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DELIVERABLE REPORT

REPORT ON THE REQUIRED CONDITIONS FOR AND APPRENTRICESHIP PROGRAM IN THE TECHNOLOGY INFRASTRUCTURE (TI)

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	Name	Partner	Date
Authored by	C. Madec [WP5.1 Leader], O. Napoly	CEA	29/08/2019
Reviewed by	P. Fabbricatore [WP5 Leader]	INFN	27/12/2018
Approved by	O. Napoly [AMICI coordinator]	CEA	31/12/2018

1. INTRODUCTION

The purpose of Work Package 5 ‘Industrialization’ is to propose actions and methods that would benefit industrialization of the construction of future European Research Infrastructures (RI), based on Accelerators and Superconducting Magnets. This benefit should be evaluated from the cost, schedule and performance of the products, processes and services provided by Industry. Assisting European companies to match the challenging quality and performance requirements set by the laboratories in charge of the RI project realization would have the extra benefit of placing European Industry in a position to compete and take a major part in the construction of new Research Infrastructures worldwide. The actions and methods set forward by AMICI WP5 must, in all cases, abide by the rules of fair commercial competition in Europe and worldwide and hence exclude any direct or indirect subsidies to companies.

To this aim, the role of the Technology Infrastructure (TI), comprehended the network of Technological Facilities (TFs) owned and made available by the National Laboratories (NLs) to realize the RI construction work, is pivotal toward industrialization: *the TI is where industry products/services are transformed into RI-facility constituents, in compliance with RI specifications*. This transformation process is illustrated in Figure 1 for the European XFEL project, showing the routing of industrial products towards TFs, and their transformation into tunnel-ready accelerator components. In this particular case, two locations concentrated most of the industrial products and services: DESY-Hamburg dealing mostly with accelerator component acceptance, involving RF tests for cavities and cryomodules, and CEA-Saclay dealing mostly with cryomodule component acceptance and assembly, and producing cryomodules ready for qualification. The role of CIEMAT and IN2P3 was also crucial in testing magnets and RF couplers made by industry and accepting them for assembly.

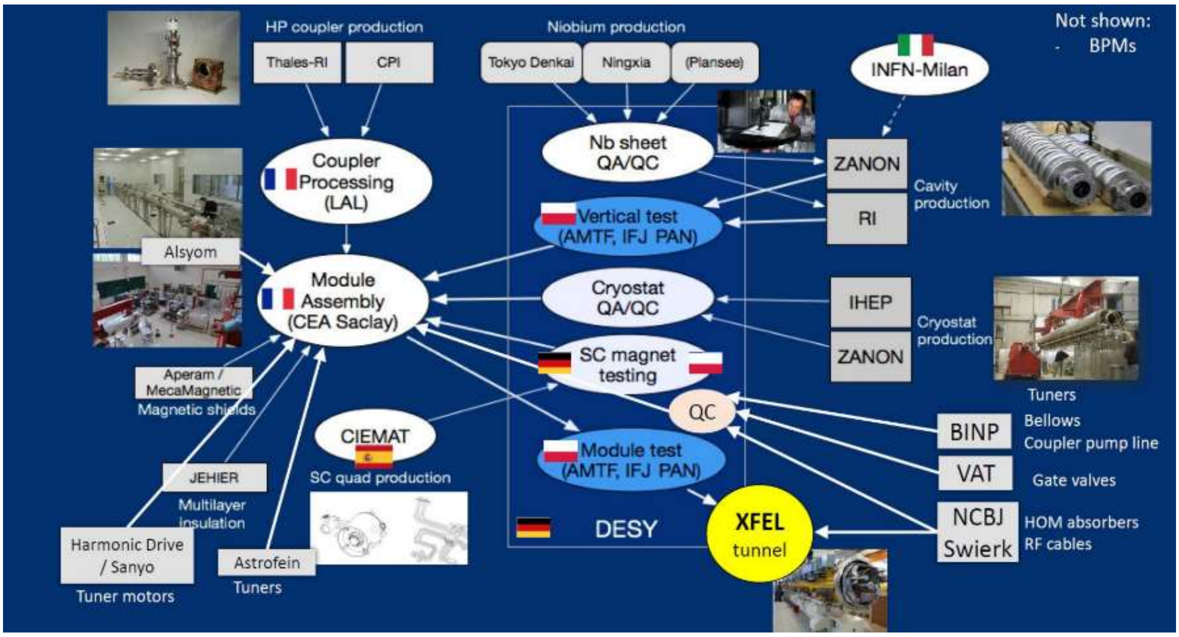

Figure 1: Schematic flow-down of industry-made accelerator components through Technological Facilities, to the European- XFEL tunnel installation.

In general and independently of the RI funding and organization schemes, the TI acts as the *intermediate link* between Industry and the RI project and hence bears two interfaces in this function: one upstream with industry through outsourcing contracts, and one downstream with the Research Infrastructure through Project Agreements as schematized in Figure 2. The recent advent of the 'In-Kind Contribution' economic model for RI construction has reinforced this intermediary role and, at the same time, it breaks down and distributes the construction work over several Technological Facilities with diverse engineering cultures and approaches.

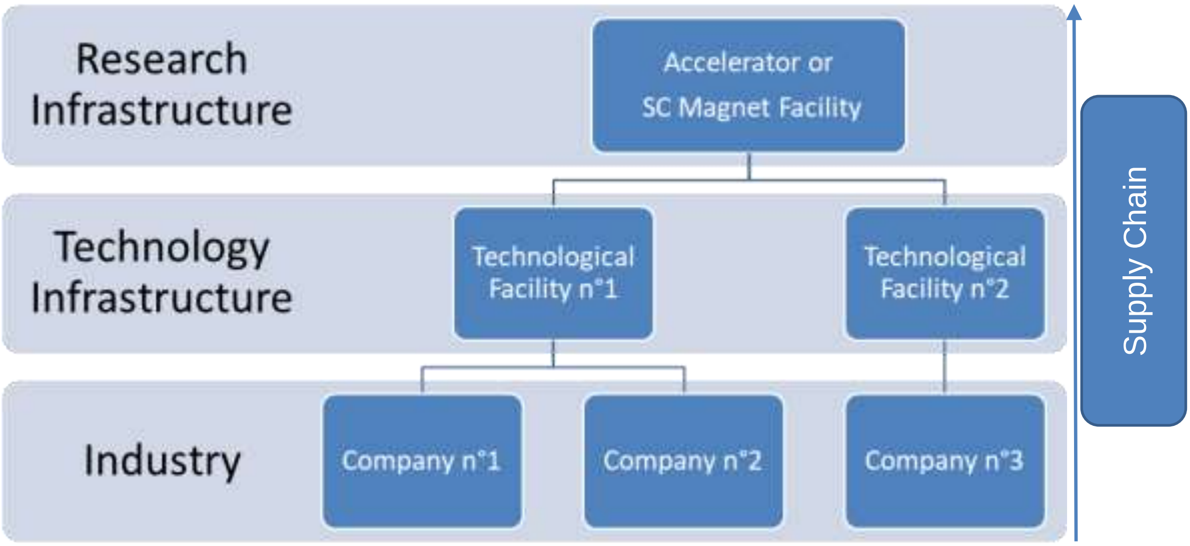

Figure 2: Simplified scheme of the industrialized construction of an RI facility from the upstream Industry to the downstream Research Infrastructure, highlighting the pivotal function of the Technology Infrastructure

The European XFEL example above illustrates also that the processes taking place at the Technological Facilities encompass a large variety of technical activities, with a wide variety of complexity and work duration. They range from the income reception of simple industrial products (e.g., hardware), the acceptance or survey of critical constituents (e.g., vacuum systems, power amplifiers, or complex mechanical parts), the conditioning and acceptance test of high technology items (e.g., RF cavities, RF couplers, or SC coils) to the integration (assembly, welding) and test of whole assemblies (e.g., magnet cryostats or SRF cavity cryomodules). It is worth noting that manufacturing seldom occurs at the TFs, but quasi-exclusively in industry.
For whatever level of complexity and work duration, all processes require skilled and trained personnel using professional equipment and applying well-defined engineering rules to implement quality, traceability and sometime certification of the components delivered to the Research Infrastructure.

For these activities to result in installation-ready RI components, the conformance and quality of the incoming industrial product is critical: any deviation or defect causes extra work at the TFs inducing extra costs, delays and possibly poorer performance, depending on the repair decision and scope.

In this report, we identified two main coordinated actions with the aim of establishing first industrial expertise, and then assuring production conformance and quality:

1) assist companies to achieve the proper level of manufacturing competence and skills, and
2) strengthen the mutual understanding of both industry and TFs engineering practices.

These actions are the subject of the following section 2 and section 3.

2. TRAINING IN THE TECHNOLOGY INFRASTRUCTURE

2.1. MOTIVATION

The process of upgrading industry to the expertise of laboratories in key techniques reaching high technology Readiness levels (TRL) shall be continuously updated along the trends that are crucial for the further development of Research Infrastructures. Many examples of such developments that occurred in Technological Facilities can be found in the fields of high intensity ion sources, superconducting coils using Nb3Sn and high-temperature superconducting cables, surface preparation of superconducting cavities, clean room assembly of accelerating cryomodules, etc. Continuing this process for new developments is needed to bring the supply chain to the challenging performance requirements set by the laboratories in charge of the RI project realization.

Training in the Technology Infrastructure facilities has the supplementary benefits:

- of providing hands-on training to young engineers and technicians from industry, with the possibility of extended interactions within the TI laboratories,
- of establishing a network between TI and technical universities and technology institutes by hosting apprenticeship programs mostly directed towards the education of highly qualified technicians, with the possibility of exchanges with the TI laboratories,
- of creating a pool of experts in the young generation of engineers and technicians, and
- of disseminating the use of high standards to be followed for the demanding technologies that are emerging.

For reference, the Annex reports the findings of the AMICI-Industry working group initiated by the AMICI-Industry Days in Padua (March 2017) regarding the current practices of industry training at four laboratories (DESY, STFC, INFN and CEA). It also provides an assessment of the training programs available in the public and private sectors for standard and general competences in widely used techniques.

2.2. RECOMMENDATIONS

For the future of our field and activities, training activities are mandatory to sustain new development and form the new generation of technicians and engineers. However, for training directed to industry, companies are ready to send personnel to the TI, at their own cost, only if commercial contracts are within 2-3 years future.

Hence the following recommendations:

- Establish apprenticeship programs with Technical Universities and Institutes for highly qualified technicians;
- Support common programs and exchanges for apprentices among the TI;
- propose to industry a continuously updated catalog of information and training sessions to key technologies reaching high TRL soon to be industrialized;
- Include that catalog in the industry-oriented existing national funding schemes, and propose the principle of a training certificate.
- For standard competences (e.g., magnetic measurements, vacuum technology, RF technology), training and apprenticeship are already available in the public and private sectors, and no action is required from the TI.

3. HARMONIZING SYSTEM ENGINEERING AND QA PRACTICES

3.1.1. Motivation

Once the key techniques have reached high TRL and are ready for manufacture in industry, following a technology transfer process that eventually included training, training activities can no longer be justified. Sustaining pre-existing expertise and avoiding a loss of know-how in industry over the duration of the RI construction entails system-engineering (SE) and quality-assurance (QA) methodology enforced at the interface between Industry and TI. The common efforts of the industry manufacturers and the technological facilities to follow-up the production are organized and managed in a contractual framework described by the SE and QA plans, as shown for instance in Figure 3.

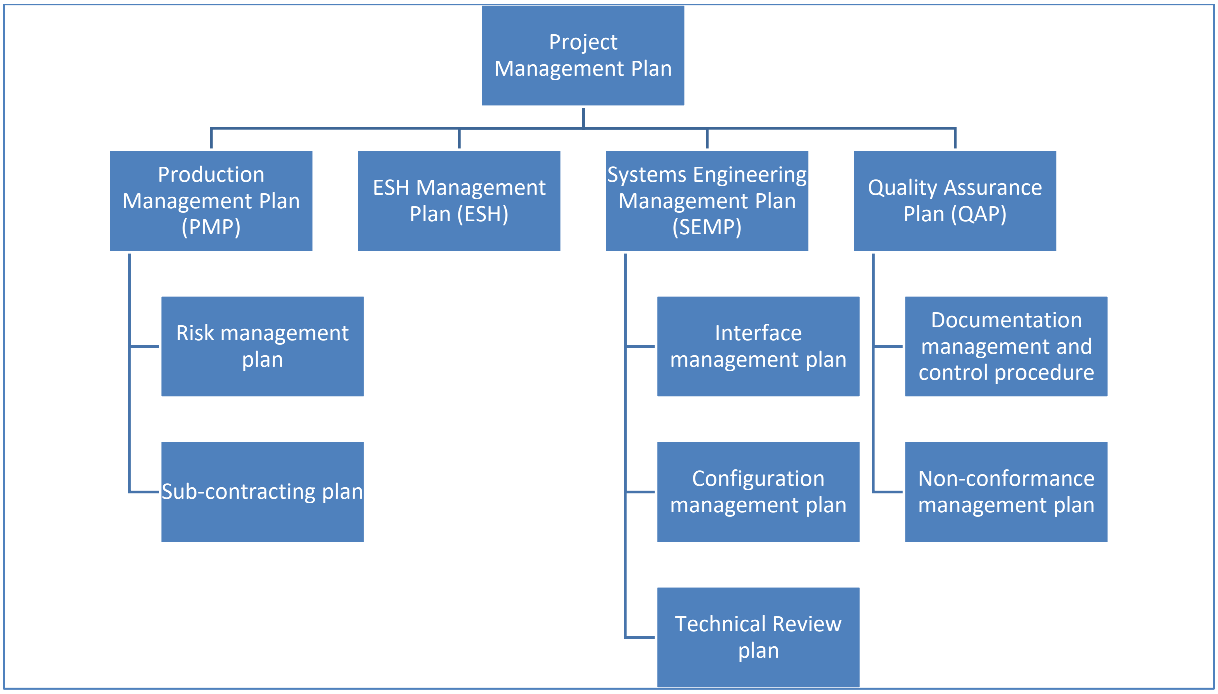

Figure 3: Schematic Project Management Plan flow-down, including the System Engineering Management Plan and the Quality Assurance Plan as key elements for ensuring the quality and conformance of industry products.

At present, there is a large diversity among the AMICI partners in their culture of setting up Management Plan architectures, and their practice to implement it for their technical contribution to the RI construction. A few institutes are following a well-defined and comprehensive methodology using commercially available product lifecycle management (PLM) software applications. As an example, Figure 4 illustrates the process ongoing for the ESS cavity production among the manufacturers, the technological facilities at INFN and DESY, and finally the ESS company.

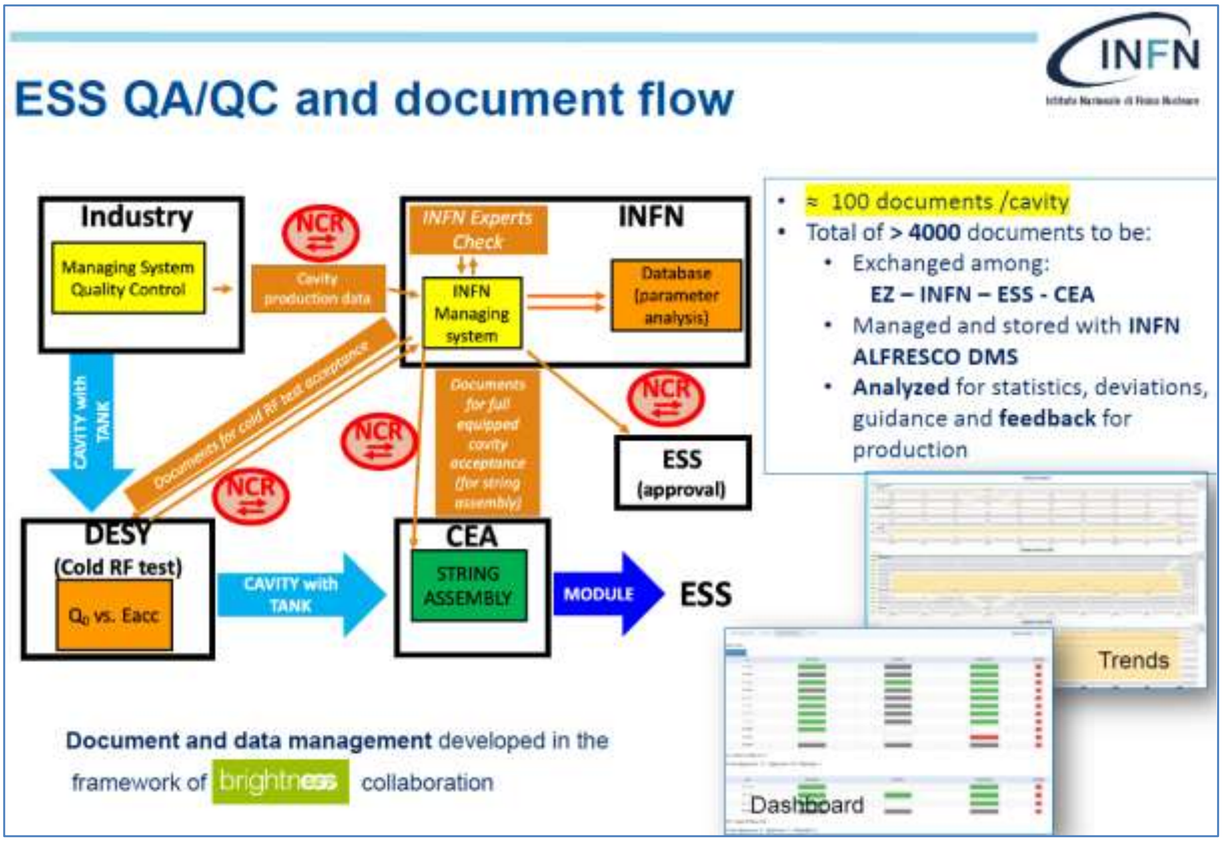

Figure 4: Workflow and QA chart for the INFN contribution to the ESS cavity production (courtesy C. Pagani)

Other institutes lack a complete suite of tools, and hence are sometimes using the management tools and methodology provided by the Research Infrastructure. Indeed, Figure 4 provides a concrete example of the intermediary role, explained above in Figure 2, held by the in the supply chain transformation of industrial products into scientific equipment. Consequently, in addition to their customer interface with Industry, technological facilities have to manage a supplier interface with the RI organization regulated by the RI Project Agreements which obligate them to set up Management Plans similar to these used with Industry but with inverse roles, the RI being the customer.

Thus, implementing an effective Management Plan, including SE and QA plans, is of paramount importance for the technological facility institutes, for their relations with both Industry and RIs.

3.2. RECOMMENDATIONS

Although not attractive to scientists, these management methods are now of general use and are inevitable to tackle the extreme system complexity of Research Infrastructure construction projects. However, their application is far from uniform across technological facilities, and their sometime exaggerated complexity leads to a loss of effectiveness.

Hence the following recommendations:

- Study the harmonization of the architecture and content of the 'Systems Engineering Management plan' and 'Quality Assurance plan', for the AMICI institutes to manage their industrial production contracts;
- Study the harmonization of the architecture and content of the 'Systems Engineering Management plan' and 'Quality Assurance plan', for the AMICI institutes to manage their future RI (in-kind) contributions;
- Educate TI experts (scientists, engineers and technicians) with respect to systems engineering and quality assurance.

4. ANNEX: AMICI-INDUSTRY WORKING GROUP REPORT ON PROFESSIONAL TRAINING AND APPRENTICESHIP IN THE TECHOLOGY INFRASTRUCTURE

4.1. METHODOLOGY

The report presents the results of the survey on the existing practices in both TI and companies, results that were discussed during a workshop organized at CEA in presence of two companies in December 2017. The outcome is presented in Section 2 of this report. In order to establish the required conditions for training and apprenticeship program, one has to identify the need for skill and competence improvement.

As all the WP5 activities are based on tight relations with industry, it was necessary to set-up a collaboration frame with the companies working in the field of accelerator and superconducting magnets. During the first three months of the project, a specific workshop was organized: the 'AMICI Partner and Industry Days for Scientific Technology Infrastructure' meeting, which took place in Padua, on April 18-19 2017. In this meeting the goals of the AMICI project were presented to the participating companies, focusing their attention in particular on the tasks and activities in which industry is going to play an important role, and to collect their comments, suggestions and expressions of interest in order to organize in the most effective way their involvement. Regarding the industry interest for the WP5 activities, between 10 and 17 companies expressed their interest in being informed about the activities of the different WP5 Tasks and between 2 and 6 companies wanted to participate in WP5 working groups.

4.2. SURVEY OF THE CURRENT PRACTICES IN LABORATORY TECHNOLOGICAL FACILITIES

Four Technological Facilities have been contacted in order to learn about their current practices.

a. At DESY :

Contracts to companies include practice and training for companies' technical staff. The contract includes the obligation to make the technical report of the industrialization study public, in such a way that the rules of fair competition are not biased. Training is done at DESY premises.

DESY provides consultancy to companies at the companies' premises (for example on clean room assembly). DESY has provided training to industry on the operation and qualification to DESY standards. DESY offered training to other laboratories' staff on their premises as well.

b. At STFC :

Training is mostly delivered by STFC staff, as they have extensive knowledge across almost all areas of particle accelerators. A small proportion of training is delivered to STFC staff by external providers in specific areas such as radiation protection, health physics and certain generic skills such as project/portfolio management. Training is financed internally by STFC. STFC staff have directly provided training to a number of external users, typically around areas of particular expertise (e.g., ultra-vacuum) or around the use and potential exploitation of particular technologies. Training is invoiced directly to the company and is often part of a bigger package (e.g., facility usage including training). STFC has some training material available, although it is typically aimed at STFC internal training requirements. The Cockcroft Institute, of which STFC is a member, has dedicated training and academic study material available to support its educational and training programs. Both STFC and the Cockcroft Institute have students who work across both the academic institutions and industry (e.g., PhD students and postdocs). A number of companies have expressed interest in hosting training events at STFC, particularly in areas that have broad applications outside of particle accelerators (e.g., vacuum, coatings, and high-power RF).

c. At INFN :

A national structure organizes training for INFN personnel in different fields. Courses can cover technical aspects such as vacuum, cryogenics, design and finite element modelling of components, and safety, as well as procedures for administrative processes, procurement, obtaining legal advice, etc. Courses are organized by INFN, while the experts and teachers can be INFN staff together with experts from industry or other institutions. Generally, INFN staff and associated personnel participate in the courses, but a determination is needed whether it can be extended in some way to industry. Participants receive an official certificate, issued by INFN or by the institution that has delivered the courses (e.g., for an ANSYS course led by ANSYS staff).

d. At CEA:

Employees follow training performed by CEA experts or outsourced. The training courses are funded by CEA. Some CEA scientists also give lectures at universities. CEA can act as a training company providing training to outside participants. The instructors can be CEA employees and/or industrial partners. CEA has trained companies on specific subjects as part of the contracts between CEA and those companies. CEA is also invited to perform audits for companies or other laboratories and can then train workers of companies or laboratories.

4.3. OTHER CONSIDERATIONS:

Before setting up a training, the TI coordination board should agree about the content of the training curriculum, and about which TFs can teach it, eventually jointly. This curriculum should be periodically reviewed and evolve with time and progress of the discipline. The TI should also be able to attest which companies have attended, register the information on a common database and issue a AMICI stamped document.

The type of courses foreseen can be:

- E-learning: it will be used as an introductory course
- On-line course: this is a course performed by a trainer at some location and followed remotely by trainees at another location.

For the topics discussed during the meeting, hands-on training is preferred. Short training sessions (1 to 2 days) with limited theoretical background (perhaps 1/2 day) and many practical experiments are favoured.

Trainees could be technicians and/or engineers. The language of the training is an issue: some trainees may understand but not speak English.

The issue of the funding of the training was raised: can a training given in a country different from the trainee's company country be included in the state law?

4.4. GENERIC TRAINING

The following Table presents a list of generic professional training courses and providers available in France.

GENERIC TRAINING		
Topics	Name of the training company and/or Website link	
Cryogenics	IUT Orsay	http://www.iut-orsay.u-psud.fr/fr/formations/offre_de_formation.html
Vacuum technology	Société Française du Vide	https://www.vide.org/formations/presentation/

	CNRS	http://rtvide.cnrs.fr/
	VARIAN-AGILENT	https://www.agilent.com/fr-fr/training-events/events/agilent-university
	40-30	http://www.trainingby4030.com/formations
Clean room	ASPEC	http://aspec.fr/activites/formations
	40-30	http://www.trainingby4030.com/formations
General Engineering	CNRS ENTREPRISES	https://cnrsformation.cnrs.fr/
	CEA INSTN	http://www-instn.cea.fr/formations/formations-continues/liste-des-formations-courtes.html
	CNAM	http://formation.cnam.fr/formation/
	Université Paris Sud Orsay	http://www.u-psud.fr/fr/formations/formation-continue.html
	IUT Orsay	http://www.iut-orsay.u-psud.fr/fr/formations/offre_de_formation.html
	Laboratoire National de Métrologie et d'Essais	https://www.lne.fr/services/formation
	FACULTE METIERS ESSONNE	https://www.facmetiers91.fr/formation-continue/les-formations/
Electricity, Electronics	IFTEC	http://www.iftec.fr/formations-iftec/
	CentraleSupelec	https://exed.centralesupelec.fr/
Electromagnetism	CEDRAT	https://www.cedrat-technologies.com/fr/services/formations.html
	CentraleSupelec	https://exed.centralesupelec.fr/
Mechanics	CETIM	https://www.cetim.fr/formation
Tooling	FACULTE METIERS ESSONNE	https://www.facmetiers91.fr/formation-continue/les-formations/
Welding	Institut de Soudure	https://www.isgroupe.com/fr/metiers/formation-certifications/Pages/formation-certification-personnels-default.aspx
	FACULTE METIERS ESSONNE	https://www.facmetiers91.fr/formation-continue/les-formations/