Management of undulators production and commissioning for the European XFEL

Suren Karabekyan

Argonne National Laboratory

October 14th, 2019

Outline

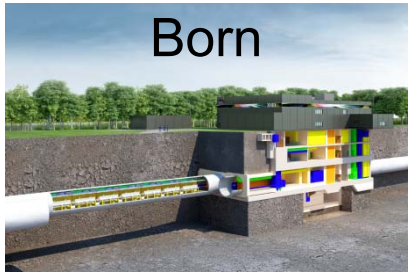
- Project overview
- Project management aspects
- Experience
  - Planning
  - Execution
- Lessons learned

Facility overview

Schenefeld

- Experiment hall
- Laboratories
- Offices

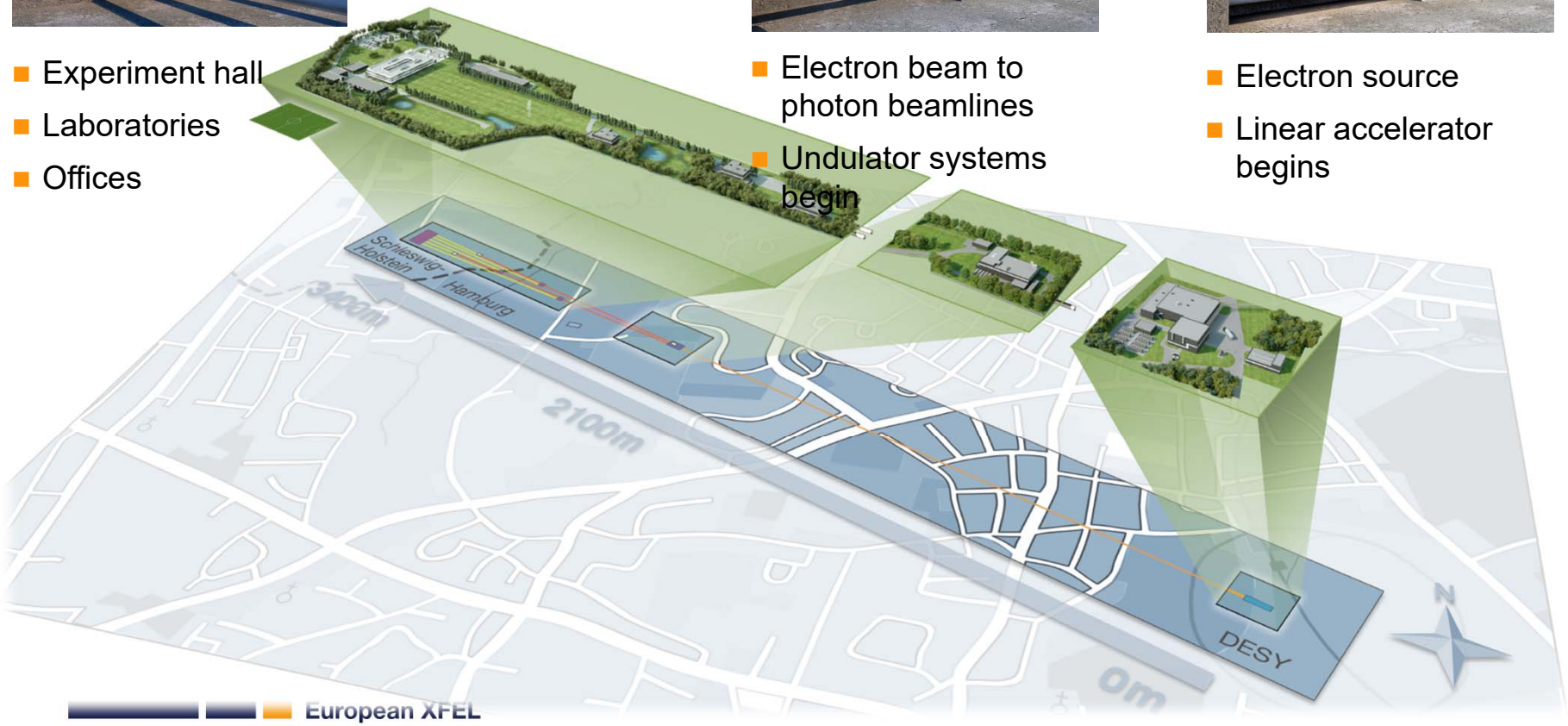
Osdorfer Born



- Electron beam to photon beamlines
- Undulator systems begin

DESY-

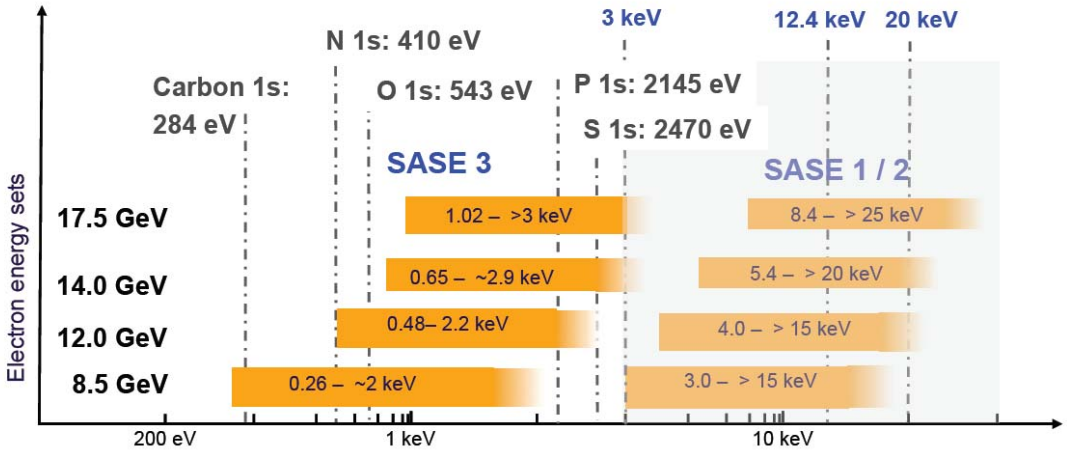
- Electron source
- Linear accelerator begins

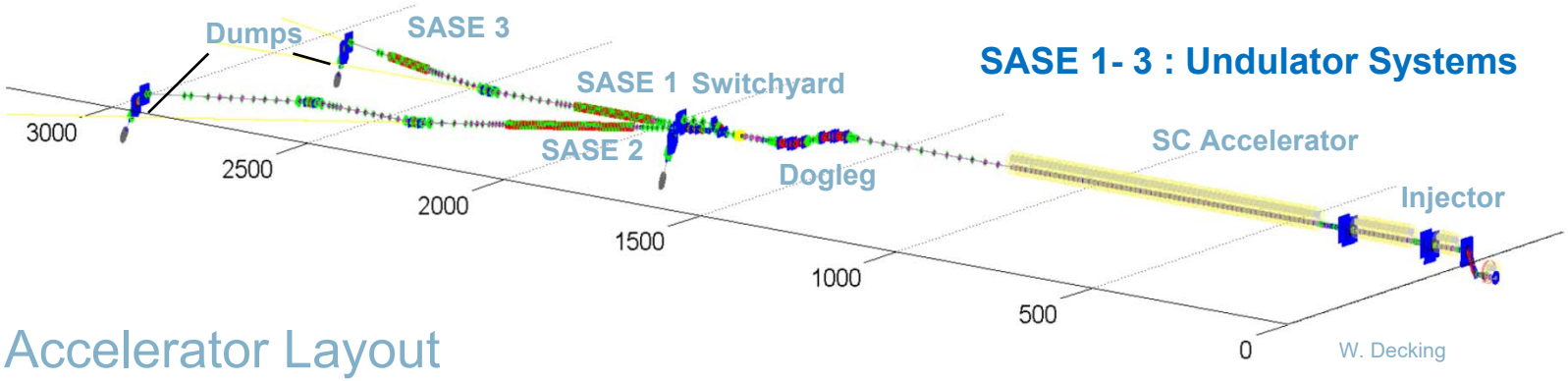


Undulator Systems

	SASE1/2	SASE3
λ_u [mm]	40	68
Operational Gap Range [mm]	10-20	10-25
K-Range	3.9–1.65	9.3-4
Radiation Wavelength Range [nm]		
@ 17.5 GeV	0.147-0.040	1.22-0.27
@ 14.0 GeV	0.230-0.063	1.90-0.42
@ 12.0 GeV	0.310-0.0828	2.44-0.621
@ 8.5 GeV	0.625-0.171	5.17-1.15
Number of Segments	35	21
System Length [m]	213.5	128.1

Photon Energy Range



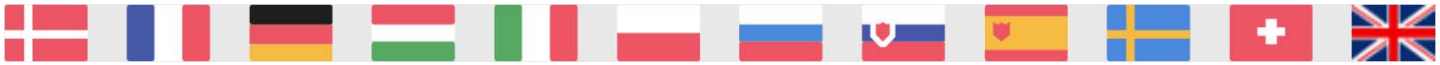


SASE 1- 3 : Undulator Systems

Accelerator Layout

Repetition rate: < 27000 pulses/ sec

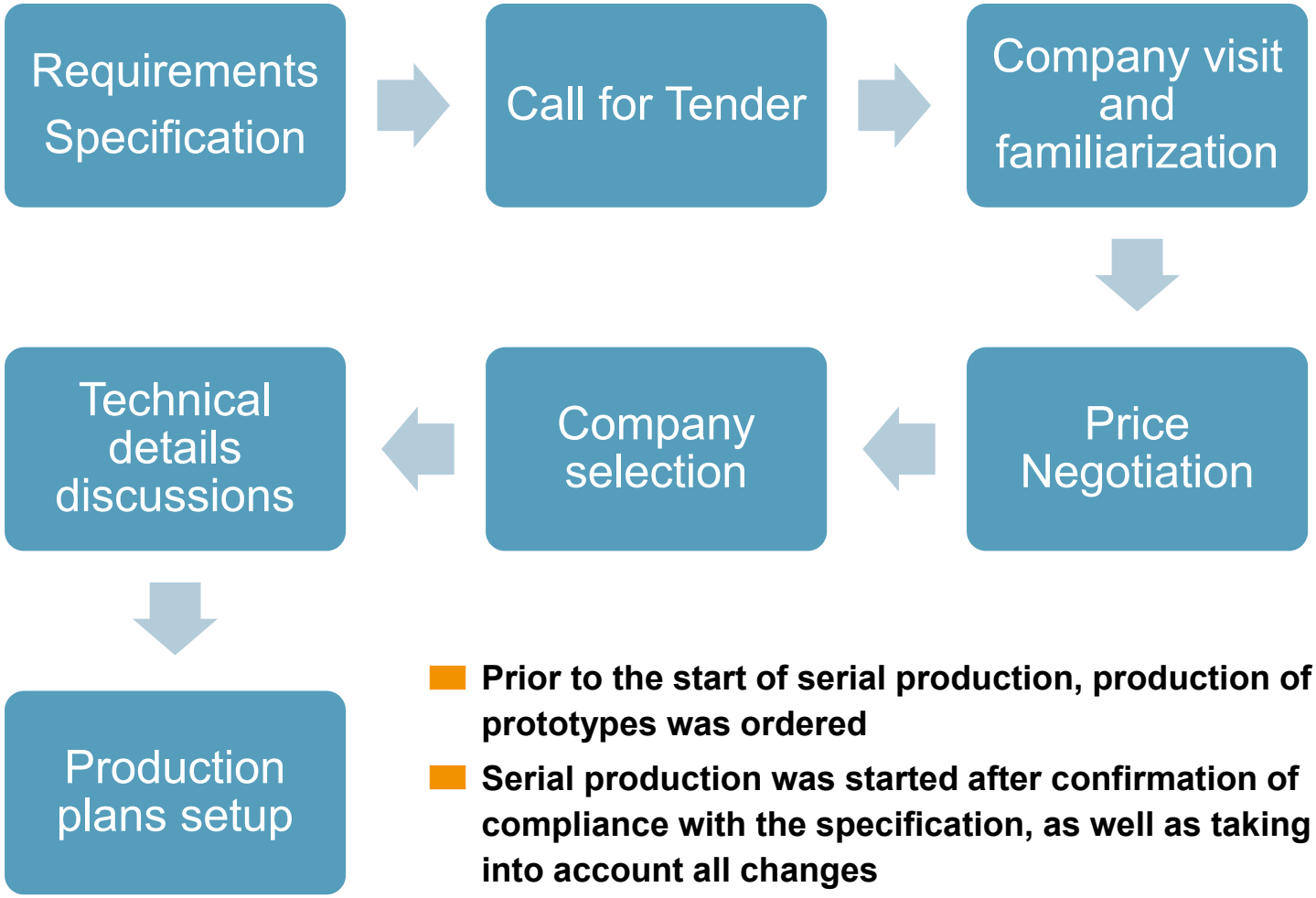
Undulators Production Project Planning



12 countries are participating in the European XFEL project

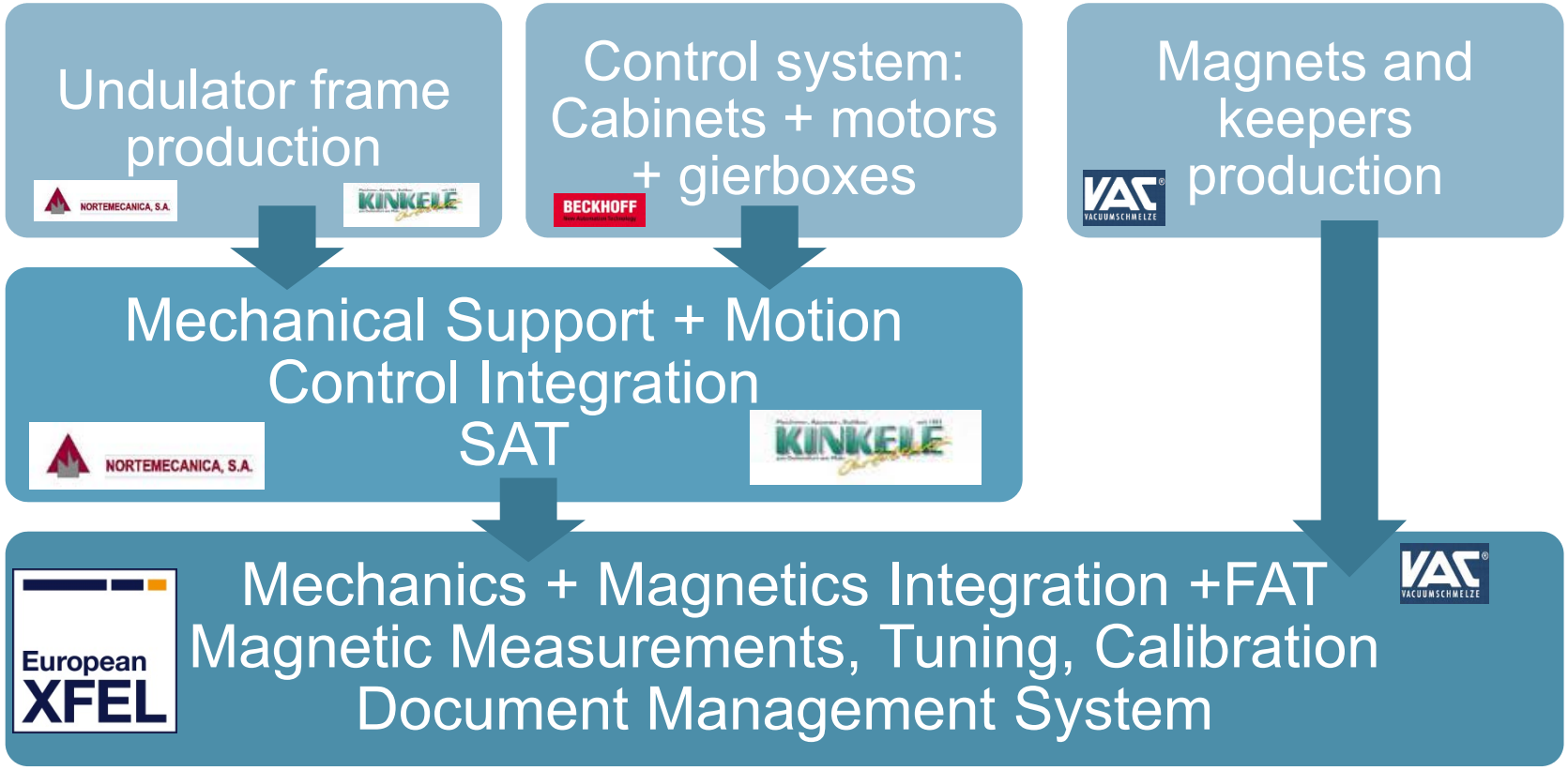
- Looking for the possibility of in-kind contribution
- Selection of partners
- Project coordination
  - Laboratory visits, technical discussions
  - Specifications
  - Instructional documentation
  - Meetings organization
  - Weekly videoconferences
  - Preparations for using Electronic Document Management System (EDMS)
  - Documentation process introduction
  - Archiving

Undulators Production Ordering Process Flow



- **Prior to the start of serial production, production of prototypes was ordered**
- **Serial production was started after confirmation of compliance with the specification, as well as taking into account all changes**

Production Process Flow



Serial Production of Undulator Segments:

External Production in Industry

Mechanical Support Systems

Local Control Systems

BECKHOFF
New Automation Technology

Magnetic Structuress

VAC
VACUUMSCHMELZE

Production at European XFEL in Hall 5

Steps @ XFEL.EU:

- Mounting of magnetic structures
- Local Control System Commissioning
- Magnetic Measurements & Tuning
- Documentation, Preparation for Installation

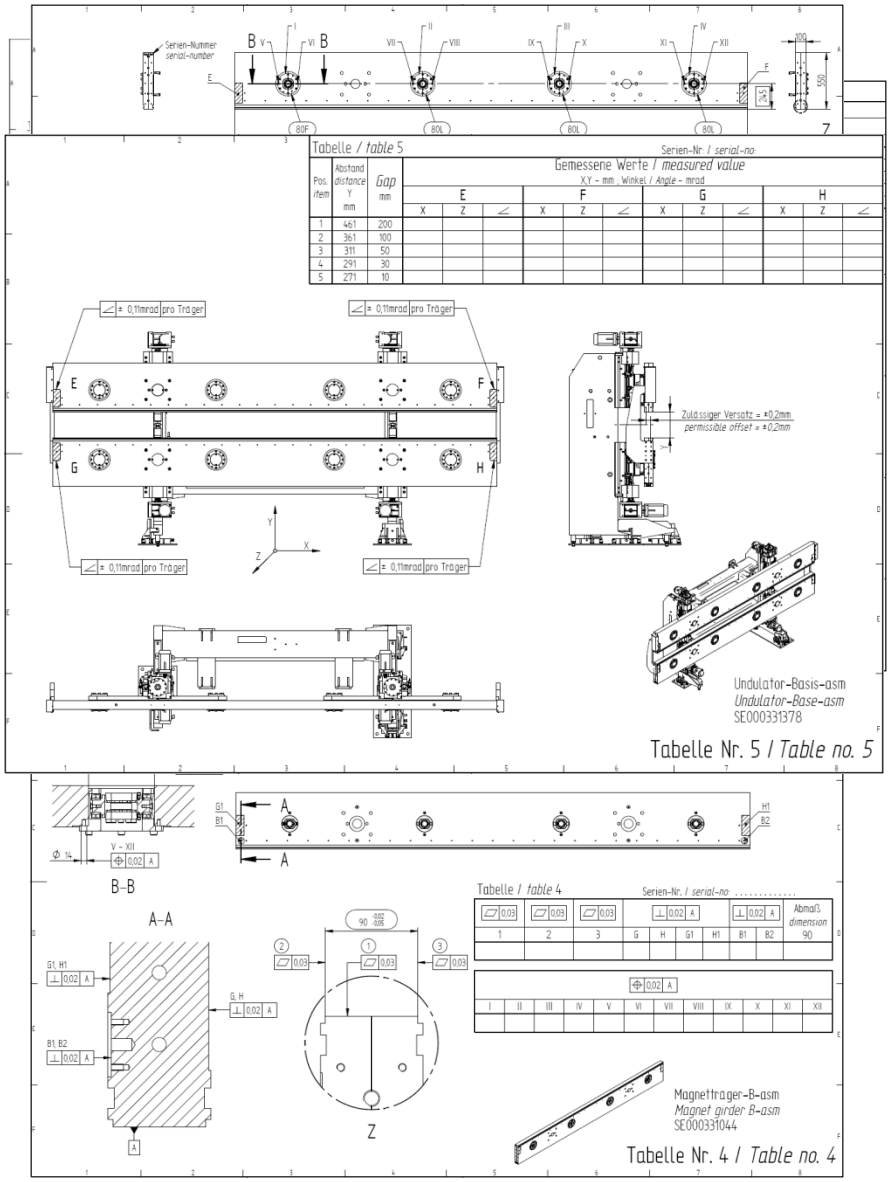
Schedule:

- Total Time ≈ 2 Years (starting Oct/12)
- Scheduled End: Oct / End 2014
- → 3 Magnetic Labs needed running in parallel
- 3 Weeks/Undulator

Hall 5 was rapidly filled up. Assembled and tuned undulators were stored in a hall, outside of DESY premises .

Quality Plan - Undulator Segments
Process Specification - FAT

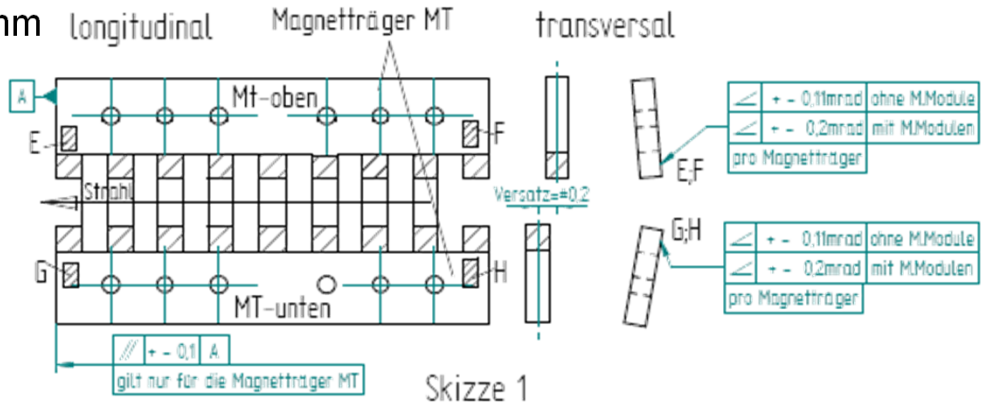
- Test of welding seams
- Surface Treatment documentation
- Non-Conformance, Change Management
- Factory Acceptance Test (FAT)
  - Support Frame Quality, App, (Table 1)
  - Support Frame with Drives, (Table 2)
  - Girder Quality, (Tables 3 & 4)
  - Final Test of Support System, (Table 5)
  - Undulator-Checklist: Flawless Operation
- Certificates and Dimensional Control documents
  - Inspection Reports
  - Laser Tracker Reports



Quality Plan - Undulator Segments
Process Specification – SAT

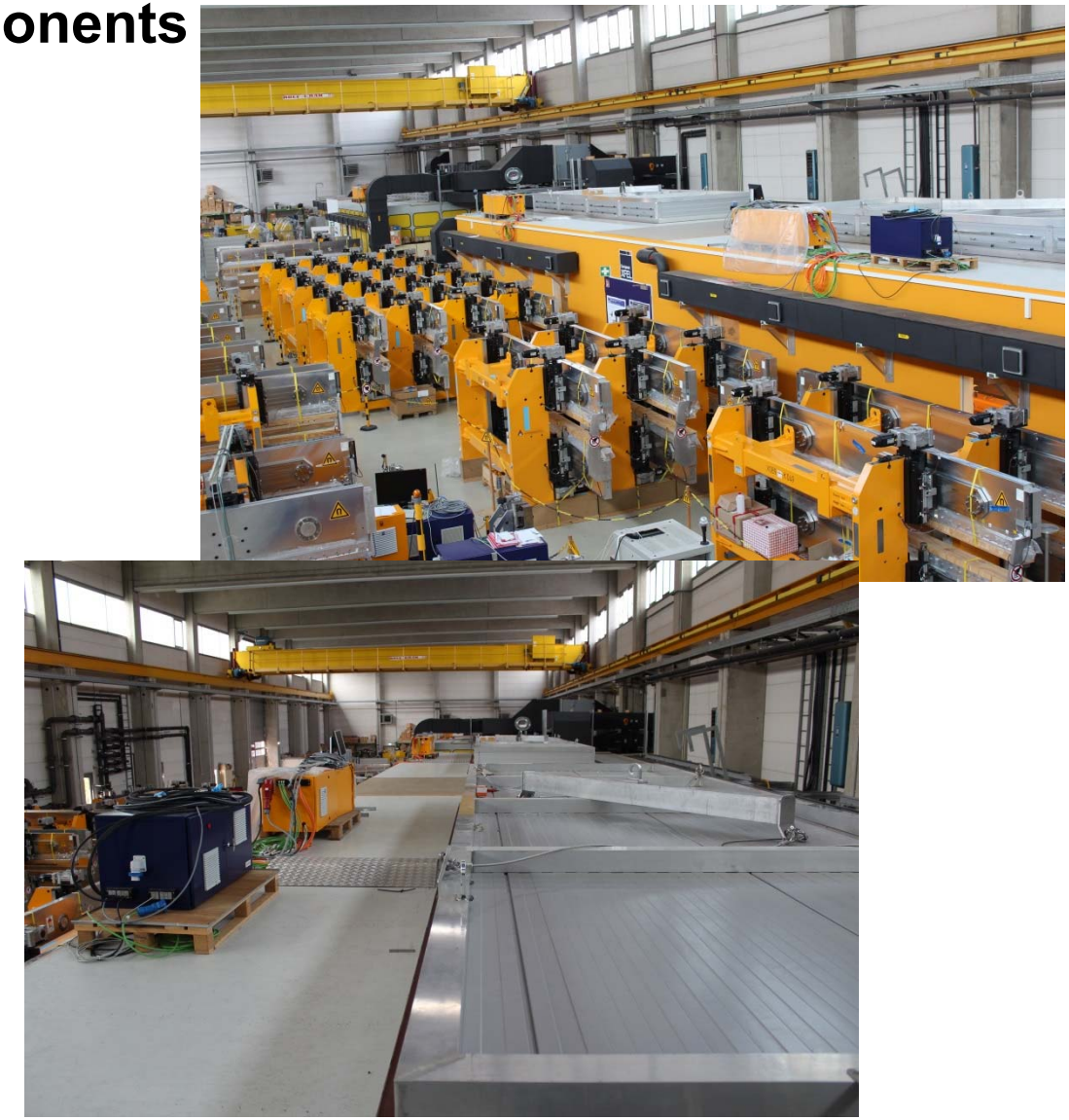
- The SAT should demonstrate the full operability of the support structure under full magnetic forces. This includes:
  - Dimensional precision of the girder mounting
  - Precision of the guiding system
  - Angular alignment and distortion of the girders on the basis of the reference surfaces when subject to magnetic forces

- These measurements are a proof of the final state. The following measurements need to be done as a function of the gap:
  - Transverse girder position (z). Max offset: ± 0.25mm
  - Girder inclination on both ends on the Top and bottom girders using a precise frame spirit level
    - ► Max. Tilt of a magnet girder without magnet structure: ± 0.11mrad
    - ► Max. Tilt of a magnet girder with magnet structure: ± 0.20mrad
  - Longitudinal position. Max offset: ± 0.1mm



Quality Plan - Undulator Segments Testing of Control Components

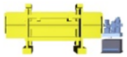
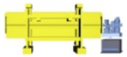
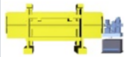
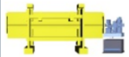
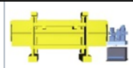
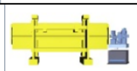
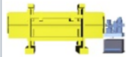
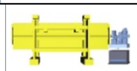
- For the magnetic commissioning of the undulator it was necessary to bring it into the magnetic measurement hutch.
- Control of all undulators introduced to the hutch can be carried out using the same rack
- It was decided to commission the undulator with the assigned control rack.
- During this commissioning, a complete set of tests was carried out.
- The hardware related errors was about 5% of the system



Quality Plan for XFEL Undulator Segments Documentation and Archiving

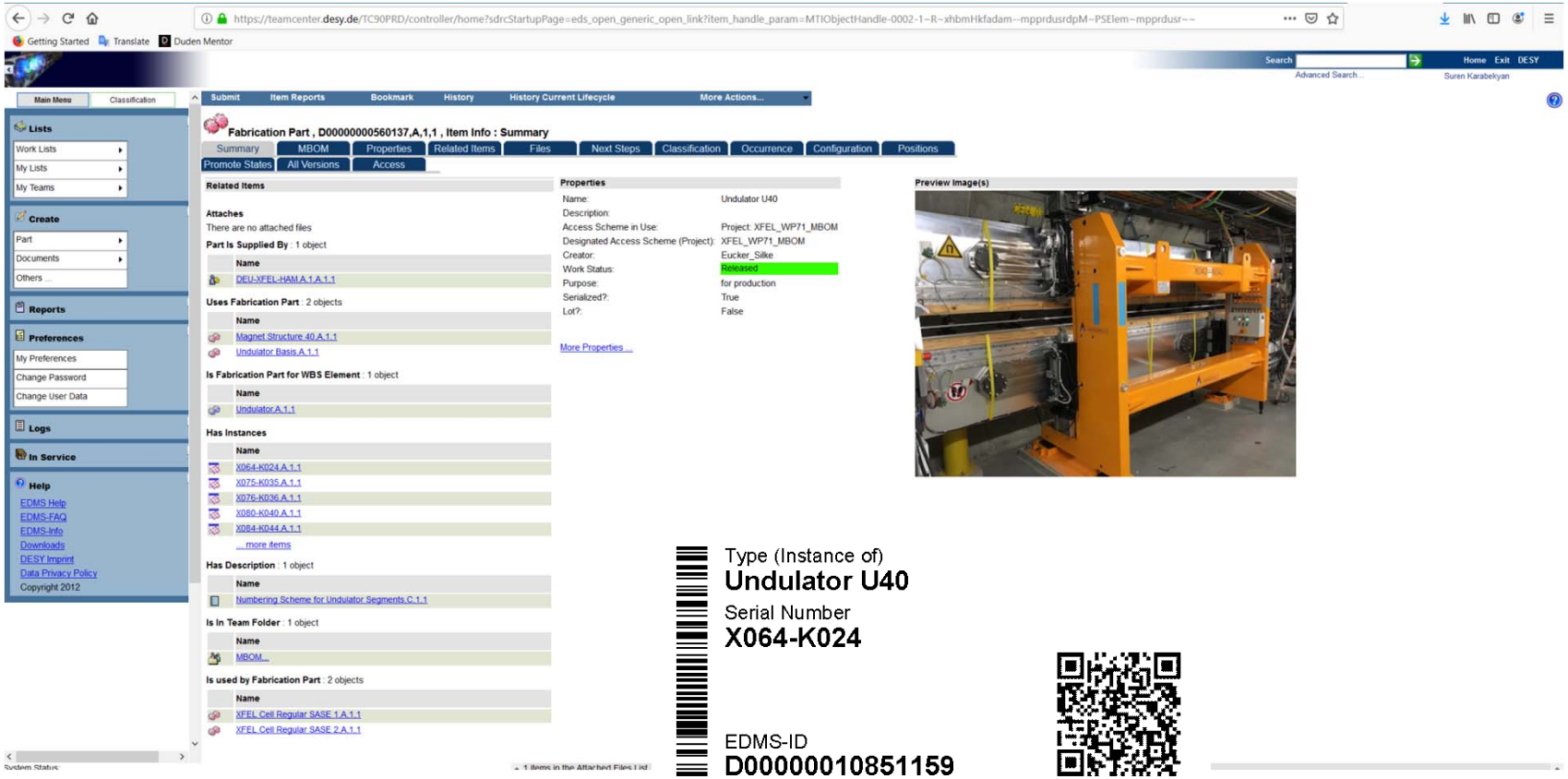
- EDMS schooling → upload rights of the documents to the companies
- Archiving all documents, protocols, certificates into the EDMS
- Supervising and controlling by the XFEL responsible

SASE 1 - XTD 2
10.10.2019 21:00:04 (CE(S)T)

XFEL Cell Regular SASE 1	Cell01.SA1	Cell02.SA1	Cell03.SA1	Cell04.SA1	Cell05.SA1	Cell06.SA1	Cell07.SA1	Cell08.SA1	Cell09.SA1	Cell10.SA1	Cell11.SA1	Cell
												
Undulator U40 XFEL Diagnostics Undulator			X069-K029	X062-K022	X008-N006	X044-K004	X002-K002	X064-K024	X058-K018	X050-K010	X045-K005	
XFEL-Undulatorkammer	XFEL-Undu-Kammer-010	XFEL-Undu-Kammer-035	XFEL-Undu-Kammer-019	XFEL-Undu-Kammer-047	XFEL-Undu-Kammer-062	XFEL-Undu-Kammer-051	XFEL-Undu-Kammer-048	XFEL-Undu-Kammer-058	XFEL-Undu-Kammer-049	XFEL-Undu-Kammer-056	XFEL-Undu-Kammer-061	XFEL-U
Aircoil Big SASE 1+3			0102	0123	0132	0131	0130	0134	0133	0135	0125	
Aircoil Small			0020	0030	0031	0032	0021	0022	0023	0024	0025	
XFEL Intersection Start SASE XFEL Intersection Regular SASE	I084	I024	I015	I017	I085	I079	I060	I088	I063	I076	I057	
Phase Shifter			PS070-I010	PS076-I016	PS063-I003	PS067-I007	PS071-I011	PS068-I008	PS074-I014	PS066-I006	PS085-I025	
BLM: Beam Loss Monitor	XFEL_BLM_0069	XFEL_BLM_0076	XFEL_BLM_0121	XFEL_BLM_0086	XFEL_BLM_0096	XFEL_BLM_0087	XFEL_BLM_0077	XFEL_BLM_0078	XFEL_BLM_0088	XFEL_BLM_0099	XFEL_BLM_0089	XF
BLM: Beam Loss Monitor	XFEL_BLM_0160	XFEL_BLM_0081	XFEL_BLM_0122	XFEL_BLM_0091	XFEL_BLM_0097	XFEL_BLM_0092	XFEL_BLM_0082	XFEL_BLM_0083	XFEL_BLM_0093	XFEL_BLM_0098	XFEL_BLM_0094	XF
XQA Quadrupole with Chamber	QA.2241.SA1	QA.2247.SA1	QA.2253.SA1	QA.2259.SA1	QA.2266.SA1	QA.2272.SA1	QA.2278.SA1	QA.2284.SA1	QA.2290.SA1	QA.2296.SA1	QA.2302.SA1	
XQA Quadrupole Magnet	XQA084	XQA079	XQA016	XQA063	XQA096	XQA060	XQA107	XQA062	XQA061	XQA031	XQA104	
Quadrupole Chamber	FEL_VQ3_074	FEL_VQ3_057	FEL_VQ3_070	FEL_VQ3_043	FEL_VQ3_067	FEL_VQ3_071	FEL_VQ3_066	FEL_VQ3_052	FEL_VQ3_054	FEL_VQ3_072	FEL_VQ3_050	F
BPM and Pumping Unit	FMB_114_2013_PU	FMB_037_2013_PU	FMB_031_2013_PU	FMB_034_2013_PU	FMB_029_2013_PU	FMB_024_2013_PU	FMB_047_2013_PU	FMB_050_2013_PU	FMB_023_2013_PU	FMB_019_2013_PU	FMB_039_2013_PU	FME
BPME: Beam Position Monitor E	FMB_114_2013	FMB_037_2013	FMB_031_2013	FMB_034_2013	FMB_029_2013	FMB_024_2013	FMB_047_2013	FMB_050_2013	FMB_023_2013	FMB_019_2013	FMB_039_2013	FI
Pumping Unit	FEL_VU2_022	FEL_VU2_001	FEL_VU2_031	FEL_VU2_034	FEL_VU2_029	FEL_VU2_024	FEL_VU2_009	FEL_VU2_010	FEL_VU2_075	FEL_VU2_019	FEL_VU2_002	F
Ion getter pump	301266107	301266109	301266803	301268603	301266110	301268604	301266802	301268605	301268615	301268508	301267603	
Quadrupole Mover	Q032-R029	Q033-R030	Q092-H045	Q093-H046	Q014-R011	Q015-R012	Q037-R034	Q036-R033	Q042-R039	Q043-R040	Q087-H040	
BPM Support	MI47964	MI47911	MI47907	MI47960	MI47963	MI47920	MI47974	MI47971	MI47970	MI47972	MI47969	
I-Section Table	MI47889	MI47829	MI47820	MI47822	MI47890	MI47884	MI47865	MI47893	MI47868	MI47881	MI47862	
Height Adjustment Unit	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	HeightAdjust-Lot-01	Heig
Turn Buckle	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	TurnBuckle-Lot-01	Tur
Tilt Safety Device	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	TiltSafety-Lot-01	Til
I-Section Pedestal	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISecPedestal-Lot-01	ISec

Quality Plan - Undulator Segments Documentation and Archiving

- All Related Items are linked
- Easy access to the database and all related items using QR code



Intersection

- Undulator System Group is responsible for the following components: Quadrupole Mover, Phase Shifter, Air coils, Support basies, Intersection Control Racks,
- 9 companies were producing the intersection
- Factory and Site acceptance tests have been requested

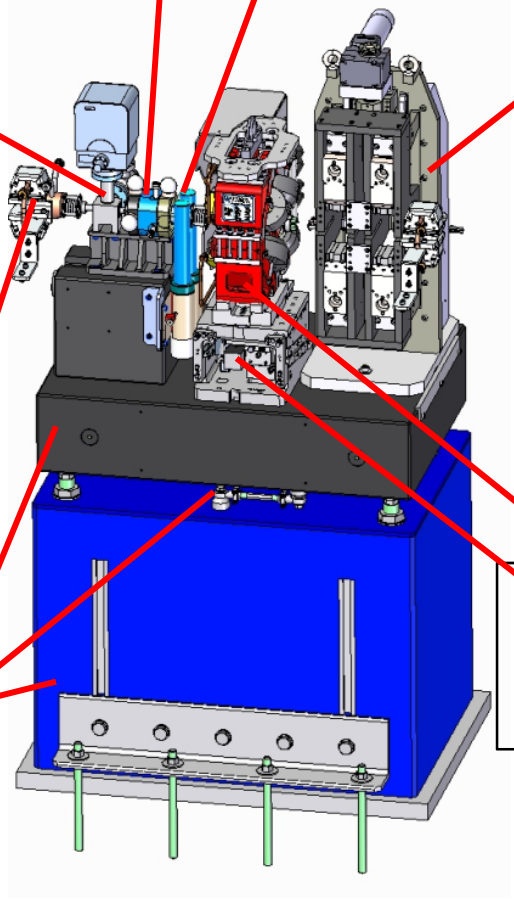
WP71
Intersection control racks

WP17
Re-entrant Cavity BPMs+ Electronics

WP17
Beam Loss Monitors

WP71
Phase Shifters

WP19
Vacuum System



WP12
Quadrupoles

WP71
Air Coil Correctors

WP71
Quadrupole Movers

WP71
Support Bases
Adjustors
Concrete Pillars

Quality Plan - Intersection Components In-Kind Contribution Case

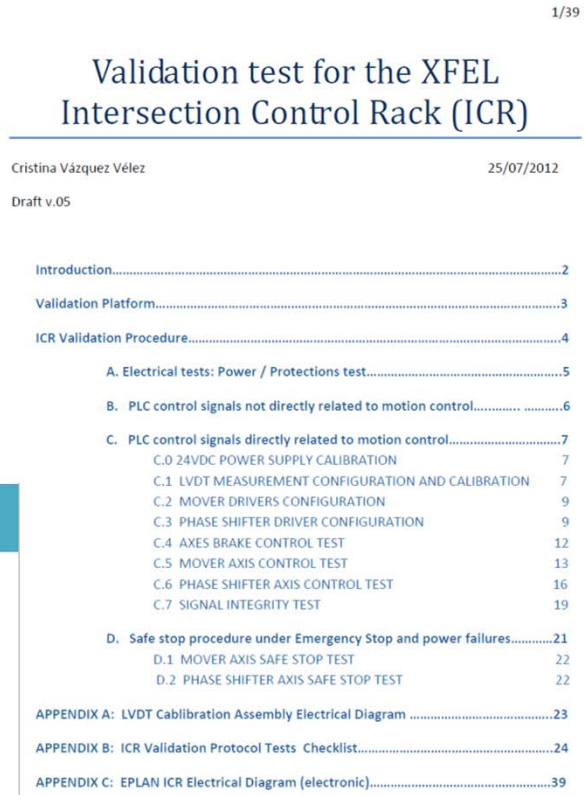
- Quadrupole Movers and Intersection Control Racks have been produced in Spain
- Collaborating institute - Ciemat
- Ciemat organized the call for tenders in Spain
- For each product three companies were qualified
- Each company produced one prototype
- After the comparison of the prototypes a vendor was selected
- Documentation by Ciemat
  - Technical specification
  - Validation test
  - EPLAN
- Documentation for FAT
- EDMS archiving


Technical Specifications for the Supply of the Intersection Control Racks (ICRs) for the European XFEL

CIEMAT

Electrical Engineering Unit

3rd rev. – 23/07/2013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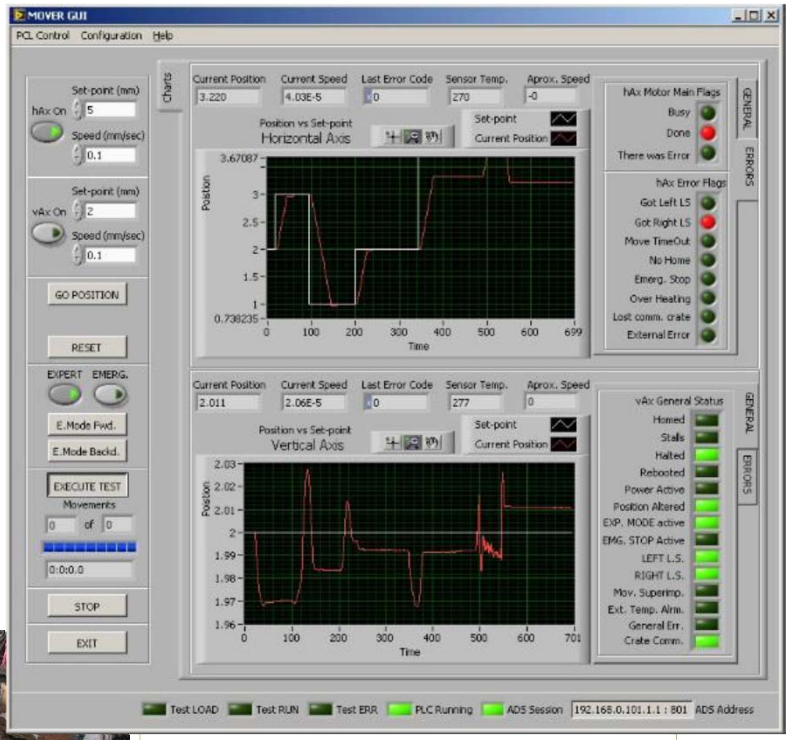
Validation test for the XFEL Intersection Control Rack (ICR)

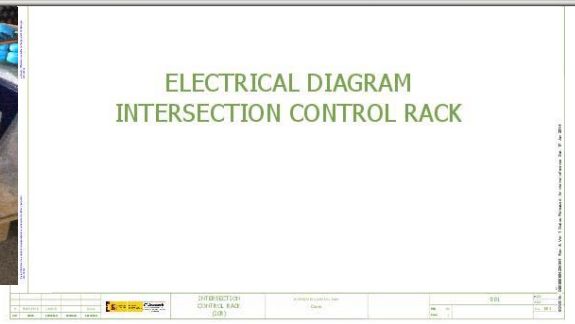
Cristina Vázquez Vélez 25/07/2012

Draft v.05

Quality Plan - Intersection Components In-Kind Contribution Case - SAT

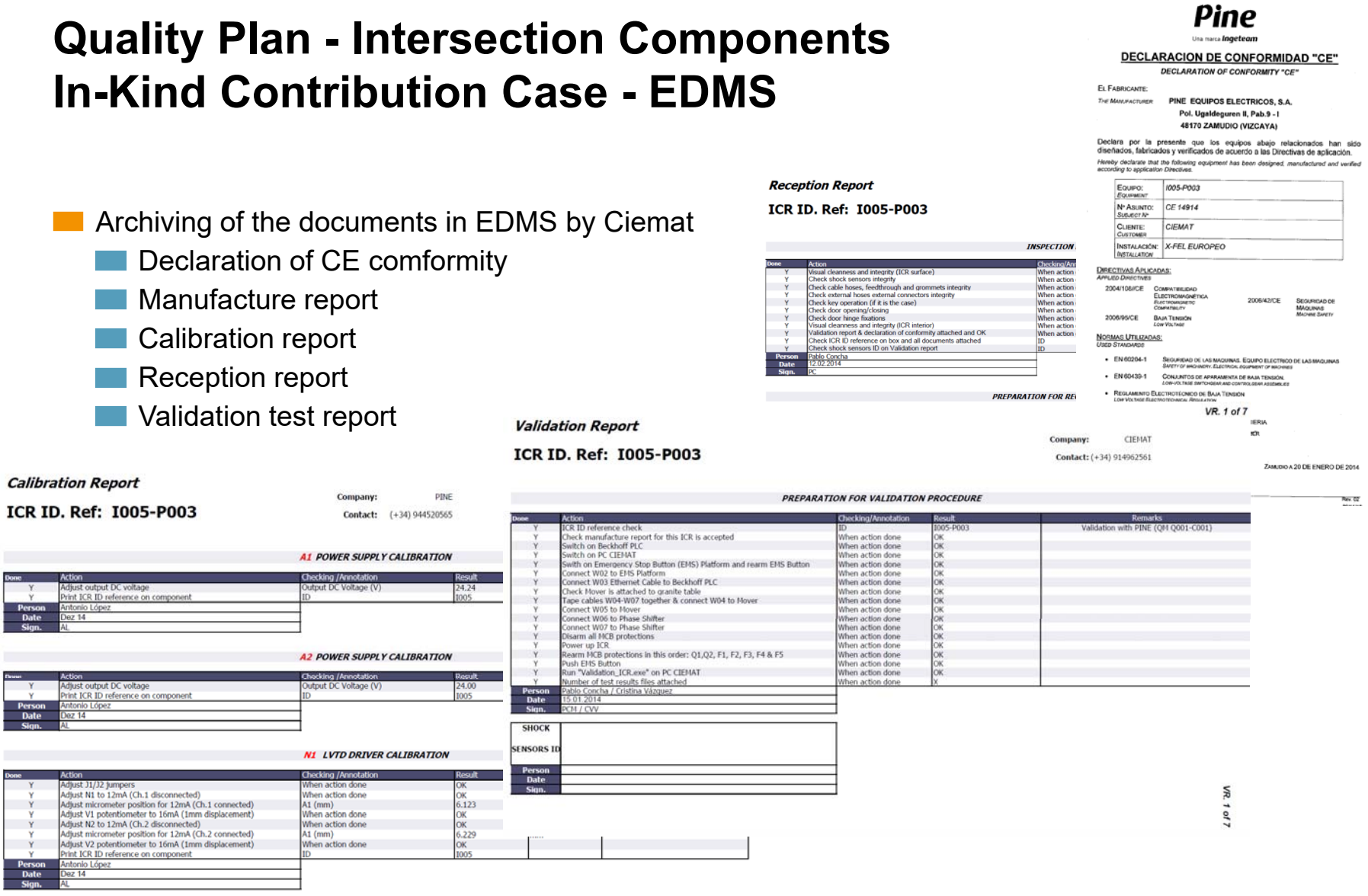
- Air conditioned and thermo stabilized hutch (XFEL)
- Infrastructure, granite stone, requesting hardware (XFEL)
- Supervisory Control And Data Acquisition (SCADA) program was created by Ciemat
- After delivery to XFEL the SAT was organized by Ciemat





Quality Plan - Intersection Components In-Kind Contribution Case - EDMS

- Archiving of the documents in EDMS by Ciemat
  - Declaration of CE comformity
  - Manufacture report
  - Calibration report
  - Reception report
  - Validation test report



Pine
Una marca Ingeteam

DECLARACION DE CONFORMIDAD "CE"
DECLARATION OF CONFORMITY "CE"

EL FABRICANTE:
THE MANUFACTURER PINE EQUIPOS ELECTRICOS, S.A.
Pol. Ugaldeguren II, Pab.9 - I
48170 ZAMUDIO (VIZCAYA)

Declara por la presente que los equipos abajo relacionados han sido diseñados, fabricados y verificados de acuerdo a las Directivas de aplicación.
Hereby declarate that the following equipment has been designed, manufactured and verified according to application Directives.

EQUIPO: EQUIPMENT	I005-P003
Nº ASUNTO: SUBJECT Nº	CE 14914
CLIENTE: CUSTOMER	CIEMAT
INSTALACIÓN: INSTALLATION	X-FEL EUROPEO

DIRECTIVAS APLICADAS: APPLIED DIRECTIVES
2004/108/CE COMPATIBILIDAD ELECTROMAGNÉTICA ELECTROMAGNETIC COMPATIBILITY
2006/42/CE SEGURIDAD DE MÁQUINAS MACHINE SAFETY
2006/95/CE BAJA TENSIÓN LOW VOLTAGE

NORMAS UTILIZADAS: USED STANDARDS
- EN 60204-1 SEGURIDAD DE LAS MAQUINAS. EQUIPO ELECTRICO DE LAS MAQUINAS SAFETY OF MACHINERY. ELECTRICAL EQUIPMENT OF MACHINES
- EN 60439-1 CONJUNTOS DE APARAMENTA DE BAJA TENSIÓN. LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES
- REGLAMENTO ELECTROTÉCNICO DE BAJA TENSIÓN LOW VOLTAGE ELECTROTECHNICAL REGULATION

VR. 1 of 7

ZAMUDIO A 20 DE ENERO DE 2014

Reception Report
ICR ID. Ref: I005-P003

INSPECTION

Done	Action	Checking/An
Y	Visual cleanness and integrity (ICR surface)	When action
Y	Check shock sensors integrity	When action
Y	Check cable hoses, feedthrough and grommets integrity	When action
Y	Check external hoses external connectors integrity	When action
Y	Check key operation (if it is the case)	When action
Y	Check door opening/closing	When action
Y	Check door hinge fixations	When action
Y	Visual cleanness and integrity (ICR interior)	When action
Y	Validation report & declaration of conformity attached and OK	When action
Y	Check ICR ID reference on box and all documents attached	ID
Y	Check shock sensors ID on Validation report	ID
Person	Pablo Concha	
Date	12.02.2014	
Sign.	PC	

PREPARATION FOR RE

Validation Report
ICR ID. Ref: I005-P003

Company: CIEMAT
Contact: (+34) 914962561

PREPARATION FOR VALIDATION PROCEDURE

Done	Action	Checking/Annotation	Result	Remarks
Y	ICR ID reference check	ID	I005-P003	Validation with PINE (QM Q001-C001)
Y	Check manufacture report for this ICR is accepted	When action done	OK	
Y	Switch on Beckhoff PLC	When action done	OK	
Y	Switch on PC CIEMAT	When action done	OK	
Y	Swith on Emergency Stop Button (EMS) Platform and rearm EMS Button	When action done	OK	
Y	Connect W02 to EMS Platform	When action done	OK	
Y	Connect W03 Ethernet Cable to Beckhoff PLC	When action done	OK	
Y	Check Mover is attached to granite table	When action done	OK	
Y	Tape cables W04-W07 together & connect W04 to Mover	When action done	OK	
Y	Connect W05 to Mover	When action done	OK	
Y	Connect W06 to Phase Shifter	When action done	OK	
Y	Connect W07 to Phase Shifter	When action done	OK	
Y	Disarm all MCB protections	When action done	OK	
Y	Power up ICR	When action done	OK	
Y	Rearm MCB protections in this order: Q1,Q2, F1, F2, F3, F4 & F5	When action done	OK	
Y	Push EHS Button	When action done	OK	
Y	Run "Validation_ICR.exe" on PC CIEMAT	When action done	OK	
Y	Number of test results files attached	When action done	X	
Person	Pablo Concha / Cristina Vázquez			
Date	15.01.2014			
Sign.	PCH / CVV			

SHOCK SENSORS ID	
Person	
Date	
Sign.	

VR. 1 of 7

Calibration Report
ICR ID. Ref: I005-P003

Company: PINE
Contact: (+34) 944520565

A1 POWER SUPPLY CALIBRATION

Done	Action	Checking /Annotation	Result
Y	Adjust output DC voltage	Output DC Voltage (V)	24.24
Y	Print ICR ID reference on component	ID	I005
Person	Antonio López		
Date	Dez 14		
Sign.	AL		

A2 POWER SUPPLY CALIBRATION

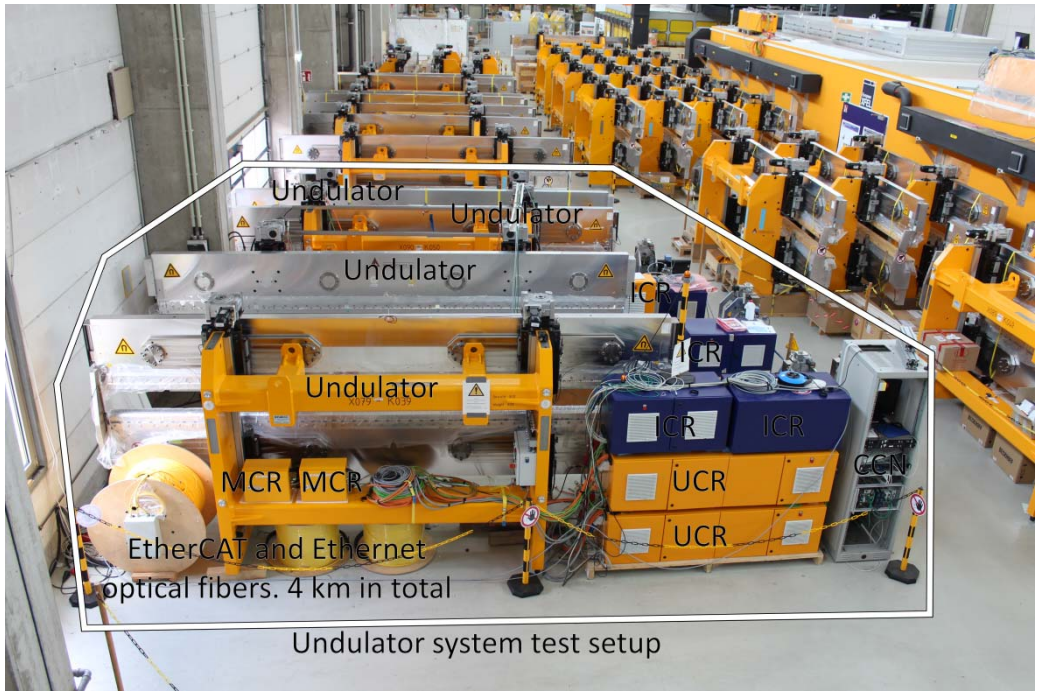
Done	Action	Checking /Annotation	Result
Y	Adjust output DC voltage	Output DC Voltage (V)	24.00
Y	Print ICR ID reference on component	ID	I005
Person	Antonio López		
Date	Dez 14		
Sign.	AL		

N1 LVTD DRIVER CALIBRATION

Done	Action	Checking /Annotation	Result
Y	Adjust J1/J2 jumpers	When action done	OK
Y	Adjust N1 to 12mA (Ch.1 disconnected)	When action done	OK
Y	Adjust micrometer position for 12mA (Ch.1 connected)	A1 (mm)	6.123
Y	Adjust V1 potentiometer to 16mA (1mm displacement)	When action done	OK
Y	Adjust N2 to 12mA (Ch.2 disconnected)	When action done	OK
Y	Adjust micrometer position for 12mA (Ch.2 connected)	A1 (mm)	6.229
Y	Adjust V2 potentiometer to 16mA (1mm displacement)	When action done	OK
Y	Print ICR ID reference on component	ID	I005
Person	Antonio López		
Date	Dez 14		
Sign.	AL		

Quality Plan - Undulator System
Undulator system test setup

- The system is controlled by a central control node (CCN), which is located about 1 km away from the undulator system
- CCN communicates with the undulator cells over optical fibers
- Media converter racks are used to convert signals from copper carriers to optical fiber carriers and vice versa



- It was obvious that all components should be tested before installation in the tunnel
- An undulator system test setup with 4 cells was built in the undulator hall
- It was used for developing the global control system software three years ahead of the installation of the system in the tunnel.

Lessons learned

- Beckhoff control system integration in companies
- Wiring on the undulator frame
- Male types plug for the phase shifter stepping motor
- Cabling issues in the tunnel
- Every piece of hardware must be tested before installation in the tunnel