CHALLENGES TO ASSEMBLE 100 CRYOMODULES FOR E-XFEL

SRF13 | Catherine MADEC

www.cea.fr
To assemble 100 accelerator cryomodules with a throughput of 1 per week!

operated by an industrial contractor on the Saclay site and CEA infrastructures with CEA supervision
CHALLENGES

- Technical:
  - Get the infrastructure ready
  - Get the tooling ready
  - Get the assembly procedure ready
  - Get the CEA team trained
  - Get the quality insurance system implemented
  - Set-up QA/QC and MBOM
  - Get results

- Calendar:
  - 1 CM per week
  - Nov 2015

- Ressources:
  - Industrial ressource
  - CEA ressource

- Performances
- Components availability
PHASES OF THE PROJECT

2. Preparation of Infrastructure and Tooling 2009 – 2010
3. Pre-industrial study and prototyping 2010 – 2012
   - Preindustrial study
   - Training and Commissioning at Saclay with XFEL Prototype Modules (PXFEL2 and PXFEL3)
   - Leading to Restricted Call for Tender signed in July 2012
4. XFEL module assembly by industry operator 2012 - 2015
PHASE 2: DEDICATED ASSEMBLY BUILDINGS

XFEL Village ~ 1350 m²

- Clean rooms
- Assembly halls
- Offices
- Warehouse

Bldg 124 North 25x15 m²
Bldg 126 North 40x11 m²
Bldg 126 South 30x17 m²
the XFEL Village
PHASE 2: WORKSTATIONS IN ASSY HALLS

the XFEL Village

Warehouse

Shipment Area
SH-WS1 & 2
PHASE 2 : WORKSTATIONS IN ASSY HALLS

the XFEL Village
PHASE 2 : WORKSTATIONS IN ASSY HALLS

the XFEL Village

Clean room Area
CO-WS1 & 2
SA-WS1 & 2
PHASE 2: WORKSTATIONS IN ASSY HALLS

the XFEL Village

Alignment Area AL-WS1 & 2
Roll-out Area RO-WS1 & 2
PHASE 2: WORKSTATIONS IN ASSY HALLS

Coupler Area CO-WS1 & 2

Cantilever Area CA-WS1

the XFEL Village
PHASE 2: WORKSTATIONS IN ASSY HALLS

the XFEL Village
PHASE 2: TOLLING, RENOVATION, CLEAN ROOM
### PHASES OF THE PROJECT

1. **Preliminary study subcontracted**  
   2007 – 2008

2. **Preparation of Infrastructure and Tooling**  
   2009 – 2010

3. **Pre-industrial study and prototyping**  
   2010 – 2012
   - Preindustrial study
   - Training and Commissioning at Saclay with XFEL Prototype Modules (PXFEL2 and PXFEL3)
   - Leading to Restricted Call for Tender signed in July 2012

4. **XFEL module assembly by industry operator**  
   2012 - 2015
PHASE 3 : PROTOTYPING

GOAL : to get the « Factory » ready

- Implement the pre-industrial study
- Check the infrastructures
- Check the tools
- Check the procedures
- Train the CEA-IRFU team
- Prepare all the documentation templates
- Set-up the QA/QC and MBOM
- Feedback from the assemblies
- With the support of DESY colleagues
PHASE 3 : PROTOTYPING

The team (~10 persons) has operated:

- the module disassembly of PXFEL2_1 (started 24/08/2010)
- the module re-assembly of PXFEL2_1
- the string and module assembly of PXFEL3_1 (02/05/2011 – 26/10/2011) using DESY cavity posts and clean room tools
- the string and module assembly of PXFEL2_2 (30/01/2012 – 04/09/2012) using CEA cavity posts and clean room tools

Prototype modules PXFEL2&3 were made from a special production of cryogenic distribution systems (‘cold mass’) and vacuum vessels, and from ‘FLASH’ recycled cavities, couplers, tuners, etc…
PHASE 3 : PROTOTYPING

Check:
✓ Infrastructures
✓ Tools
✓ Procedures

CEA team trained
→ no degradation

→ PXFEL2_2 ;
→ Average gradient ~ 24 MV/m , XFEL conform !
→ But individual performance were degraded
In the process of assembling cryomodule, it is mandatory for traceability to **gather, record, process and archive** the complete configuration and fabrication information for each cryomodule

The MBOM also includes inspection to be performed, the tests to be recorded, the assembly procedures etc... The XFEL cryomodule MBOM contains roughly 500 lines

It uses DESY’s Engineering Data Management System (EDMS).
The MBOM defines how a specific part type (fabrication part) is produced and from which components. The part gets fabricated in a physical part and assembled to other physical parts to form one cryomodule. This is recorded in the Bill of Material BOM.
### Physical Part, D000000111111189,A,1,1, Item Info : BOM

#### Configuration: No saved configuration.

<table>
<thead>
<tr>
<th>EDMS-ID</th>
<th>Description</th>
<th>Work Status</th>
<th>Disposition Type</th>
<th>Installation Date/Time</th>
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<tr>
<td>D000000111111189,A,1,1</td>
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<td>In-Service</td>
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<td>D00000010845279,A,1,1</td>
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<td>3_06_8326/0.000 #0002 Cav1 Gate Valve Support</td>
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**EXAMPLE : PHYSICAL PARTS**

<table>
<thead>
<tr>
<th>Related Items</th>
<th>Summary</th>
<th>BOM</th>
<th>Properties</th>
<th>Related Items</th>
<th>Next Steps</th>
<th>All Versions</th>
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</thead>
<tbody>
<tr>
<td>Has Fabrication Documentation : 5 objects</td>
<td></td>
<td></td>
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<tr>
<td>Has Description : 1 object</td>
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<tr>
<td>Is Instance of : 1 object</td>
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<td></td>
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<td>Is Affected by : 2 objects</td>
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<td>Is Used By Physical Part : 1 object</td>
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</table>

**Properties**

- **Description:** XM-3_CCP_CP Coupler Cold Part (TTF3) A1.1

**Incoming Inspection Report: Coupler Cold Part**

<table>
<thead>
<tr>
<th>Part Information</th>
<th>Part</th>
<th>Fate Part Name</th>
<th>Fate Part EDMID</th>
<th>PP Aronym</th>
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<tr>
<td>TWG 3E</td>
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<td>CCP 1</td>
<td></td>
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<tr>
<td>CCP 2</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Contact Information**

- Name: X.FEL.WPD
- Phone: 0000000000
- Email: xfelwpd@cea.fr

**Additional Remarks and Observations**

- Accepted with reservations
Cold ceramics caps: missing holes, mis-oriented valves, protruding screws

DESCRIPTION:
Vis du capot de protection de la céramique non-percés + trous de fixation manquants + vannes à positionner

Cold ceramics caps from XFEL-Thales production: missing holes, mis-oriented valves, protruding screws

Reference documents:

TECHNICAL INVESTIGATIONS:
The six cold ceramics caps from the XFEL-Thales production have only 12 holes, instead of 16 like in the corresponding flange of the cold coupler (see picture 1 below). Moreover, the addition of one nut between each screw and the cap and the mis-orientation of the valve around its fixation point creates a conflict with the cold coupler assembly tool, rendering this assembly impossible as is.

The missing holes will allow the insertion of the only 3 instead of 4 rods necessary to assemble the shells for 70 K interface shells at a later stage.

The functionality of the cap holes is explained in the table below (see picture 2 below)
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4. XFEL module assembly by industry operator 2012 – 2015

Pre-serie modules: XM-3, XM-2, XM-1
Serie module: XM1 to XM100
Tender process: ALSYOM, best technical offer, has been selected by CEA.

The contract has to be awarded on 27 July 2012 for the integration of 83 cryomodules + 20 in option.

Up to 29 people will be on Saclay site during ~2 ½ years

Kick-off meeting : 05/09/2012

Review of Quality Plan and Management Plan : 27/09/12 with DESY

After one year, these people are GOOD and the CEA-Alsyom collaboration is EXCELLENT!
INDUSTRIAL CONTRACT:
ALSYOM MANAGEMENT PLAN

Executive VP

Program Manager
1*

Industrial Director

Program Unit Manager in Production
Site Manager
1*

Quality Manager

Quality Engineer / Cleanliness
1*

Stock and Production Controller
1

Method Expert
1*

Workshop Manager
SSE Manager
1*

Quality controllers
2 (1**)

Stock / Warehouseman
1**

Operators and technicians for the assembly
20 (4**)

Off site

29 persons on site

* from mid-sept. 2012

** from beg-febr. 2013

C. Madec | SRF13-THIOA02 | 26/09/2013 | PAGE 28
Observation phase which covers the assembly of XM-3 by CEA with ALSYOM staff as observers. Initially, this phase starts at T0 (20 August 2012) until T0 + 4 months (20 December 2012). Extended to April 2013.

XM-3 first pre-series module is made with parts from XFEL production lines, except for cavities (large-grain RI cavities) and couplers (TTF3 RI couplers).
In total 43 Non-Conformance Reports (NCR) were issued for XM-3, some global, about 13 NCR under the responsibility of CEA: one main reason for 7 month assembly.
Average individual cavity gradients reaches 32 MV/m.

Gradient is 29 MV/m when cavities are powered by pairs.

Seven cavities are reproducing VT gradient.

Cavity 1 is degraded from 31 MV/m down to 23 MV/m usable gradient.

Three cavities reached gradients above 38 MV/m.

Cryogenics losses are lower than specified (MOP029).

This successful test is qualifying CEA team and procedures and partially CEA infrastructure and industrial feasibility.

The partial qualification lays in the fact that cavities and couplers are pre-industrial and the clean room vacuum system was not complete.

Weldings certification would have to be reworked in order to install this module in the injector for 2014.
Training phase which covers the assembly of XM-2 and XM-1 by mixed CEA-Alsyom teams (co-activity or transfer of knowledge) from $T_1 = T_0 + 4$ months till $T_1 + 6$ months.

XM-2 first pre-series module was made with parts from XFEL production lines, e.g. first eight EZ cavities, except for couplers (TTF3 RI couplers); 18 wks/14wks. XM-2 is at DESY getting ready for testing.

XM-1 has started on August 2013 first pre-series module made with parts from XFEL production lines, including cavities and couplers; still under assembly.
### XM-2 NCR

<table>
<thead>
<tr>
<th>NCR Reference</th>
<th>NCR EDMIS ID</th>
<th>Sub-assembly</th>
<th>Serial N°</th>
<th>Acronym</th>
<th>WS</th>
<th>Origin</th>
<th>Detection</th>
<th>Description</th>
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<tbody>
<tr>
<td>CEA-XFEL-RNC-12-047</td>
<td>D*1023155</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
<td>AC3C49, AC3C4A, TW1012</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Bond position of screws on ceramic protection cap + Presence of water inside cold ceramic cap</td>
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<td>CEA-XFEL-RNC-12-047</td>
<td>D*1022172</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
<td>CA110512</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Bonded rods too long on cavity beamtube adapter flange - short side</td>
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<tr>
<td>CEA-XFEL-RNC-12-047</td>
<td>D*1024014</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
<td>CA00510</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>High Q Antenna flange misaligned</td>
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<tr>
<td>CEA-XFEL-RNC-12-047</td>
<td>D*1024015</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
<td>CA00510</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Cavity elbow valve misaligned</td>
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<tr>
<td>CEA-XFEL-RNC-12-047</td>
<td>D*1024016</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
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<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Water entered inside 2P-He pipe and tank during washing operation in the Bellend</td>
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<td>CEA-XFEL-RNC-12-047</td>
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<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
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<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Protective plastic bags are damaged (holes)</td>
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<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
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<td>CEP</td>
<td>REC</td>
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<td>PRODUCTION</td>
<td>Valve on the cold ceramic cap misaligned</td>
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<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
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<td>REC</td>
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<td>PRODUCTION</td>
<td>Connectors on the cold ceramic caps not properly screwed</td>
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<td>REC</td>
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<td>PRODUCTION</td>
<td>Stainless steel screws on cold ceramic caps of the coupler</td>
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<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Water inside cavity elbow valve</td>
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<td>CEA-XFEL-RNC-12-047</td>
<td>D*1024022</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
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<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Residual pressure of 2.5 ± 0.2 mbar was read from the two P2R261 gauges</td>
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<td>CEA-XFEL-RNC-12-047</td>
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<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
<td>CA00510</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Fingerprints and dust on the TIG wire</td>
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<td>CEP</td>
<td>REC</td>
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<td>PRODUCTION</td>
<td>Couplel lower clamps in contact with pick-up flange</td>
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<td>PRODUCTION</td>
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<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
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<td>REC</td>
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<td>PRODUCTION</td>
<td>Light scratches on the antenna of the cold part</td>
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<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Presence of visible particles inside beam tube</td>
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<tr>
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<td>D*1024029</td>
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<td>CA00510</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>High Q Antenna flange and cavity flange (long side) misaligned</td>
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<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Flange of elbow valve is dirty</td>
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<td>D*1024031</td>
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<td>CA00510</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Quick Cavity venting up to 6 mbar</td>
</tr>
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<td>D*1024032</td>
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<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Marks on inside waves of the cavity bellow</td>
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<td>D*1024033</td>
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<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Residual pressure of 2 3± 0.2 mbar was read from the two P2R261 gauges</td>
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<td>D*1024034</td>
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<td>CEP</td>
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<td>PRODUCTION</td>
<td>Metallic chips in threads of needle supports</td>
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<td>CEA-XFEL-RNC-12-047</td>
<td>D*1024035</td>
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<td>REC</td>
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<td>PRODUCTION</td>
<td>Quick Cavity venting up to 6 mbar</td>
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<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Marks on inside waves of the cavity bellow</td>
</tr>
<tr>
<td>CEA-XFEL-RNC-12-047</td>
<td>D*1024037</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
<td>CA00510</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Residual pressure of 2 3± 0.2 mbar was read from the two P2R261 gauges</td>
</tr>
<tr>
<td>CEA-XFEL-RNC-12-047</td>
<td>D*1024038</td>
<td>XM-2, CEP, Coupler Cold Part (TTF3)</td>
<td>CA00510</td>
<td>CEP</td>
<td>REC</td>
<td>PRODUCT</td>
<td>PRODUCTION</td>
<td>Metallic chips in threads of needle supports</td>
</tr>
</tbody>
</table>

**NOTA:** For Physical Parts not released in EDMIS, the NCRs cannot be uploaded in the system.

---

**XM-2 NCR**

**Decreasing number**
7 assembly area +1
=> 8 weeks of assembly

Ramp-up : XM1 to XM8 : 2 weeks per area
=> 16 weeks

Ramp-up from Sept. 2013 to Dec. 2013

Production : Dec. 2013 on
INDUSTRIAL CONTRACT: PRODUCTION PHASE

Production phase which covers the assembly of XM1 to XM80 by Alsyom from $T_2 = T_0 + 9$ months (September 2\textsuperscript{nd} 2013) till $T_2 + 24$ months (20 May 2015).

Production phase (option) which covers the assembly of XM81 and XM100 by Alsyom from $T_3$ (5 April 2015) till $T_3 + 6$ months (5 October 2015).
Le futur est toujours beau ..... 
.... Le présent est difficile

Future is always beautiful.....
.... Present is tough
Ideally the tooling definition should be included in the industrial contract.

This was impossible with our project timeline and readiness: e.g. the clean room was delivered in Nov. 2009.

The contract specifies that the Industrial Operator is only responsible of the standard tools, while CEA is responsible for the specific tools and their maintenance.

*The contract is essentially ‘Man and Engineering Power’*

As a consequence, the industrial operator will criticize the infrastructure layout and the tooling made available to him:

- e.g. cavity reception area,
- e.g. cavity support and pre-alignment tools in the clean room,
- e.g. layout of shipment vs. VV storage area

*Some of the criticisms come too early, missing the global scheme.*

*Some of the criticisms will lead to a better optimized production.*
### Input Data Readiness for the Industry Transfer

<table>
<thead>
<tr>
<th>@</th>
<th>CfT</th>
<th>Kick-off</th>
<th>Prod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure and Tooling (in the broad sense, e.g. cavity supports)</td>
<td>80%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>Cryomodule Configuration</td>
<td>70%</td>
<td>85%</td>
<td>100%</td>
</tr>
<tr>
<td>Cryomodule Documentation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– PBS (or MBOM)</td>
<td>30%</td>
<td>70%</td>
<td>100%</td>
</tr>
<tr>
<td>– Availability of Drawings</td>
<td>30%</td>
<td>70%</td>
<td>100%</td>
</tr>
<tr>
<td>Assembly Documentation (WBS)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Availability of Assembly Procedures</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>– Availability of Control Procedures</td>
<td>50%</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>– Availability of Regulation (PED, Safety)</td>
<td>20%</td>
<td>75%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Ratios are 100 % (cf. cavity production, or AMTF).

**Industry start production with 100% of Input Data in their Resource Planning software (ERP)**

<table>
<thead>
<tr>
<th></th>
<th>CfT</th>
<th>Kick-off</th>
<th>Prod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Quality of the Process (RF acceptance)</td>
<td>60%</td>
<td>60%</td>
<td>100%</td>
</tr>
</tbody>
</table>
PRE-SERIES TRAINING PHASE: INITIAL SCHEDULE (1/3 BIS)

• Couplers NonConformity
The Cavity Alignment Procedure had to be repeated 4 times, essentially due to mishandling by CEA and a technical problem on the needle bearings fixtures: → 1 calendar month, instead of 3 days.
Ajilon was subcontracted to perform the pre-industrial study with the achieved goal of:

- Tools definition
- Assembly Procedures with the non mechanical operations
- Schedule
- PBS – EBOM
- Risk Analysis
- Interruption Scenarios
- Inventory Management
- List and implantation of Services and Fluid Distribution
- Listing of Parts and Its Packaging
- Description of Reception Process & Controls

Using experience gained at DESY
Conclusion

- seven cavities are degraded with $\Delta E_{acc} = 7$ MV/m lost on average
- very strong field emission on cavity n°1 (AC128), again! (string vented and pumped from cavity n°1 end)
- Z162 has experienced two cold coupler connections, with the same coupler
- all cavities but Z139 (position n°3) have suffered from one (seldom two) non-conformity during the cold coupler or string assembly (e.g. water in the angle valve body)
- AC128 (pos. n°1) and AC115 (pos. n°2) share the same non-conformity, namely the accidental fast venting of the common coupler traveling waveguide box.
**Cavities Non Conformity**

**INDUSTRIAL CONTRACT : NCR**

**Non Conformance Report**

- **Equipment:** CAVITY
- **Serial Number:** XM-3
- **Change Request:**

  **Occurrence phase:**
  - Control: Reception
  - Manufacturing: Acceptance
  - Design/validation: Destockage
  - Integration: Others

  **Integration level:**
  - Equipment: X
  - Others: Reception

  **Workstation:**
  - Reception

  **Title:** Deviation of the Pin in the longitudinal position

  **Description:**
  We observed on the cavity AC158 that the assembly of the newly produced magnetic shield was too tight (cf. pictures page 2).
  Under the indication from DESY, this led to the systematic measurement of the distance from the middle of the cavity bracket to the AC158 103 mm instead of the nominal 93 mm +/− 2 mm.
  This result was reproduced for all eight XM-3 cavities AC114, AC146, AC151, AC152, AC154, AC156, AC157, AC158.

  **Technical documents:**

  **Technical investigations:**
  On the cavity was measured a deviation on the PIN (draw. 02L, pos. 4) in the longitudinal position:
  The nominal distance from the cavity bracket center to the PIN center is 93 mm – measured 103 mm.
  The nominal distance from the coupler flange center to the PIN is (100.02 mm) – measured 93 mm.

  **Corrective actions:**
  The connection of the cavity string to the cold mass will have to be given a particular attention in view of the shrinkage of the cold mass during cool-down.

  **Preventive actions:**
  Check of the helium tank dimensions for the industrially produced cavities.

  ** Clearance of actions:**
  - **Technical Manager:** J-P. Charrier
  - **Quality Assurance Manager:** C. Cloué
  - **Project:** CEA

  **Accelerator Consortium manager:** D. Reschke (CO)
PHASE 3: OUTPUT OF PRE-INDUSTRIAL STUDY
ASSEMBLY PROCEDURES

1. Identify the correct side of the assembly. It is opposite to the axis of symmetry and aligned with the tank.

2. Chock and verify that all the screws are tight. (2-4 mm tolerance)

3. Chock and verify that the MIS with its washer is inserted in the support flanges of the motor unit from the inside.

4. Support the M16 bolts and P16 33x33 and G16 bolt with 7 FL 42KG S2000.

5. Remove the clamping fixture from the side of the inner nut pad, leave the bottom side in place.

6. Screw the first solid plate on the side of the motor frame in the lower part of the M16 shoulder and should point toward the cover.

7. While holding the motor in its vertical position, start screwing the adjusting screw on the bottom (the one with spherical head).

8. Screw the adjusting screw at the bottom until a good contact between the frames. Solid plate and cover is reached, then screw 1/8 turn more for further tightening.

C. Madec | SRF13-THIOA02 | 26/09/2013 | PAGE 47
Prototype by MecaMagnetic for PXFEL configuration (warm-up tube with flange)

Pre-series by MecaMagnetic for XFEL configuration (warm-up tube with Ti/SS transition): benchmarking XM-3 cavities!
Pre-series by MecaMagnetic for XM-2 cryomodule
Super-insulation blankets have been qualified (PXFEL2_1 and PXFEL3_1).

The 40/80 K super-insulation blanket (2x15 layers):

- costs about 4 k€
- saves 1 day on cantilever and about 7 p.day (balance at ~600 € / day)
- saves about 30 W @ 40 K with respect to multilayers (30 + 29 separators).

<table>
<thead>
<tr>
<th>Cryo loss at</th>
<th>PXFEL 3</th>
<th>PXFEL 3_1 cooldown Dec 2011</th>
<th>PXFEL 3_1 cooldown Feb 2012</th>
<th>PXFEL 2_3 cooldown March 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 / 80 K</td>
<td>134 W</td>
<td>96 W</td>
<td>97-102 W</td>
<td>95 W</td>
</tr>
</tbody>
</table>

Negotiations with Jehier allowed about 10% reduction / CfT offer, through:

- more flexible (rapid) delivery rate
- simplification of 2K blankets fabrication

70 K blankets ordered in advance for XM-3, XM-2, XM-1 (delivered in June 2012)
70 K Blankets:
Prototype by Jehier for PXFEL2_2
2 K Blankets: Prototype by Jehier for XM-2