 Beam-102 Beam-103 Beam-104 Beam-105 Beam-106 Beam-107 Beam-108 Beam-109 Beam-110 Beam-111 Beam-112 Beam-113 Beam-114 Beam-115 Beam-116 Beam-117 Beam-118 Beam-119 Beam-120 Beam-121 Beam-122 Beam-123 Beam-124 Beam-125 Beam-126 Beam-127 Beam-128 Beam-129 Beam-130 Beam-131 Beam-132 Beam-133 Beam-134 Beam-135 Beam-136 Beam-137 Beam-138 Beam-139 Beam-140 Beam-141 Beam-142 Beam-143 Beam-144 Beam-145 Beam-146 Beam-147 Beam-148 Beam-149 Beam-150 Beam-151 Beam-152 Beam-153 Beam-154 Beam-155 Beam-156 Beam-157 Beam-158 Beam-159 Beam-160 Beam-161 Beam-162 Beam-163 Beam-164 Beam-165 Beam-166 Beam-167 Beam-168 Beam-169 Beam-170 Beam-171 Beam-172 Beam-173 Beam-174 Beam-175 Beam-176 Beam-177 Beam-178 Beam-179 Beam-180 Beam-181 Beam-182 Beam-183 Beam-184 Beam-185 Beam-186 Beam-187 Beam-188 Beam-189 Beam-190 Beam-191 Beam-192 Beam-193 Beam-194 Beam-195 Beam-196 Beam-197 Beam-198 Beam-199 Beam-200 Beam-201 Beam-202 Beam-203 Beam-204 Beam-205 Beam-206 Beam-207 Beam-208 Beam-209 Beam-210 Beam-211 Beam-212 Beam-213 Beam-214 Beam-215 Beam-216 Beam-217 Beam-218 Beam-219 Beam-220 Beam-221 Beam-222 Beam-223 Beam-224 Beam-225 Beam-226 Beam-227 Beam-228 Beam-229 Beam-230 Beam-231 Beam-232 Beam-233 Beam-234 Beam-235 Beam-236 Beam-237 Beam-238 Beam-239 Beam-240 Beam-241 Beam-242 Beam-243 Beam-244 Beam-245 Beam-246 Beam-247 Beam-248 Beam-249 Beam-250 Beam-251 Beam-252 Beam-253 Beam-254 Beam-255 Beam-256 Beam-257 Beam-258 Beam-259 Beam-260 Beam-261 Beam-262 Beam-263 Beam-264 Beam-265 Beam-266 Beam-267 Beam-268 Beam-269 Beam-270 Beam-271 Beam-272 Beam-273 Beam-274 Beam-275 Beam-276 Beam-277 Beam-278 Beam-279 Beam-280 Beam-281 Beam-282 Beam-283 Beam-284 Beam-285 Beam-286 Beam-287 Beam-288 Beam-289 Beam-290 Beam-291 Beam-292 Beam-293 Beam-294 Beam-295 Beam-296 Beam-297 Beam-298 Beam-299 Beam-300 Beam-301 Beam-302 Beam-303 Beam-304 Beam-305 Beam-306 Beam-307 Beam-308 Beam-309 Beam-310 Beam-311 Beam-312 Beam-313 Beam-314 Beam-315 Beam-316 Beam-317 Beam-318 Beam-319 Beam-320 Beam-321 Beam-322 Beam-323 Beam-324 Beam-325 Beam-326 Beam-327 Beam-328 Beam-329 Beam-330 Beam-331 Beam-332 Beam-333 Beam-334 Beam-335 Beam-336 Beam-337 Beam-338 Beam-339 Beam-340 Beam-341 Beam-342 Beam-343 Beam-344 Beam-345 Beam-346 Beam-347 Beam-348 Beam-349 Beam-350 Beam-351 Beam-352 Beam-353 Beam-354 Beam-355 Beam-356 Beam-357 Beam-358 Beam-359 Beam-360 Beam-361 Beam-362 Beam-363 Beam-364 Beam-365 Beam-366 Beam-367 Beam-368 Beam-369 Beam-370 Beam-371 Beam-372 Beam-373 Beam-374 Beam-375 Beam-376 Beam-377 Beam-378 Beam-379 Beam-380 Beam-381 Beam-382 Beam-383 Beam-384 Beam-385 Beam-386 Beam-387 Beam-388 Beam-389 Beam-390 Beam-391 Beam-392 Beam-393 Beam-394 Beam-395 Beam-396 Beam-397 Beam-398 Beam-399 Beam-400 Beam-401 Beam-402 Beam-403 Beam-404 Beam-405 Beam-406 Beam-407 Beam-408 Beam-409 Beam-410 Beam-411 Beam-412 Beam-413 Beam-414 Beam-415 Beam-416 Beam-417 Beam-418 Beam-419 Beam-420 Beam-421 Beam-422 Beam-423 Beam-424 Beam-425 Beam-426 Beam-427 Beam-428 Beam-429 Beam-430 Beam-431 Beam-432 Beam-433 Beam-434 Beam-435 Beam-436 Beam-437 Beam-438 Beam-439 Beam-440 Beam-441 Beam-442 Beam-443 Beam-444 Beam-445 Beam-446 Beam-447 Beam-448 Beam-449 Beam-450 Beam-451 Beam-452 Beam-453 Beam-454 Beam-455 Beam-456 Beam-457 Beam-458 Beam-459 Beam-460 Beam-461 Beam-462 Beam-463 Beam-464 Beam-465 Beam-466 Beam-467 Beam-468 Beam-469 Beam-470 Beam-471 Beam-472 Beam-473 Beam-474 Beam-475 Beam-476 Beam-477 Beam-478 Beam-479 Beam-480 Beam-481 Beam-482 Beam-483 Beam-484 Beam-485 Beam-486 Beam-487 Beam-488 Beam-489 Beam-490 Beam-491 Beam-492 Beam-493 Beam-494 Beam-495 Beam-496 Beam-497 Beam-498 Beam-499 Beam-500 Beam-501 Beam-502 Beam-503 Beam-504 Beam-505 Beam-506 Beam-507 Beam-508 Beam-509 Beam-510 Beam-511 Beam-512 Beam-513 Beam-514 Beam-515 Beam-516 Beam-517 Beam-518 Beam-519 Beam-520 Beam-521 Beam-522 Beam-523 Beam-524 Beam-525 Beam-526 Beam-527 Beam-528 Beam-529 Beam-530 Beam-531 Beam-532 Beam-533 Beam-534 Beam-535 Beam-536 Beam-537 Beam-538 Beam-539 Beam-540 Beam-541 Beam-542 Beam-543 Beam-544 Beam-545 Beam-546 Beam-547 Beam-548 Beam-549 Beam-550 Beam-551 Beam-552 Beam-553 Beam-554 Beam-555 Beam-556 Beam-557 Beam-558 Beam-559 Beam-560 Beam-561 Beam-562 Beam-563 Beam-564 Beam-565 Beam-566 Beam-567 Beam-568 Beam-569 Beam-570 Beam-571 Beam-572 Beam-573 Beam-574 Beam-575 Beam-576 Beam-577 Beam-578 Beam-579 Beam-580 Beam-581 Beam-582 Beam-583 Beam-584 Beam-585 Beam-586 Beam-587 Beam-588 Beam-589 Beam-590 Beam-591 Beam-592 Beam-593 Beam-594 Beam-595 Beam-596 Beam-597 Beam-598 Beam-599 Beam-600 Beam-601 Beam-602 Beam-603 Beam-604 Beam-605 Beam-606 Beam-607 Beam-608 Beam-609 Beam-610 Beam-611 Beam-612 Beam-613 Beam-614 Beam-615 Beam-616 Beam-617 Beam-618 Beam-619 Beam-620 Beam-621 Beam-622 Beam-623 Beam-624 Beam-625 Beam-626 Beam-627 Beam-628 Beam-629 Beam-630 Beam-631 Beam-632 Beam-633 Beam-634 Beam-635 Beam-636 Beam-637 Beam-638 Beam-639 Beam-640 Beam-641 Beam-642 Beam-643 Beam-644 Beam-645 Beam-646 Beam-647 Beam-648 Beam-649 Beam-650 Beam-651 Beam-652 Beam-653 Beam-654 Beam-655 Beam-656 Beam-657 Beam-658 Beam-659 Beam-660 Beam-661 Beam-662 Beam-663 Beam-664 Beam-665 Beam-666 Beam-667 Beam-668 Beam-669 Beam-670 Beam-671 Beam-672 Beam-673 Beam-674 Beam-675 Beam-676 Beam-677 Beam-678 Beam-679 Beam-680 Beam-681 Beam-682 Beam-683 Beam-684 Beam-685 Beam-686 Beam-687 Beam-688 Beam-689 Beam-690 Beam-691 Beam-692 Beam-693 Beam-694 Beam-695 Beam-696 Beam-697 Beam-698 Beam-699 Beam-700 Beam-701 Beam-702 Beam-703 Beam-704 Beam-705 Beam-706 Beam-707 Beam-708 Beam-709 Beam-710 Beam-711 Beam-712 Beam-713 Beam-714 Beam-715 Beam-716 Beam-717 Beam-718 Beam-719 Beam-720 Beam-721 Beam-722 Beam-723 Beam-724 Beam-725 Beam-726 Beam-727 Beam-728 Beam-729 Beam-730 Beam-731 Beam-732 Beam-733 Beam-734 Beam-735 Beam-736 Beam-737 Beam-738 Beam-739 Beam-740 Beam-741 Beam-742 Beam-743 Beam-744 Beam-745 Beam-746 Beam-747 Beam-748 Beam-749 Beam-750 Beam-751 Beam-752 Beam-753 Beam-754 Beam-755 Beam-756 Beam-757 Beam-758 Beam-759 Beam-760 Beam-761 Beam-762 Beam-763 Beam-764 Beam-765 Beam-766 Beam-767 Beam-768 Beam-769 Beam-770 Beam-771 Beam-772 Beam-773 Beam-774 Beam-775 Beam-776 Beam-777 Beam-778 Beam-779 Beam-780 Beam-781 Beam-782 Beam-783 Beam-784 Beam-785 Beam-786 Beam-787 Beam-788 Beam-789 Beam-790 Beam-791 Beam-792 Beam-793 Beam-794 Beam-795 Beam-796 Beam-797 Beam-798 Beam-799 Beam-800 Beam-801 Beam-802 Beam-803 Beam-804 Beam-805 Beam-806 Beam-807 Beam-808 Beam-809 Beam-810 Beam-811 Beam-812 Beam-813 Beam-814 Beam-815 Beam-816 Beam-817 Beam-818 Beam-819 Beam-820 Beam-821 Beam-822 Beam-823 Beam-824 Beam-825 Beam-826 Beam-827 Beam-828 Beam-829 Beam-830 Beam-831 Beam-832 Beam-833 Beam-834 Beam-835 Beam-836 Beam-837 Beam-838 Beam-839 Beam-840 Beam-841 Beam-842 Beam-843 Beam-844 Beam-845 Beam-846 Beam-847 Beam-848 Beam-849 Beam-850 Beam-851 Beam-852 Beam-853 Beam-854 Beam-855 Beam-856 Beam-857 Beam-858 Beam-859 Beam-860 Beam-861 Beam-862 Beam-863 Beam-864 Beam-865 Beam-866 Beam-867 Beam-868 Beam-869 Beam-870 Beam-871 Beam-872 Beam-873 Beam-874 Beam-875 Beam-876 Beam-877 Beam-878 Beam-879 Beam-880 Beam-881 Beam-882 Beam-883 Beam-884 Beam-885 Beam-886 Beam-887 Beam-888 Beam-889 Beam-890 Beam-891 Beam-892 Beam-893 Beam-894 Beam-895 Beam-896 Beam-897 Beam-898 Beam-899 Beam-900 Beam-901 Beam-902 Beam-903 Beam-904 Beam-905 Beam-906 Beam-907 Beam-908 Beam-909 Beam-910 Beam-911 Beam-912 Beam-913 Beam-914 Beam-915 Beam-916 Beam-917 Beam-918 Beam-919 Beam-920 Beam-921 Beam-922 Beam-923 Beam-924 Beam-925 Beam-926 Beam-927 Beam-928 Beam-929 Beam-930 Beam-931 Beam-932 Beam-933 Beam-934 Beam-935 Beam

... 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

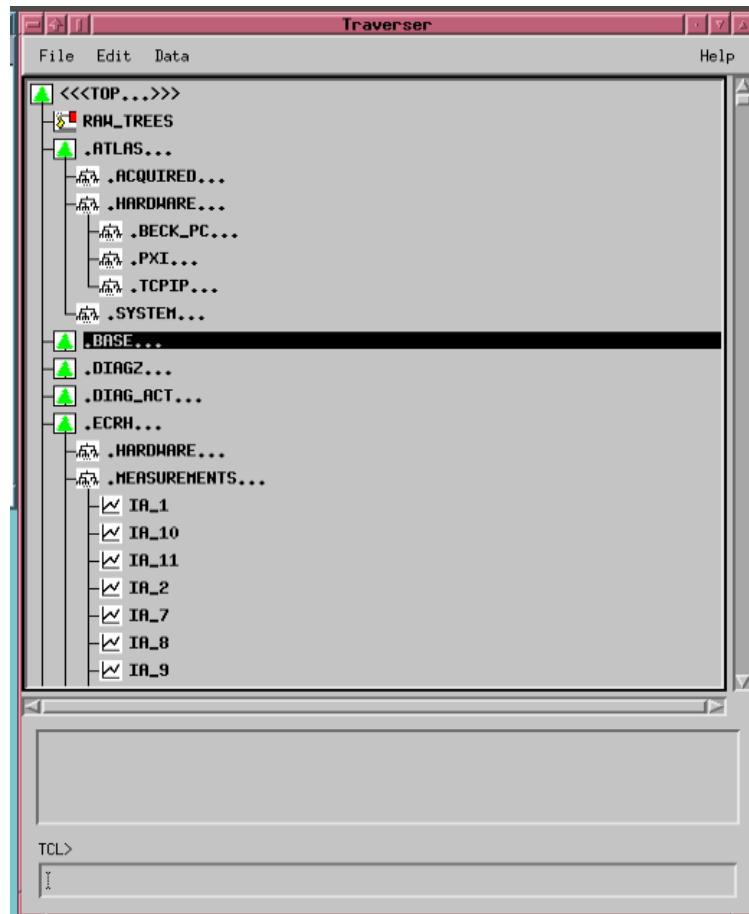
-> this is **1 TB of data for one shot ! 40 TB in one day...**

- 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)
 - Electronics can help : pre-ACQ treatment of analog signals

- 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**

- 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?



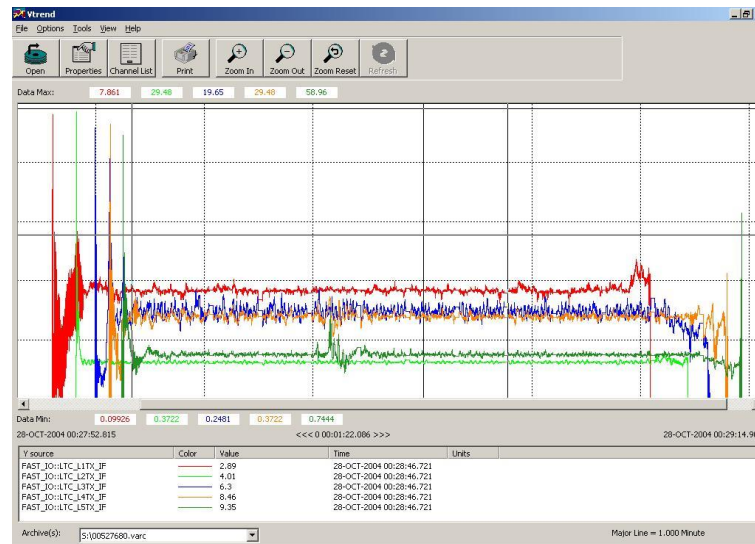
- **Challenge** : let authorized people in, keep everyone else out
- One powerful protocol : **SSH** (Secure SHell)
 - Ensures both authentication and encryption
 - Tunable based on hosts, users, groups, etc.
 - Passwordless key-pair authentication
 - X11 forwarding
 - Tunneling, proxy jumping
 - Command 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

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



read

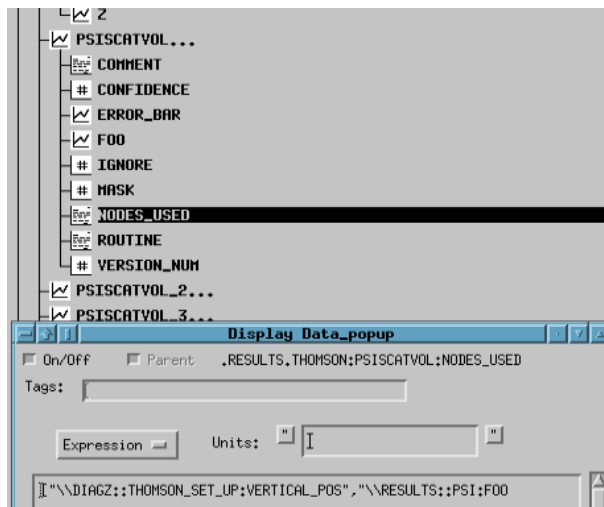
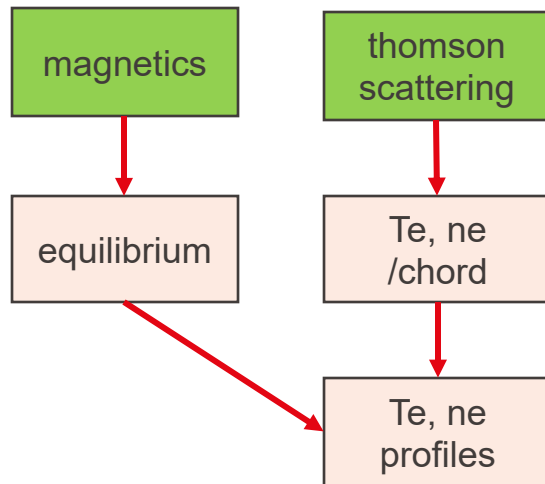
write



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



- **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 searching**, grouping, etc
 - > average, min/max, steps, ramps, coarse timegrid....

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

- 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

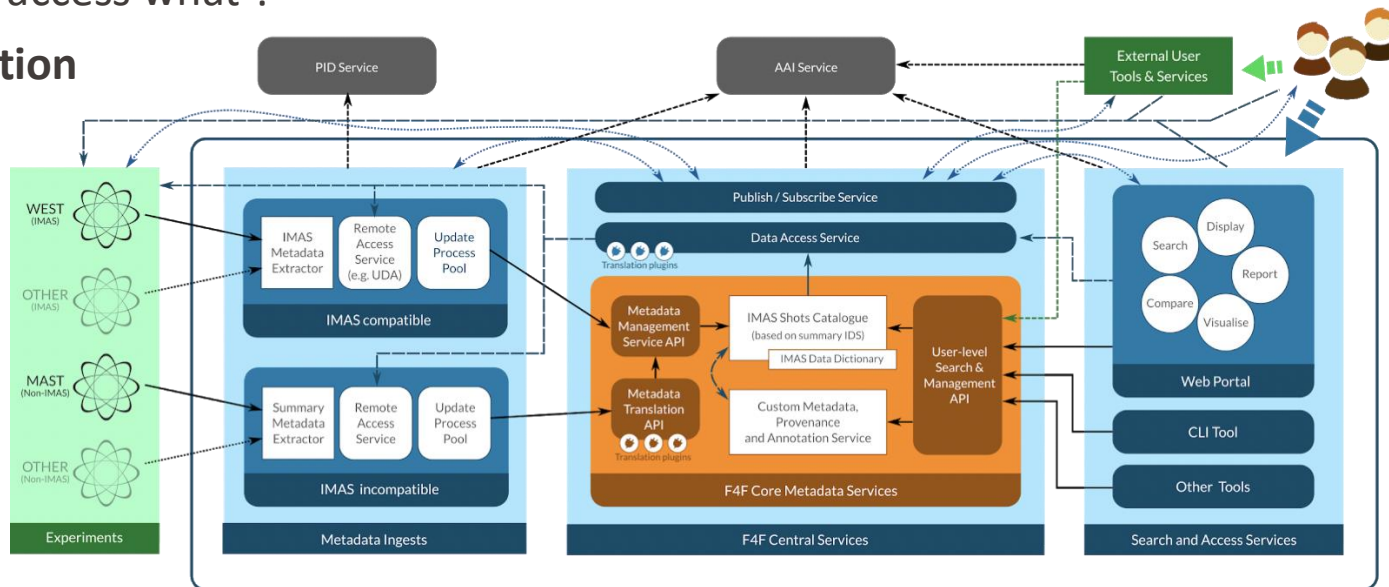
-> So far, a satisfactory global data versioning system is still missing at TCV

- 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



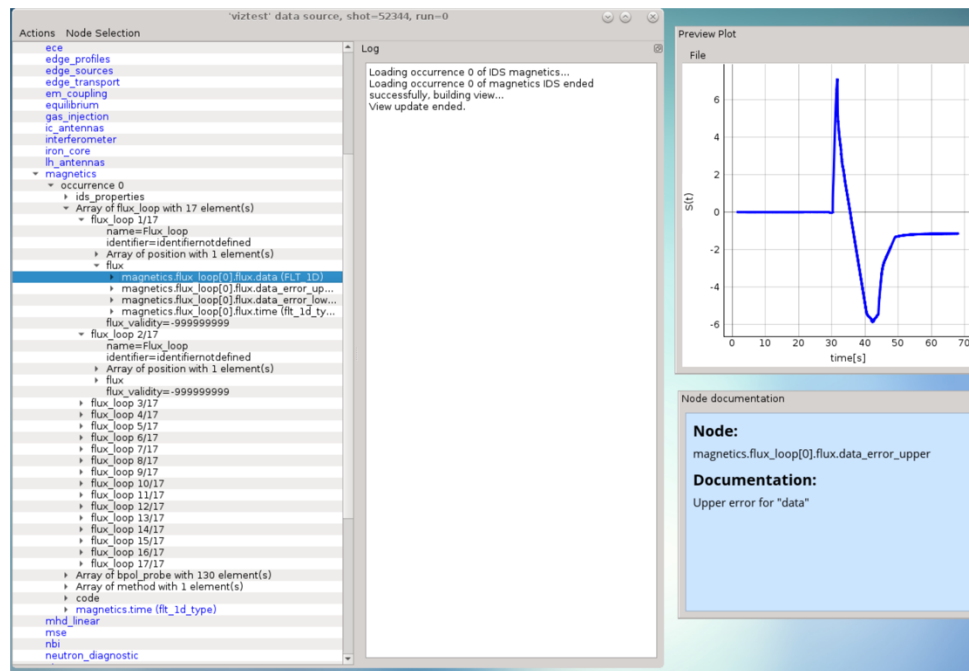
- **Integrated Modelling and Analysis suite (IMAS)**

- Interconnected software for ITER modelling
- Modular selection of components

IMASViz

- **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



IMAS Data Model 3.34.0

Heating systems

Diagnostics

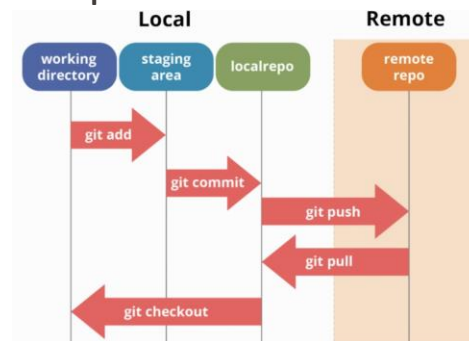
amns_data	disruption	iron_core	reflectometer_profile
barometry	distribution_sources	langmuir_probes	refractometer
bolometer	distributions	lh_antennas	sawteeth
bremssstrahlung_visible	divertors	magnetics	soft_x_rays
calorimetry	ec_launchers	mhd	spectrometer_mass
camera_ir	ece	mhd_linear	spectrometer_uv
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

- **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

- 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

- 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)

- 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

Monitoring Inventory Reports Configuration Administration

Dashboard Problems Overview Web Latest data Graphs Screens Maps Discovery Services

Global view

Edit dashboard



All dashboards / Global view

System information

Parameter	Value	Details
Zabbix server is running	Yes	localhost:10051
Number of hosts (enabled/disabled/templates)	135	46 / 0 / 89
Number of items (enabled/disabled/not supported)	3540	3005 / 481 / 54
Number of triggers (enabled/disabled [problem/ok])	1736	1053 / 683 [24 / 1029]
Number of users (online)	5	2
Required server performance, new values per second	37.03	

Problems by severity

Host group	Disaster	High	Average	Warning	Information	Not classified
Linux servers	1	3	15	3		
Templates/Operating systems			1			
Virtual machines			1			

Local



Problems

Time	Info	Host	Problem • Severity	Duration	Ack	Actions	Tags
2023-04-30 01:00:40		TSM server	RAID array device MD md127 is in check sync action on TSM server	2d 8h 27m	No		
April							
2023-03-11 04:01:35		sppcp126	Free disk space is less than 20% on volume /	1m 22d 4h	No		
2023							
2022-12-09 09:44:39		spscvs7	Zabbix agent on spscvs7 is unreachable for 5 minutes	4m 23d 22h	No	4	
2022-12-08 15:19:18		icvm0046.epfl.ch	Zabbix agent on icvm0046.epfl.ch is unreachable for 5 minutes	4m 24d 17h	No	4	
December							
2022-11-18 19:02:12		spscvs8	Free disk space is less than 20% on volume /data	5m 14d 13h	No		
2022-11-03 09:51:01		spscvs6	Free disk space is less than 20% on volume /data-vboxadmin	5m 29d 22h	No		
November							
2022-10-29 04:31:10		tcvdata	Free disk space is less than 20% on volume /Terra16	6m 5d 4h	No		
October							
2022-06-26 18:08:30		spclipc1	Zabbix agent on spclipc1 is unreachable for 5 minutes	10m 9d 15h	No	2	

Favourite maps

No maps added.

Favourite graphs

No graphs added.

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 :

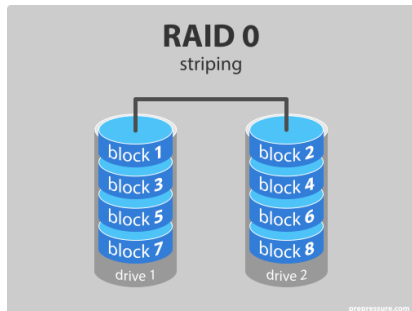
- 100 Mbps : 11 MB/s
- 1 Gbs : 110 MB/s
- 10 Gbs : 1100 MB/s

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

RAID array

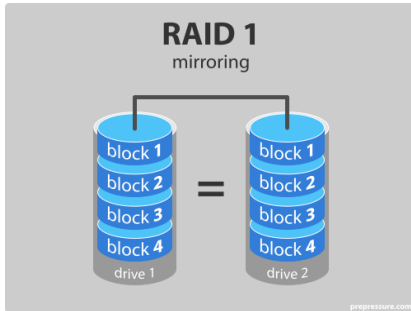
Redundant Array of Independent Disks

RAID0 : striping



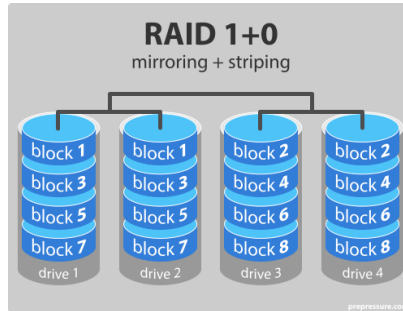
Fast but risky

RAID1 : mirror



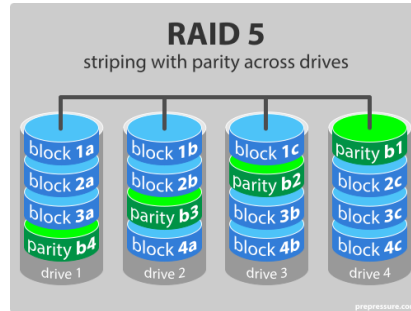
Safe but slow

RAID10 : combine



Fast and safe
but expensive

RAID5 : parity



Fast (read)
and safe

- **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**

- **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

- **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)

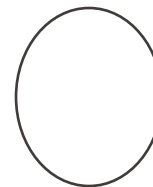
SPC IT team



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