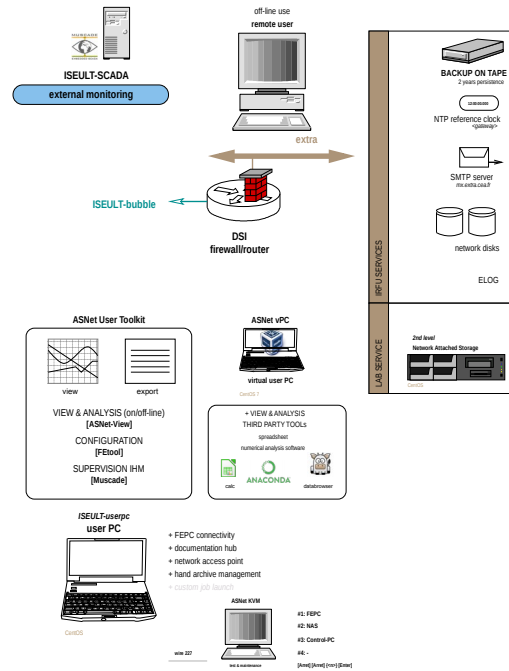
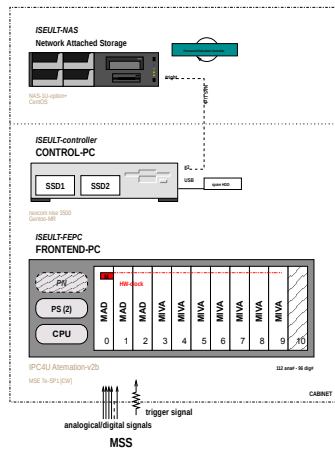


DATA COLLECTION FOR ANALOGICAL MAGNET SECURITY SYSTEMS

AT CEA-IRFU

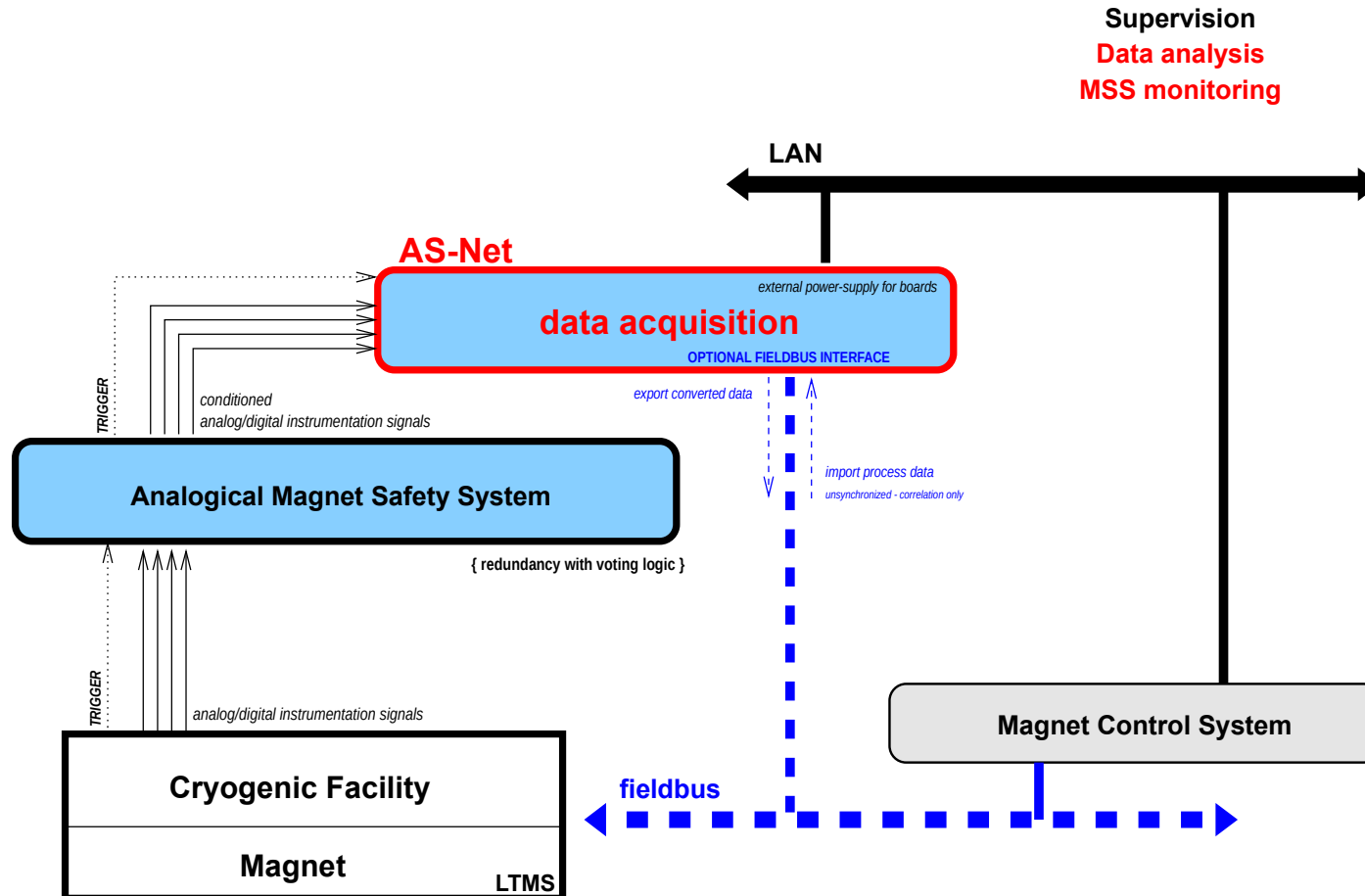
JÉRÔME ALLARD [CEA-IRFU-DIS-LDISC]

FILE BASED STORAGE			
	daily stream	local storage	archive storage
continuous kHz	20GB (5GB)	20 days	1 year = 1.5-10 (compressed) months
reduced stream [10Hz]	500MB (200MB)	60 days	20 years = 1-4 (compressed) years
event triggered acquisition 10kHz		last 20	last 50 (with associated kHz data)



INTRODUCTION

ASNet stands for **Acquisition System over Network**. 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

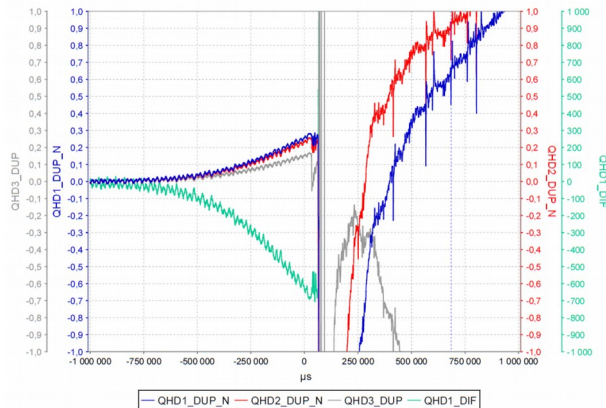
A superconducting magnet is a tricky machine that may experience a **quench**. **Magnet Safety System** (MSS) will then operate and turn the system off. A posteriori analysis will then follow. But in any case data recording turns out to be essential.

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]

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

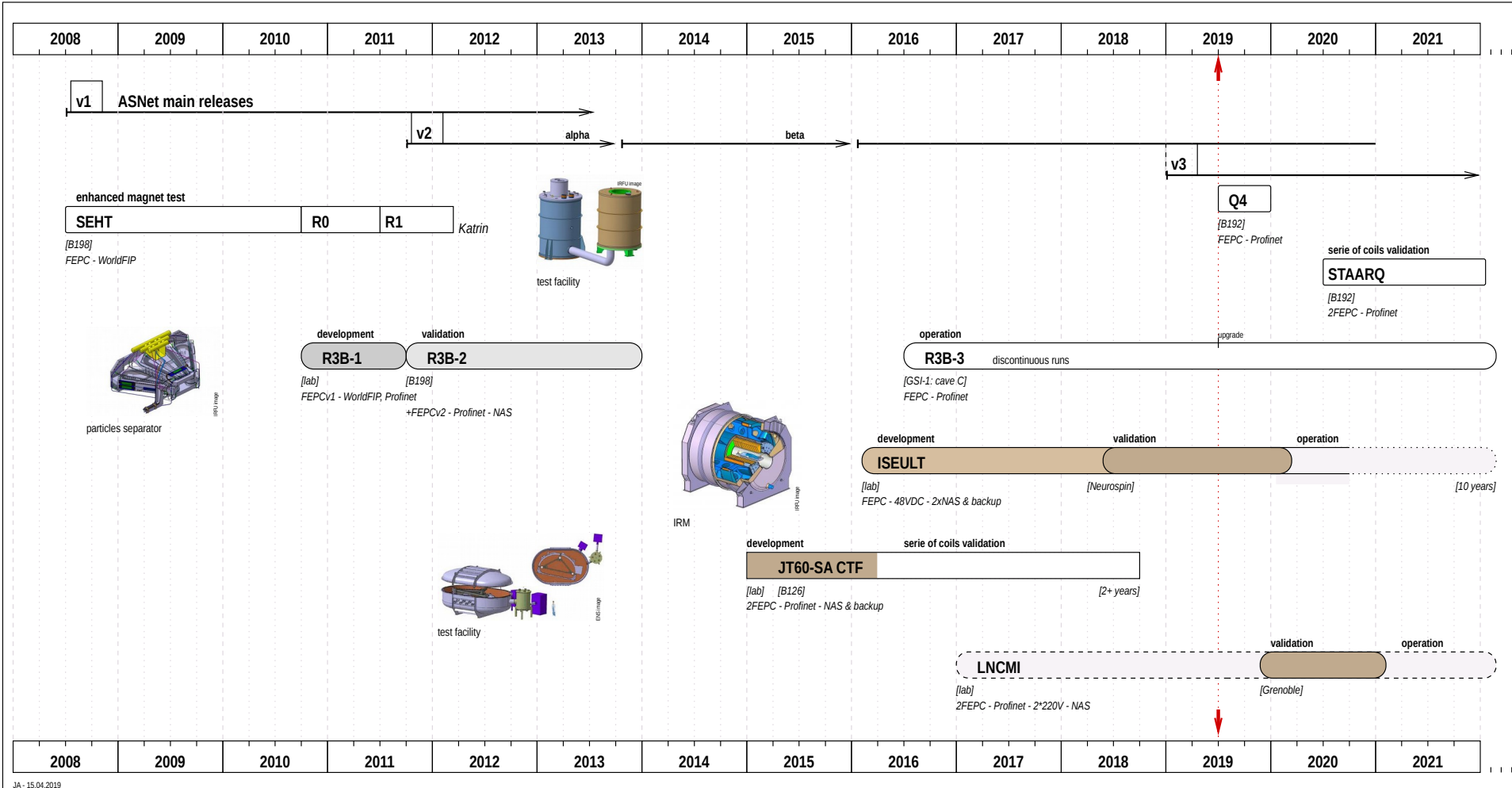
2004 - R&D developing a custom board: MIVA

2008 - deployed as 2nd acquisition system for **Station Essai Huit Testla**



SEHT mechanical view [IRFU]

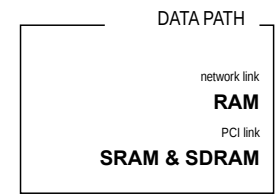
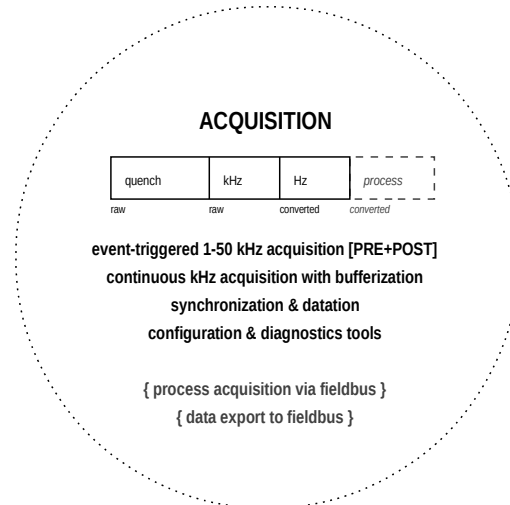
ASNet FAMILY OVERVIEW



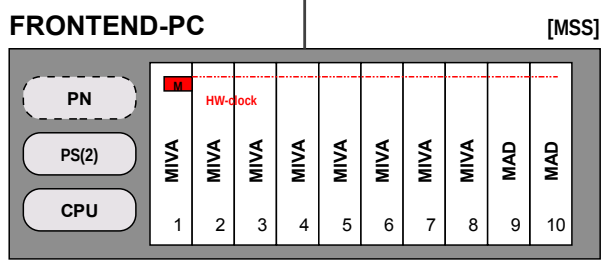
JA - 15.04.2019

A LAYERED AND MODULAR ARCHITECTURE

ACQUISITION LAYER - OVERVIEW



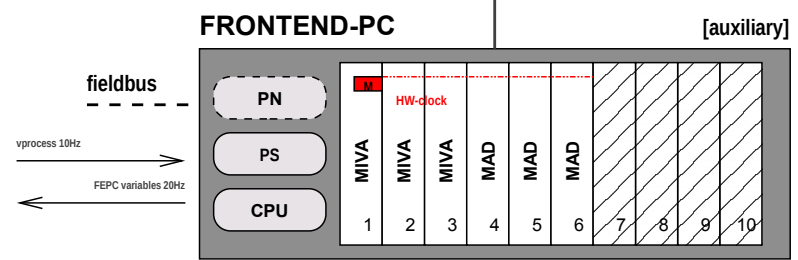
PC4U 220VAC-48VDC
MIVA/MAD external power supply



IPC4U Atemation-v2b
MSE 7e-SP1 [CW]



MSS analogical/digital signals



IPC4U Atemation-v2b
MSE 7e-SP1 [CW]



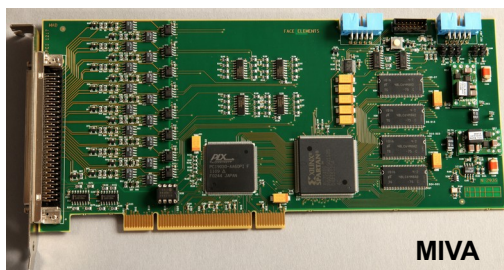
trigger signal



auxiliary analogical/digital signals

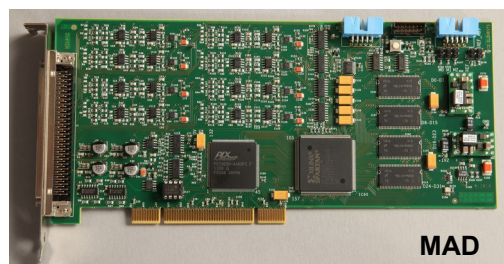
A custom analog card: MIVA

- 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



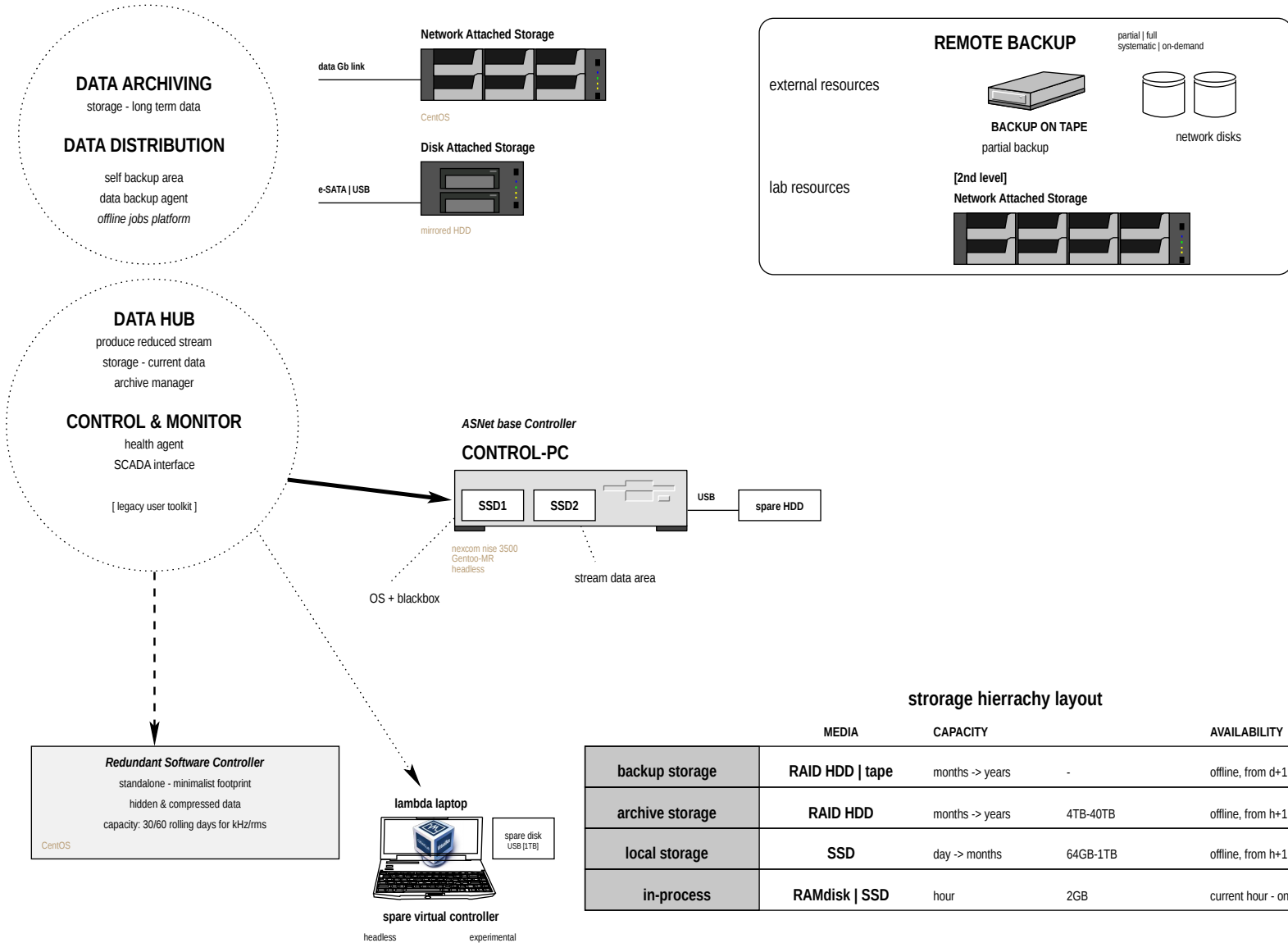
MIVA sister for digital inputs: MAD

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



Inside the rack

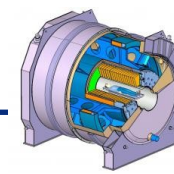
CONTROLLER & ARCHIVING LAYERS



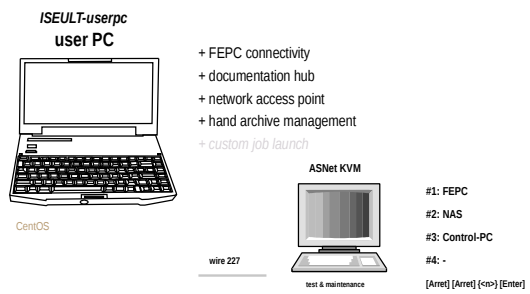
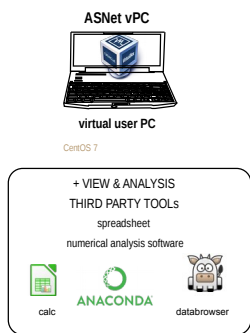
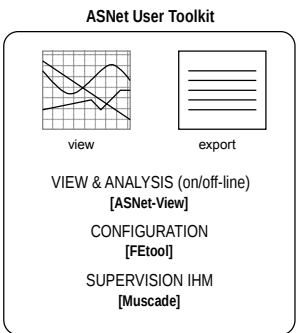
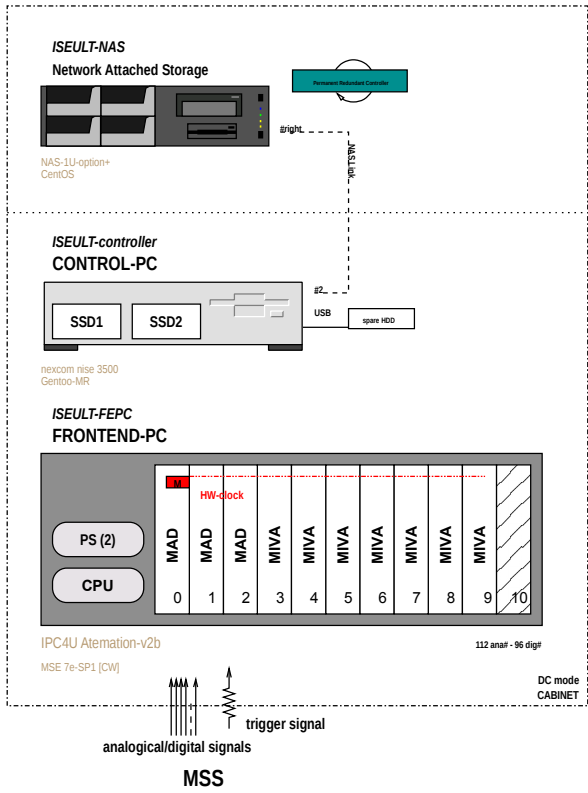
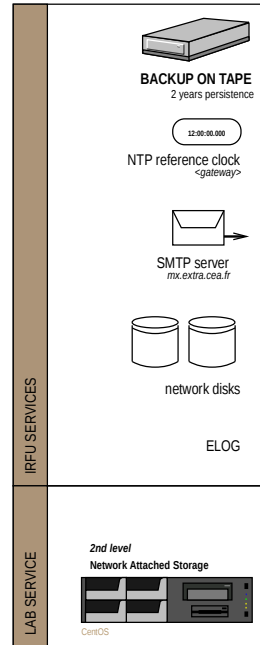
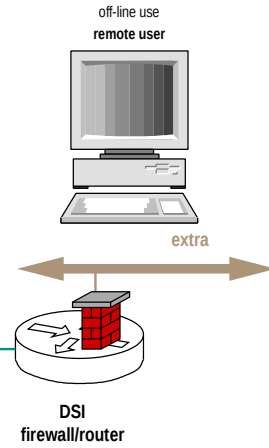
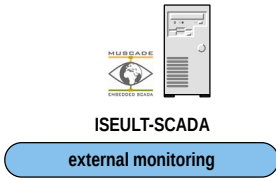
storage hierarchy layout

	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



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

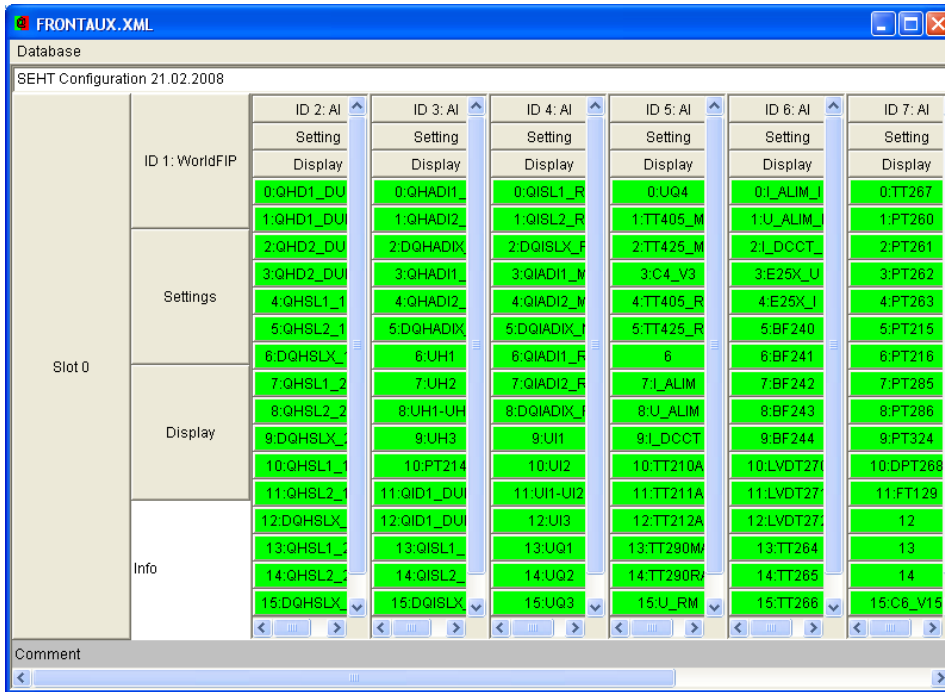


10 years interruptionless operation
3xMSS with voting logic

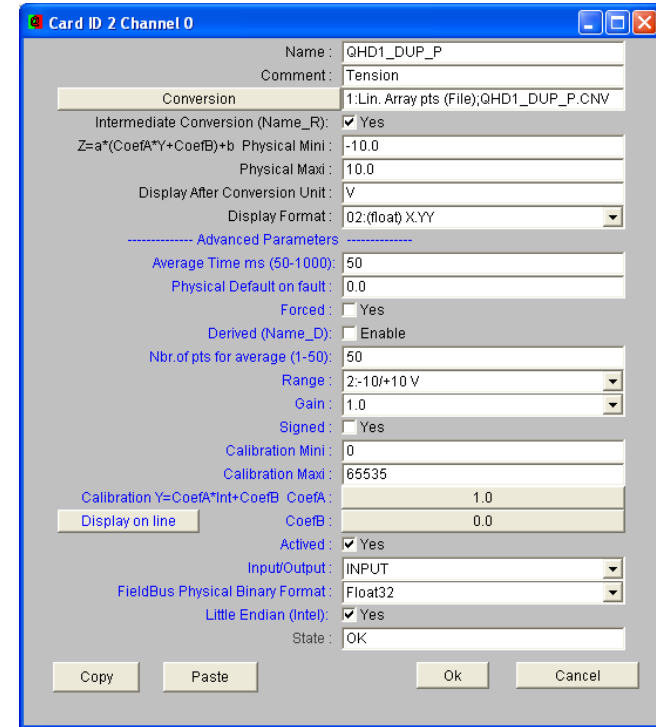
ASNET THROUGH USE CASES

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



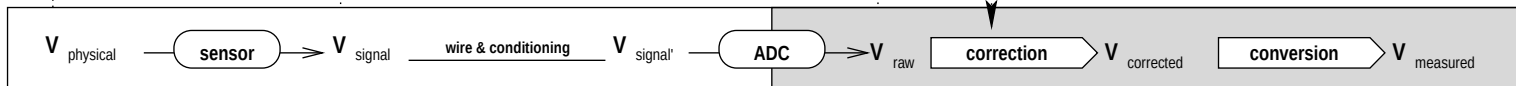
ID 2: AI	ID 3: AI	ID 4: AI	ID 5: AI	ID 6: AI	ID 7: AI
Setting	Setting	Setting	Setting	Setting	Setting
Display	Display	Display	Display	Display	Display
0:QHD1_DU	0:QHADI1	0:QISL1_R	0:UQ4	0:U ALIM_J	0:TT267
1:QHD1_DU	1:QHADI2	1:QISL2_R	1:TT405_M	1:U ALIM_J	1:PT260
2:QHD2_DU	2:DQHADIK	2:DQISLX_F	2:TT425_M	2:U_DCCT_	2:PT261
3:QHD2_DU	3:QHADI1	3:QIADI1_M	3:C4_V3	3:E25X_U	3:PT262
4:QHSL1_1	4:QHADI2	4:QIADI2_R	4:TT405_R	4:E25X_J	4:PT263
5:QHSL2_1	5:DQHADIK	5:DQIADIX_L	5:TT425_R	5:BF240	5:PT215
6:DQHSLX_	6:UH1	6:QIADI1_R	6	6:BF241	6:PT216
7:QHSL1_2	7:UH2	7:QIADI2_R	7:U ALIM	7:BF242	7:PT265
8:QHSL2_2	8:UH1-UH	8:DQIADIX_L	8:U ALIM	8:BF243	8:PT286
9:DQHSLX_	9:UH3	9:UH1	9:U_DCCT	9:BF244	9:PT324
10:QHSL1_	10:PT214	10:UH2	10:TT210A	10:LVDT27	10:DPT268
11:QHSL2_	11:QID1_DU	11:UH1-UH2	11:TT211A	11:LVDT27	11:FT129
12:DQHSLX	12:QID1_DU	12:UH3	12:TT212A	12:LVDT27	12
13:QHSL1_	13:QISL1	13:UQ1	13:TT290M	13:TT264	13
14:QHSL2_	14:QISL2	14:UQ2	14:TT290R	14:TT265	14
15:DQHSLX	15:DQISLX	15:UQ3	15:U_RM	15:TT266	15:C6_V15



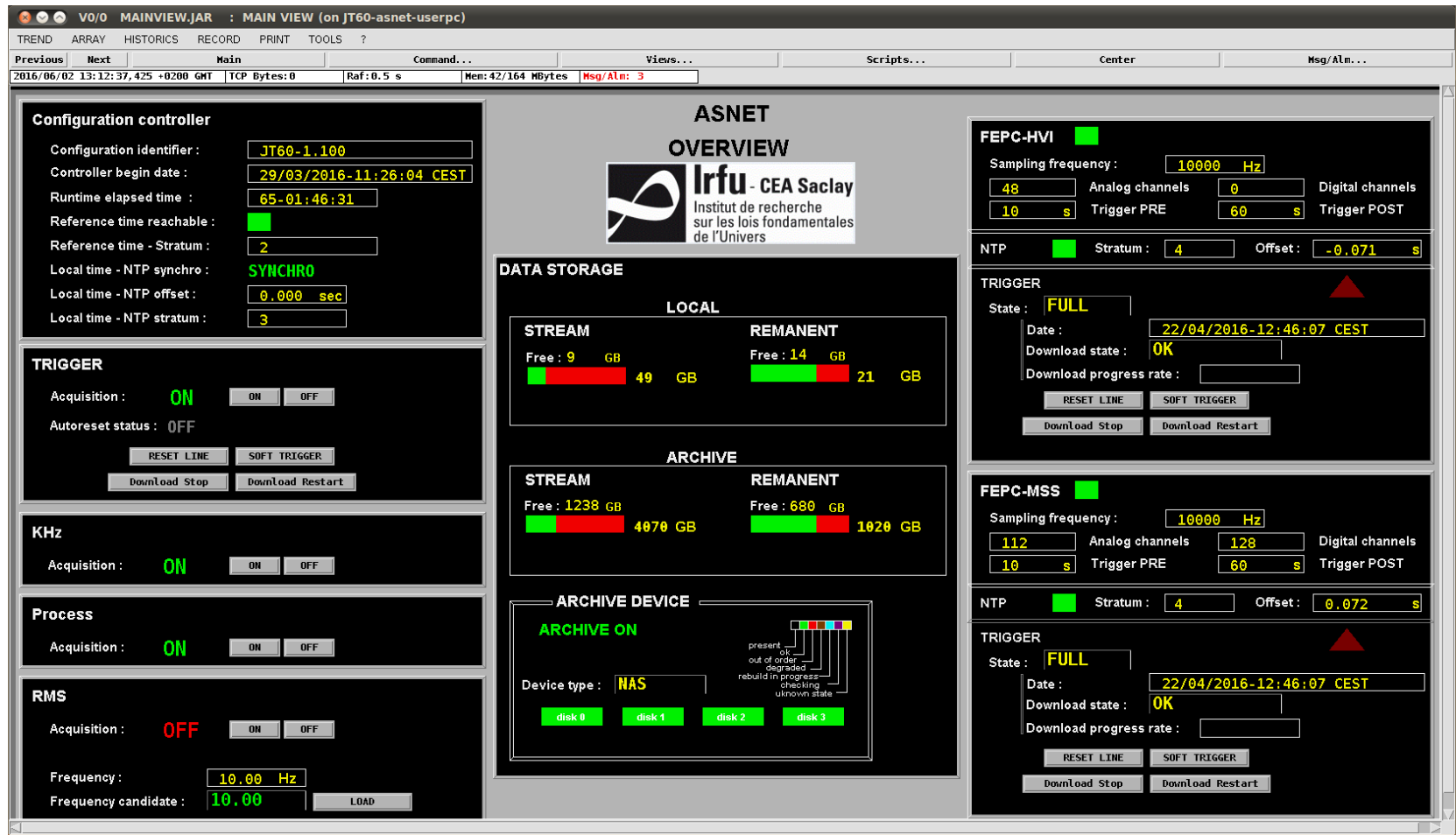
Name: QHD1_DUP_P
 Comment: Tension
 Conversion: 1:Lin. Array pts (File):QHD1_DUP_P.CNV
 Intermediate Conversion (Name_R): Yes
 $Z = a * (\text{CoefA} * Y + \text{CoefB}) + b$ Physical Mini: -10.0
 Physical Max: 10.0
 Display After Conversion Unit: V
 Display Format: 02:(float) X.YY
 ----- Advanced Parameters -----
 Average Time ms (50-1000): 50
 Physical Default on fault: 0.0
 Forced: Yes
 Derived (Name_D): Enable
 Nbr. of pts for average (1-50): 50
 Range: 2:-10/+10 V
 Gain: 1.0
 Signed: Yes
 Calibration Mini: 0
 Calibration Max: 65535
 Calibration $Y = \text{CoefA} * \text{Int} + \text{CoefB}$ CoefA: 1.0
 CoefB: 0.0
 Display on line:
 Active: Yes
 Input/Output: INPUT
 FieldBus Physical Binary Format: Float32
 Little Endian (Intel): Yes
 State: OK

references [bounds +/-]

calibration



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.

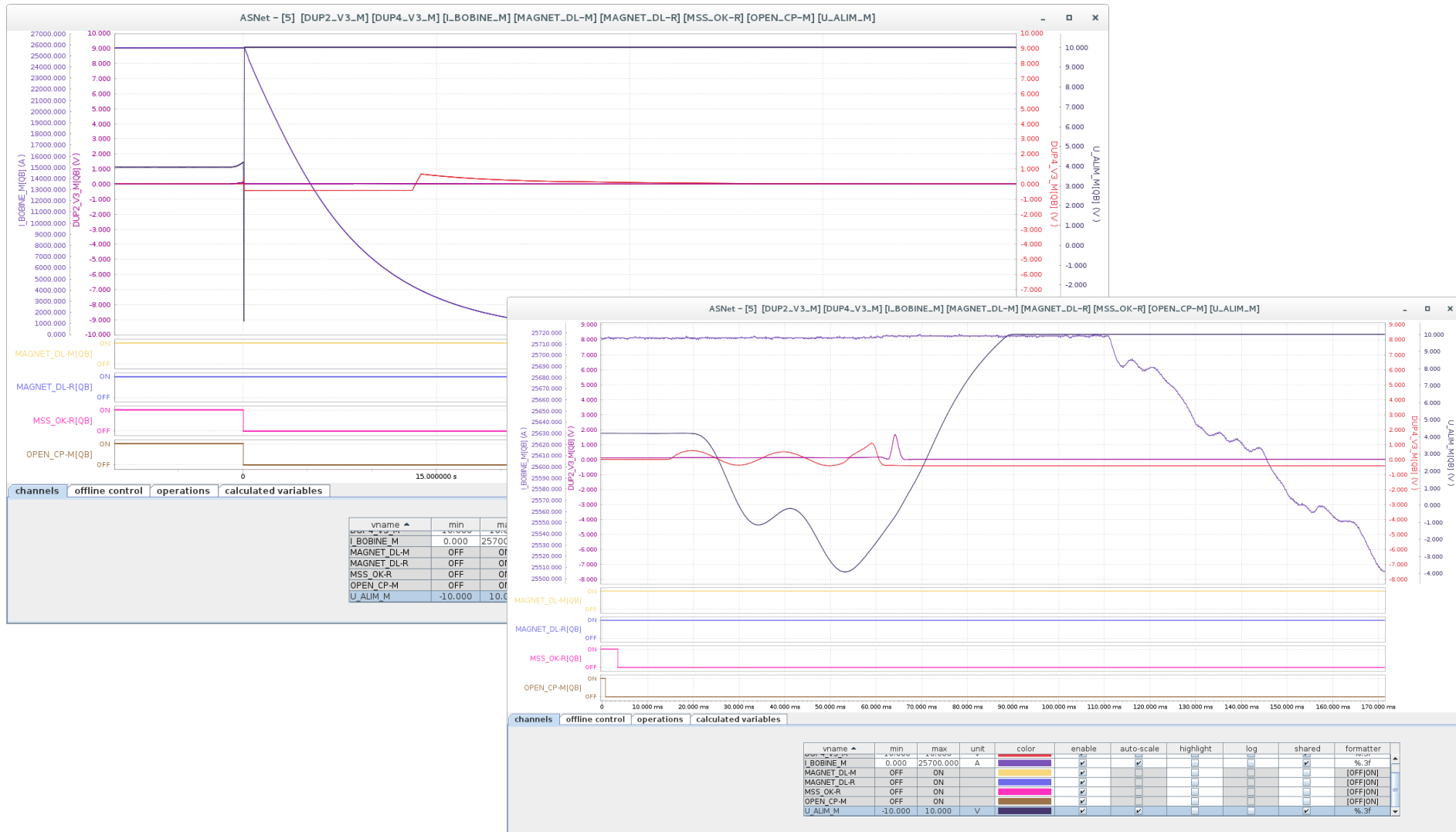


The screenshot displays the Muscade interface for ASNET, showing various monitoring and control panels. The interface is titled "ASNET OVERVIEW" and includes the following sections:

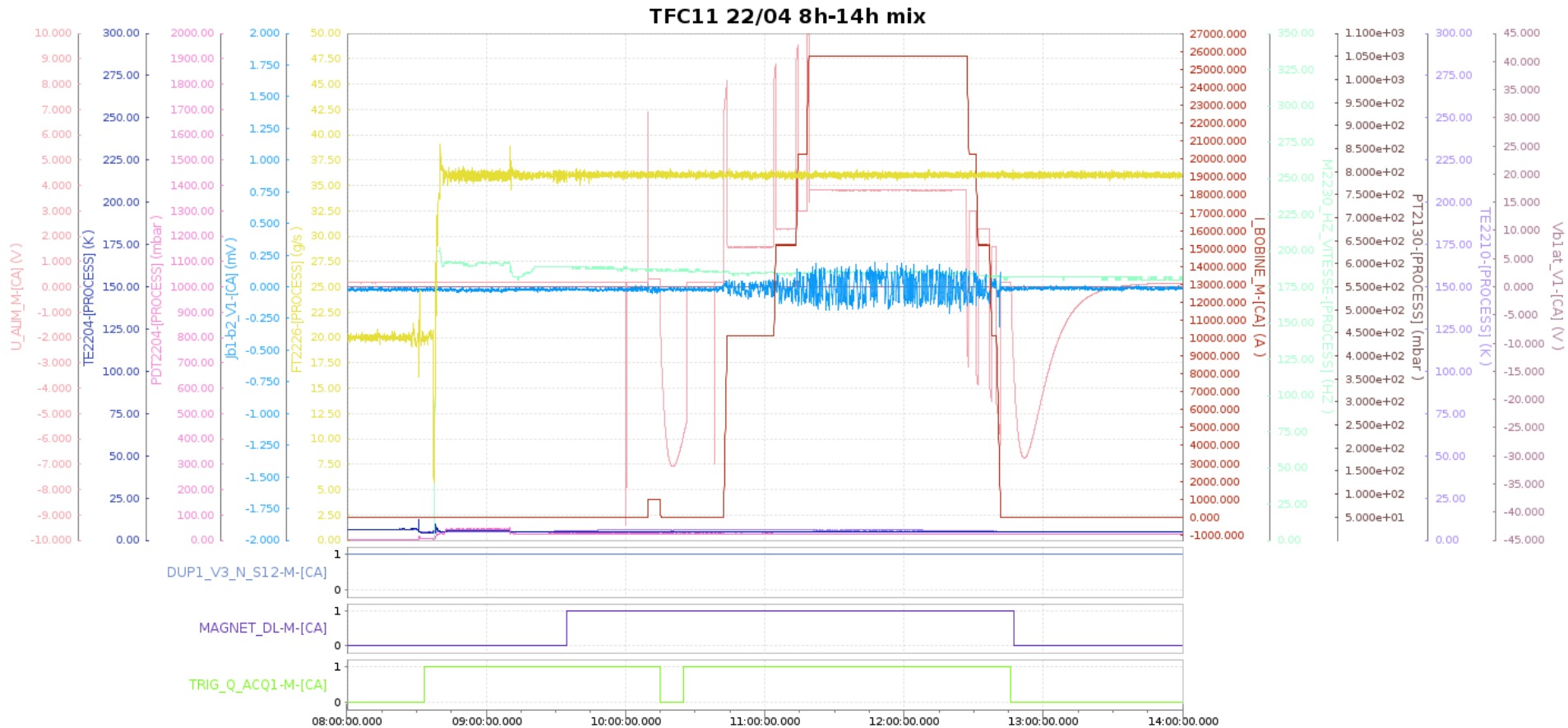
- Configuration controller:** Configuration identifier: JT60-1.100; Controller begin date: 29/03/2016-11:26:04 CEST; Runtime elapsed time: 65-01:46:31; Reference time reachable: ON; Reference time - Stratum: 2; Local time - NTP synchro: SYNCHRO; Local time - NTP offset: 0.000 sec; Local time - NTP stratum: 3.
- TRIGGER:** Acquisition: ON; Autoreset status: OFF; Buttons: RESET LINE, SOFT TRIGGER, Download Stop, Download Restart.
- KHz:** Acquisition: ON; Buttons: ON, OFF.
- Process:** Acquisition: ON; Buttons: ON, OFF.
- RMS:** Acquisition: OFF; Frequency: 10.00 Hz; Frequency candidate: 10.00; Button: LOAD.
- ASNET OVERVIEW:** Irfu - CEA Saclay logo and text: Institut de recherche sur les lois fondamentales de l'Univers.
- DATA STORAGE:**
 - LOCAL:** STREAM: Free: 9 GB; 49 GB used; REMANENT: Free: 14 GB; 21 GB used.
 - ARCHIVE:** STREAM: Free: 1238 GB; 4070 GB used; REMANENT: Free: 680 GB; 1020 GB used.
- ARCHIVE DEVICE:** ARCHIVE ON; Device type: NAS; Buttons: disk 0, disk 1, disk 2, disk 3.
- FEPC-HVI:** Sampling frequency: 10000 Hz; Analog channels: 48; Digital channels: 0; Trigger PRE: 10 s; Trigger POST: 60 s; NTP: Stratum: 4; Offset: -0.071 s; TRIGGER: State: FULL; Date: 22/04/2016-12:46:07 CEST; Download state: OK; Download progress rate: []; Buttons: RESET LINE, SOFT TRIGGER, Download Stop, Download Restart.
- FEPC-MSS:** Sampling frequency: 10000 Hz; Analog channels: 112; Digital channels: 128; Trigger PRE: 10 s; Trigger POST: 60 s; NTP: Stratum: 4; Offset: 0.072 s; TRIGGER: State: FULL; Date: 22/04/2016-12:46:07 CEST; Download state: OK; Download progress rate: []; Buttons: RESET LINE, SOFT TRIGGER, Download Stop, Download Restart.

WORKING WITH EVENT TRIGGERED DATA

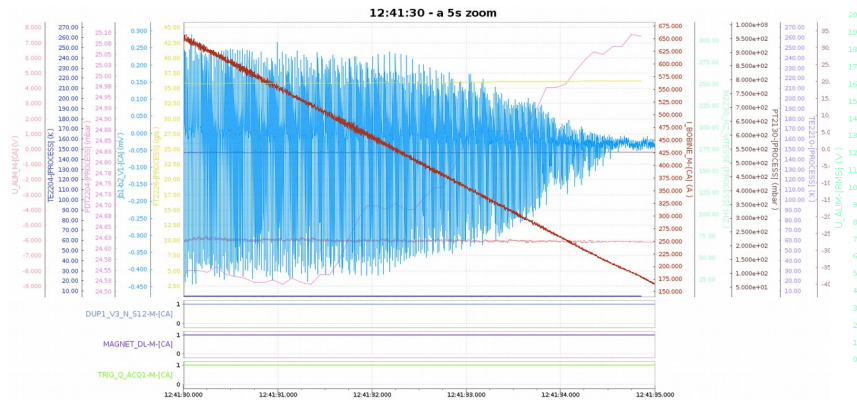
Once a trigger occurs a snapshot around event is made with a resolution up to 20us (*blackbox feature*). Analysis can then begin...



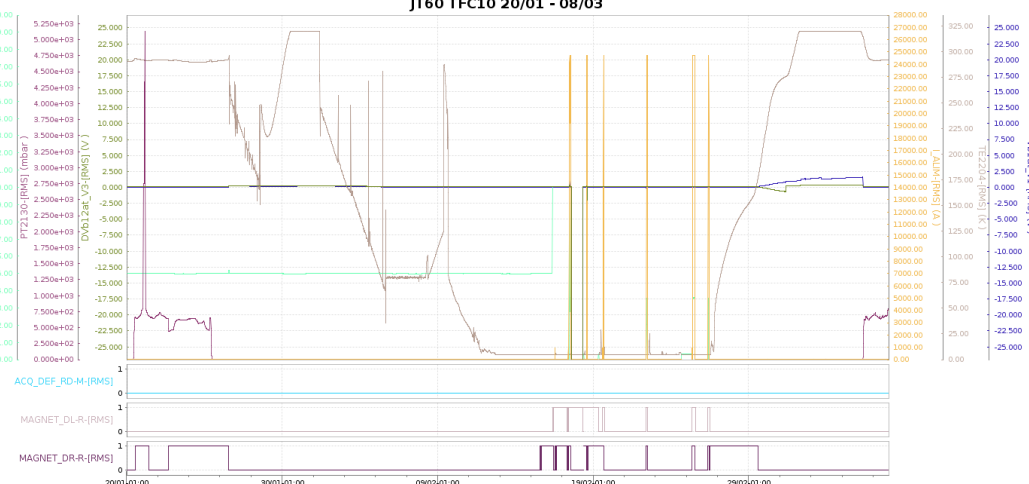
Data acquisition is continuous with a **synchronous kHz** stream and an optional 10Hz fieldbus **process stream**. We can then extract offline, from controller or archive storage, working at hour or ms scale, superimposing source for correlation if necessary...



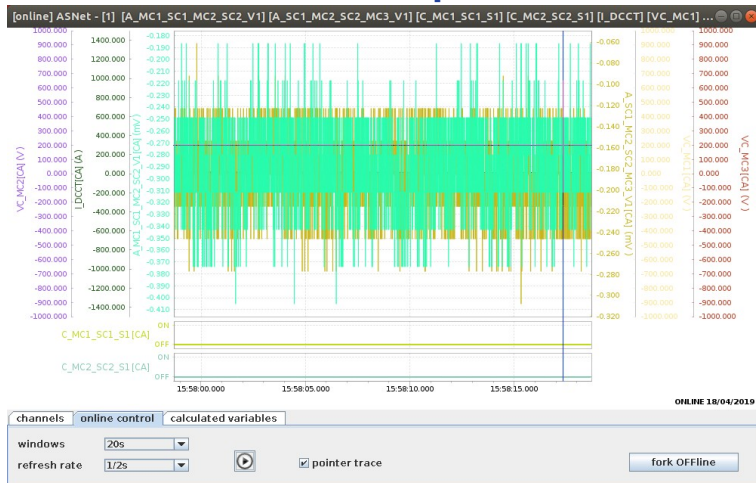
zoom anywhere



use for long trends

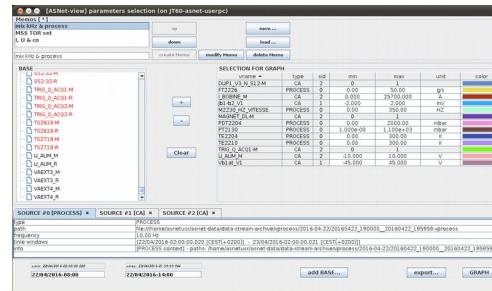


online oscilloscope feature

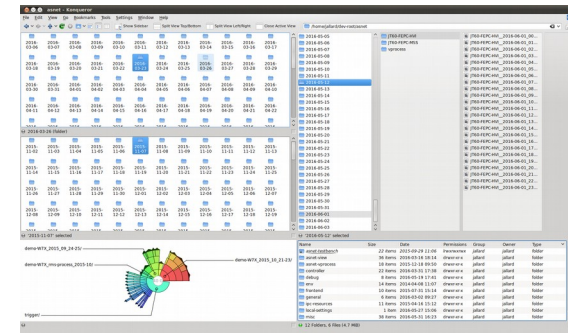


Thanks to reduced stream ASNet is usable with long time windows, typically weeks, for example to follow magnet cooling or summarize a coil testing cycle...

mix source as wanted



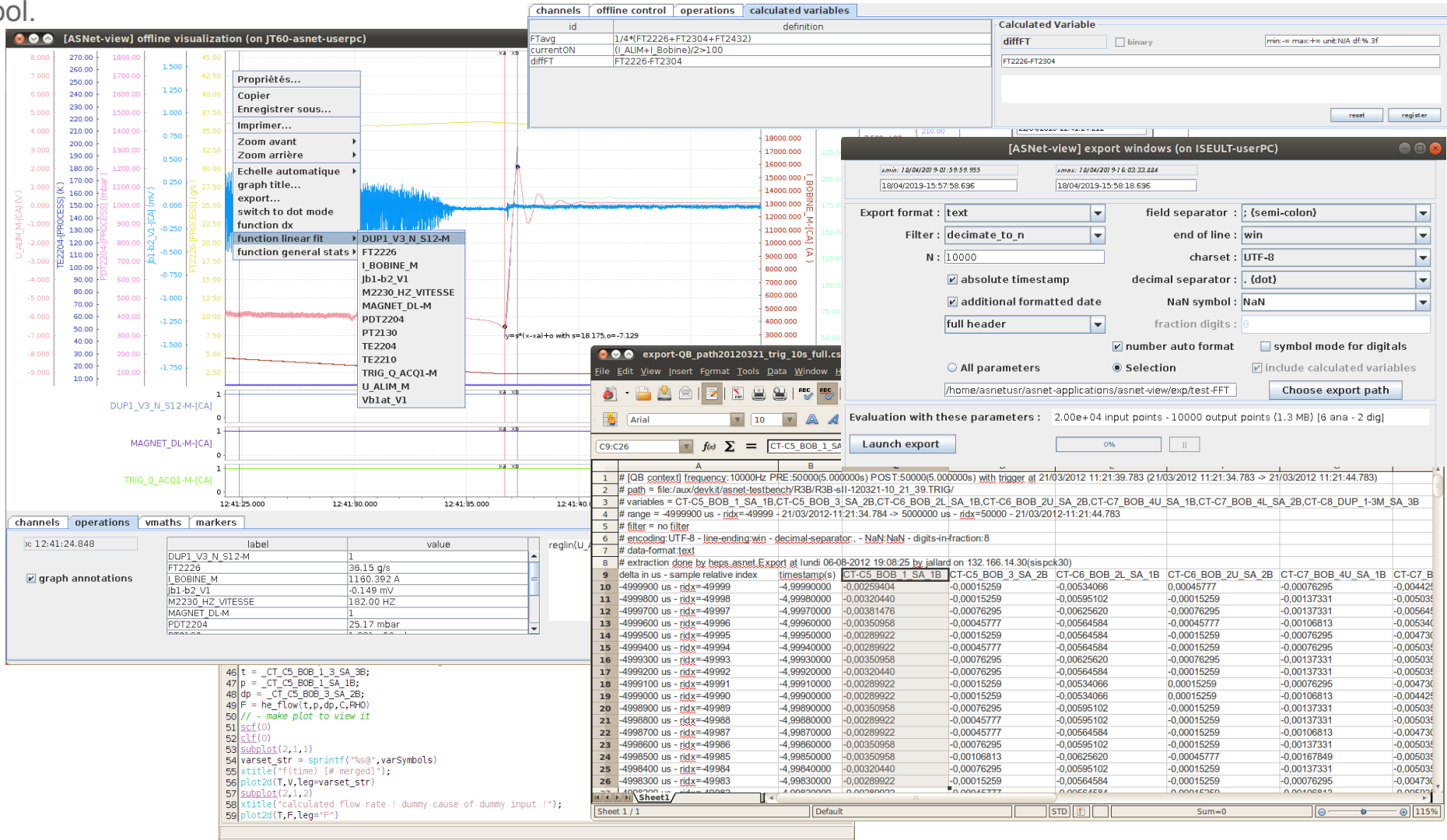
access data inside archive



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.

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.



The screenshot displays the ASNet-view software interface, which is used for data visualization and analysis. The main window shows a plot of current (I_BOBINE_M) and flow rate (FT2226) over time. A context menu is open over the plot, listing various mathematical functions such as 'function linear fit', 'function general stats', and 'function dx'. An 'export-QB' window is also visible, showing the export format settings (Text) and the export path. The bottom of the interface shows a table of calculated variables and their values, along with a command line for plotting.

label	value
DUP1_V3_N_S12-M	1
FT2226	36.15 g/s
I_BOBINE_M	1160.392 A
Ib1-b2_V1	-0.149 mV
M2230_HZ_VITESSE	182.00 HZ
MAGNET_DL-M	1
PDT2204	25.17 mbar

```
46 t = _CT_C5_BOB_1_3_SA_3B;  
47 p = _CT_C5_BOB_1_SA_1B;  
48 dp = _CT_C5_BOB_3_SA_2B;  
49 F = he_flow(t,p,dp,C,RHD)  
50 // - make plot to view it  
51 scf(0)  
52 clf(0)  
53 subplot(2,1,1)  
54 varset_str = sprintf('%s@',varSymbols)  
55 xtitle('f(time) [# merged]');  
56 plot2d(T,V,leg=varset_str)  
57 subplot(2,1,2)  
58 xtitle('calculated flow rate: ! dummy cause of dummy input: !');  
59 plot2d(T,F,leg='F')
```

[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.

```

F4E-coil_TFC20.cfg
-----
# JT60 project
# CEA Saclay - IRFU/SIS
# 24/03/2016: base
# 16/01/2017: adaptation for 2nd production = + CP_F-M, I_BOBINE_M for junctions
# F4E export parameters for coil n°20 [Alstom]
# -----

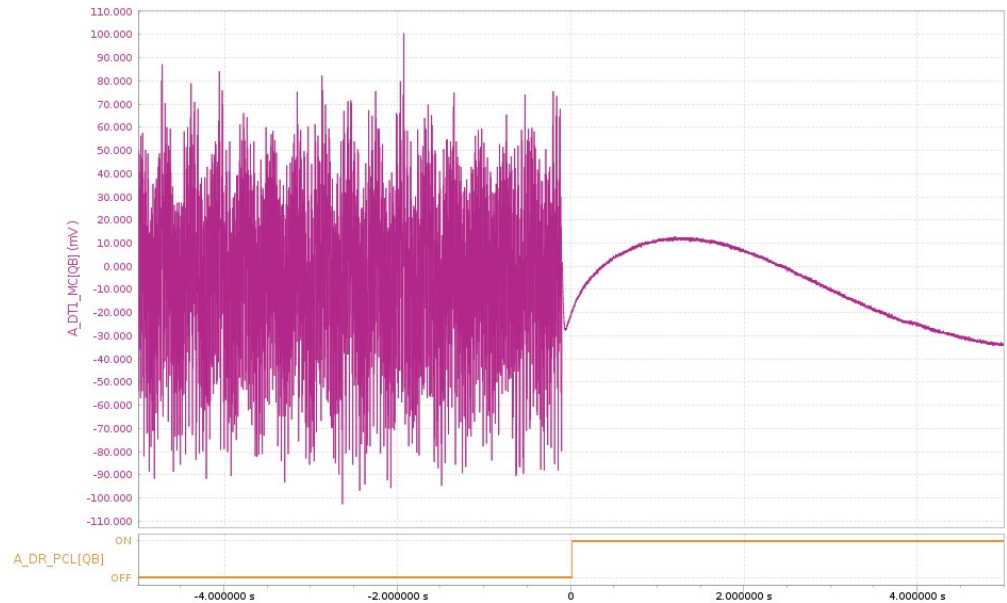
# -- export id, typically based on coil number
test-set = TFC20

# -- F4E trigger settings
F4E-trigger {
  # .. list of MSS & HVI variables
  variables =
  # from MSS >
  API_DL-M, API_DR-M, CP_F-M, DUP1_V3_M, DUP2_V3_M, DUP3_V3_M, DUP4_V3_M, DUP5_V3_M, DUP6_V3_M,
  I_BOBINE_M, MAGNET_DL-M, MAGNET_DR-M, MSS_DL-M, MSS_DR-M, OPEN_CP-M, SL1-R_V1_M, SL2-M_V2_M, U_ALIM_M,
  # from HVI >
  Vb1at_V1, Vb1g1_V1, Vb2at_V2, Vb2g1_V2, Vb3at_V1, Vb3g1_V1, Vb4at_V2, Vb4g1_V2, Vb5at_V1,
  Vb5g1_V1, Vb6at_V2, Vb6g1_V2
  # .. list of trigger ids
  # for each trigger id we can use either date (ex:17/02/2016-14:51) or folder base name
  (ex:TRIGGER_2016-02-18_16-21). mix is possible.
  triggers = 15/01/2018-15:36
}

# -- F4E vprocess settings
F4E-vprocess {
  # list vprocess days. we can also use intervals.
  # ex: 25/01/2016, [ 01/02/2016 > 08/03/2016 ]
  days = [ 05/01/2018 > 23/01/2018 ]
}

# -- F4E junction settings
F4E-junction {
  # .. list HVI & MSS variables
  variables =
  # from HVI >
  Jb1-b2_V1, Jb2-b3_V2, Jb3-b4_V1, Jb4-b5_V2, Jb5-b6_V1, Jbob-LS1_V1, Jbob-LS2_V2, Vb1at_V1,
  Vb2at_V2, Vb3at_V1, Vb4at_V2, Vb5at_V1, Vb6at_V2, Vbtat_V2, Vpickat_V2,
  # from MSS >
  CP_F-M, I_BOBINE_M
  # .. list periods to export as a list of date interval
  # ex: [ 26/02/2016-10:00 > 26/02/2016-12:30 ], [ 28/02/2016-16:00 > 28/02/2016-16:30 ]
  tests = [ 16/01/2018-09:00 > 16/01/2018-11:30 ]
}
    
```

[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.

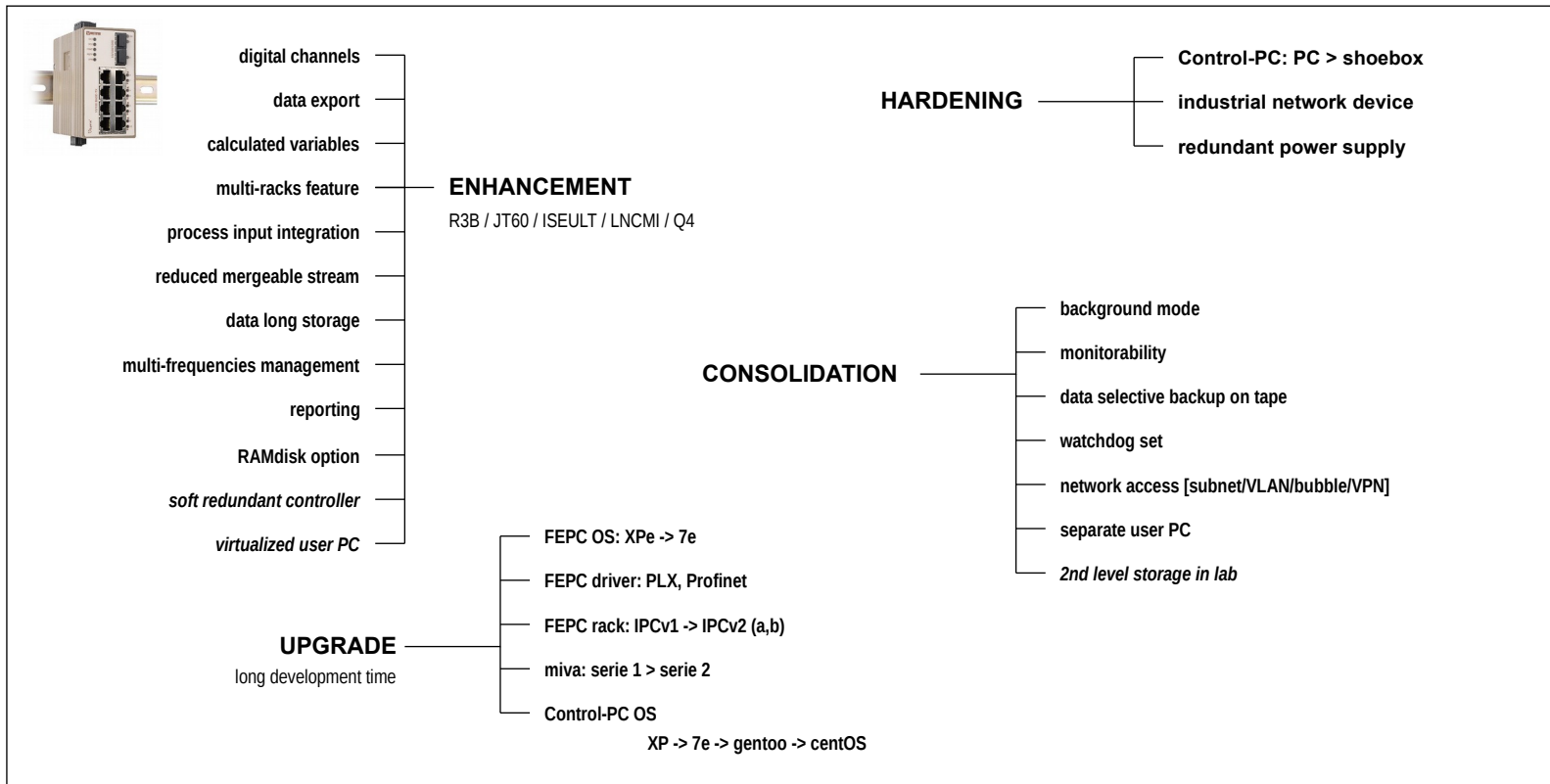


[STAARQ test stand facility (future)] Both analog and digital MSS will be installed. Our legacy analog MSS acquisition system will make its traditional job. It will also record digital MSS input signals and be used as reference for a new acquisition implementation attempt.

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*



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 → †

- Worn 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 swappiness 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.Lecoïnte, 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.Lecoïnte, J.Allard
	Electrical support	A.Lotodé

THANKS FOR YOUR ATTENTION