The remote positioning of the LHC inner triplets

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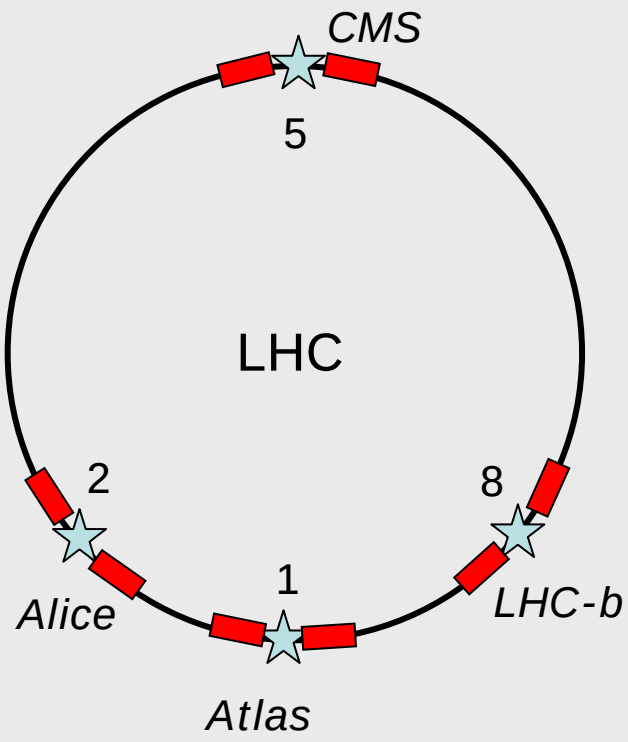
A. Herty
H. Mainaud Durand
A. Marin

Overview

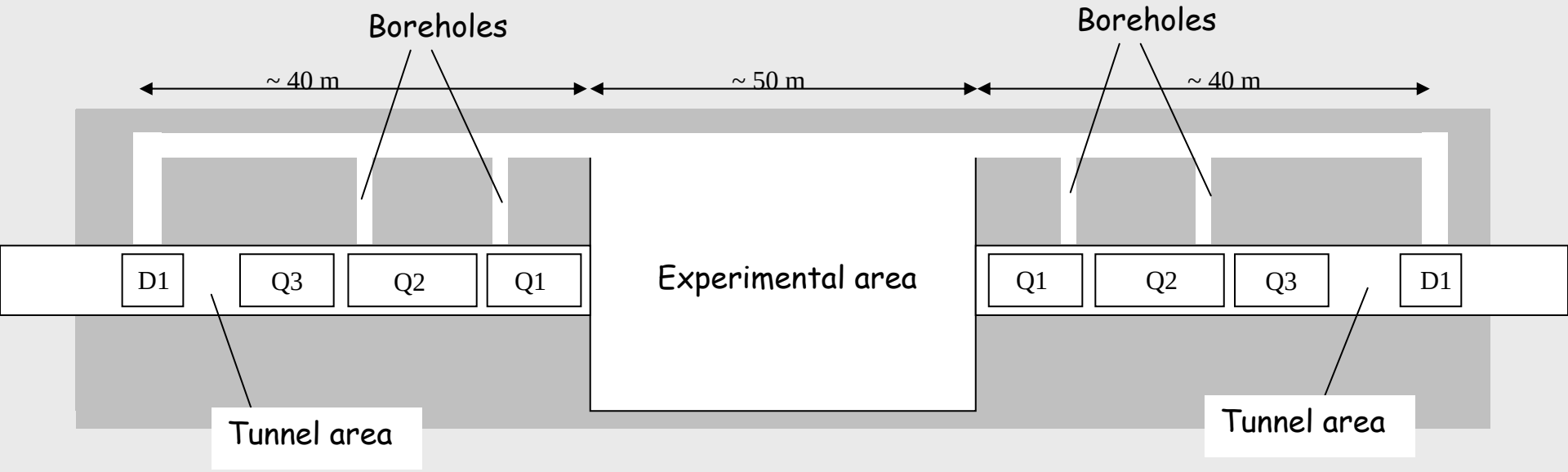
- Introduction
- The sensors
- The motors
- The repositioning
- Conclusions

Introduction

- The LHC accelerator
  - 27 km of proton-proton beam
  - 4 experiments
- The LHC inner triplets
  - low β quadrupoles for the final focus
  - 3 on each side of the 4 experiments



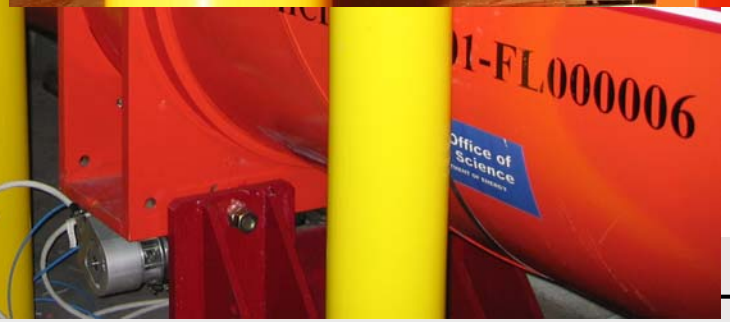
Alignment requirements



- Inside a triplet : 0.1mm at 1σ
- Collinearity :
  - in z : 0.1 mm at 1 σ
  - in x : 0.2 mm at 1 σ for IP2, 8
  - in x : 0.1 mm at 1 σ for IP1, 5 = > Survey galleries
- Stability : several μm
- Permanent monitoring and remote alignment system

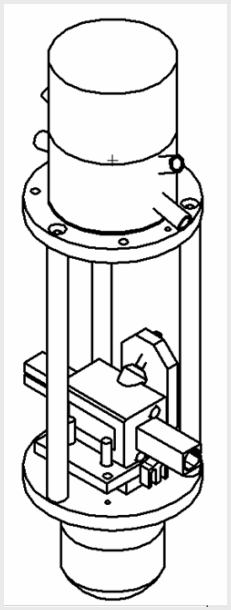
The sensors

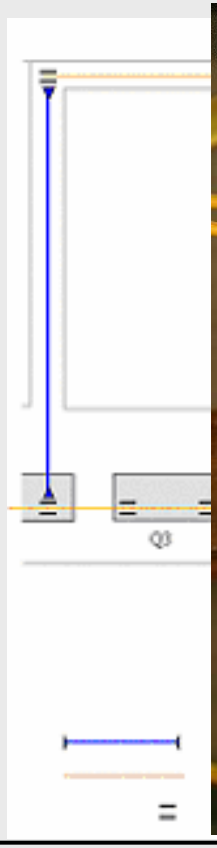
- HLS for verti

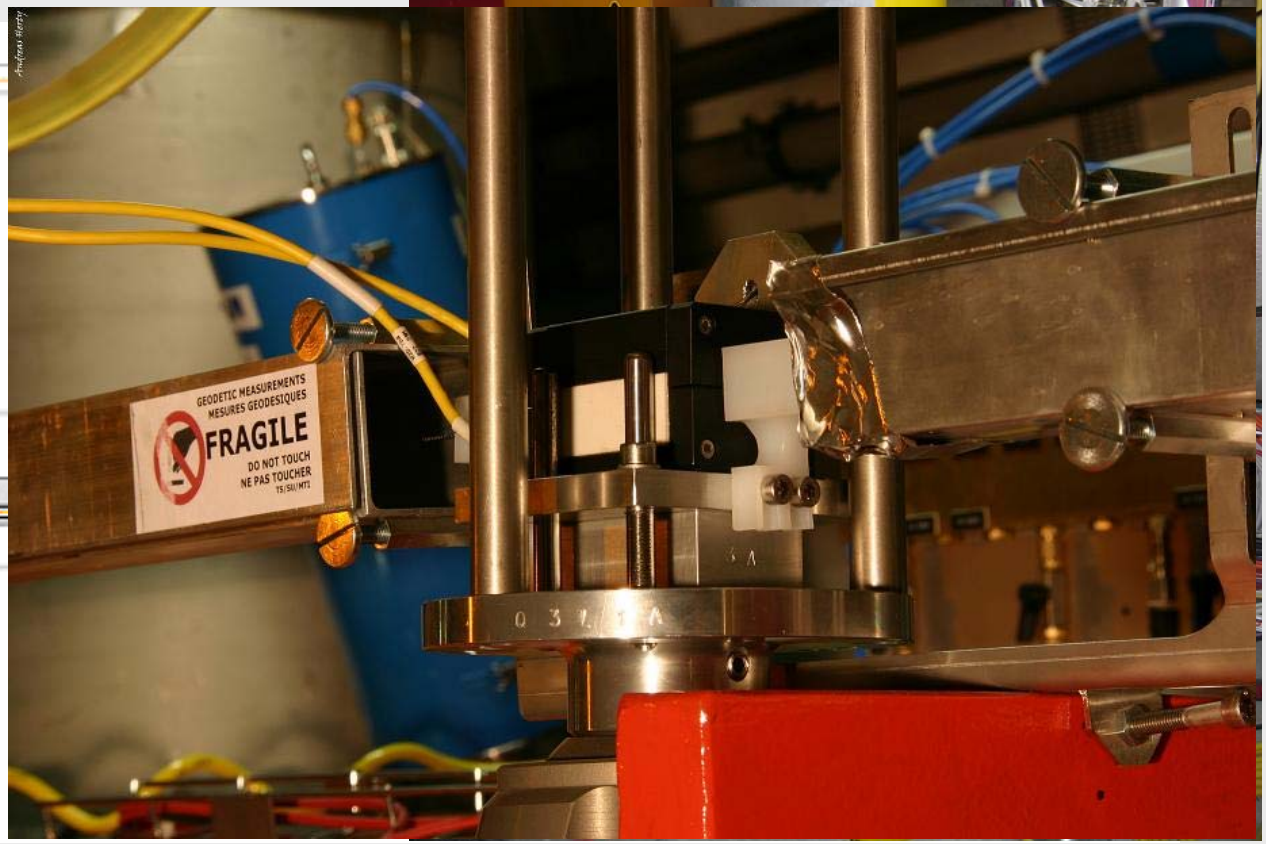


The sensors

- WPS for horizontal and v
- No monitoring in longitud

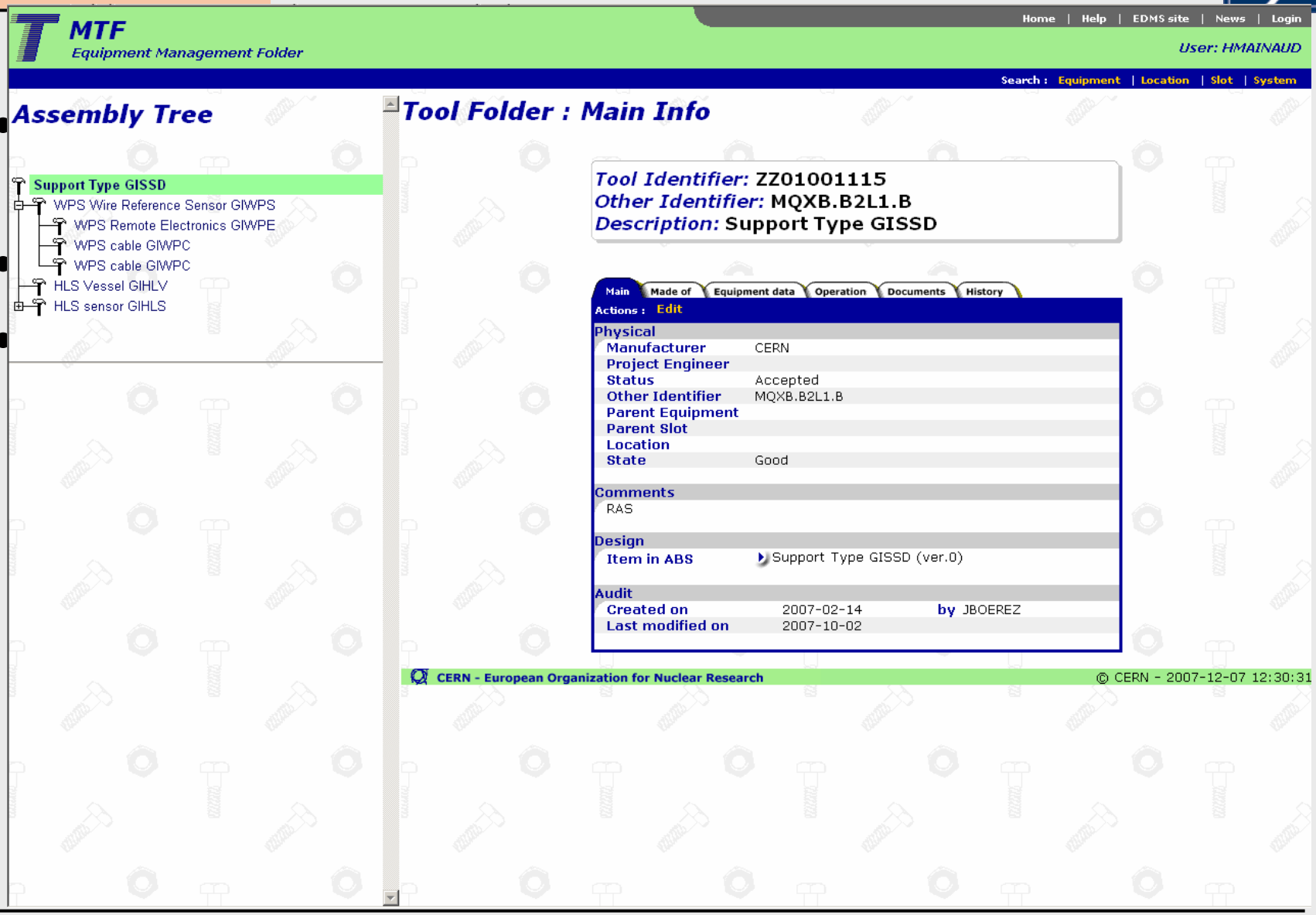






The UPS galleries

The sensors


MTF
Equipment Management Folder
Home | Help | EDMS site | News | Login
User: HMAINAUD
Search : Equipment | Location | Slot | System
Assembly Tree
Support Type GISSD
WPS Wire Reference Sensor GIWPS
WPS Remote Electronics GIWPE
WPS cable GIWPC
WPS cable GIWPC
HLS Vessel GIHLV
HLS sensor GIHLS
Tool Folder : Main Info
Tool Identifier: ZZ01001115
Other Identifier: MQXB.B2L1.B
Description: Support Type GISSD
Main
Made of
Equipment data
Operation
Documents
History
Actions : Edit
Physical
Manufacturer CERN
Project Engineer
Status Accepted
Other Identifier MQXB.B2L1.B
Parent Equipment
Parent Slot
Location
State Good
Comments
RAS
Design
Item in ABS Support Type GISSD (ver.0)
Audit
Created on 2007-02-14 by JBOEREZ
Last modified on 2007-10-02
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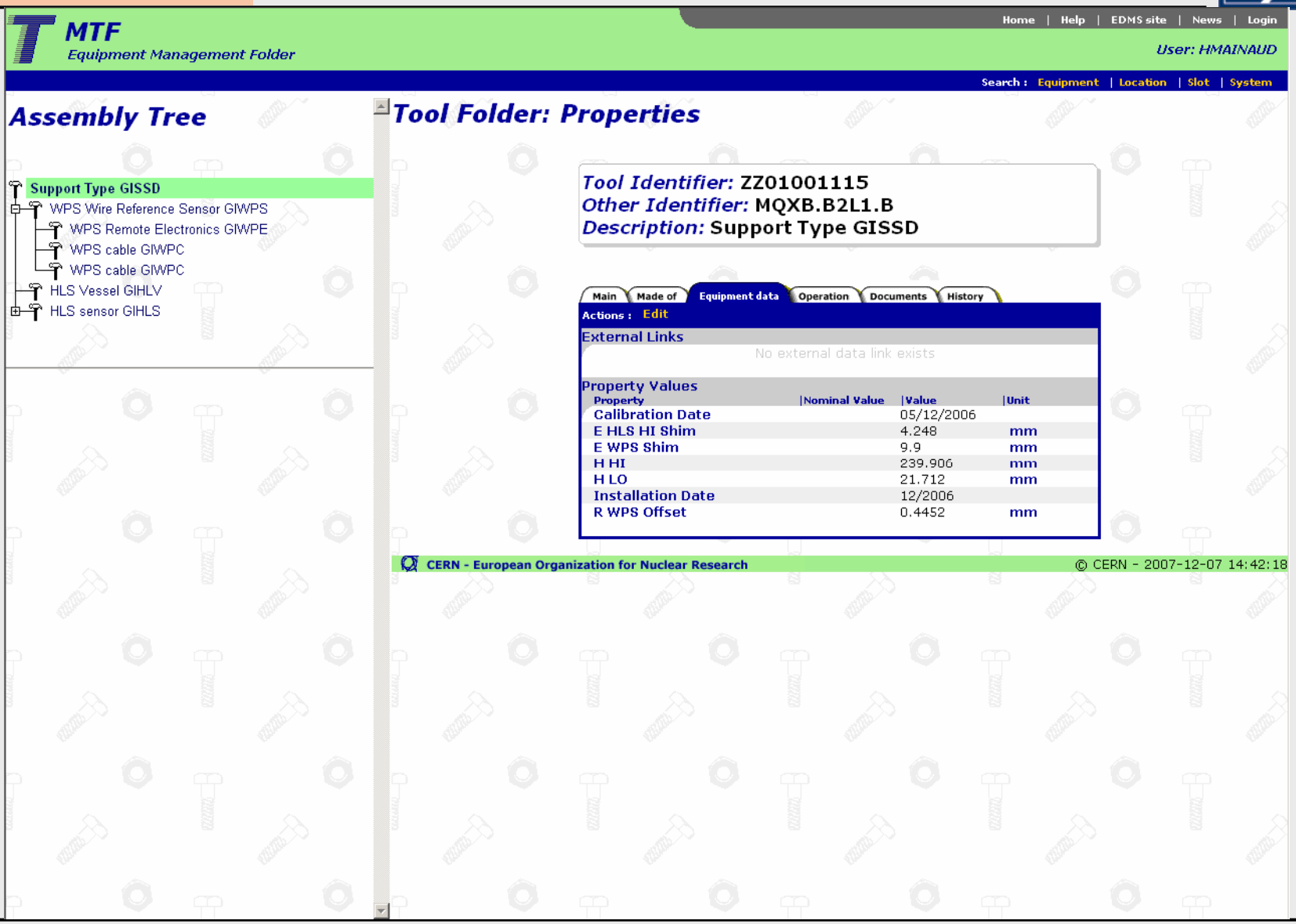
The sensors


MTF
Equipment Management Folder
Home | Help | EDMS site | News | Login
User: HMAINAUD
Search : Equipment | Location | Slot | System
Assembly Tree
Support Type GISSD
WPS Wire Reference Sensor GIWPS
WPS Remote Electronics GIWPE
WPS cable GIWPC
WPS cable GIWPC
HLS Vessel GIHLV
HLS sensor GIHLS
Tool Folder: Properties
Tool Identifier: ZZ01001115
Other Identifier: MQXB.B2L1.B
Description: Support Type GISSD
Main
Made of
Equipment data
Operation
Documents
History
Actions : Edit
External Links
No external data link exists
Property Values
Property | Nominal Value | Value | Unit
Calibration Date | | 05/12/2006 |
E HLS HI Shim | | 4.248 | mm
E WPS Shim | | 9.9 | mm
H HI | | 239.906 | mm
H LO | | 21.712 | mm
Installation Date | | 12/2006 |
R WPS Offset | | 0.4452 | mm
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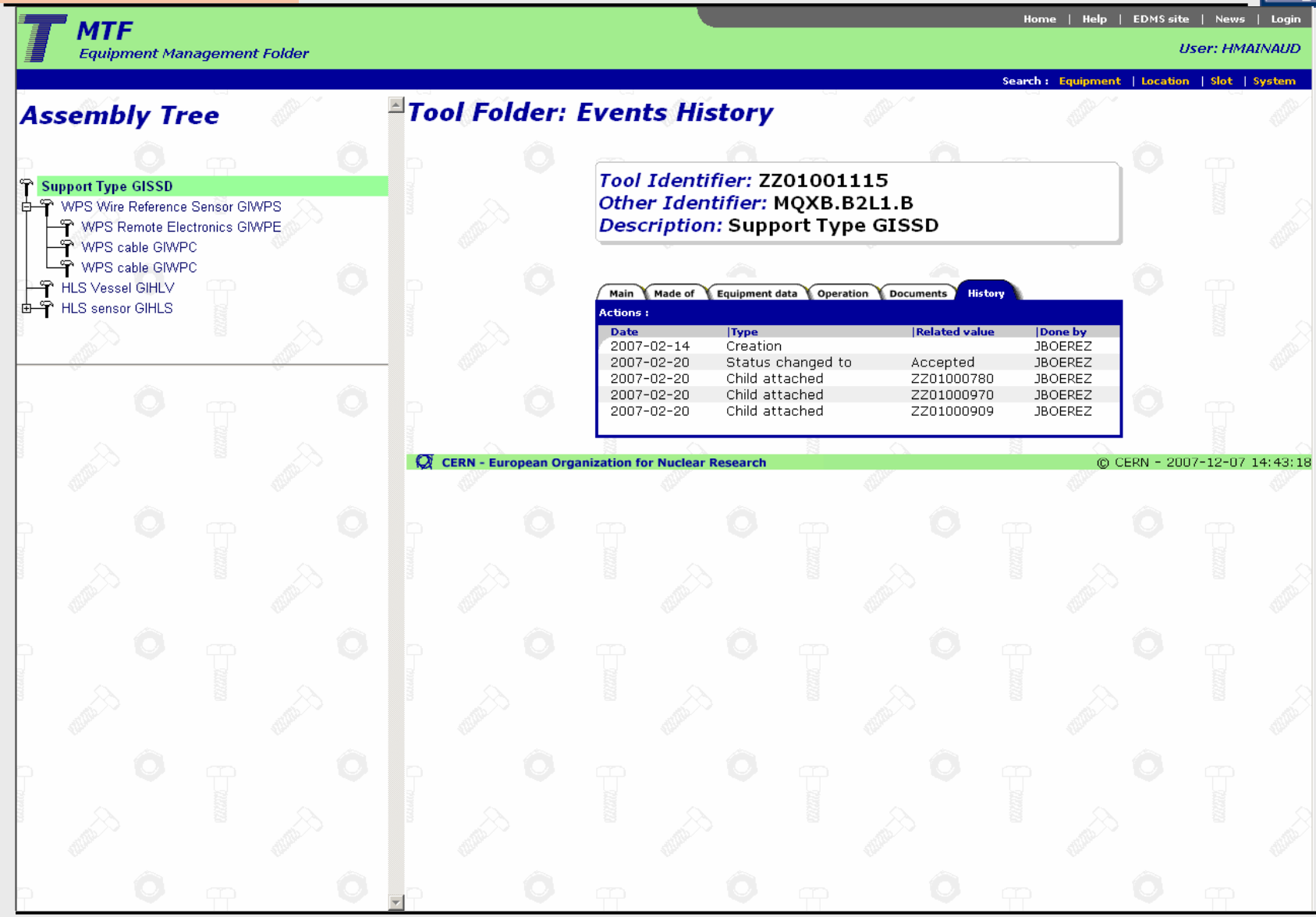
The sensors


MTF
Equipment Management Folder
Home | Help | EDMS site | News | Login
User: HMAINAUD
Search : Equipment | Location | Slot | System
Assembly Tree
Support Type GISSD
WPS Wire Reference Sensor GIWPS
WPS Remote Electronics GIWPE
WPS cable GIWPC
WPS cable GIWPC
HLS Vessel GIHLV
HLS sensor GIHLS
Tool Folder: Events History
Tool Identifier: ZZ01001115
Other Identifier: MQXB.B2L1.B
Description: Support Type GISSD
Main
Made of
Equipment data
Operation
Documents
History
Actions :
Date | Type | Related value | Done by
2007-02-14 | Creation | | JBOEREZ
2007-02-20 | Status changed to | Accepted | JBOEREZ
2007-02-20 | Child attached | ZZ01000780 | JBOEREZ
2007-02-20 | Child attached | ZZ01000970 | JBOEREZ
2007-02-20 | Child attached | ZZ01000909 | JBOEREZ
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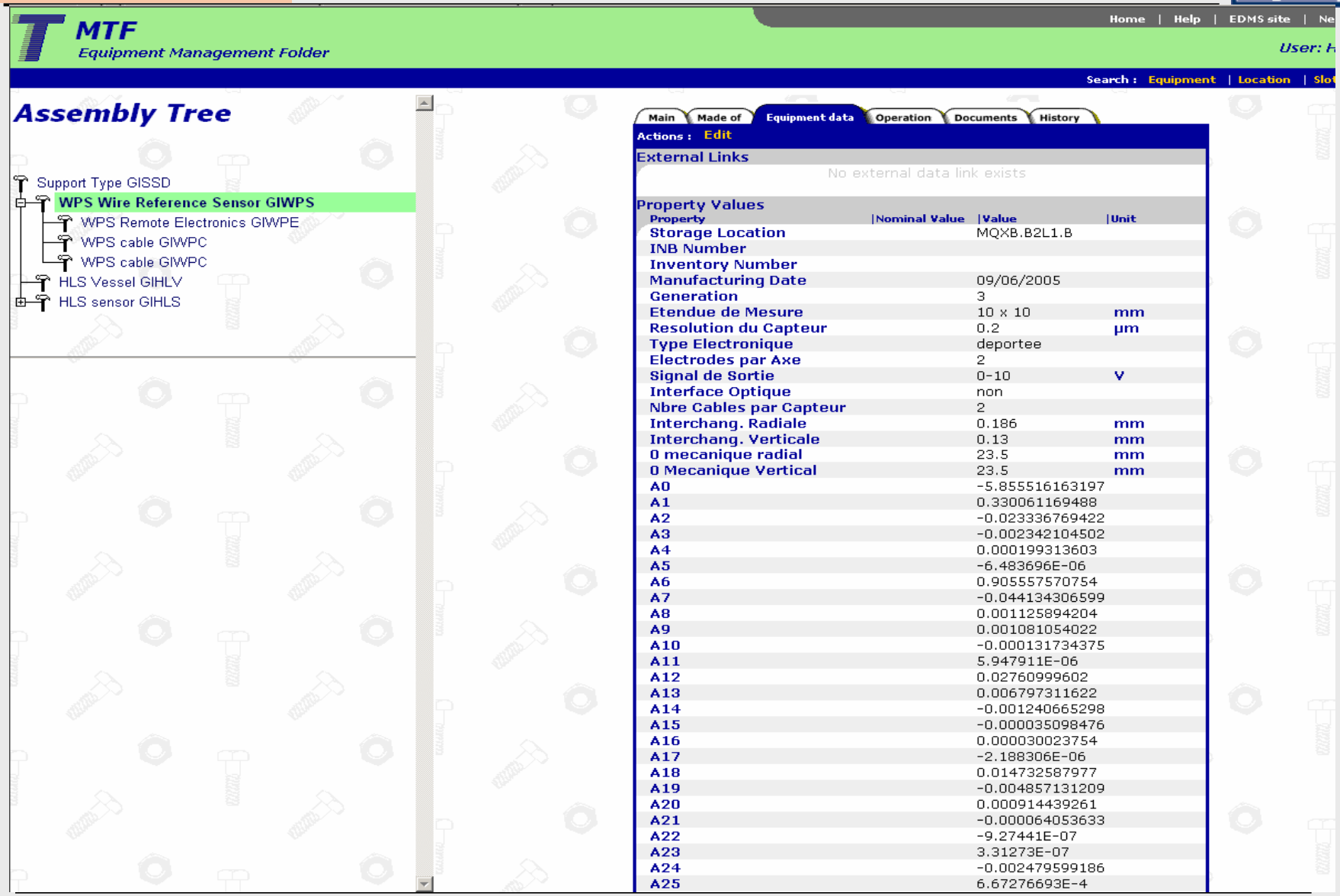
The sensors


MTF
Equipment Management Folder
Home | Help | EDMS site | Ne
User: H
Search : Equipment | Location | Slot
Assembly Tree
Support Type GISSD
WPS Wire Reference Sensor GIWPS
WPS Remote Electronics GIWPE
WPS cable GIWPC
WPS cable GIWPC
HLS Vessel GIHLV
HLS sensor GIHLS
Main
Made of
Equipment data
Operation
Documents
History
Actions : Edit
External Links
No external data link exists
Property Values
Property | Nominal Value | Value | Unit
Storage Location MQXB.B2L1.B
INB Number
Inventory Number
Manufacturing Date 09/06/2005
Generation 3
Etendue de Mesure 10 x 10 mm
Resolution du Capteur 0.2 µm
Type Electronique deportee
Electrodes par Axe 2
Signal de Sortie 0-10 V
Interface Optique non
Nbre Cables par Capteur 2
Interchang. Radiale 0.186 mm
Interchang. Verticale 0.13 mm
0 mecanique radial 23.5 mm
0 Mecanique Vertical 23.5 mm
A0 -5.855516163197
A1 0.330061169488
A2 -0.023336769422
A3 -0.002342104502
A4 0.000199313603
A5 -6.483696E-06
A6 0.905557570754
A7 -0.044134306599
A8 0.001125894204
A9 0.001081054022
A10 -0.000131734375
A11 5.947911E-06
A12 0.02760999602
A13 0.006797311622
A14 -0.001240665298
A15 -0.000035098476
A16 0.000030023754
A17 -2.188306E-06
A18 0.014732587977
A19 -0.004857131209
A20 0.000914439261
A21 -0.000064053633
A22 -9.27441E-07
A23 3.31273E-07
A24 -0.002479599186
A25 6.67276693E-4

Commissioning

(2.A) Vidange HLS Q1 22.11.2007

15.11.2007

(1) Déplacement au niveau Q1

Classe	Numéro	Pt	Dist.Cumulé		09H00	11H00	DY	DDY	DDY THEO	DELTA
MBXW	4L1		26596.33420		-0.19170	-0.20660	0.01490	-0.44550	-0.44550	0.0
MQXA	3L1	A	26606.39640		-0.78300	-0.91185	0.12885	-0.33155	-0.32830	-3.3
MQXA	3L1	B	26610.59624		-0.57985	-0.75550	0.17565	-0.28475	-0.27938	-5.4
MQXB	2L1	A	26616.04436		-0.73950	-0.97975	0.24025	-0.22015	-0.21592	-4.2
MQXB	2L1	B	26625.11969		-0.83430	-1.19000	0.35570	-0.10470	-0.11021	5.5
MQXA	1L1	A	26630.37316		0.04245	-0.37305	0.41550	-0.04490	-0.04902	4.1
MQXA	1L1	B	26634.58159		-0.08390	-0.54430	0.46040	0.00000	0.00000	0.0

Classe	Numéro	Pt	Dist.Cumulé		09H00	11H00	DX	DDX	DDX THEO	DELTA
MBXW	4L1		26596.33420		-0.59685	-0.56410	-0.03275	1.17835	1.17835	0.0
MQXA	3L1	A	26606.39640		-1.26855	-0.92545	-0.34310	0.86800	0.86835	-0.3
MQXA	3L1	B	26610.59624		-2.67330	-2.20125	-0.47205	0.73905	0.73896	0.1
MQXB	2L1	A	26616.04436		-0.32185	0.31550	-0.63735	0.57375	0.57111	2.6
MQXB	2L1	B	26625.11969		-0.11895	0.79495	-0.91390	0.29720	0.29151	5.7
MQXA	1L1	A	26630.37316		1.40035	2.48455	-1.08420	0.12690	0.12966	-2.8
MQXA	1L1	B	26634.58159		0.05170	1.26280	-1.21110	0.00000	0.00000	0.0
			m		mm	mm	mm	mm	mm	µm

mesures OK, fil validé

Dz	difference start- end
Dzz	shifted to Zero for theorem of intersecting lines
Dzz theo	theoretical value obtained from intersecting lines
Delta	difference between Dzz and Dzz theo

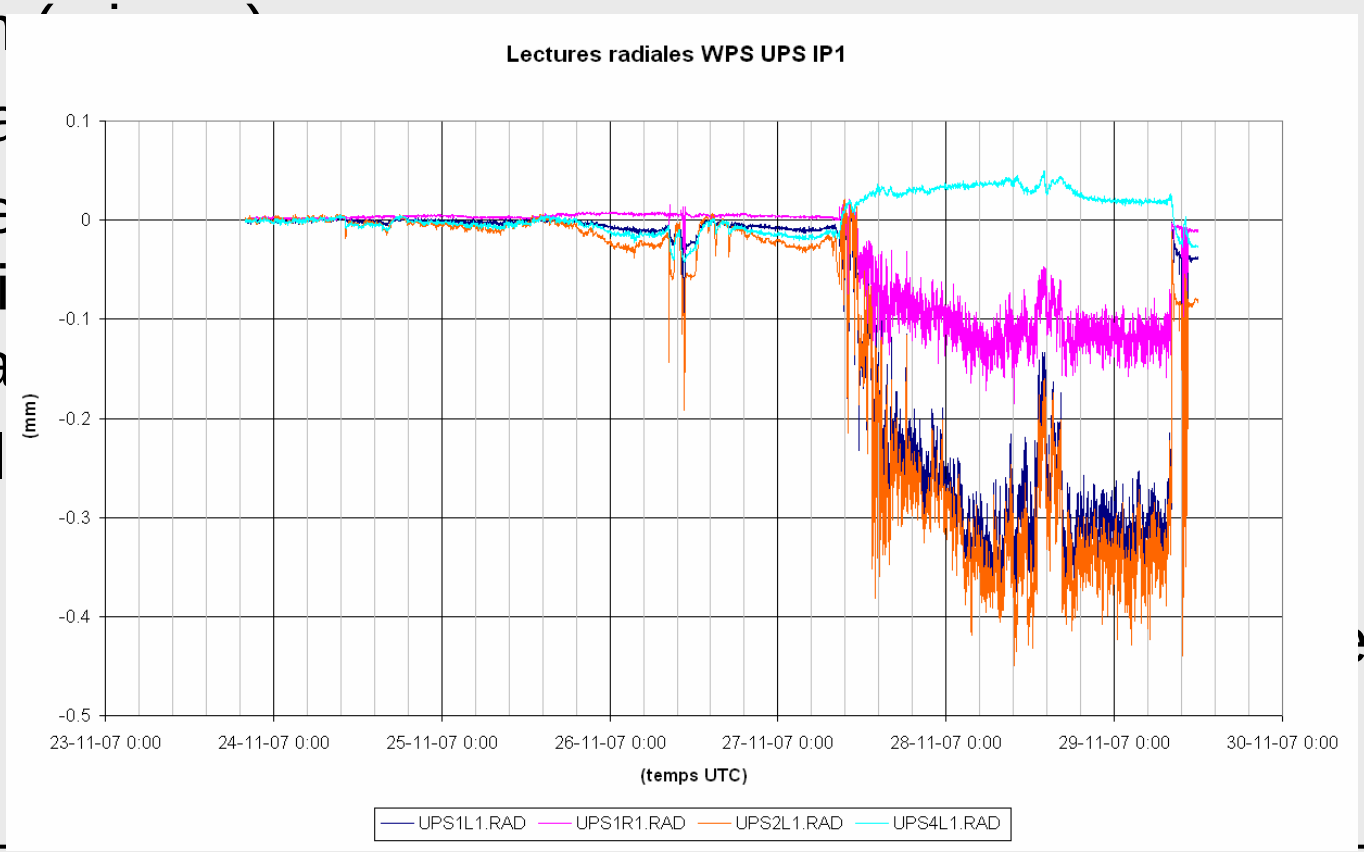
triplet 0.15201

HLS validated on triplet (TRI)

communation between cavern and triplet > 75 min ... DIFF therefore different

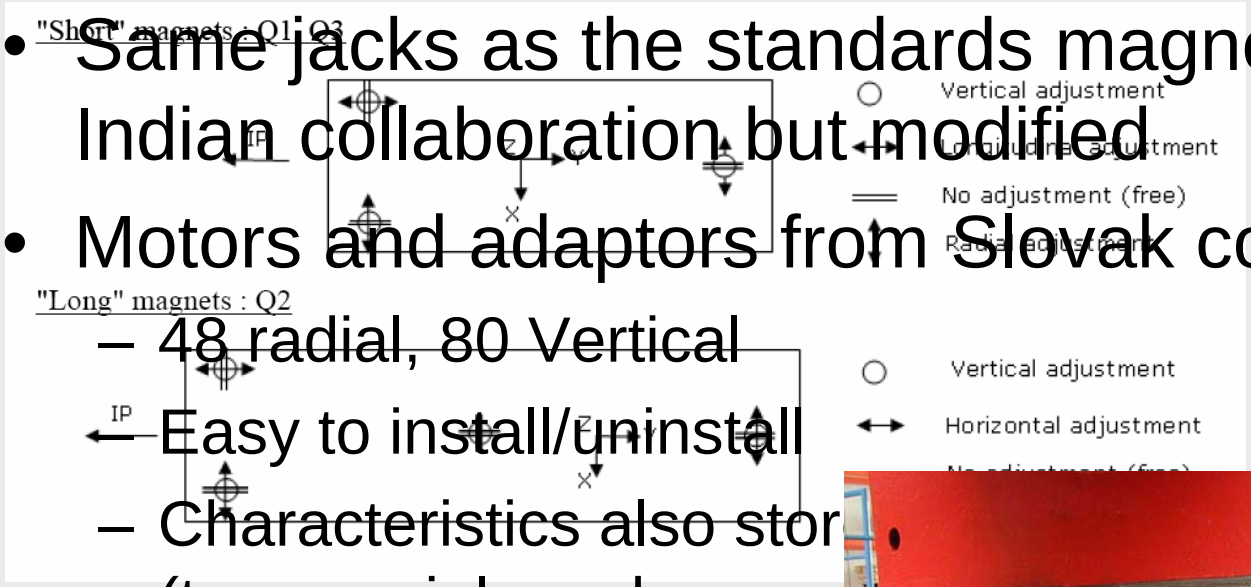
First results

- 5 triplets out of 8 are equipped
  - Stabilisation of HLS for tilt adjustment 100 s within 1 µm (rms)
  - Sta
  - Ele
    nei
    ma
  - sol
    -
    -



Jacks and Motors

- Same jacks as the standards magnets from Indian collaboration but modified
- Motors and adaptors from Slovak company ZTS
  - 48 radial, 80 Vertical
  - Easy to install/uninstall
  - Characteristics also stor
    (type, serial number, rep



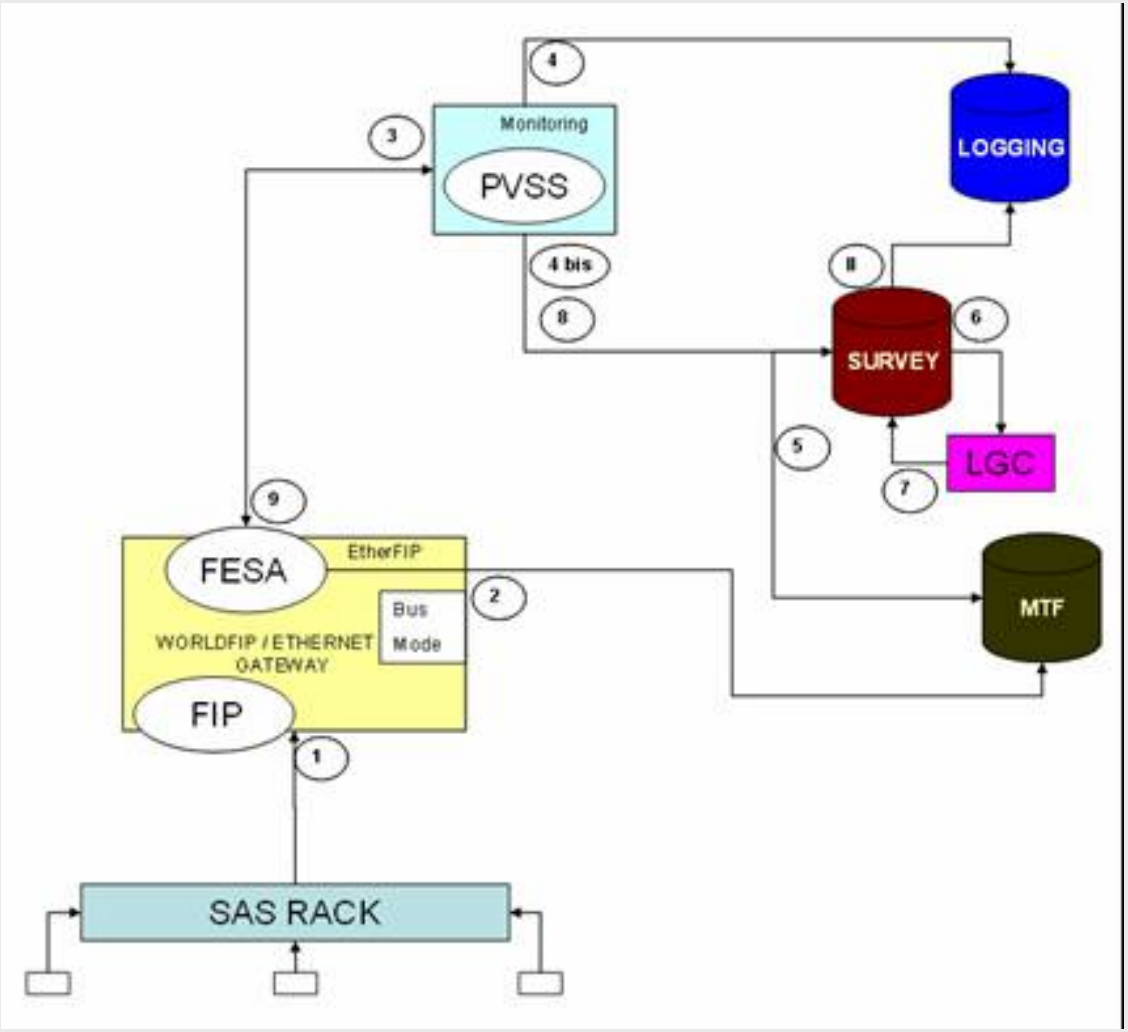
Motors

- Quality control
  - All motors and adaptors tested individually
  - Each couple motor/adaptor tested on a 15 t spare magnet
- Installation
  - Once the alignment systems are installed
  - Ethernet connection to display sensors value close to the magnet to be equipped
  - Small movement of 0.1 mm max during installation

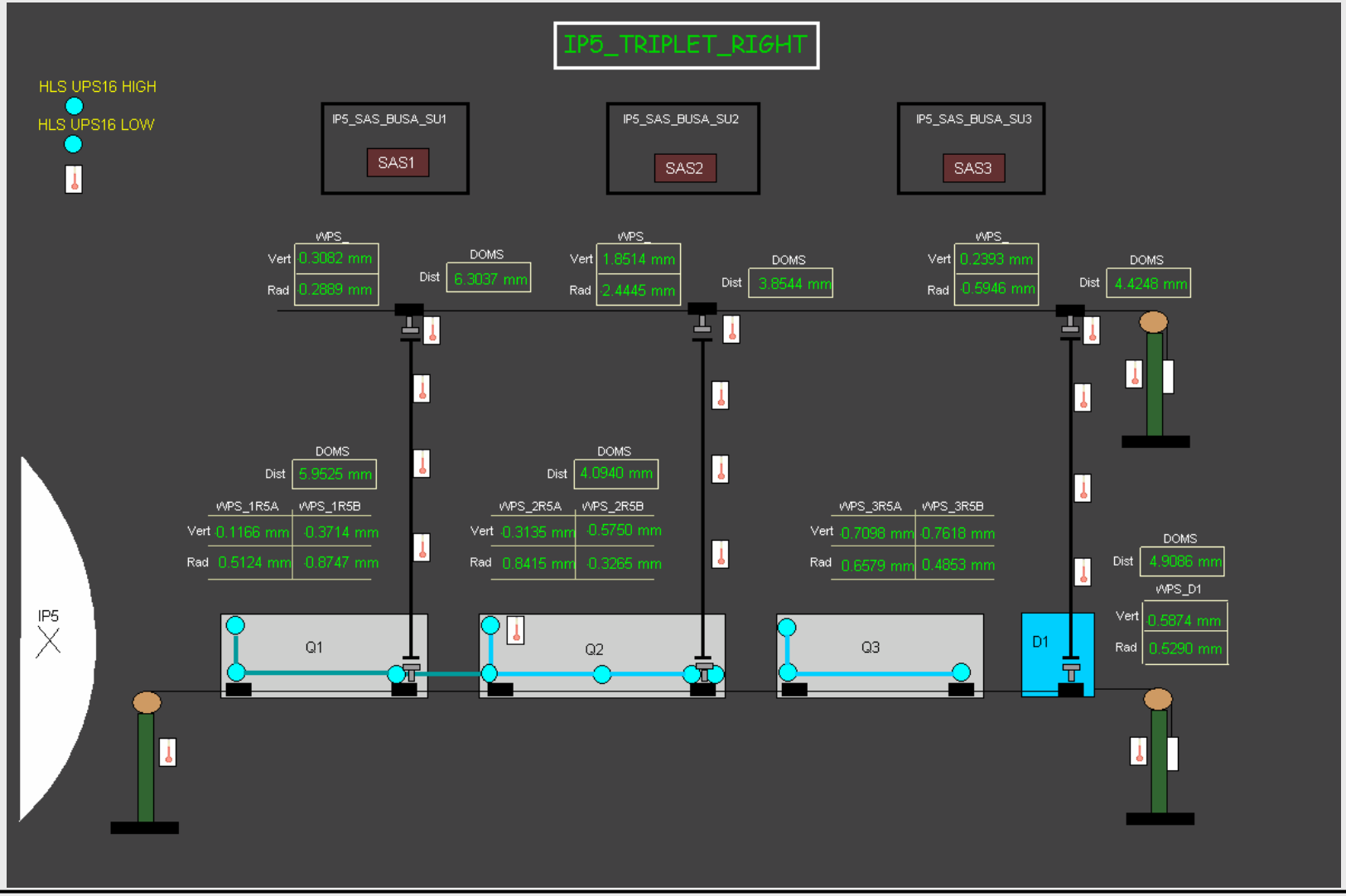
Remote repositioning

- It is NOT an active repositioning
- The repositioning is decided by Physicists who calculate new magnet positions
- Values have to be transformed to displacements :
  - At the level of the sensors
  - At the level of the motors
- Displacements are carried out
- New measurements taken by sensors and new position calculated

Remote repositioning



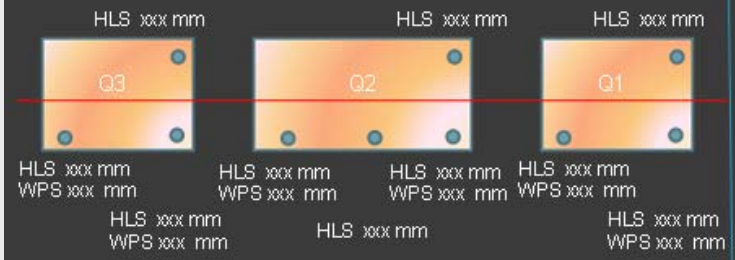
PVSS

- 
IP5_TRIPLET_RIGHT
HLS UPS16 HIGH
HLS UPS16 LOW
IP5_SAS_BUSA_SU1
SAS1
IP5_SAS_BUSA_SU2
SAS2
IP5_SAS_BUSA_SU3
SAS3
WPS
Vert 0.3082 mm
Rad 0.2889 mm
DOMS
Dist 6.3037 mm
WPS
Vert 1.8514 mm
Rad 2.4445 mm
DOMS
Dist 3.8544 mm
WPS
Vert 0.2393 mm
Rad 0.5946 mm
DOMS
Dist 4.4248 mm
DOMS
Dist 5.9525 mm
WPS_1R5A WPS_1R5B
Vert 0.1166 mm 0.3714 mm
Rad 0.5124 mm 0.8747 mm
DOMS
Dist 4.0940 mm
WPS_2R5A WPS_2R5B
Vert 0.3135 mm 0.5750 mm
Rad 0.8415 mm 0.3265 mm
WPS_3R5A WPS_3R5B
Vert 0.7098 mm 0.7618 mm
Rad 0.6579 mm 0.4853 mm
DOMS
Dist 4.9086 mm
WPS_D1
Vert 0.5874 mm
Rad 0.5290 mm
IP5
Q1
Q2
Q3
D1

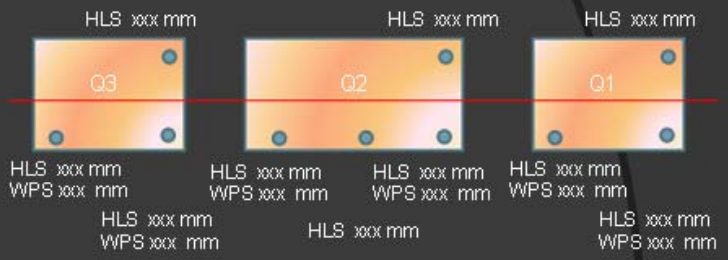
PVSS

VISUALISATION EXPERT

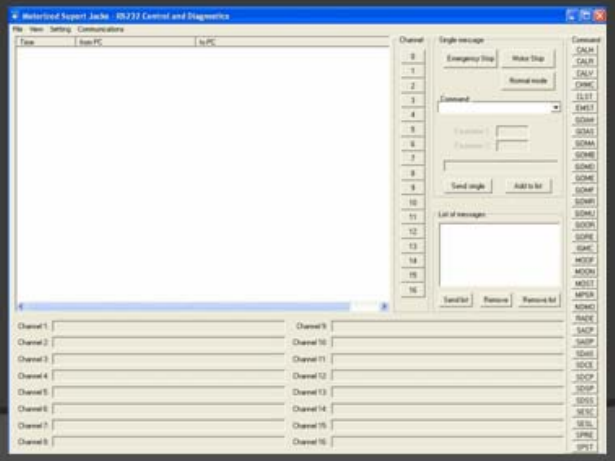
Values observed on sensors at time before positioning



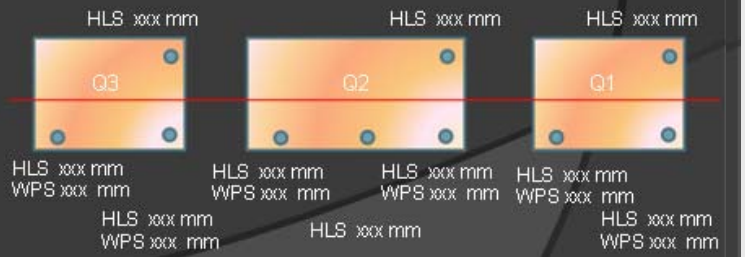
Theoretical new values on sensors after displacement of beam



Automatic Movement to do on motors



Values on sensors during positioning of magnet



Repositioning strategy

- to adjust the tilt
- to carry out the radial displacements
- to control the tilt and re-adjust the tilt if necessary
- to carry out the vertical displacements, knowing that the same displacements must be applied on the tilt jacks in order to keep the tilt adjusted.
- The repositioning will be performed within several iterations. The backlash on the jack being important (about 8°), the displacement must always be carried out keeping the same direction.

Data Processing

- All data stored in the LOGGING database for off-line analysis
- Calculation of the new position with LGC
  - Creation of an LGC input file with :
    - Theoretical data (SURVEY db)
    - Measurements (PVSS)
    - Sensors, calibration, position, constants (MTF db)
  - LGC generates an ouput with the new deviations of the magnets
  - The values are sent to PVSS in the « client » interface

First results

- At the present time, the repositioning can be carried out on a local mode
- Repositioning is possible within a few μm
- HLS and WPS readings have good correlation after a stabilisation time

Conclusions

- 5 out of 8 triplets are completely equipped with measuring and repositioning systems
- Both systems seem to meet their requirements
- Some EMI effects in the process to be solved
- The next pieces of the puzzle to be installed before end of April