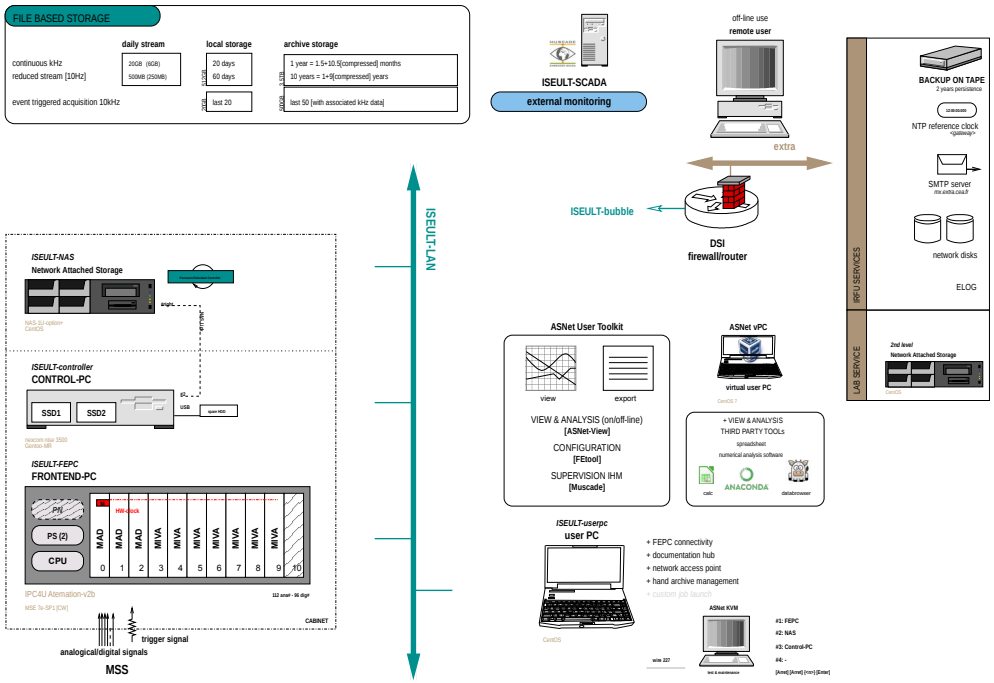
DATA COLLECTION FOR ANALOGICAL MAGNET SECURITY SYSTEMS AT CEA-IRFU

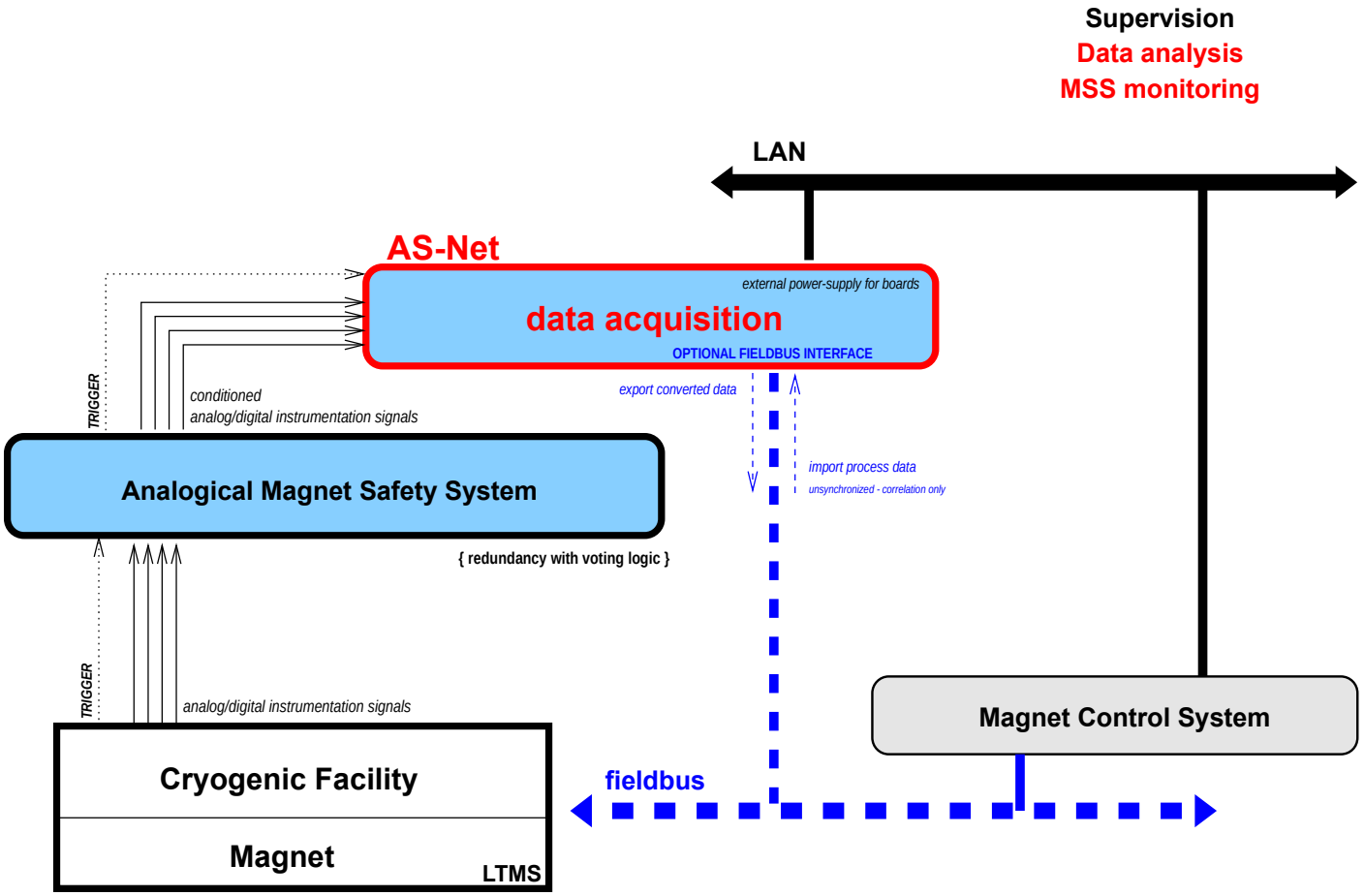
JÉRÔME ALLARD [CEA-IRFU-DIS-LDISC]



3rd International Workshop of the Superconducting Magnets Test Stands

INTRODUCTION

ASNet stands for **A**cquisition **S**ystem over **Net**work. It is designed as an external acquisition module for **CEA-IRFU analogical Magnet Safety System**. It has been deployed for over 10 years on test stands or around big custom magnet.



A LAB STORY FROM 2003

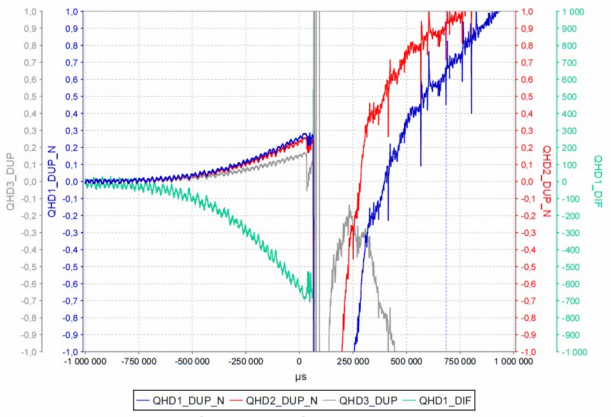
AN ACQUISITION PRIMARY NEED

A **superconducting magnet** is a tricky machine that may experience a **quench**. **Magnet Safety System** (MSS) will then operate and turn the system off. A posteriori analysis will then follows. But in any case data recording turns out to be essential.

MSS needs an acquisition module

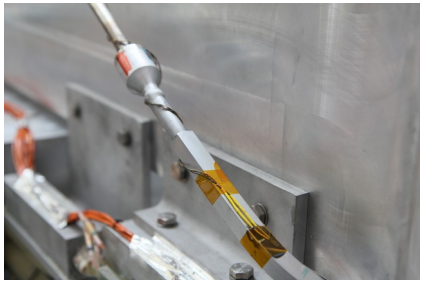
- Reliable **quench event recording** as a **black box**
- **Oscilloscope** feature: **on-line** & **offline** as monitoring purpose
- Ability to handle tens/hundreds of channels – 50-200 analog or digital
- Compatible with magnet physics - 1-100ms celerity & 2min disturbance time windows around trigger
- Slow trends expected to be observable – hours, days
- **Synchronous** acquisition
- Work with physical values & symbols

like an airplane black box as feature n°1



a quench record *[FM]*

bundle of signals to record *[YQ]*



temperature sensor around magnet *[YQ]*

FROM PROTOTYPE TO OPERATION

Implementation concepts for Acquisition System on Network

- **Industrial PC** & embedded **general purpose OS** - a ++ technology basis for development
- Real-time tasks handled in **electronics**
- **Modularity** & **configurability** first - channels, sampling, time windows for quench, conversions
- Interactive use for magnet tests or background mode for operation
- Share data with process via local **fieldbus**
- Offer a long term view for slow trends
- **Additional storage** system to keep long term data
- AS-Net status visible by a local supervision

→ Reliable but non critical system – trade off

→ Juggle with multiple frequencies – source/distribution/storage/extraction

R&D, development and finally first deployment

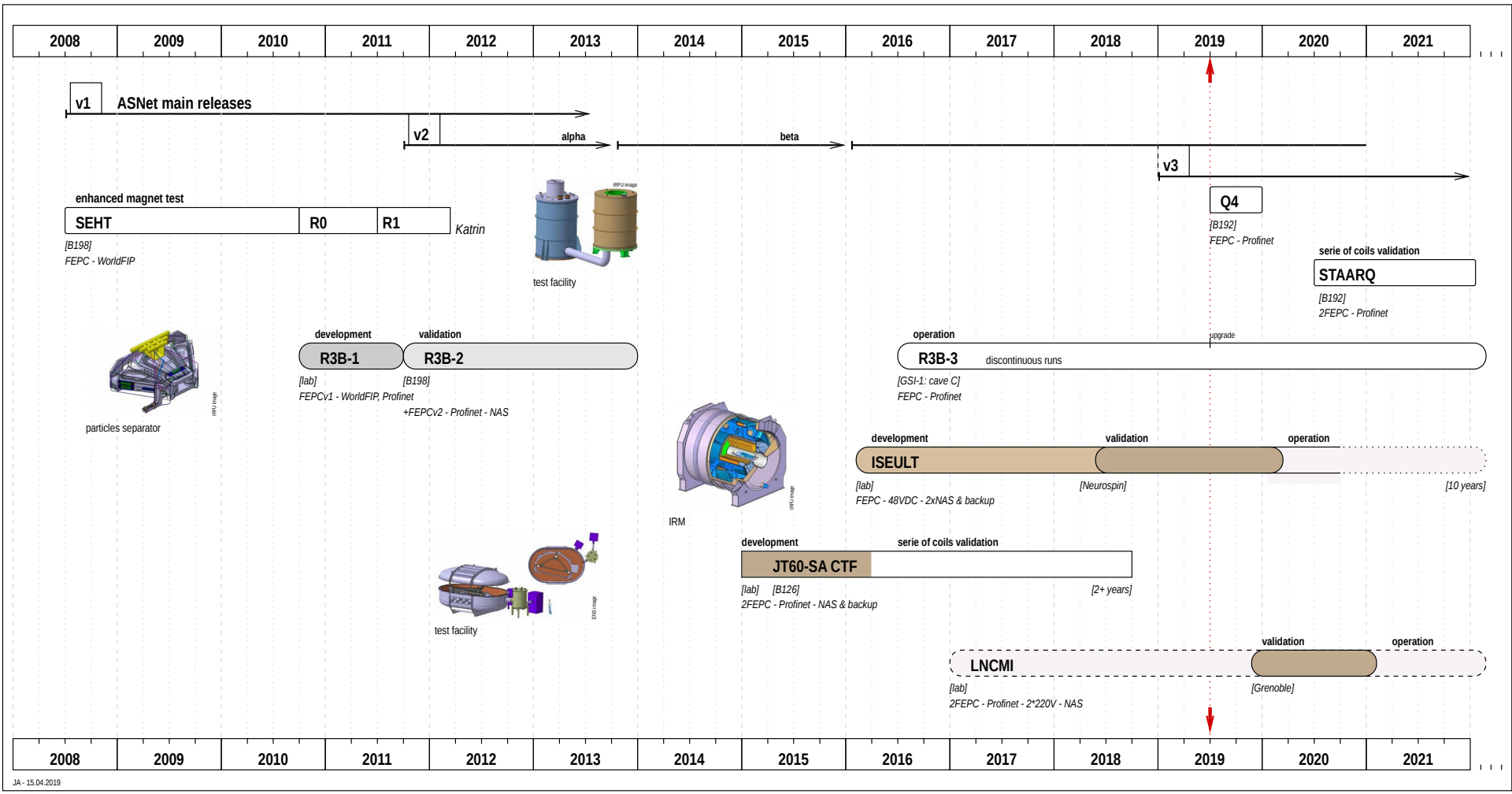
2003 - First test with a COTS board - DAQ2205

2004 - R&D developing a custom board: MIVA

2008 - deployed as 2nd acquisition system for **S**tation **E**ssai **H**uit **T**estla

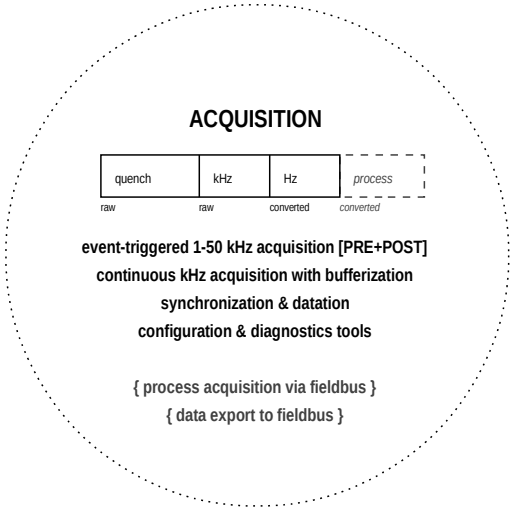
SEHT mechanical view *[IRFU]*

ASNet FAMILY OVERVIEW



A LAYERED AND MODULAR ARCHITECTURE

ACQUISITION LAYER - OVERVIEW



DATA PATH

network link

RAM

PCI link

SRAM & SDRAM

PC4U 220VAC-48VDC

MIVA/MAD external power supply

experience LAN

FRONTEND-PC **[MSS]**

fieldbus

PN

PS(2)

CPU

M

HW-clock

MIVA 1 | MIVA 2 | MIVA 3 | MIVA 4 | MIVA 5 | MIVA 6 | MIVA 7 | MIVA 8 | MAD 9 | MAD 10

vprocess 10Hz

FEPC variables 20Hz

IPC4U Atemation-v2b

MSE 7e-SP1 [CW]

FRONTEND-PC **[auxiliary]**

fieldbus

PN

PS

CPU

M

HW-clock

MIVA 1 | MIVA 2 | MIVA 3 | MAD 4 | MAD 5 | MAD 6 | 7 | 8 | 9 | 10

vprocess 10Hz

FEPC variables 20Hz

IPC4U Atemation-v2b

MSE 7e-SP1 [CW]

MSS analogical/digital signals

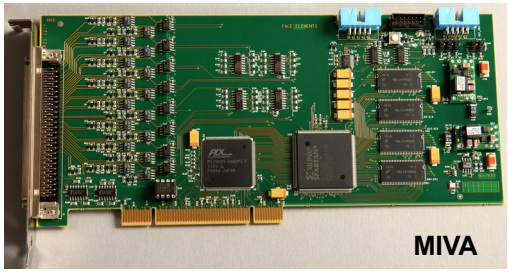
trigger signal

auxiliary analogical/digital signals

ACQUISITION LAYER – MIVA & MAD INSIDE [1/2]

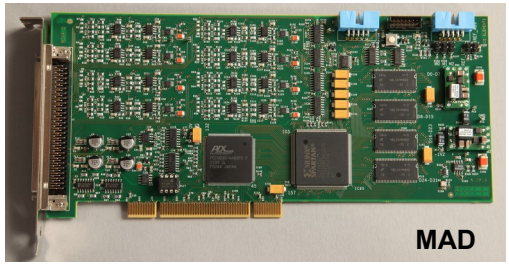
A custom analog card: MIVA

- 16 **analog** input channels with 16bits ADC, voltage/current
- **1-50 kHz** sampling rate
- **Synchronization** signal with other boards **[master/slave]**
- External power supply
- Quench buffer **[256 MB SDRAM – 8 M samples]** – black box feature, triggered
- Real-time buffer **[6 kB SRAM – 500 samples]** – continuous acquisition feature
- PCI board for **[PLX bridge]**
- Processing via FPGA **[VHDL]**
- Simulation functions


MIVA

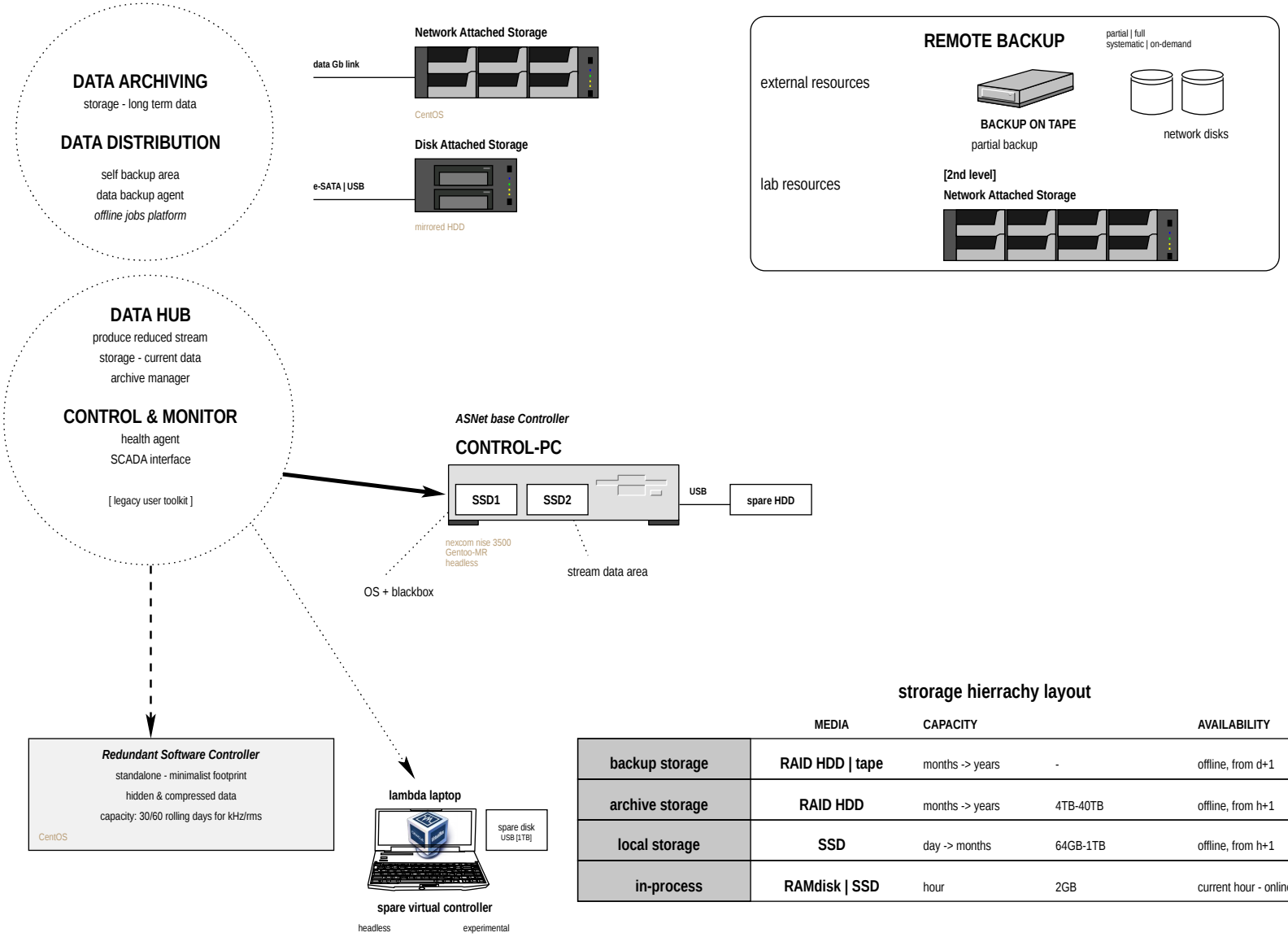
MIVA sister for digital inputs: MAD

- Design same as MIVA but for digital inputs
- 32 digital input channels


MAD


Inside the rack

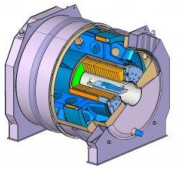
CONTROLLER & ARCHIVING LAYERS



storage hierrachy layout

	MEDIA	CAPACITY		AVAILABILITY
backup storage	RAID HDD | tape	months -> years	-	offline, from d+1
archive storage	RAID HDD	months -> years	4TB-40TB	offline, from h+1
local storage	SSD	day -> months	64GB-1TB	offline, from h+1
in-process	RAMdisk | SSD	hour	2GB	current hour - online

DEPLOYMENT OVERVIEW - ISEULT EXAMPLE



CEA - Saclay

FILE BASED STORAGE

	daily stream	local storage	archive storage
continuous kHz (kHz: 240kB/s)	20GB (6GB)	512GB: 20 days	3.5TB: 1 year = 1.5+10.5[compressed] months
reduced stream [10Hz]	500MB (250MB)	60 days	10 years = 1+9[compressed] years
event triggered acquisition 10kHz		20GB: last 20	500GB: last 50 [with associated kHz data]

ISEULT-SCADA

external monitoring

off-line use

remote user

extra

ISEULT-bubble

DSI

firewall/router

IRFU SERVICES

BACKUP ON TAPE

2 years persistence

NTP reference clock

<gateway>

SMTP server

mx.extra.cea.fr

network disks

ELOG

LAB SERVICE

2nd level

Network Attached Storage

CentOS

ISEULT-LAN

ISEULT-NAS

Network Attached Storage

NAS-1U-option+

CentOS

ISEULT-controller

CONTROL-PC

SSD1

SSD2

USB

spare HDD

nexcom nise 3500

Gentoo-MR

ISEULT-FEPC

FRONTEND-PC

PS (2)

CPU

HW-clock

MAD 0

MAD 1

MAD 2

MIVA 3

MIVA 4

MIVA 5

MIVA 6

MIVA 7

MIVA 8

MIVA 9

MIVA 10

IPC4U Atemation-v2b

MSE 7e-SP1 [CW]

112 ana# - 96 dig#

DC mode

CABINET

trigger signal

analogical/digital signals

MSS

ASNet User Toolkit

view

export

VIEW & ANALYSIS (on/off-line)

[ASNet-View]

CONFIGURATION

[FEtool]

SUPERVISION IHM

[Muscade]

ASNet vPC

virtual user PC

CentOS 7

+ VIEW & ANALYSIS

THIRD PARTY TOOLs

spreadsheet

numerical analysis software

calc

ANACONDA

databrowser

ISEULT-userpc

user PC

CentOS

+ FEPC connectivity

+ documentation hub

+ network access point

+ hand archive management

+ custom job launch

ASNet KVM

wire 227

test & maintenance

#1: FEPC

#2: NAS

#3: Control-PC

#4: -

[Arret] [Arret] [<n>] [Enter]

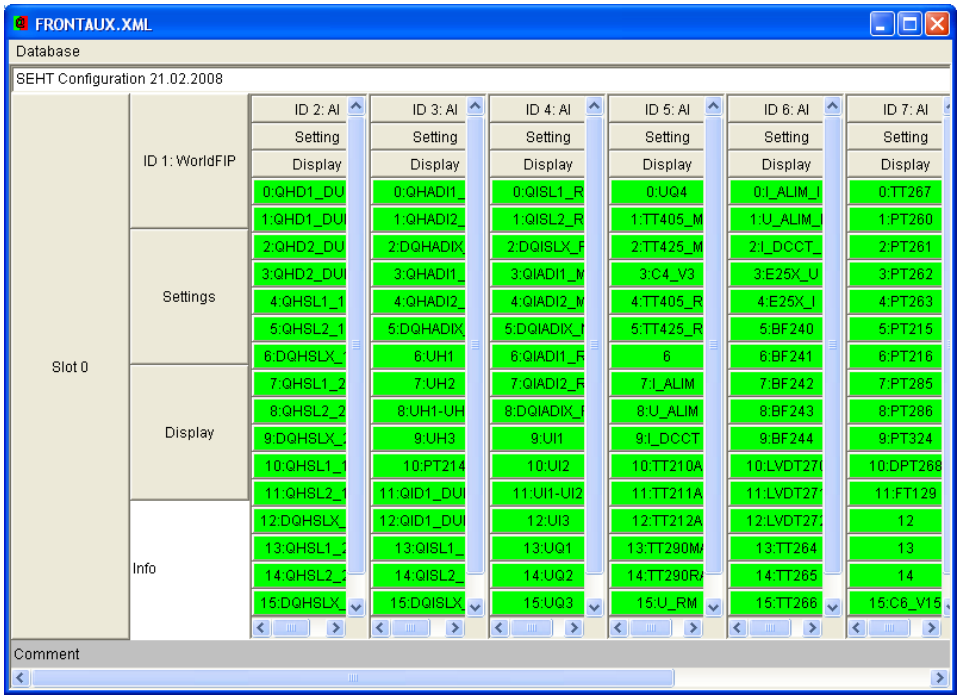
10 years interuptionless operation

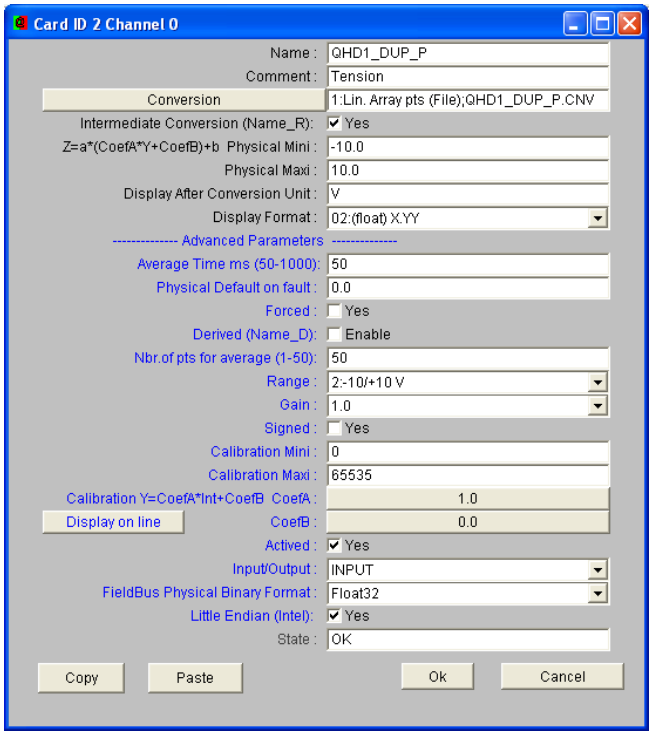
3xMSS with voting logic

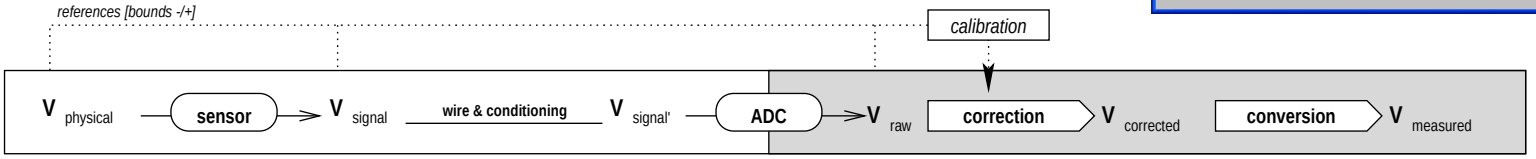
ASNET THROUGH USE CASES

CONFIGURATION & CALIBRATION STEP

- Before use a configuration has first to define through **FEtools**
  - racks, boards
  - channels: names, unit, range, conversion…
  - quench parameters: sampling rate, time window, master
  - fieldbus interface: variables to export
- Each channel must be calibrated with a reference – wizard for linear correction





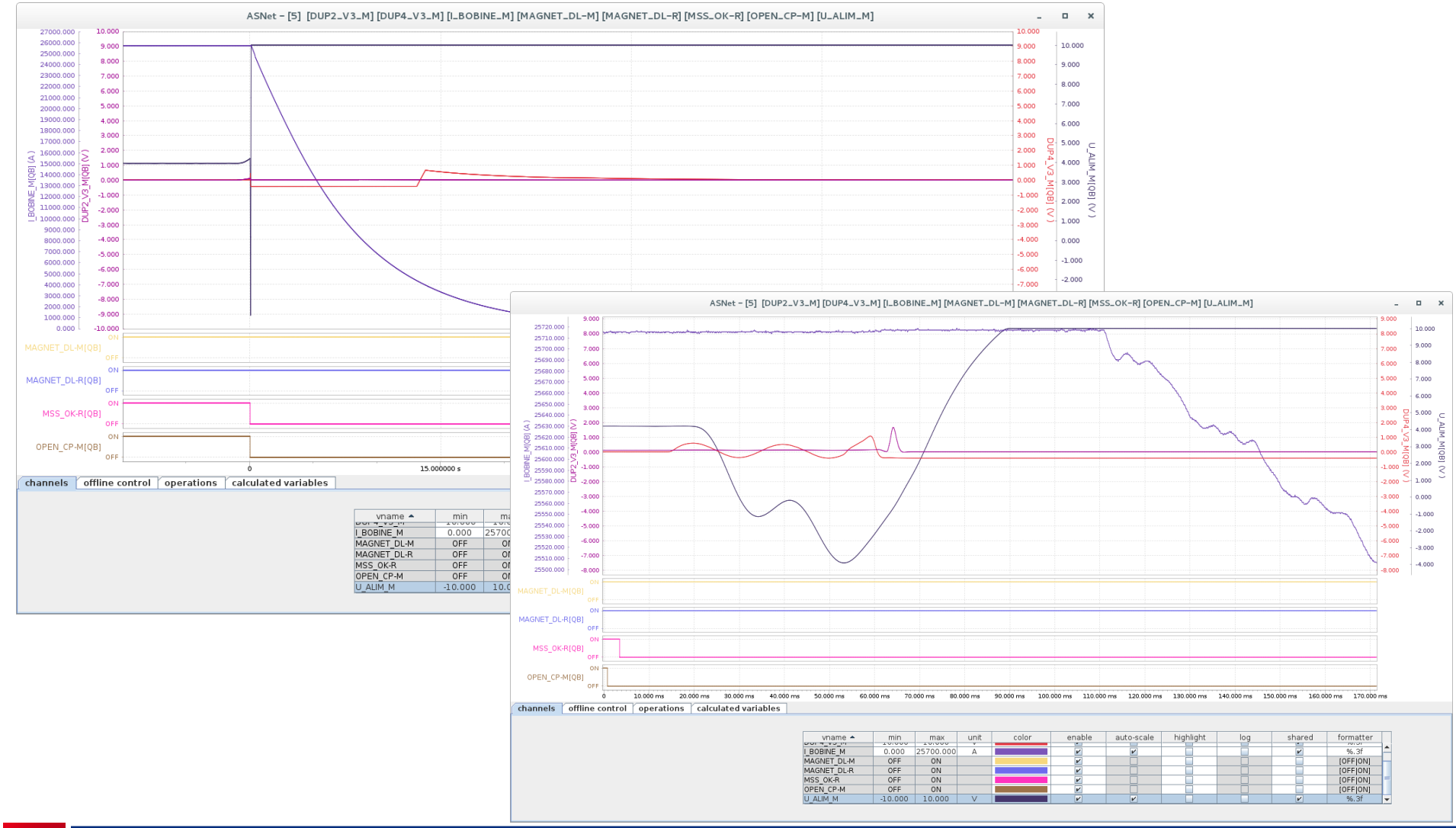


SYSTEM MONITORING & DRIVING

System is user monitored and driven through a **Muscade** interface. This may be integrated to the experiment SCADA, which allows triggering alarms for example to ask for maintenance on NAS disks, to warn about a wrong timing or to notify immediately a quench event.

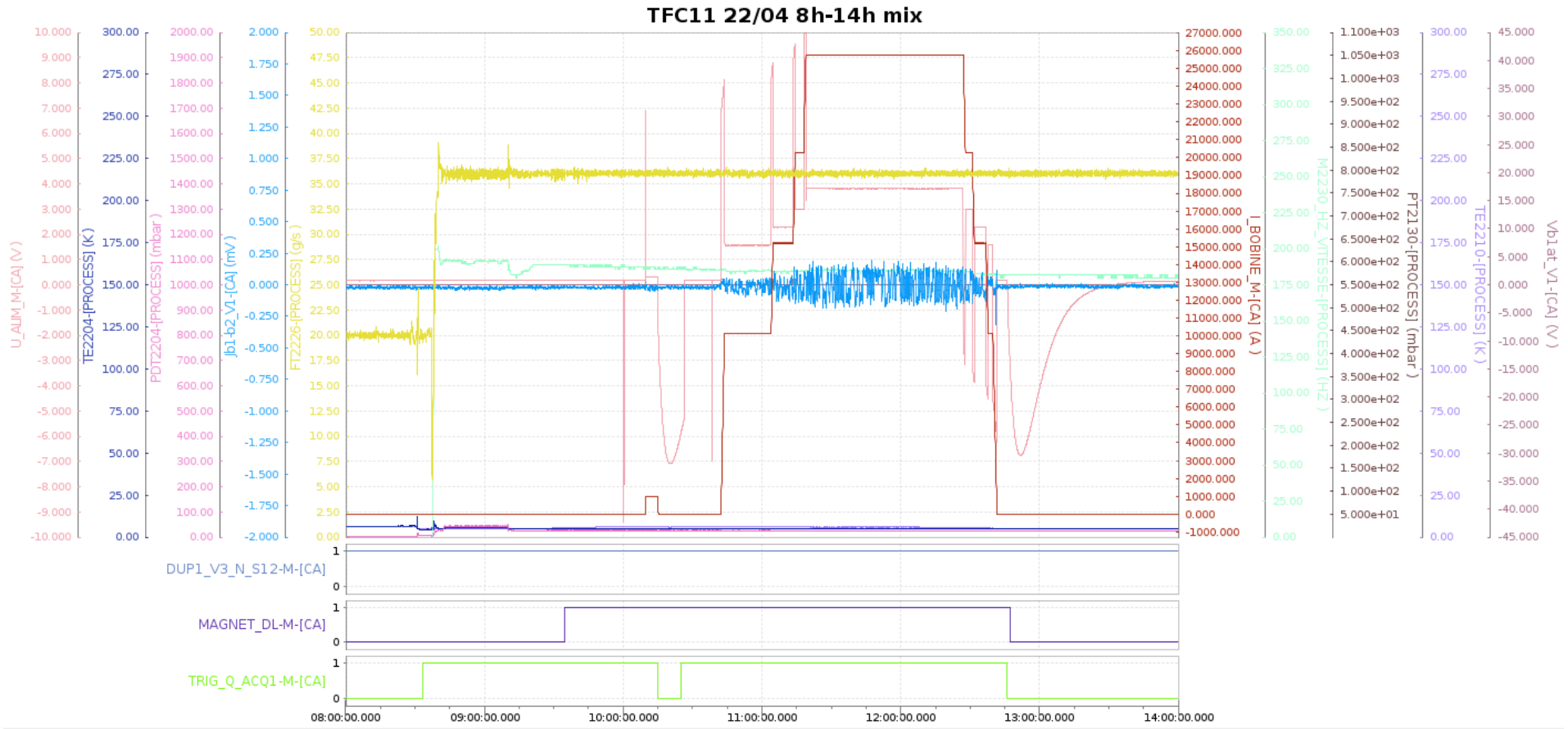
WORKING WITH EVENT TRIGGERED DATA

Once a trigger occurs a snapshot around event is made with a resolution up to 20us (***blackbox feature***). Analysis can then begin...



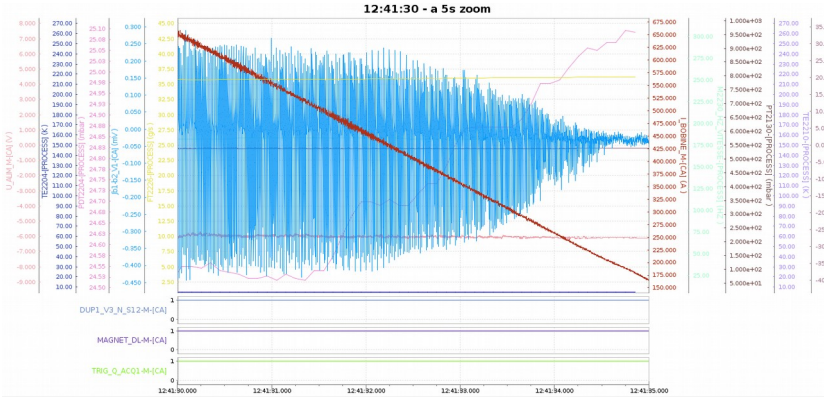
WORKING WITH CONTINUOUS DATA STREAMS ½

Data acquisition is continuous with a **synchronous kHz** stream and an optional 10Hz fieldbus **process stream**. We can then extract offline, from controller or archive storage, working at hour or ms scale, superimposing source for correlation if necessary...

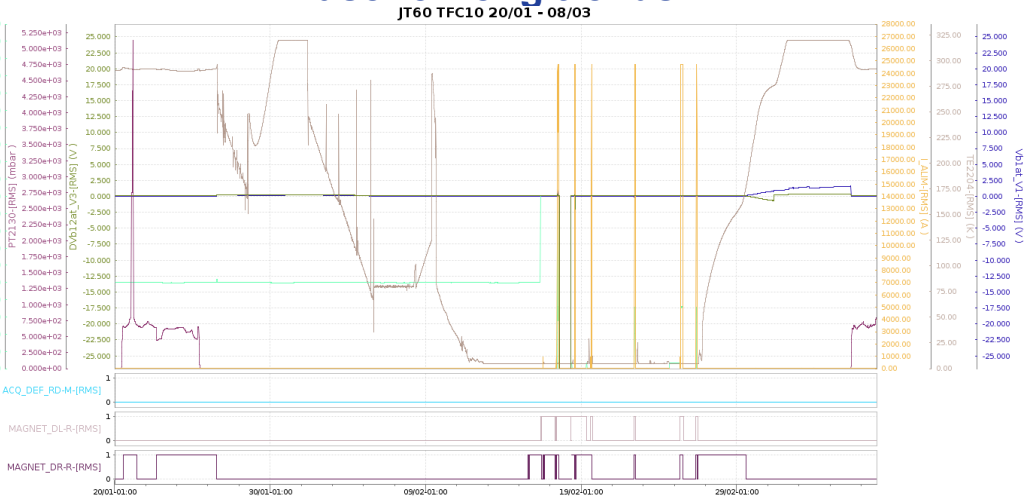


WORKING WITH CONTINUOUS DATA STREAMS 2/2

zoom anywhere



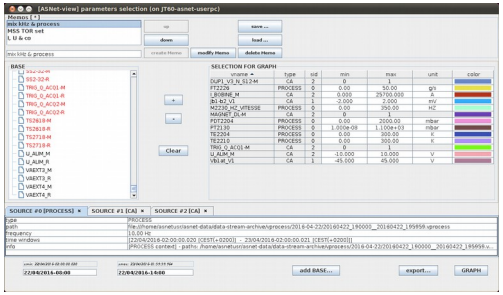
use for long trends



online oscilloscope feature

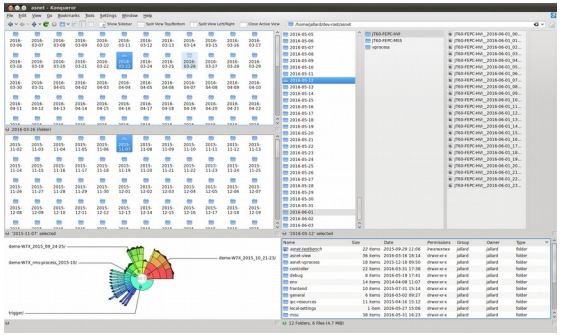
On dedicated user PC an online view is available to monitor each channel (kHz or process). It is particularly useful for testbench or full-scale test configurations.

mix source as wanted



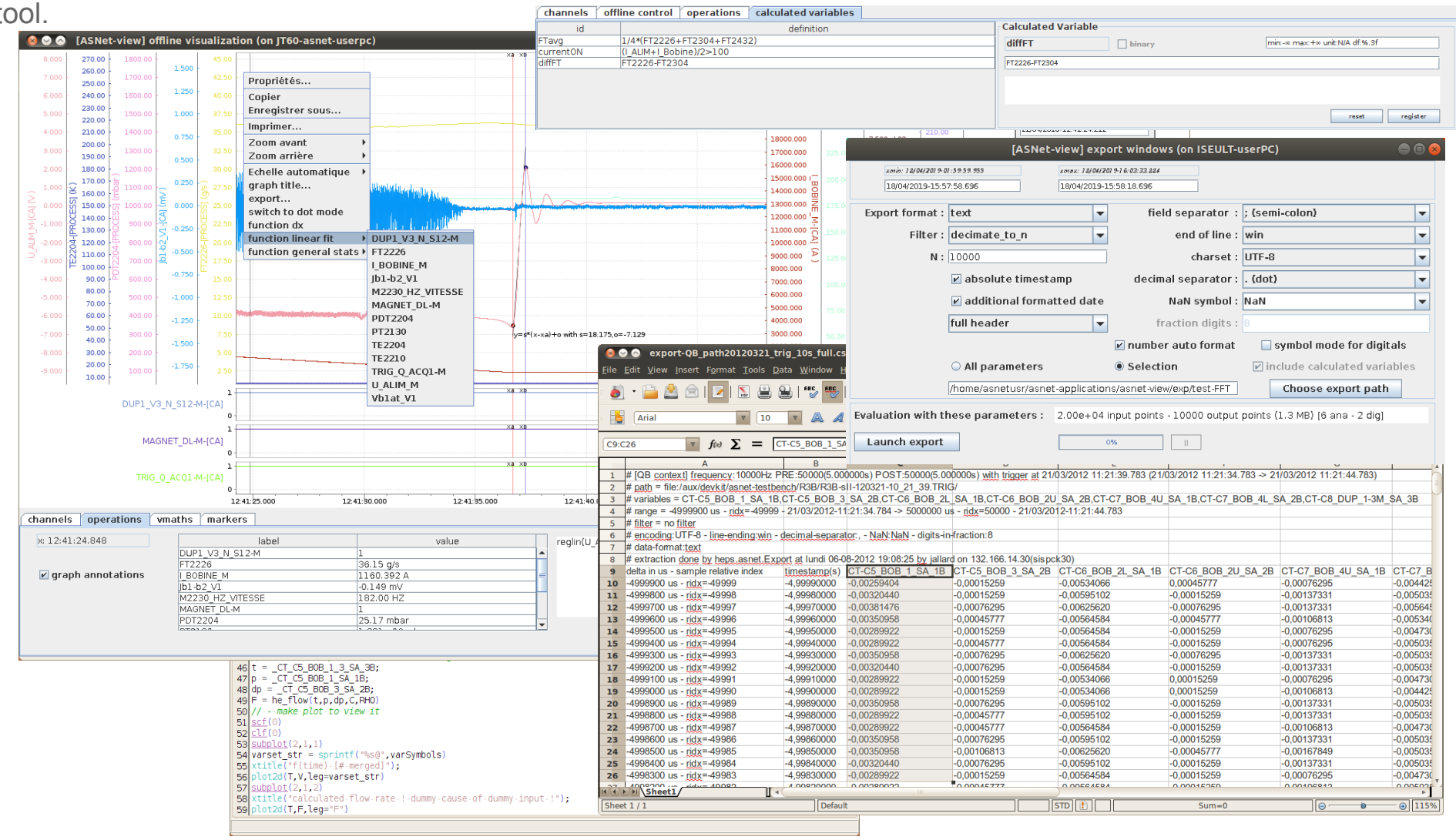
Thanks to reduced stream ASNet is usable with long time windows, typically weeks, for example to follow magnet cooling or summarize a coil testing cycle…

access data inside archive



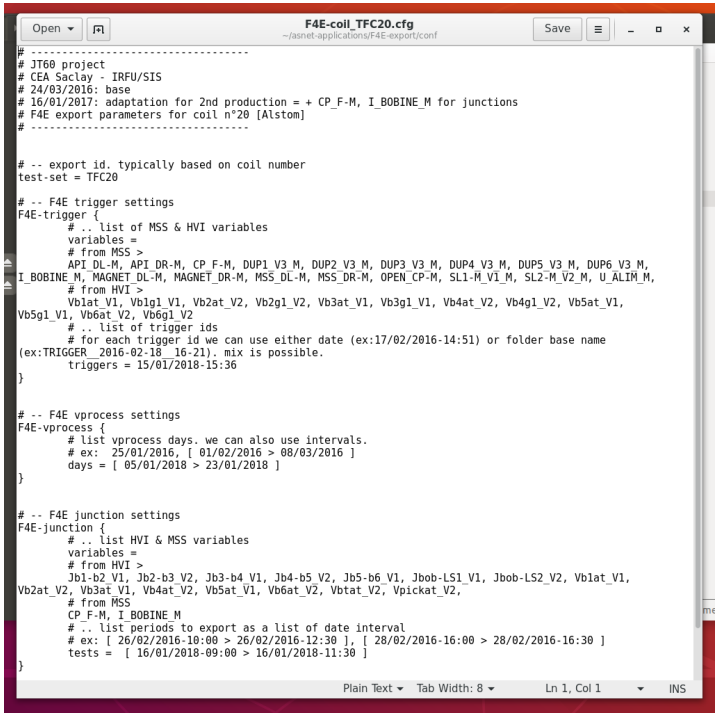
ANALYZE MORE IN DEPTH

A few **mathematical functions** are available in viewer. So are some **calculated variables**. But for more in depth analysis just **export** a data subset and work elsewhere with a spreadsheet software or other numerical analysis tool.

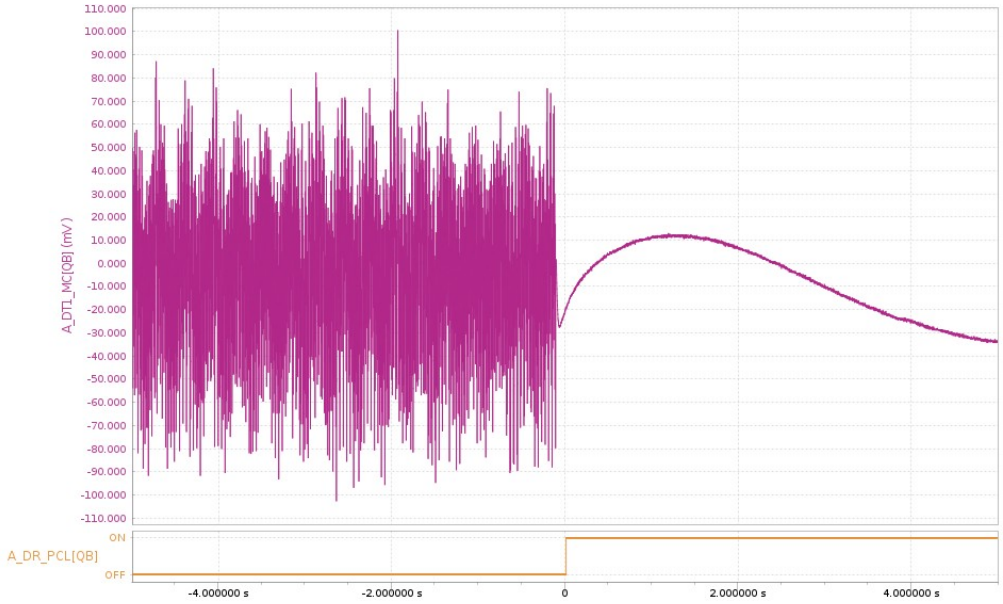


SPECIAL USES

[JT60] Due to data proximity and computational resource NAS may be used for offline jobs. In JT60 we use it to produce a user defined data compilation for each tested coil.



[ISEULT - experimental] we are currently trying to analyze miscellaneous noise for instance in correlation with power supply mode. Idea is that in continuous magnet mode, a noise change may indicate something significant.



[STAARQ test stand facility (*future*)] Both analog and digital MSS will be installed. Our legacy analog MSS acquisition system will make its traditional job. It will also record digital MSS input signals and be used as reference for a new acquisition implementation attempt.

ASNET INTERNALS

HANDLING BOTH OPERATION AND DEVELOPMENT

- Sum additional project requests & contexts – *manage a modular and homogeneous version*
- Have an operational & validated solution for operation – *moderate upgrade, use versioning*
- Take into account expected long lifetime – *choose robust hardware, buy spare*
- Allow system evolution – *work on new deployment window, test on redundant chain, use idle facility, cross project feedback*
- Offer maximum availability – *implement redundancy, add monitoring & reporting, fault-tolerance. Virtualization may also help*
- Reduce maintenance constraints – *be tolerant to degraded mode, include remote access*

ENHANCEMENT
R3B / JT60 / ISEULT / LNCMI / Q4
- digital channels
- data export
- calculated variables
- multi-racks feature
- process input integration
- reduced mergeable stream
- data long storage
- multi-frequencies management
- reporting
- RAMdisk option
- *soft redundant controller*
- *virtualized user PC*

HARDENING
- Control-PC: PC > shoebox
- industrial network device
- redundant power supply

CONSOLIDATION
- background mode
- monitorability
- data selective backup on tape
- watchdog set
- network access [subnet/VLAN/bubble/VPN]
- separate user PC
- *2nd level storage in lab*

UPGRADE
long development time
- FEPC OS: XPe -> 7e
- FEPC driver: PLX, Profinet
- FEPC rack: IPCv1 -> IPCv2 (a,b)
- miva: serie 1 > serie 2
- Control-PC OS
  XP -> 7e -> gentoo -> centOS

TOWARD A RESILIENT SYSTEM: LONG IS THE ROAD...

CEA - Saclay

Feedback on typical unexpected incidents

- Out of order system disk on NAS
- Unexplained NAS ECC memory error with a temporary loss of a 4GB stick
- Emergency stop punch on cabinet before electrical maintenance we were not aware...
- Cement dust environment in an experience hall…
- Flooding in remote backup room after severe weather and building issue

SSD: sensitive use & a bit specific compared to HDD

good bandwidth, constant time access, parallelism prone but caution with write intensive application → †

- Weared symptoms : file system errors, read-only file system
- Caution with write amplification effect: you may write much more than expected
- On linux compulsory use of ext4 with noatime & discard options
- Caution with swap: no swap or minimize it via swapiness variable
- Increasing disk size gives more lifetime (linear)
- Accurate Monitoring via SMART (nowadays)
- Intermediate RAMdisk minimizes SSD wear

NEXT STEPS

Main limitations:
→ Custom hardware is painful to produce & test. Nowadays COTS boards exist
→ System is too much person dependent
→ Bad initial options we live with: legacy file format, time stamping, FEPC windows platform

Make it work better (developpement & test in-progress...)

- enhanced anaconda python console for immediate expert analysis
- more integrated math functions: derivative, integration, FFT
- export to standard format: hdf,…
- out-of-band management option
- rewrite fieldbus interface
- data transparency rms / kHz / trigger
- on-line mode with long time windows
- on-demand archiving
- manage acquisition configuration
- manage a experiment database for users

Make it work further

- Use standard framework (EPICS?)
- Use COTS hardware for acquisition layer (CompactRIO,PXI,uTCA?)

RE-BASEMENT NEEDED TO BE COMPATIBLE WITH DIGITAL MSS

A PROTOTYPE IN OPERATION WITH A BEST EFFORT POLICY
LONG LIFETIME EXPECTED
DEVELOPMENT STILL IN PROGRESS…
RE-BASEMENT NEEDED FOR FUTURE

A TEAM WORK

Electronics works project management	F.Molinié
MIVA/MAD design	S.Sube, P.DeAntoni
MIVA/MAD embedded programming	S.Sube
Frontend custom code	C.Walter, J.Allard
Fieldbus interface WordFip/Profinet	G.Durand, J-L.Fallou
Controller core code	C.Walter, J.Allard
Data extraction	C.Walter, J.Allard
Archive, distribution, backup	A.Gomes, P-F.Honoré, J.F.Lecointe, J.Allard
Configuration tool	C.Walter
Visualization tool	J.Allard
Network	C.Walter, A.Gomes, J.Allard
OS	C.Walter, P.Mattei ,J.F.Le cointe, J.Allard
Experience support	C.Walter, J.F.Lecointe, J.Allard
Electrical support	A.Lotodé

THANKS FOR YOUR ATTENTION