F4E NEWS

Fusion for Energy Magazine

No. 26 / March 2019

ITER Worksite
First components installed in the Tokamak building

Milestone
Toroidal Field coil insertion accomplished

Innovation
Electrical power supply on its way to MITICA Neutral Beam Test Facility

Manufacturing
European industry to deliver In-Vessel and Diagnostics components

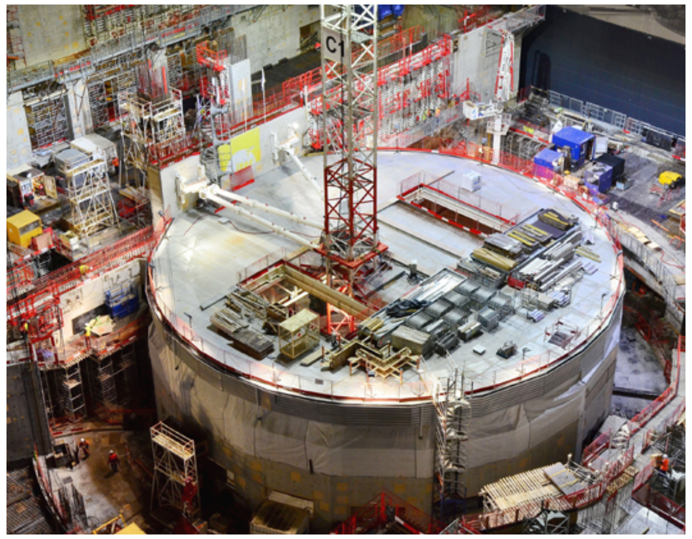
Stakeholders
F4E makes the case for ITER to the European Parliament

Europe's winding pack inserted into its case coil, SIMIC, port of Marghera, Italy © SIMIC

A new dawn rises on the ITER construction site

The crown and bioshield of the Tokamak building are completed. More facilities are ready to receive equipment.

Aerial view of the ITER construction site, December 2018, Cadarache, France © ITER Organization



The lid covering the fully-completed bioshield, Tokamak building, ITER construction site, Cadrache, France. The works have been financed by F4E, responsible for the construction of the infrastructure and facilities on-site.

The ITER crown, a solid base ring and its 18 radial walls able to support the load of 23 000 t, has been completed. The works have been financed by F4E, responsible for the construction of the infrastructure and facilities on-site.

The first metal piece of the Tokamak installed in the bioshield (a 10 m, 6.6-t feeder component delivered by China). ITER's logistics provider DAHER, European contractor VFR, and ITER engineers from the In-Cryostat Assembly Section were all involved in the operation. © ITER Organization

A workforce of 1 900 people is working round the clock to conclude the works of the biggest fusion experiment. The walls and floors of the emblematic building which will house the "heart" of the ITER device have come a long way. We stand a few metres away from the Tokamak complex to take stock of the progress. It's hard to concentrate because there is a lot happening: cranes are lifting steel bars, more concrete is being poured, workers wearing their white hardhats are continuously on the move, loaders are moving materials, pipes are inserted in galleries. There are definitely more buildings and facilities ready and the pieces of this construction puzzle are falling into place. Similarly, the manufacturing of components on-site is taking off. More tooling is being assembled in the Assembly Hall, the works are advancing in the Cryostat workshop, the Cryoplant, and the fabrication of magnets is accelerating in the Poloidal Field coils factory. It's a site in fast motion.

The first level of the Diagnostics building ready for handover to contractors for the beginning of systems installation. The embedded plates visible on all surfaces will allow contractors to attach the supports required to install various systems. © ITER Organization

"In spite of the work organised in three shifts it still feels like a race against time. Then again, you have turning points in the construction roadmap which make you think we are on the right track. We have completed the concrete bioshield cylinder and the concrete crown where the device will be installed. We recently installed the feeder of ITER's fourth poloidal field coil – the first of a long list of components for this building. As works are progressing, we are handing over the buildings to ITER Organization to start of assembly of various plant systems," explains Romaric Darbour, Deputy Project Manager for Buildings, Infrastructure and Power Supplies. Towards the end of 2018, F4E delivered formally to ITER Organization the cooling water infrastructure.

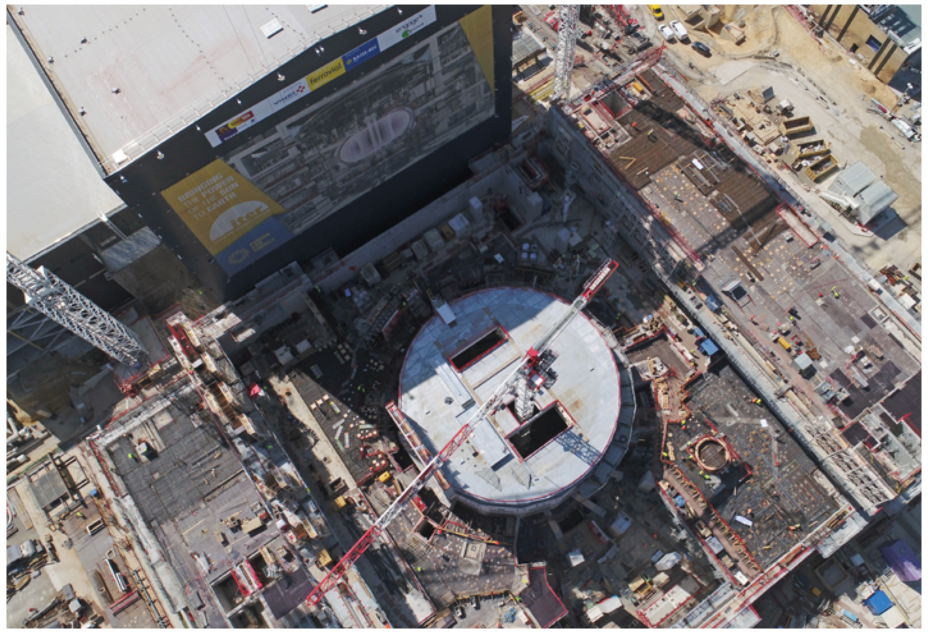
Workforces have almost completed painting the first floor of the Tokamak building, and the finishing works of the concrete crown will be concluded by the end of March. Meanwhile civil engineering works on its seventh floor (Level 5) are advancing at full speed. On average, it is calculated that every six months another floor of the building will be completed to be handed over to ITER Organization in order to proceed with the assembly of systems. By September 2019 a significant part of the Tokamak building crane hall steel structure will be erected, fabricated, and pre-assembled. By March 2020 it will be completely erected. In the adjacent Diagnostics building, workers have started works on the sixth floor.

Civil engineering and finishing works are ongoing in the Radio Frequency building so as to continue with the installation of equipment. The completion of the Magnets Power Conversion buildings in February signal another major delivery from Europe to all Parties.

The handover of the cooling tower zone from F4E to the ITER Organization, ITER Construction site, Decemeber 2018, Cadarache, France. Now the ITER team will supervise the installation of equipment sent by India © ITER Organization

2000 eyes to oversee the works at the ITER Tokamak complex

An army of fiducial nests to safeguard the installation of components.



Aerial view of the Tokamak complex where the biggest fusion device will be installed. ITER construction site, Cadarache, France © SNC Engage

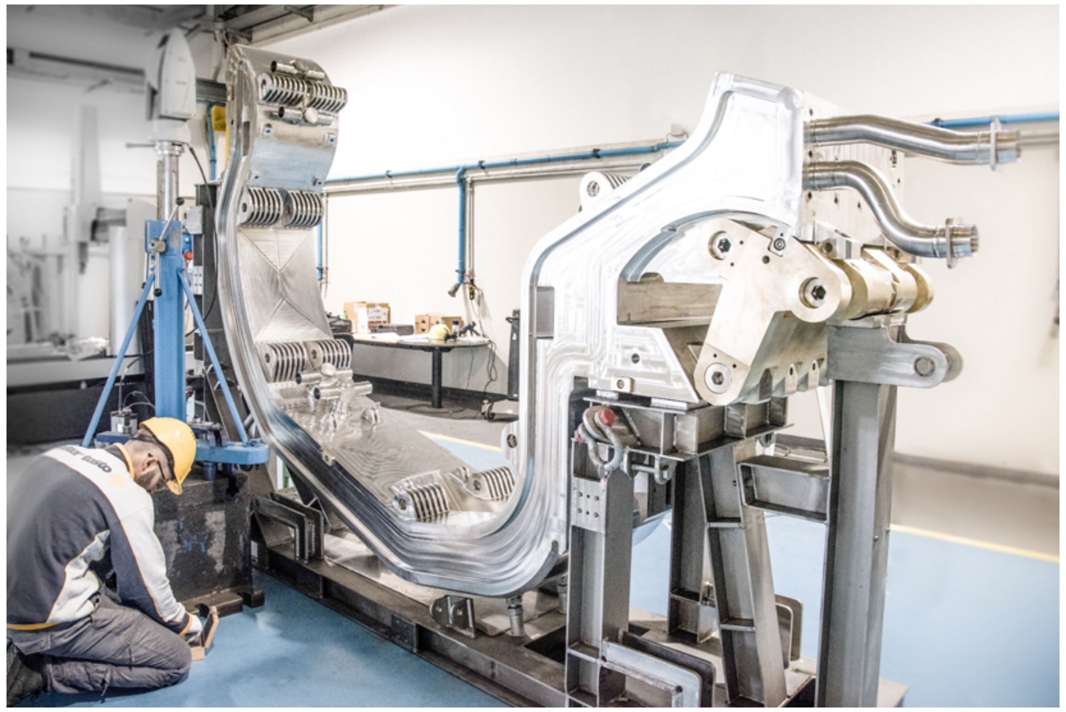
ITER counts at least 10 million components which will need to be fitted carefully in the machine. But that's not all. The list grows if one takes into consideration the civil engineering equipment and infrastructure which will be required to house the biggest-ever fusion device. Engineers are striving for milimetric accuracy and in spite of the XL size of the ITER machine, space is a real issue because it is limited. Consequently, everything needs to be installed neatly and accurately. Take for instance of the position of the embedded plates in the Tokamak building or the assembly of the massive equipment. It's a jigsaw where all parts are interconnected. A titanic operation that can only be carried out with the help of metrology, a discipline traced in Ancient Greece, where the word comes from, which means the science of measurement.

Around 1 900 people are directly involved in the civil engineering works of ITER with various contractors and subcontractors. The interfaces are multiple, at times they need to be revised, and in the end everything must come together in a seamless manner. The Metrology groups of F4E and ITER Organization have embarked on a mission to set up a network that will help contractors to carry out their work with precision. Fiducial nests with the help of laser beams will identify the exact coordinates of each component at the Tokamak complex. Colleagues from IO have designed and simulated the network layout using SpatialAnalyzer® metrology software to mark the exact locations of these nests. Parallel to this, the last 18 months, F4E has been working with SETIS/PES, a Franco-British consortium, to carry out the installation of the nests and conduct the measurements. So far, 1 400 of these watchful "eyes" have been positioned on-site and another 600 will follow. Thanks to the installation and the measurements provided by the fiducial nests, it has been possible to scan 10 000 embedded plates, at a rate of 300 per day, which amounts to a tenth of the total number of the embedded plates in the Tokamak complex.

"The close collaboration with our colleagues from ITER Organization has been instrumental in developing this metrology network" explains Luigi Semeraro, F4E Metrology Group Leader. "It is a great achievement if you think that we have created a sophisticated measurement system for the most complex building of the project." For Giacomo Calchi, F4E Metrology, "Good planning has been essential towards the success of this operation because we needed to respect the sequence of civil engineering works. We had to install the metrology network without disturbing the contractors working on-site." Gaël Archambeau, on behalf of SETIS, explains that "...setting up the network of fiducial nests in the Tokamak complex is an important milestone for the ITER project. Our consortium, SETIS-PES, delivers the coordinates that will allow the machine assembly activities to unfold through a single and monitored coordinates system. Our know-how and the experience we have drawn from similar projects, such as the EPR in France, are now at the service of the biggest fusion experiment."

Europe starts manufacturing the first set of ITER Divertor Cassettes

F4E signs deals with Walter Tosto, and CNIM-SIMIC consortium for the production of In-Vessel components.



European real-size prototype of ITER Divertor Cassette manufactured by Walter Tosto © Walter Tosto

From the dusk of prototyping to the dawn of manufacturing. Europe is beginning a new chapter in the field of ITER In-Vessel components with the signature of two deals for the production of 19 cassette bodies out of the 58 (54 + 4 spare) which must be delivered.

F4E has signed one contract with Walter Tosto and another contract the CNIM-SIMIC consortium. The works are expected to last approximately five years and once completed, the equipment will be handed over to ITER Organization to assemble the rest of the components (the outer-vertical target, the dome and the inner-vertical target). In line with F4E's phased-production approach, the remaining 39 cassette bodies will be manufactured at later stage. Remember these pieces of equipment are not required for ITER's first plasma, hence, the calendar applying to them is a bit different.

The ITER Divertor, consists of 54 cassettes, which cover the lower part of the machine. It is one of the components that will experience part of the high plasma temperatures. It is estimated that the highest heat deposition on the surface of the cassette could be in the range of 20MW/m^2. The plasma impurities will be diverted to fall on this massive "ashtray" covering an area of 142 m^2. Each ITER Divertor Cassette measures 0.8 x 2.3 x 3.5 m and weighs roughly 8 t.

Meticulous manufacturing and an eye for detail are necessary for the fabrication of the ITER Divertor Cassette. "Extreme precision in machining, expertise in welding and inspection are indispensable. The tolerances to be achieved in some of its features are in the scale of 0.1 mm," explains Laurent Guerrini, F4E's Technical Project Officer who has been following the manufacturing of the prototypes delivered by Walter Tosto and the CNIM-SIMIC consortium.

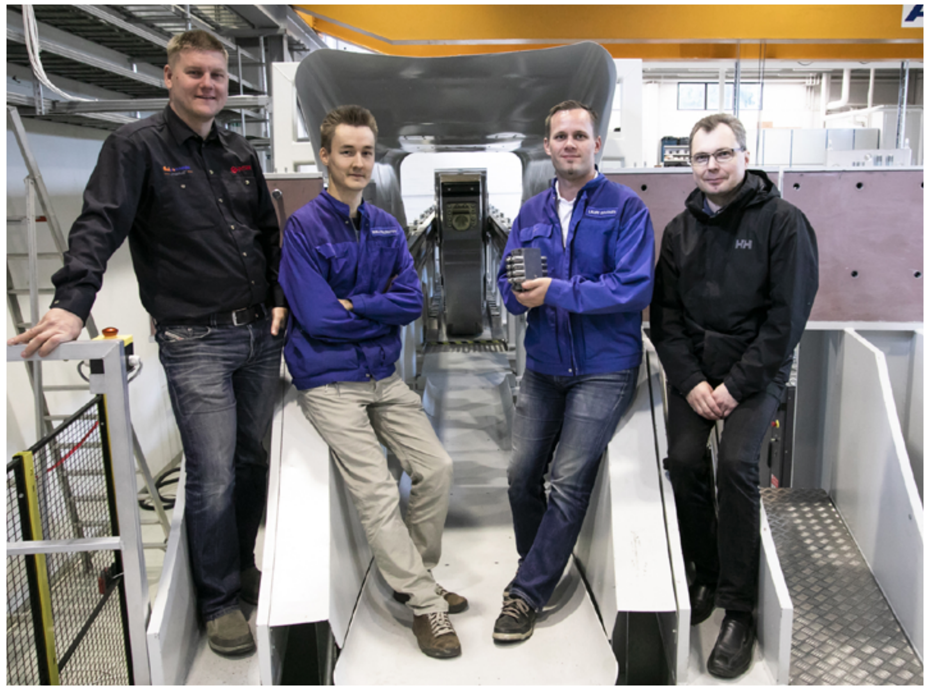
It all started in 2012 with the signature of a procurement arrangement with ITER Organization. Then, F4E conducted a market survey, identified the technologies required for the fabrication of this component, and one year later launched a call for the production of the first real-size prototypes. The race started with three bids offering the best set skills matching value for money. Two of them carried on until the finish line: Walter Tosto, and the CNIM-SIMIC consortium.

Patrick Lorenzetto, F4E's Head of In-Vessel Project Team, confirms that "this is the outcome of the very good collaboration between various teams in F4E, ITER Organization and the companies involved. The signature of the two contracts shows that Europe is now ready to proceed with the manufacturing of the first series of the ITER Divertor's Cassette body."

Can ITER transform the future of digital hydraulics?

Discover the potential of fusion spin-offs

F4E collaborates with Tampere University of Technology, Fluiconnecto and Tamlink to test the potential of this technology using water.



The group of Finnish engineers involved in this technical achievement, (L-R) Harri Sairiala (Fluiconnecto Oy, responsible of the valve design and manufacturing), Miika Paloniitty (TUT, researcher and our special water valve advisor), Lauri Siivonen (Tamlink Oy, project coordinator), Matti Linjama (TUT Adjunct Professor) ©TUT

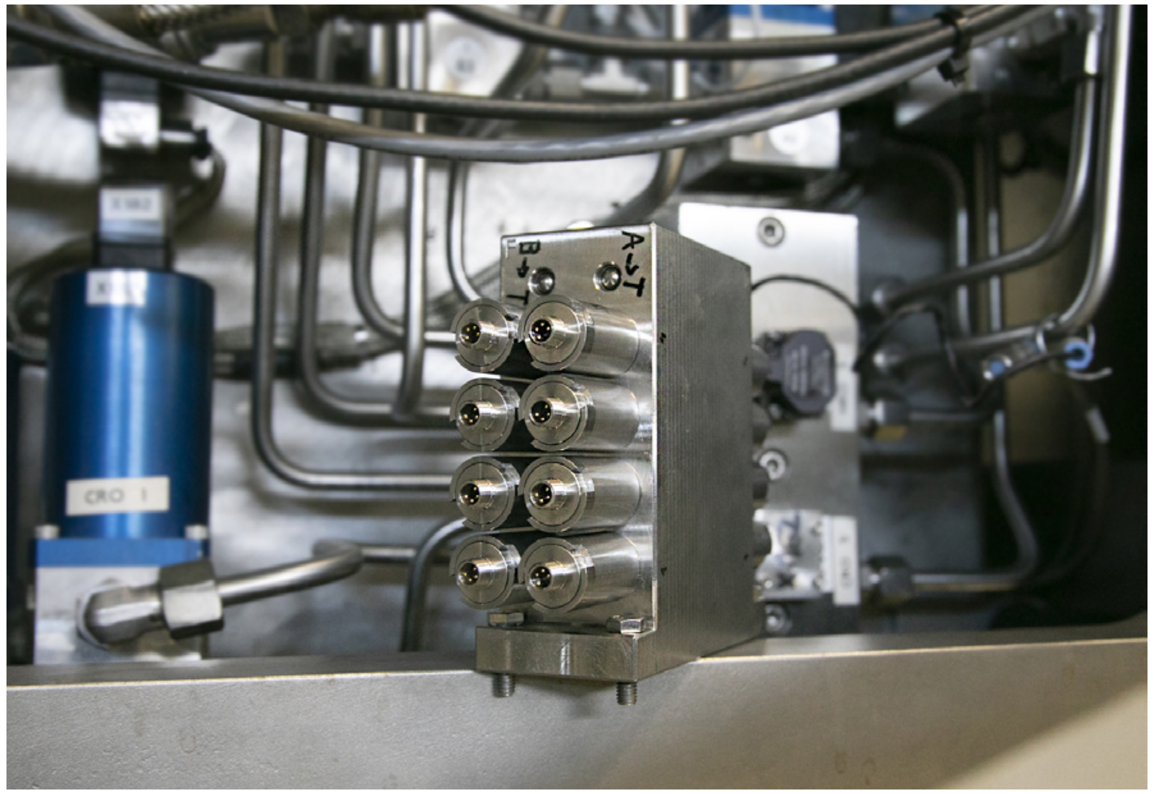
Industry has already entered unchartered territory manufacturing ITER's complex components which will be shipped at different stages from all over the world to Cadarache, where they will be assembled and carefully positioned. Everything needs to fit in the limited space reserved for each component, and as if this wasn't complicated enough, the tooling that will be used to repair them will also need to be developed from scratch.

At times, technical maintenance will need to be carried out remotely and with extreme precision. Engineers will not be able to enter the machine. They will need to rely on cameras and use agile and smart tooling to access a labyrinth of equipment. One example is the ITER Divertor, located in the lower part of the machine, consisting of 54 cassettes measuring 0.8 x 2.3 x 3.5 m weighing 10 t each (including plasma facing components). This is the part of the machine where the temperature of the superhot plasma will be felt most. The divertor cassettes will form the machine's massive "ashtray" where the hot ashes and impurities will be diverted to, and eventually, fall in. It is foreseen that these components will be replaced up to three times during ITER's lifecycle. Europe is responsible for the development of the ITER Divertor Remote Handling System and one of the tricky subjects that F4E and its industrial partners are dealing with is choosing the right technology to lift and handle the heavy divertor cassettes.

Originally, F4E was considering using servo valves as part of the remote handling system. Although, they offered accurate tracking, tests showed that they lacked robustness and wore off easily. On top, any particle in the water could block their operation causing significant problems.

For this reason, F4E signed a contract with Tampere University of Technology (TUT), Fluiconnecto Oy and Tamlink Oy to explore the use of digital valves as an alternative. The system relies on a set of 16 fast, small and simple on/off valves working simultaneously to achieve the required performance. After months of trials, the engineers concluded that the digital valves present several merits. First, they are more resilient. Second, contrary to servo valves where the system relies solely on one, digital valves offer a combination of various valves and in the event of failure there is a backup to fall back on guaranteeing continuity. Third, as trials pointed out, the digital valve system demonstrated a new state-of-the-art control performance.

The successful results motivated TUT, Fluiconnecto and Tamlink to explore the commercial potential of this technology. Digital water hydraulic valves could be used in the fields of transport, aeronautics, construction, industry and machining. Where there is a need for extra muscle to lift and move loads with precision, there is a niche for this promising patent. Tamlink and TUT have been working the last 20 years in this field. For example,



The digital hydraulic valve is the result of collaboration between the Tampere University of Technology, Fluiconnecto and Tamlink. The EU has financially supported this initiative.

Bosch Rexroth has licensed this technology operating with oil. In fact, digital oil valves of such kind are used in some of Finland's high speed trains.

One would think that the same valves could be used in ITER. But the technical requirements state clearly that oil cannot be an option. Salvador Esque, F4E Technical Officer following the contract explains "… due to the restrictions we have with the use of oil when moving the ITER components in vacuum and under radiation, we started looking for alternatives. We decided with our industrial partners to opt for water. Now, we have a solid basis to explore this technology further and to validate it. We will soon be starting with the second phase of tests replicating the ITER environment and we will be upgrading the valves."

F4E has made this breakthrough possible by co-financing a number of improvements to the valves' design. The grant helped TUT to conduct trials for hundreds of hours using a test load simulating the weight of an ITER divertor cassette. The EU's involvement in ITER and the potential to stimulate spin-offs are important to Carlo Damiani, F4E Project Manager for Remote Handling. "This is a success story that could yield commercial benefits. The collaboration of R&D centres and companies, making the transition from fusion to other areas of work, shows the diverse mix of technologies we use and their far-reaching application. It is another example demonstrating how the EU can further increase Finland's high rank in innovation."

Lauri Siivonen, Tamlink Project coordinator, believes that digital hydraulics are a strong candidate for ITER. "The tests showed superior tracking accuracy. In spite of some faults detected during the long-term tests, their performance overall was not seriously affected. The project was carried out in line with the scheduled time and resources."

Harri Sairiala, technical responsible of Fluiconnecto adds "…we have been working with ITER water hydraulic maintenance tools for almost 20 years. The digital valve technology paves the way for new interesting possibilities to achieve reliable, accurate and efficient motion control. ITER is probably the most demanding environment we can imagine for a hydraulic system. If we successfully address this challenge, then we will have many possibilities in more traditional industrial applications in future."

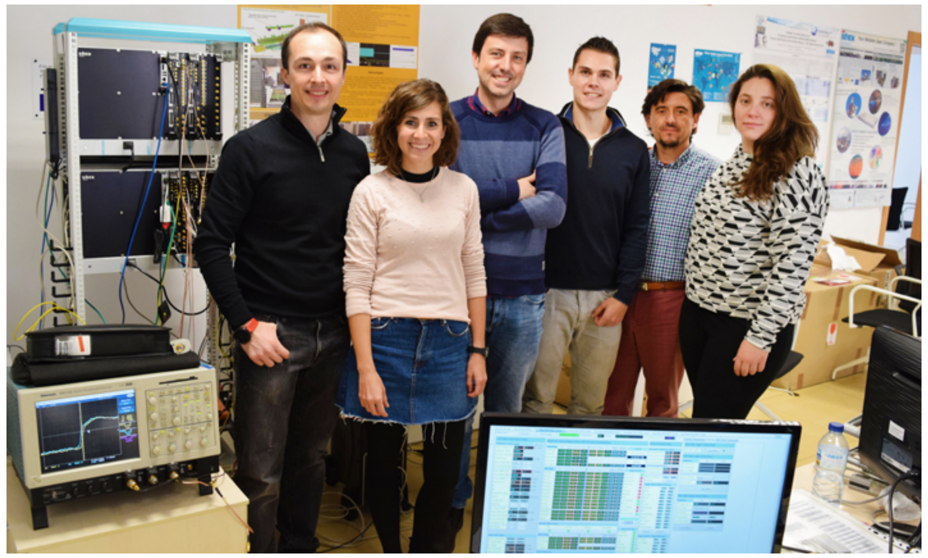
Matti Linjama, Adjunct Professor at TUT, and inventor of digital hydraulics, explained that "this joint venture with F4E, Tamlink and Fluiconnecto has been fruitful. The digital hydraulic solution offers a unique combination of performance and reliability. The project is a good example of transferring research to an application."

Next, the digital valves will be installed in the Divertor Test Platform (DTP2), an ITER test facility in Tampere. On the basis of their performance, experts will decide how to use them in the biggest fusion device.

Seven solutions develops software and hardware that enhance the operation of accelerators

How a fusion project in Japan motivated a Spanish SME to set a new a benchmark.

Almost 12 years ago, with the financial support of the European Union, Seven Solutions was set up. The small company, counting seven founders as their workforce at the time, brought together academics from the University of Granada and few of their graduates who wished to pursue a career in Big Science projects. They all had a technical background and promised to look for solutions in the fields of physics and astrophysics. Naturally, projects managed by CERN (Switzerland) or ESA (Paris) were in line with their field of expertise. Fusion projects building on transnational collaboration, like the International Fusion Materials Irradiation Facility (IFMIF) bringing together Europe and Japan, were also on their radar. And while many get cold feet about playing a role in large projects because they feel they are out of their league, Seven Solutions plucked up more confidence and offered their skills.



The team of Seven Solutions involved in the development of equipment for the IFMIF-EVEDA projects of the Broader Approach Agreement, signed between Europe and Japan.

Today the company counts 38 employees and has recently opened offices in the US and another in Germany. How did they manage to defy all odds and successfully added to their list of success stories: radiofrequency equipment for accelerators; software and firmware which will enhance their operation by measuring with high precision the beam energy and its position?

Miguel Mendez, one of the first employees of Seven Solutions, and Head of High Energy Physics, recently visited F4E to sign a licence agreement. The company will be allowed to explore the commercial potential of the hardware and software they developed, which is used in LIPAc– a prototype accelerator which is part of IFMIF. The results of this project will feed into DONES, the DEMO Oriented Neutron Source, which is planned to operate in Granada.

The company enjoyed its first big break with CERN. They developed time transfer and synchronisation devices for large control systems. The technology they used is known as White Rabbit -- it can synchronise devices in sub-nanosecond time transfer. Seven Solutions brought this technology to industry with the design of the first switch which included this feature. The company continued to demonstrate its expertise in various projects, and after building a partnership with CIEMAT they targeted IFIMIF. They offered to deliver hardware and software using White Rabbit technology in order to make the system operate more precisely.

They were selected by F4E, co-ordinating Europe's contribution to IFMIF, and have so far signed three contracts. When the first piece of hardware was successfully installed, the need for new functionalities and further optimisation was identified. The engineers wanted to boost the overall performance of the system for the high power supply amplifiers and in parallel increase its safety.

Discover the potential of fusion spin-offs

"We developed software which could be universally used with accelerators improving the overall operation of their systems, their timing distribution and safety. LIPAc is state-of-the-art equipment and we had the privilege to run the software there for the first time. The results have been positive. Overall, we wanted to improve the RF control system devices by introducing novel features which take advantage of this ultra-accurate synchronisation technology," Miguel Mendez explains. They succeeded in distributing the Radio Frequency (RF), controlling and measuring with precision the beam energy and its location. This qualified as a breakthrough. In essence we have a new and innovative product in the market. Initially, three people were involved in this project and currently there are five working full-time and three working part-time due to the increasing volume of work. "The development of this software has opened us the door to high-energy physics and to projects such as ITER , the ESS or experiments using RF control systems. It may also be of relevance in medicine, where accelerators are also being used for cancer therapy," he explains.

Equipment developed by Seven Solutions, used in their collaboration with CIEMAT. © Seven Solutions

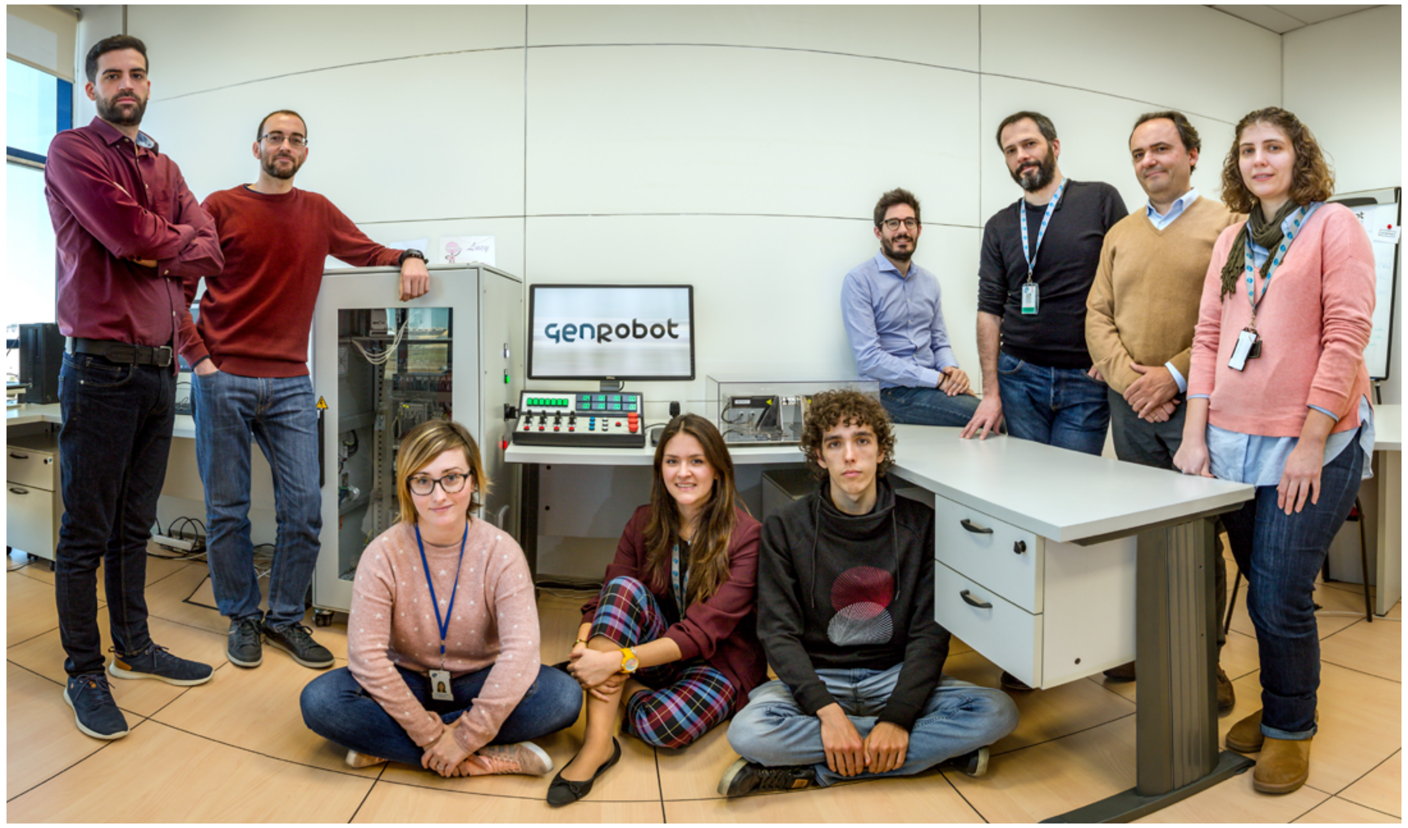
The company was set up as a start-up, building a bridge between academia and enterprise. The founders are firm believers that both public and private entities can mutually help one another by investing in R&D and by taking a commercial risk they can have an impact in the market. "The technically demanding environment in fusion has created the need for further advancements. We, at F4E, encourage our industrial partners to push forward know-how because it also raises the prospect for spin-offs. The case of Seven Solutions beautifully demonstrates how an SME, with a proven track record in its domain, can take a step forward joining an international project, grow in terms of expertise and get ready to launch a new product in the market," says Gebhart Leidenfrost, F4E's Chief Financial Officer in charge of commercial activities.

(L-R) Miguel Mendez, Head of High Energy Physics, and Gebhart Leidenfrost, F4E's Chief Financial Officer in charge of commercial activities, on the day of the signature of the licence agreement.

Discover the potential of spin-offs

GENROBOT- the software that Europe will use in its share of ITER Remote Handling systems

The application will plug and control several machines simultaneously.



Representatives of GTD and F4E around the test bench of GENROBOT, GTD offices, Madrid, Spain. GENROBOT will be used to adapt and configure robotics equipment which will operate as part of Europe's ITER Remote Handling system. (Image Courtesy: Rod New house)

Remote Handling brings together the systems and tooling which will be required to inspect, repair, move and replace the components that will be exposed to radiation. Given the fact that humans will not enter ITER's massive vessel, all maintenance works will be carried out remotely. Teams from Europe and Japan are working relentlessly with companies and laboratories to design and manufacture the pieces of equipment that will allow us to perform these tasks. Man-in-the-loop robotics such as manipulators, movers, cranes and actuators will be deployed to work with extreme precision. Like a choreography where everyone has a role to play and every single step matters, they all have to "dance" to the same music and understand in their coded language what needs to be done.

The multilingual environment of the European Union was the birthplace of a software which helps various pieces of robotic equipment to communicate and work together as part of the same system. The foundations of the idea are traced in the European Commission's Joint Research Centre (JRC) in Ispra, Italy, where GENERIS was born. The software was masterminded by a team

GENROBOT will be used to adapt and configure robotics equipment which will operate as part of Europe's ITER Remote Handling system, GTD, Madrid, Spain

of engineers, led by F4E's Emilio Ruiz Morales, who at the time was working in Ispra. The application has made excellent use of the know-how stemming from R&D projects financed by the JRC in areas such as mobile robotics for surveying nuclear storage, and telerobotics surgery with tactile feedback. GENERIS inspired F4E and GTD to create GENROBOT, a new software which will be part of the European Remote Handling systems in ITER.

"This software allows us to install a sense of harmony in the operating system and to rigorously control all ITER Remote Handling machines that Europe has to manufacture. Engineers can adapt and configure it to operate various robotics equipment. Thanks to GENROBOT we have made time and cost savings. Above all, we have developed an industrial software system of outstanding quality, complying with SIL-2 IEC 61508 standards, which is a novelty for the market," explains Ruiz Morales.

Carlo Damiani, heading F4E's ITER Remote Handling systems, highlights how ITER's technically demanding environment has become a driving force for further innovation. "In the case of GENROBOT, we made excellent use of EU funded research. With further investment from our side we made an innovative software that suits our needs and potentially those of other areas using remote applications such as nuclear decommissioning, defense, medicine and space," he explains.

"GENROBOT allowed us to enter the robotics market by contributing through our expertise in safety-critical software. For us it has been an interesting journey which helped us acquire new capabilities and made us step out of our comfort zone," explains Alejandro Cantos, GTD Robotics Manager.

"We are now in a position to use all the know-how obtained with GENROBOT and to offer solutions to other markets. Being part of Europe's contribution to ITER is a dream come true. It is one of the most important projects in the world upon which the future of the energy depends." The testing phase of GENROBOT at GTD is soon coming to an end. Further fine-tuning is expected to be carried out during the first semester of 2019. Then, it will travel to ITER's Remote Handling Facility, Tampere, Finland, where experts will receive training to perform various tests at the Divertor Test Platform (DTP2).

ITER In-Vessel component ready to take the heat

Europe and Russia start testing F4E's first full-scale prototype of the Inner-Vertical Target.

Efremov Institute members of staff - V. Kuznetsov, A. Volodin, A. Komarov, A. Malyshev, N. Stepanov, together with the representative of F4E, P.Gavila (second on the right), and M. Palermo from Ansaldo Nucleare (first on the right), standing in front of F4E's first full-scale ITER Inner-Vertical Target prototype before it is inserted in the vacuum vessel. The tests will be performed at the Efremov Institute, Saint Petersburg, Russia.

The wooden box containing ITER's first Inner-Vertical Target (IVT) prototype left from the workshop of Ansaldo Nucleare (Genoa, Italy) and travelled at least 2 800 km to reach the doorstep of the Efremov Institute (Saint Petersburg, Russia) in order to go through its first tests. Don't feel any pity for this piece of equipment leaving the moderate European climate for a chillier one. It is meant to be resistant and eventually in the ITER machine it will be one of the components that will be exposed to the super-hot temperatures of the plasma. This is why engineers call it a "plasma-facing component".

The IVT prototype, weighing 0.5 t and measuring approximately 1.5 m, is made of 1104 tungsten blocks, which to the eyes of a layman resemble to thick "tiles" made of steel. Its shiny surface is wrapped carefully because it is brittle. In spite of the fact that it can sustain high heat fluxes, its surface can easily be cracked. Each of the eight rows of the tungsten blocks is piled onto a copper alloy pipe in which pressurised water will flow to cool it down. At the Efremov Institute, the host of the ITER Divertor Test Facility, there is an upbeat feeling of anticipation because the staff will get to test this full-scale component for the first time ever. "It's an important milestone attracting the attention of F4E's stakeholders because it will pave the way to manufacturing the real IVT" explains Pierre Gavila, managing this contract on behalf of F4E.

As the equipment gets unwrapped, a series of inspections is carried out to cross-check that it hasn't been damaged in any way. Then the prototype is assembled on equipment which will be used to carry out the tests. It is positioned on a special kind of "table" that can be easily manipulated so as to advance with the water connections and work on the final preparations. The "table" is then rolled inside a vacuum chamber-where in tests will be carried out.

The surface of the prototype will be "divided" into three test areas which will be subjected distinct temperatures. Each area will be tested at a certain heat flux and for a given number of cycles. The curved parts will receive 5 000 cycles at 5 MW/m^2 and the two straight parts 5 000 cycles at 10 MW/m^2, followed by 300 cycles at 20 MW/m^2 respectively. Almost like the "test of fire", these rigorous trials using high-power electron irradiation, will help us discover how much this equipment can take. The tests are expected to run until early 2019. Then, the prototype of the plasma facing unit will be dismounted, packed and returned to Ansaldo Nucleare. Once received, the IVT prototype manufacturing will be completed, and testing will be concluded later in 2019.

"This is the first time an In-Vessel full-scale prototype, produced in line with the ITER requirements, is tested at such length," elaborates Gavila. "The tests will help us to validate the materials, the machining and the route to manufacturing in order to draw lessons for the production of the ITER component."

Remote Handling design for ITER Diagnostics port plugs successfully validated

"These successful tests have shown conclusively that our Diagnostic Shielding Module is well-optimised for remote handling maintenance of port-based diagnostics, a key milestone in our design activities", observes Fabien Seyvet, F4E's Project Manager for Diagnostics port integration activities, after witnessing tests on a full-size mock-up at the RACE centre for robotics and autonomous systems in Culham, UK.

In order to get a good view of the ITER plasma, many of ITERs diagnostics must sit right at its edge: in one of the most challenging environments on ITER. Fortunately, Diagnostic Shielding Modules, or DSMs, are there to provide them a safe home. These steel structures, which are mounted in many of ITERs port plugs and weigh up to 3 t each, support and protect the delicate Diagnostic components whilst shielding from ITERs neutrons. F4E will supply nine such modules; installed in the five Diagnostics port plugs (of 18 in total on ITER) that F4E is providing.

Because the DSMs, and the diagnostics themselves, cannot be handled by humans, maintenance and repair must be done by Remote Handling. Designing a DSM for compatibility with such a difficult task has been a driving requirement behind F4E's Diagnostics port integration activities but the only way to know if the hard work had paid off, was to test in a realistic environment and with actual remote handling tools.

Testing involved critical remote handling operations for the DSM, including splitting the 'clam-shell' design into two halves, and installation/removal of mock-ups for components of the ITER Edge Thomson Scattering (ETS) diagnostics system. The tests were led by experts from RACE, part of the UK Atomic Energy Authority's (UKAEA) facilities at Culham, UK (also site of the world's largest tokamak, JET). Observing the tests were members of F4E's Diagnostics Project Team, representatives of ITER IO as well as of IDOM, F4E's partner company dealing with the design and integration of the Diagnostic port plugs under F4E's responsibility. Also keeping a close eye on the events were members of the Japanese Domestic Agency for ITER, who designed the ETS system.

"We are happy that the Remote Handling compatibility of our Diagnostics DSM design has been proven. We appreciate the collaboration we have had with the Japanese Domestic Agency, our partner company IDOM ADA and ITER IO – together we have paved the way for this favourable result. The experience and qualified staff of RACE have also enabled us to achieve these good results and given us the confidence that our designs will succeed once manufactured", says Glenn Counsell, F4E's Diagnostics Project Team Leader.

With the confirmation of Remote Handling compatibility now received, IDOM ADA will concentrate on developing further the port designs, in view of the future manufacturing and assembly phases.

Members of UKAEA's RACE facility, who led the tests, together with representative of F4E, ITER IO, the Japanese Domestic Agency and IDOM ADA, who designed the DSM.

Preparations underway to give electrical power to MITICA

F4E has installed most of the equipment that will connect the second experiment of the ITER Neutral Beam Test Facility to the grid.

The power supply for the Residual Ion Dump (RID), manufactured by OCEM PE, financed by F4E, has been delivered to MITICA - the second experiment of the ITER Neutral Beam Test Facility, Consorzio RFX, Padua, Italy. On the left, the Acceleration Grid Power Supplies Conversion System, produced by NIDEC ASI, financed by F4E.

In the outskirts of Padua (Italy), at the leafy entrance of Consorzio RFX, a truck has received permission to deliver a bulky piece of equipment at the rear end of its premises where the ITER Neutral Beam Test Facility (NBTF) is located. MITICA, which stands for Megavolt ITER Injector and Concept Advancement, is expected to play a crucial role in the heating systems of the biggest fusion device. Its aim is to develop a Neutral Beam Injector (NBI) prototype similar to the one that will operate in ITER and monitor its performance through various tests.

"Through MITICA we will learn how to manufacture the NBIs that ITER will require in order to deliver the extremely high plasma temperatures" explains Tullio Bonicelli, heading the F4E team for the European contribution to the Neutral Beam, Electron Cyclotron, Power Supplies and Sources. Although neutral beam injection is routinely used for heating gas in fusion devices, MITICA will reach some "mythical" levels of power compared to the existing test beds. It is the result of the in-kind contributions of F4E, the ITER Domestic Agency of Japan, their suppliers, and Consorzio RFX, the host of the facility.

We spoke to Loris Zanotto, working at Consorzio RFX as Deputy Programme Manager for the NBTF, and Project Leader for the Power Supplies, to understand the significance of this milestone. "I feel that the completion of the MITICA power supplies is an outstanding achievement. An important step towards the first-ever neutral beam injector for ITER," he says. "I am very impressed by the extraordinary commitment of the NBTF Team in this challenging project, which is at the very limit of the available power supplies and high voltage technology. We look forward to operating MITICA and to collaborating with all involved partners for the future of fusion and ITER."

Europe and Japan are the two parties responsible for the provision of MITICA's power supplies. All of Europe's equipment has been manufactured. The cost of the equipment, financed by F4E, comes to a total of approximately 22 million EUR. NIDEC ASI, OCEM PE and Siemens are the three companies directly involved.

NIDEC ASI, an Italian medium-size company specialising in industrial electrical systems has produced the Acceleration Grid Power Supplies Conversion System (AGPS-CS). Basically, this piece of equipment will take power from the grid at 22kV AC (Alternating Current) and together with five DC (Direct Current) generators, produced by ITER Japan, will convert it into 1 MV DC. Ultimately, this current will reach the injector to accelerate the ion beam. "Nearly all of the equipment that will give power to MITICA is here" explains Daniel Gutierrez, F4E Technical Officer following this contract. "Our collaboration with NIDEC for the production of the AGPS power supplies began in autumn 2015. Two and a half years later, we are pleased to announce that their units are installed, fully operational, after having gone through extremely demanding factory and site acceptance tests. As the works for equipment of the ITER NBTF are coming to an end, we are now starting the production of the ITER units," he concludes.

Ettore Merli, NIDEC ASI Project Manager, confirms that "from the start we established a partnership with F4E, and the other parties, that went beyond that of a customer-supplier. We looked together for solutions respecting the technical requirements of the project, its schedule and cost. Our contribution to ITER is of strategic importance because it allows us to work in an international environment which promotes cutting-edge technology."

Installing in MITICA's High Voltage Deck, produced by Siemens, the Ion Source Power Supply equipment manufactured by OCEM PE.

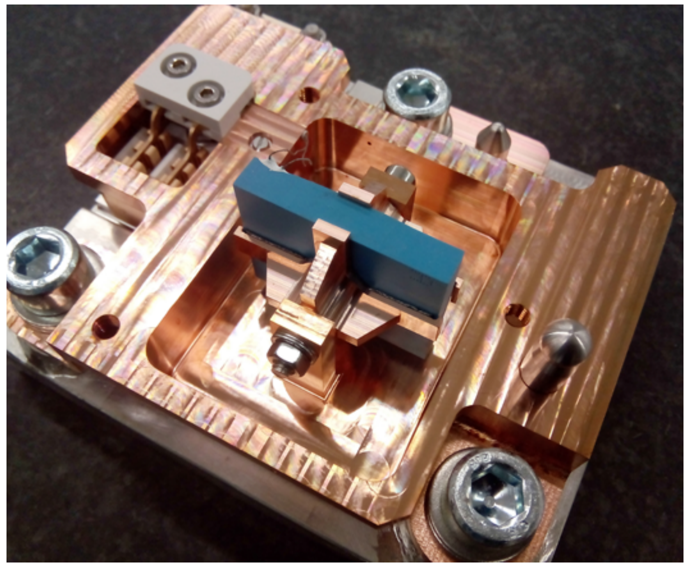
More equipment has arrived at MITICA — this time from OCEM PE. The company has manufactured the units that will supply an average voltage of 25 kV to the Residual Ion Dump (RID), whose role will be "to catch" any of the ions left after the beam has been neutralised. The collaboration between F4E and OCEM PE dates back to 2010 for the manufacturing of power supplies for SPIDER, MITICA (the two NBTF experiments), and ITER.

Giuseppe Taddia, OCEM PE General Manager, recalls: "…today we are almost halfway of the entire supply of equipment, which also includes the units for ITER. Our involvement in the project has boosted our competitiveness and our ability to produce equipment fit for a very demanding environment."

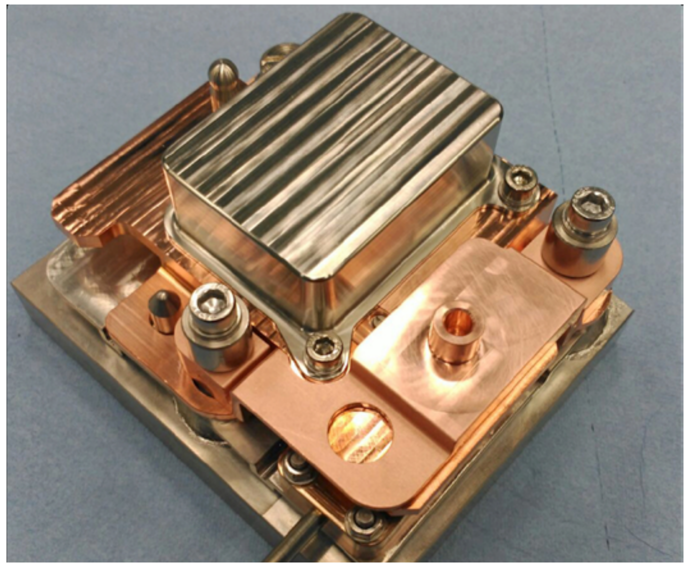
The ISEPS equipment (Ion Source and Extraction Power Supply), was also delivered in December, which will be part of the High Voltage Deck manufactured by Siemens, already installed in the NBTF. The arrival of the ISEPS equipment from OCEM PE, signaled the completion of Europe's contribution to MITICA's power supplies.

Contract signed for Inner Vessel Coil Mechanical Platforms

Sgenia to manufacture 450 platforms into which diagnostic sensors will be integrated, for installation in ITER.



The upper part of the mock-up of the platform that will be manufactured by Sgenia © ITER IO



The lower part of the mock-up of the platform that will be manufactured by Sgenia © ITER IO

F4E has signed a contract worth 1.3 million EUR with Spanish company Sgenia for the manufacturing of platforms into which diagnostic sensors will be integrated, for installation inside the ITER machine. The purpose of these platforms is to provide mechanical support, protection and electrical connectivity for the sensors. This is the largest manufacturing contract placed to date by F4E Diagnostics Project Team.

The sensor-platform assemblies are to be installed on the inner surface of the ITER vacuum vessel in order to measure the local magnetic field around the ITER plasma. Sgenia will produce a total of 450 platforms. Work started in the beginning of October 2018 with a first batch of platform parts scheduled to be delivered in one year's time.

The platforms will boast special features including coatings of tungsten to prevent electomagnetic waves within the ITER machine reaching the sensors; special grade steel and copper zinconium in order to minimise the production of unwanted waste materials; and special ceramic machined to high accuracy where electrically insulating structures are needed.

As the sensors need to be precisely aligned in the ITER vessel to perform their function, the platforms will include features to enable laser-based surveying of their final installation. The platforms contain a large number of intricate parts that are tightly integrated to form a compact assembly, to fit within very limited space available inside the ITER Vacuum Vessel.

Most of the platforms will be constructed in two parts: a base to be permanently welded to the ITER Vacuum Vessel and a 'cradle' housing the sensor, to be bolted to the base, making it removable with remote handing tools to enable replacement of sensors in case they become faulty during the operating life of ITER.

The platforms were designed by ITER IO, with assistance from F4E during the early design stages.

Pre-Compression Rings facility ready. Let the tests begin!

ITER Organization, F4E and CNIM unveil tooling that will put components under pressure.

The tooling which will be releasing a force of 36 000 t to test the quality of the ITER Pre-Compression Rings, CNIM, La Seyne-sur-Mer, France.

A group of engineers working in the ITER project has arrived at a brand new 140 m^2 workshop located in La Seyne-sur-Mer, south of France. The small town takes pride in having one of Europe's finest shipbuilding yards. But as of today, it is the host of a facility where some of the equipment of the biggest energy experiment will be tested. CNIM, a company with a long history in the fabric of the community, has completed in collaboration with Douce Hydro the ITER Pre-Compression Rings test facility. The contract has been awarded to the consortium by ITER Organization. The conceptual designs of the facility and its technical progress have been followed by F4E.

In the centre of the workshop a large piece of equipment consisting of 36 actuators is ready to flex its muscles exercising a force of 1000 t each. They will test the quality of each of the pre-compression rings by checking their resilience to high loads. When one of them is positioned on the tool, the 36 actuators will start to operate simultaneously, maintaining an accuracy of 0.1 mm while releasing a total force of 36 000 t. It is similar to the pressure exercised by 6 000 African elephants, the biggest mammals living on land, when they walk. The stress tests will last a few hours and will be supplemented by other tests to confirm that the creep and fatigue performances are also adequate.

Approximately 40 people have been working round the clock the last 18 months to meet the tight schedule making sure that the facility is fully operational. The first tests will be performed during the first quarter of the year when the first pre-compression rings prototypes will be delivered. "F4E and ITER Organization, in collaboration with the CNIM/Douce Hydro consortium, have worked very hard to deliver this infrastructure on record time. The good team spirit and the commitment of all parties to see this project through have helped us to meet our tight deadline," explains Luigi Semeraro, F4E Metrology Group Leader.

Ions to travel through 8960 holes at top energy

F4E together with ALSYOM-SEIV will deliver the powerful beam source for ITER Neutral Beam Test Facility.

(L-R) Representatives of F4E, ITER Organization, Consorzio RFX, ALSYOM-SEIV at the kick-off meeting of all parties held in Barcelona, Spain.

At MITICA (Megavolt ITER Injector and Concept Advancement), Europe, Japan, ITER Organization, and Consorzio RFX will test one of the heating systems of ITER – a full-scale prototype of the Neutral Beam Injector (NBI) that will operate at full beam power (17 MW).

F4E signed a contract for approximately 20 million EUR with ALSYOM-SEIV (ALCEN group) to deliver the MITICA beam source. The equipment consists of two main parts: a radio frequency ion source and an accelerator of seven grids. The beam source will measure 3 x 3 x 4.5 m and will weigh in total 15 t. Inside this piece of equipment, negative ions will be produced. Thanks to a powerful accelerator they will travel at top energy through 8960 holes and eventually will crush on the calorimeter, which measures beam power based on the level of the heat produced. Given the fact that MITICA mimics the ITER NBI, scientists will be able to make several calculations. For instance, they will be able to have good estimates of the heating power that will be transmitted to the ITER plasma. It will take roughly four years for the equipment to be ready and the teams from F4E, ALSYOM-SEIV, ITER Organization, and Consorzio RFX will be fully involved in its fabrication.

"In mid-2015 we started putting on paper the specifications of the beam source and then worked our way through the tender", explains Antonio Masiello managing this contract on behalf of F4E. "The signature of the contract is the result of years of work, consultations and technical meetings bringing together experts from the Neutral Beam community. Now it's time to convert the specs into equipment."

"The variety of the technologies required to manufacture the MITICA beam source demonstrate the capacity of ALSYOM-SEIV to deliver complex systems required by ITER and Big Science projects in general. We are very proud and excited to reinforce our long term partnership with F4E, ITER Organization and Consorzio RFX through this challenging project where quality and timing are of pivotal importance," explained Eric Griguet, Head of sales and marketing fos Alstom.

Pierluigi Zaccaria, Project Leader for the Neutral Beam Test Facility (NBTF) Thermo-mechanics, working in Consorzio RFX, elaborates on the significance of this milestone for the host institute. "The signature of the contract for the MITICA beam source marks the beginning for a key prototype component of ITER–Heating Neutral Beam Injectors. We have reached this milestone by using the best expertise in plasma physics, beam optics, high voltage insulation, heat removal and stress/fatigue mitigation. The joint efforts and close collaboration of skilled researchers, engineers and physicists from NBTF Team and the ALSYOM-SEIV consortium will be the key for managing and solving the challenging technological issues we will experience during manufacturing. Meanwhile, the operation of the SPIDER beam source at the NBTF site in Padua, offers a great opportunity to an already competent team of experts to get better prepared for the operation and optimisation of MITICA."

For ITER Organization, the MITICA beam source, is the most critical and challenging component for the ITER Neutral Beam Injectors. Members of the IO Neutral Beam team explain that "the start of the F4E contract to manufacture this component is an important milestone for the NBTF Team, the community of experts working in neutral beams, F4E and ITER. The successful delivery of this component will help us carry out experiments at MITICA, which will define the performance of the ITER Neutral Beams. This positive progression in the project is the result of extensive collaboration between F4E, IO, and RFX. Within this framework an important industrial partner, ALSYOM-SEIV, is now included, which has been entrusted to manufacture the most complex and technologically challenging beam source – the heart of MITICA and the ITER injectors."

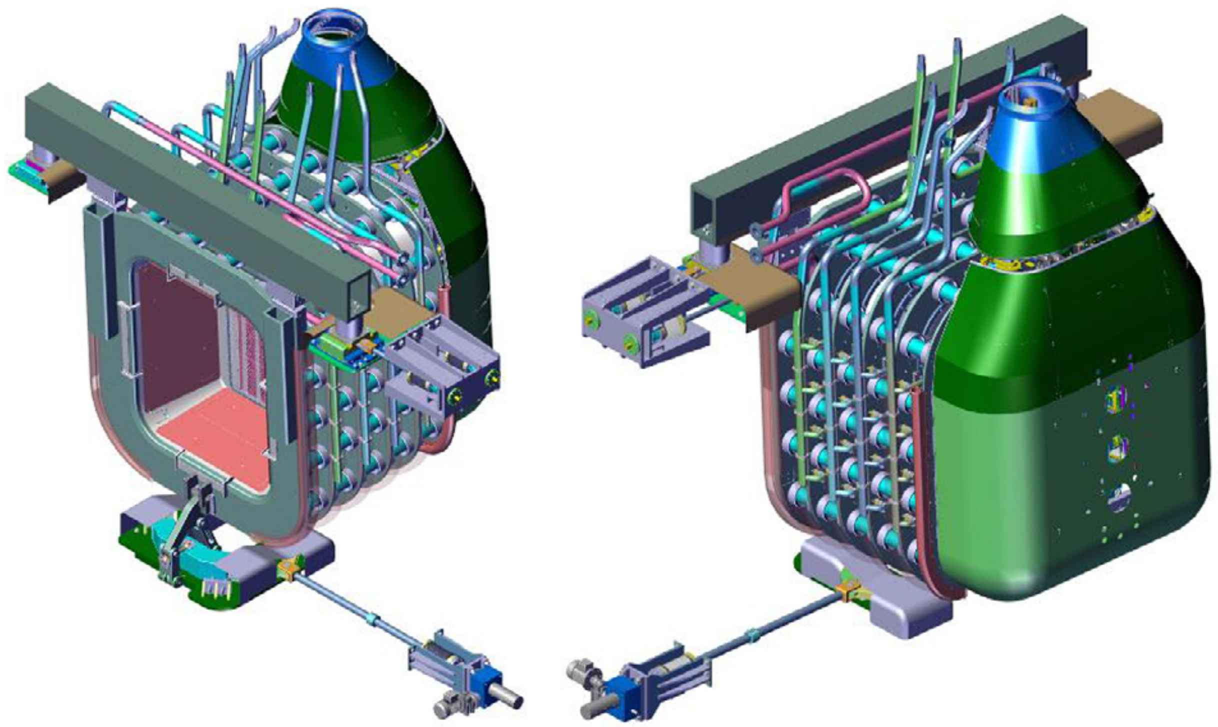


Illustration of the MITICA (Megavolt ITER Injector and Concept Advancement) beam source, part of the ITER Neutral Beam Test Facility, Consorzio RFX, Padua, Italy. The equipment, financed by F4E, consists of two main parts: a radio frequency ion source and an accelerator of seven grids. The beam source will measure 3 x 3 x 4.5 m and will weigh in total 15 t. At MITICA, a full-scale prototype of the Neutral Beam Injector (NBI) will operate at full beam power (17 MW).

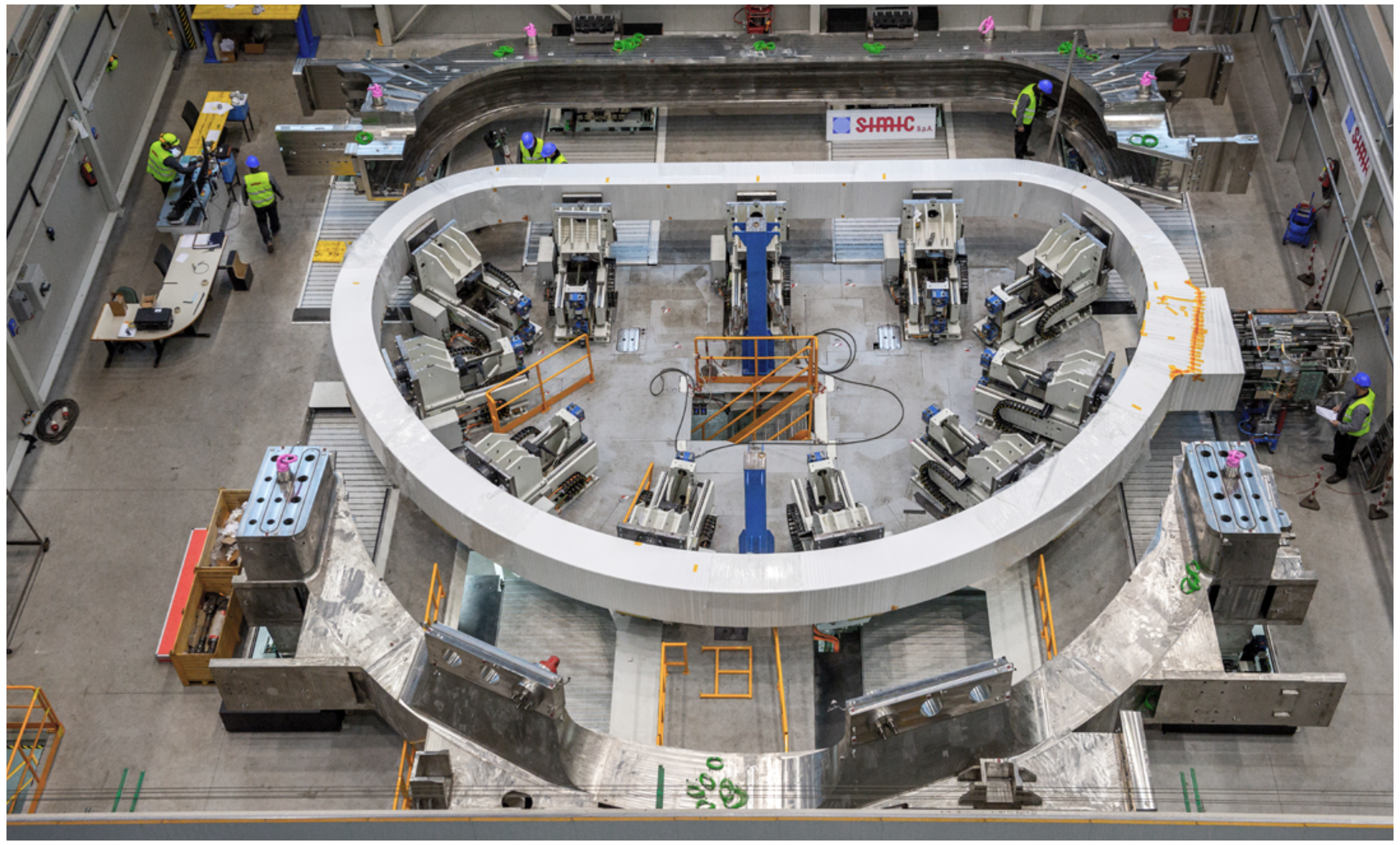
Operation Insertion accomplished

Europe unveils ITER Toroidal Field coil in its stainless steel case - a first in the history of the project.

The clock is ticking for one of the most delicate steps in the fabrication process of the ITER Toroidal Field (TF) coils. “Operation Insertion” may sound like a classified mission to be carried out by experts in a remote location. The stakes are high and there is no room for improvisation. If you didn’t know any better you would think this is the teaser for an action blockbuster. Reality, however, often surpasses fiction and can be even more fascinating. A few kilometres from Venice (Italy), at the port of Marghera, where SIMIC has one of its facilities, Europe’s first Toroidal Field coil has been inserted in its case. The massive winding pack, the inner-core of the magnet with all its equipment, measuring 14 x 9 m, weighing 110 t, is now wearing its heavy stainless steel panoply of approximately 150 t. The TF coil cases, under the responsibility of ITER Japan, have been produced by Mitsubishi Heavy Industries (Japan), and Hyundai Heavy Industries (Korea). They measure no less than 17 x 10 m and almost like an “overcoat” they will protect the magnets whose mission is to confine the super-hot plasma when ITER is up and running.

How did we reach this important technical milestone? Once a winding pack goes through the cryogenic tests it gets wrapped with Tedlar® tape. In parallel, the coil cases undergo a series of checks together with the tooling that will be used in insertion.

When technicians give the green light, the winding pack is lifted and positioned on the assembly rig. Pads are placed on the ground reflecting the D-shape geometry of the winding pack to rely upon them. With the help of the insertion tooling, the cases embrace the massive coil from left and right, and from top to bottom. Operation insertion lasts roughly one month.



Europe’s first winding pack, wrapped with Tedlar® tape, getting ready to be inserted into its coil case, SIMIC, port of Marghera, Italy © SIMIC

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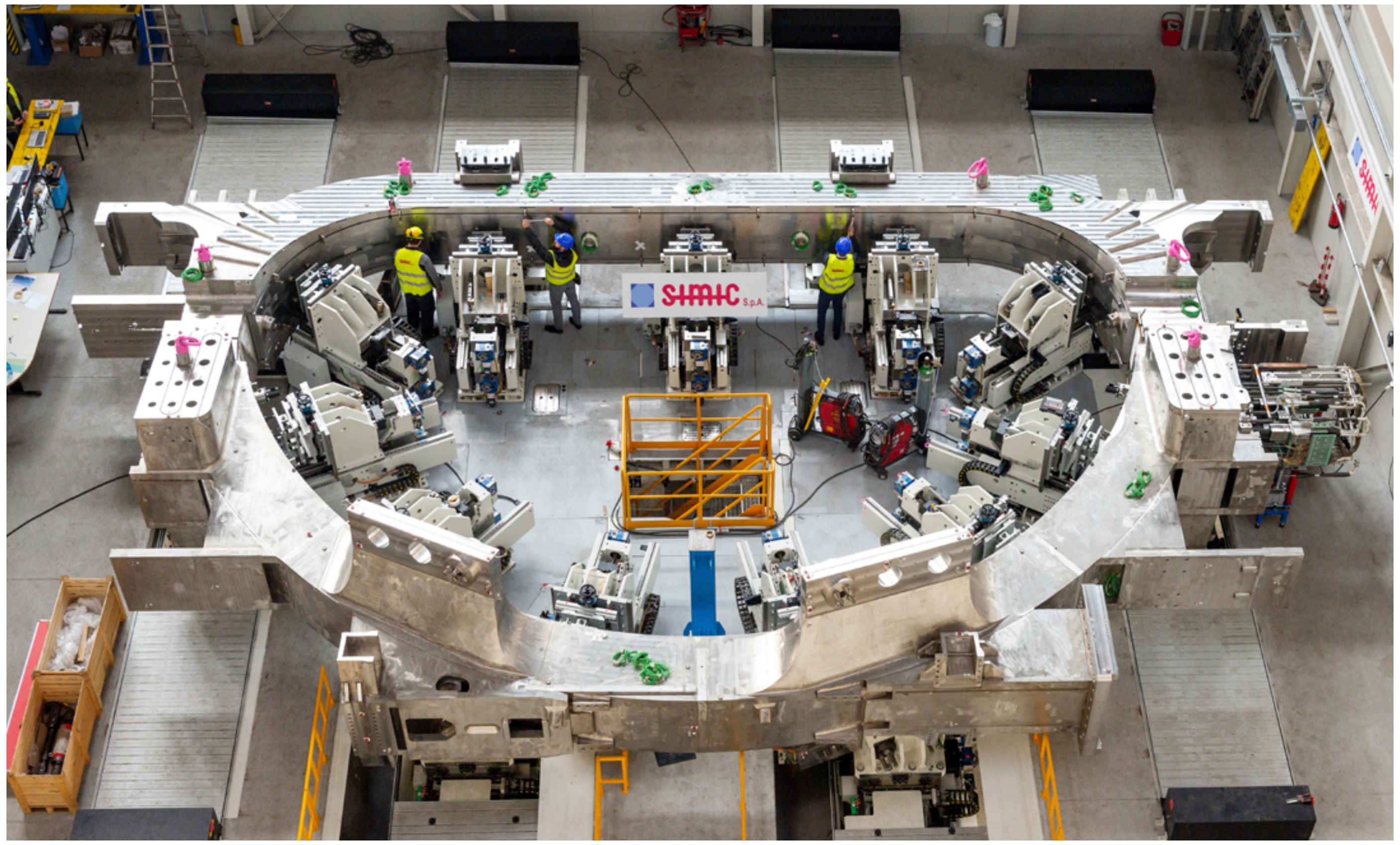
From the moment the component is tucked in its coil case it’s officially considered a TF coil. “What makes insertion such a delicate process is the size and weight of the component – roughly 300 t with its cases — plus the extreme precision required. We are working with accuracies of 0.2 mm” says Boris Bellesia, following closely this contract on behalf of F4E’s Magnets team.

After the massive magnet is inserted into its coil case it’s time to start welding. Normally, it will take between four to six months to complete the welding procedure, initially will be conducted manually, and afterwards automatically with two synchronised robots (narrow gap TIG welding). Then, for nearly two weeks, resin will be injected to fill the gap and to create a mechanical continuity between the cases and the winding pack. Once this step is concluded, it’s time to proceed with the machining of the magnet which is expected to last approximately four months. The magnet will then have to go through another round of final tests and get wrapped to be transported to ITER.

"We have concluded the production of all 70 Double Pancakes and we have successfully inserted the first TF coil in its case. We have reached this point thanks to the excellent technical work and perseverance demonstrated by the different industrial partners who have contributed to the previous manufacturing phases, and thanks to the good collaboration with ITER Organization and ITER Japan. We look forward to this new exciting manufacturing stage during which we will use, just like in the past, our problem-solving skills and our technical expertise,” explains Alessandro Bonito-Oliva, F4E Project Team Manager for Magnets.

Paolo Barbero, SIMIC Project Manager, following this operation in collaboration with F4E, confirms that the insertion of the first winding pack into the TF coil cases has been completed. “Here at SIMIC, it gives us great satisfaction to have reached one of the most important milestones in the TF coil manufacturing process. This operation is technically very challenging, mainly due to the huge size of the parts and the very tight tolerances which need to be achieved. The assembly rig, a special machine designed and manufactured specifically for this purpose, is an extremely complicated automatic gigantic tool, considered as one-of-a-kind. We are impressed by the fact that it has worked remarkably well since the very beginning. We are very satisfied with the high level of precision obtained and this will pave the way for the next manufacturing steps such as the robotized narrow gap TIG welding, where we aim to get top quality results. We would like to thank all teams which spent the last years trying to make this achievement possible.”



Europe’s winding pack inserted into its case coil, SIMIC, port of Marghera, Italy © SIMIC. It is the first time that this operation is performed in the history of the ITER project.

Mapping 10 000 tasks for ITER Divertor Remote Handling

F4E, ITER Organization, experts and companies participate in the Preliminary Design Review of the ITER Divertor Cassette Remote Handling system procured by Europe.

Members of F4E's Remote Handling team attending the workshop on radiation tolerant technologies

In the lifecycle of an ITER component design reviews are known as the moment of truth. Background knowledge, R&D results, systems designs and supporting analyses, forecasts and alternatives are presented to external experts, in-house engineers and teams managing component-interfaces in order to get their support to move to the next stage. Almost like defending a thesis in front of a panel of specialists who are there to listen and to critically question the speaker. During a two day meeting which took place at the headquarters of the ITER project (Cadarache), F4E's Remote Handling team organised the Preliminary Design Review (PDR) of the ITER Divertor Remote Handling system. Experts gathered to learn, ask and assess the work carried out by F4E and its partners.

Europe signed a contract with Assystem Energy & Infrastructure Ltd, UK's RACE centre (Remote Applications in Challenging Environments), Soil Machine Dynamics Ltd (SMD), (VTT) Finland's Technical Research Centre and the Tampere University of Technology (TUT) to work on this equipment. Carine Van Hille, following this multi-annual contract on behalf of F4E, explains why today's meeting matters. "This is the first European system from the area of Remote Handling reaching such level of maturity. The community is eager to learn more about its design and fabrication because something like this has never been done before. We are faced with the constraints of limited space in the machine, massive components which need to be remotely handled with limited viewing inside the reactor. It is truly uncharted territory. Technical teams produced over 500 documents which fed directly to the design reviewed today."

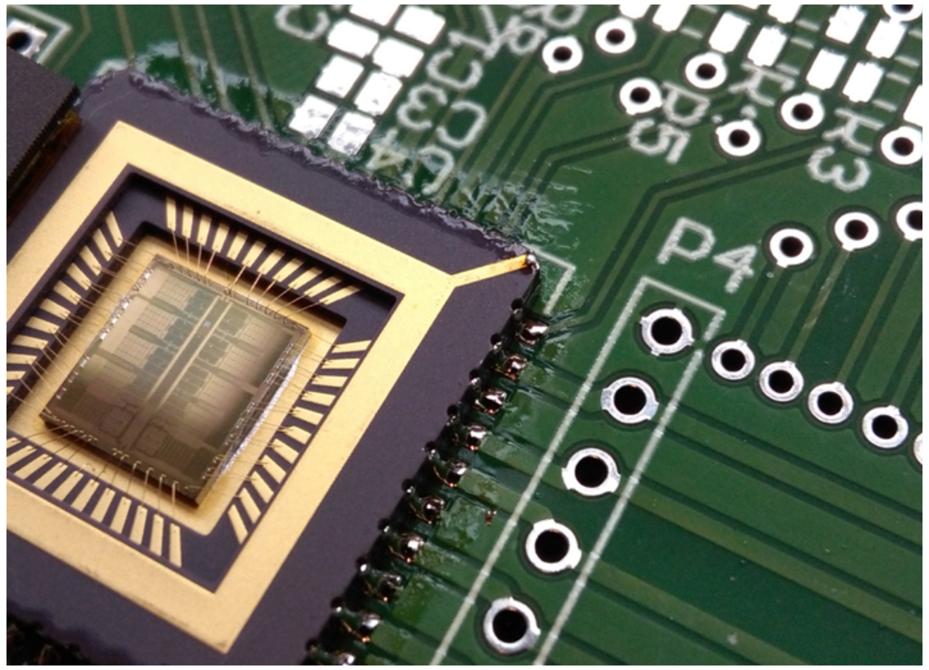
ITER's technical maintenance will partly be carried out remotely. Given the fact that engineers will not be able to enter the machine, they will have to use cameras and smart tooling to access the labyrinth of equipment with extreme precision. It is foreseen that the ITER Divertor Cassettes will be replaced several times during ITER's lifecycle. It is estimated that 10 000 tasks and 4 000 unique functions are required to be carried out in order to replace the component over six months. Man in the loop robotics, powerful computers and water hydraulics will be some of the technologies deployed to perform the task. The proposed design is incorporating radiation hard multiplexing and cameras.

The second session of the PDR was scheduled towards the end of January giving F4E the opportunity to elaborate further on the system and reply to questions raised during the first session. Following its conclusion, the chapter of the Final Design is about to begin.

"I am pleased to see years of work, producing vast amounts of engineering and R&D, culminating in this event. We want to make good use of it through the Preliminary Design Review and, with the instructions and recommendations of the panel, move on to the phase of design. We want to learn from this exercise and draw lessons for the other Remote Handling packages that will go through their respective PDRs in 2019," concludes Carlo Damiani, F4E's Project Manager for Remote Handling.

Experts discuss mix of technologies to cope with radiation

Europe unveils electronics and cameras that could do the job.



Prototype of an electronics integrated circuit chip designed by Magics, contributing to the body of work financed by F4E in the field of rad-hard multiplexers in ITER Remote Handling systems.

Once a year all experts from the ITER Domestic Agencies involved in Remote Handling systems, meet together with the companies and laboratories manufacturing the equipment, to discuss the overall progress and exchange information. The first of these workshops was organised by F4E, the second by ITER Organization. In November 2018, Europe took the initiative to plan the third workshop during which close to 60 participants met virtually to discuss the latest progress in radiation tolerant technologies.

Laura Mont Casellas, working as Technical Officer in F4E's Remote Handling systems, was responsible for the workshop. "We thought of presenting the progress we have made so far in the field of rad-hard Complementary metal-oxide-semiconductor (CMOS) cameras which are suitable for the ITER environment and will allow us to see inside the machine. Due to the space limitation we face, miniature cameras are being developed which will be installed on inspection tooling," she says. The progress results from years of intense collaboration between F4E and various companies, universities and laboratories. Magics, an SME specialised in rad-hard technologies, has designed the electronics integrated circuit chip prototype. Oxford Technologies, part of Veolia, has developed different sub-system mock-ups by bringing onboard the expertise of ISAE, Toulouse, for the image sensors. CEA-DAM has been involved in the illumination system, and the Jean Monnet University Saint Etienne for the optical system. The demonstration cameras have been successfully tested in Belgium's SCK-CEN at different levels of radiation. Next, Oxford Technologies and ISEA will develop an image sensor prototype to be integrated into future industrial nuclear cameras.

The electronics required in Remote Handling was the other subject addressed. F4E has been pushing for a smart solution given the fact that cabling must be kept to a minimum. How can the "brain" of movers and its circuit be neatly installed? Magics and Oxford Technologies, part of Veolia, have been collaborating to develop a multiplexer – in simple words a compact box of electronics — which is able to reduce the number of cables needed for the movers to carry out maintenance works in the machine. Carlo Damiani, heading F4E's Remote Handling systems, explains that "Europe presented the progress of the R&D financed by F4E because we plan using it in the components we have to deliver. On top of that, it could be of interest to other ITER Parties and their suppliers. For instance, companies are eager to learn more about the progress of the work in case it finds its way to future applications they are designing."

Last but not least, the workshop offered the possibility to Europe and Japan to inform participants on the radiation test results on commercial off-the-shelf components for the ITER In-Vessel Viewing system and the ITER Blanket Remote Handling system respectively.

Let's pump that gas from the ITER tokamak

F4E and ITER Organization sign Procurement Agreement that will deliver the cryopump systems for the torus and the cryostat.

(L-R) J. Schwemmer, F4E Director, and B.Bigot, ITER Organization Director-General, sealing the agreement for the cryopump systems

When ITER is operational the gases resulting from the fusion reaction will be pumped with the help of six cryopumps from the lower part of the torus to the roughing system, and two from the cryostat of the machine. The cryopumps, which measure 3.4 x 1.8 m and weigh about 7.8 t, will be identical for both systems. In essence, they will pump gases by absorption on charcoal coated cryopanels at 4.5 K and subsequently will treat them in a closed circuit as part of the fuel cycle.

Following the successful manufacturing of the first cryopump, a Final Design Review of the equipment took place in March 2018. In parallel, F4E launched a market survey inviting Europe's industry to declare its expertise and express its interest in the manufacturing of the components. Today engineers are ready to go ahead with the production of the eight cryopumps. A call for tender will be launched soon and the equipment is expected to be ready by 2023.

Francina Canadell Navarro, F4E Technical Officer following this contract, explains that "one of the most challenging aspects we will face is timing because our schedule is very tight. On the other hand, the production of the cryopumps offers a great learning opportunity to those working in the field of cryogenics to become familiar with the strict set of rules applying to a nuclear environment, with which ITER needs to comply. Last but not least, due to the multiple technologies required for the fabrication of the cryopumps, such as hydroforming, charcoal coating, etc., there is scope for collaboration between many companies."

A Procurement Agreement (PA) was signed between F4E and ITER Organization (IO), according to which Europe will have to deliver six cryopumps for the torus of the ITER device, two for the cryostat, and their respective auxiliary systems. The PA foresees a number of tasks for both parties, among which, Europe with its suppliers will have to manufacture the equipment, and IO will then take care of the installation, testing and commissioning.

How to dectect leaks in ITER's vacuum systems?

Vacuum systems will have an important role to play in ITER. The sheer size of the machine poses a challenge in delivering the right level of vacuum to its different components. Take for instance its vessel, with an interior of 1 400 m³, which will house the fusion reaction; the neutral beam front components, with a volume of 150 m³, which will be used to heat the super-hot plasma; or the massive cryostat, the largest stainless steel chamber ever built measuring 16 000 m³ with a pump volume for 8 500 m³, to isolate the ITER vacuum vessel and the superconducting magnets. All of the above will need to remain leak-tight, operate in vacuum and rely on a system that is able to detect and localise possible leaks. Can you imagine how difficult it must to perform these tasks in a labyrinth of equipment?

F4E has signed a Procurement Agreement (PA) with ITER Organization to develop a final design which will be used to manufacture the leak detection system for primary vacuum of the neutral beam and vacuum vessel, as well as the leak detection system for the cryostat. At a later stage, F4E will procure the Helium leak localisation systems for the cryostat and the leak detection tooling for the in-vessel components.

The connection pipes that will be used for the leak detection system will be approximately 14 m long and have a diameter of 0.5 m. The bigger the diameter of the pipe the faster technicians will be able to detect a leak. The detection units, on the other hand, will have to fit in a very restricted space. Roger Martín Fernández, managing this contract on behalf of F4E, took the opportunity to explain in broad terms the nature of the equipment and some of the main challenges. "The leak detection systems will rely on mass spectrometry instruments using Helium as tracer gas, which is standard technology. However, in the case of ITER the equipment will need to cope with strong seismic loads, radiation and significant magnetic fields. This is where things will get more complicated. We will be working closely with the vacuum industry, giving all the necessary support to design and manufacture these systems, ensuring that they comply with the strict standards enforced by the French Nuclear Authority."

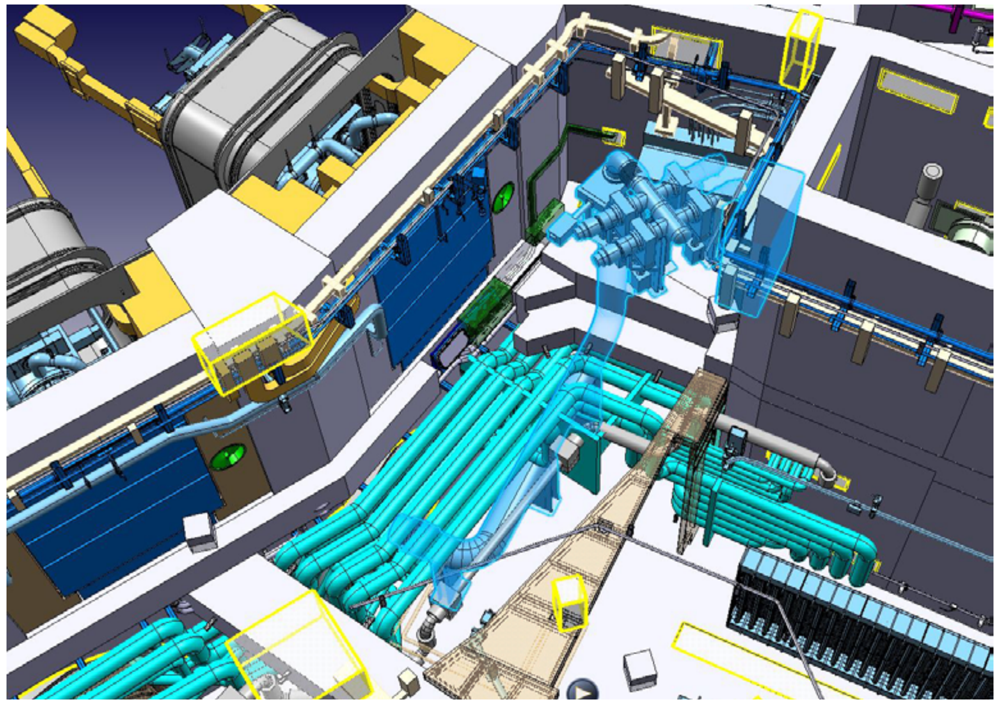


Illustration of the leak detection equipment for the ITER Vacuum Vessel

The process to fabricate the ECH Upper Launcher Blanket Shield Module prototype has been successful

The F4E-ATMOSTAT team which has ensured the qualification for the fabrication of the Electron Cyclotron (EC) Upper Launcher Blanket Shield Module

The four ITER EC Upper Launchers will each inject up to 8 MW microwave power into the ITER machine in order to aide plasma initiation and counteract plasma instabilities during the time the fusion reaction takes place. The plasma-facing structural part of the Upper Launchers is called the Blanket Shield Module (BSM) which is made up of several parts joined together by different welding techniques. The BSM will be heated up to approximately 350°C during ITER operation, thus necessitating a state of the art cooling system. In addition, since the BSM will be fully immersed in ITER's Vacuum Vessel, which is an ultra-high vacuum environment, its metal joints must be of the highest quality.

F4E, together with the French company ATMOSTAT, are working together to enhance the BSM cooling performance. Their joint efforts have resulted in improving the cooling of the flange part by refining the initial channel design. This was ensured using Hot Isostatic Pressing technologies (HIP - a method that involves pressure used to compress the metals together homogenously from every direction), with a more uniform repartition of the water channel within the flange and the definition of a manufacturing route suited for the new water channel geometry.

HIP technologies allows materials to be bonded together by forming a metallurgical bond with diffusion bonding occurring on an atomic level, extending the lifetime of critical components which are subjected to extremely high temperatures and therefore allowing the BSM to comply with the requirement of surviving the entire ITER operational lifetime.

During the HIP process stainless steel and Copper-Chromium-Zirconium alloys are bonded by simultaneously applying high pressure, equivalent to 10 km under the sea, and high temperature, similar to that of the earth at a 40 km depth. The joining is performed in special pressurised furnaces during a long and strictly controlled process. A heat treatment is applied, as a last step, to recover the material structural properties. This final treatment, intended to modify the crystalline structure of the metals, consist on a rapid cooling followed by a low temperature plateau.

To ensure the quality of their HIP process ATMOSTAT has completed a successful qualification process which included mechanical tests, ultrasonic testing and macrophotography on numerous specimens. In addition, this HIP process has also received the stamp of approval from a "Notified body" accredited by the French Nuclear Safety Authority (ASN). It was also confirmed that the BSM internal geometry was not deformed after HIP, despite the high amount of pressure that the metals had been subjected to, achieving one of the main goals of this development programme: to develop a manufacturing route to build the complex cooling geometry of the BSM.

"The qualification approval is the culmination of six months of intense testing in order to ensure that the BSM prototype will be of the highest quality and will function well. We are happy that the results of the testing were so successful. This means that we are on track for the manufacturing of the full-scale BSM prototype, which is expected to be finalised during next year. This is an important milestone for which we have been working very closely with our colleagues at ITER IO in order to ensure that will be achieved on time" says Jose Pacheco, F4E Technical Officer dealing with the BSM.

IFMIF/EVEDA – Engineering and validation of equipment in progress

The experimental facility hosting the world's longest Radio Frequency Quadrupole (RFQ) accelerator prepares for upgrades.

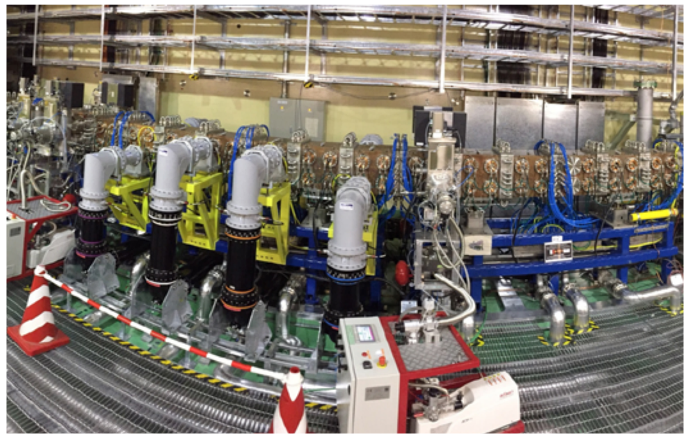
The International Fusion Materials Irradiation Facility (IFMIF)/ Engineering Validation and Engineering Design Activities (EVEDA) is one of the Broader Approach (BA) projects financed by Europe and Japan to perform research and to develop equipment in support of fusion. With the help of LIPAc, a prototype accelerator, scientists will validate the design of a neutron source which will be used to qualify materials for DEMO, the fusion machine after ITER. QST (Japan) working together with F4E, coordinating the European contributions of INFN (Italy), CIEMAT (Spain), CEA Saclay (France) and SCK-CEN (Belgium), have set up this experimental facility with the world's longest Radio Frequency Quadrupole (RFQ) accelerator, measuring 9.8 m, and its eight radio frequency lines supplying a total of 1.6 MW.

The first beam operations campaign was successfully completed. The first particles (protons) reached 2.5 MeV using 50 keV as energy to kick start the operation. The results obtained during the various tests indicate that the LIPAC design is robust enough to operate at a low current. The first beam campaign was successfully completed in August signaling real progress in the validation of the design. In parallel, the Diagnostics components have been installed and are being tested.

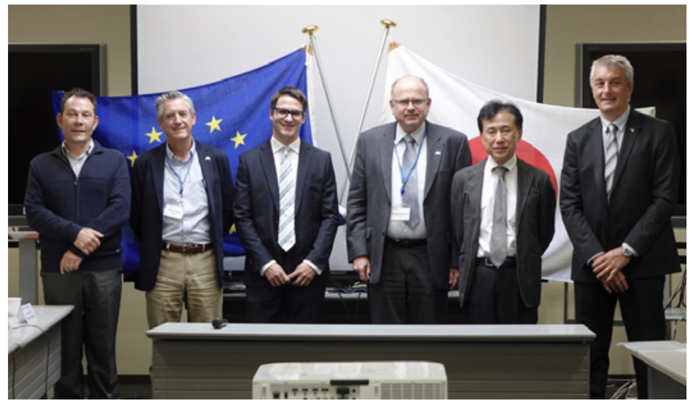
"This first important milestone is of significant importance for those who have been involved since 2014 in the installation and the commissioning of LIPAc. Obviously, we have still a lot to do and deal with several challenges until we reach the final goal. The facility up and running and we are working together to build an attractive device. I think we can all be proud of this collaboration between Europe and Japan particularly when one looks back on what we have jointly developed since 2007 together with esteemed colleagues like P. Garin, H. Matsumoto and J. Knaster" said Philippe Cara, IFMIF/EVEDA Project Leader.

Roland Heidinger, F4E European Project Manager for IFMIF/EVEDA, highlights how this achievement is closely linked to the fusion energy roadmap. "The performance of LIPAc is key to the development and operation of the fusion neutron source— the test facility for materials to be used in fusion devices. In this respect, the LIPAc team has taken a major step ahead."

Additional components like the high energy beam transport line and the high energy beam dump, manufactured by CIEMAT, are in the process of being installed. Along with the October meeting of the IFMIF/EVEDA Project Committee, the transfer of ownership of the equipment from Europe (F4E) to Japan (QST) was signed between the two Parties.



Wide angle of the LIPAc prototype accelerator, Rokkasho, Japan



In October the documents for the transfer of ownership of key LIPAc equipment was signed between F4E and QST. Contributors from CEA (Saclay) , CIEMAT (Madrid) and INFN (Legnaro) were also present

The activities also generated a certain amount of interest to policy-makers. The French Ambassador to Japan, accompanied by various attachés, visited the facility to receive information on the overall progress and the involvement of laboratories and companies from different countries. The first Commissioning and Beam Operation LIPAc workshop was also organised in November, bringing together more than 30 experts from Europe and Japan, to exchange views on the first beam operation campaign, the challenges faced during commissioning and the preparations for the next campaign.

WEST invites East to its control room

Experts from Europe and Japan follow in real time plasma experiment performed 9620 km away.

Experts gathering in the WEST control room (Cadarache, France) during the WEST-REC tests, financed by F4E, as part of the Broader Approach Agreement signed between Europe and Japan © CEA

When there is a will there is a way. Scientists from CEA's WEST (Tungsten Environment in Steady-State Tokamak) fusion experiment, Cadarache, France, virtually "hosted" in their control room several of the colleagues siting in the Remote Experimentation Centre (REC), Rokkasho, Japan. The 8 h time difference and the 9620 km of distance were not an obstacle. In fact, we will see more of these encounters in future given the fact that scientists working in REC will be allowed to follow remotely ITER experiments. This first virtual encounter, qualified as a test, marked the beginning of this trend. Collaboration and technology hold the key to making this possible. Both concepts are at the centre of the Broader Approach Agreement, signed between Europe and Japan, on a number of fusion projects which aim to push forward our know-how. The test was financed by F4E, responsible for the co-ordination of the European contribution to the Broader Approach projects, one of them being the International Fusion Energy Research Centre (IFERC) which supported this initiative.

A total of 70 scientists from both institutes, representatives from F4E, EUROfusion, local policy-makers, journalists and students took positions in the two control rooms to witness the experiment unfolding in the south of France. The moment the countdown started all eyes were glued on the screen, a few seconds later the plasma and its parameters were projected. Both control rooms burst in rounds of applause. The virtual encounter lasted approximately three hours and was the first of such kind. "Witnessing the three plasma shots in real time strengthened the bonds between the two communities as if we were all physically present at WEST experiencing the experiment," explains Susana Clement Lorenzo, following on behalf of F4E all IFERC activities. "Such initiatives help scientists to exchange know-how by sharing data, and train them to perform more of these tests in future. Next year, for instance, we plan to carry out a similar exercise with JET," she explains. Viewing a series of plasma shots from the control room of the biggest Tokamak currently operating is expected to generate a lot of enthusiasm to the members of the fusion community.

Poland rallies support for Big Science projects

ITER, CERN and ESS business opportunities get the attention of a vibrant high-tech community.

The auditorium of the Institute of Nuclear Physics in Krakow, Poland, is filled with 40 representatives from startups and SMEs who have their eyes set on Big Science business opportunities. They are young in the early thirties, switched on and ambitious. They have already participated in international technology projects by delivering tooling, electronics, software or offering their expertise. In their opinion Big Science is not only for big players. There is a level playing field for all and the time is right for them to compete. F4E, responsible for Europe's contribution to ITER, CERN and the ESS are here to brief them on the progress of the projects and most importantly on upcoming tenders, and contractors looking for sub-contractors. One key characteristic of these projects is collaboration. Tasks tend to be too big for one company and by experience smaller companies are more agile, flexible and adaptable. Therefore, there is room for infinite partnerships.

We spoke to Maciej Potocki, President of Wroclaw Technology Park, before the event started to understand the background. "Poland has potential in Big Science. Our companies have discovered the opportunities offered by this market and want to benefit from it. They have the technology and infrastructure to compete with high-tech companies from all over the world. On a day like this we want to show them how they can succeed."

Sylwia Wójtowicz, Poland's Industry Liaison Officer for CERN and F4E, director of development at Wroclaw Technology Park, has been following the evolution of big projects and has been working to make the information available in a comprehensive and accessible way. "Our aim is to integrate Polish business around Big Science, which is why we run projects such as BIG SCIENCE HUB, which premiered today, on Big Science Partner & Industry Day," she explains. "The heart of it is big-science.pl – an online platform which guides our companies on how to establish international business relations in the sector, and which shows that Polish companies are reliable and trusted partners."

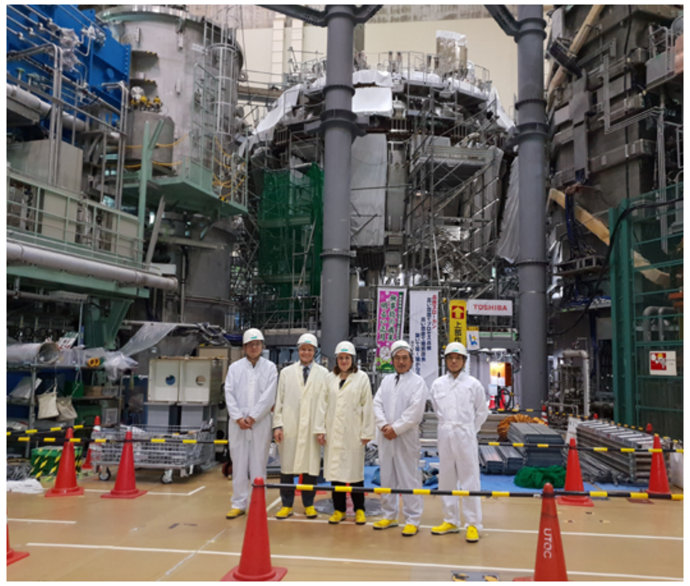
Europe's contribution to ITER is by far the largest out of all Parties and this means more business opportunities. "The F4E calls for tender have generated a lot of interest. The project is now moving into the fabrication of components in areas such as Diagnostics or in Technical Support Services. It is a market ecosystem that smaller companies feel more comfortable participating and flagging their interest" explains Benjamin Perier, representing the Market Intelligence Group. During the half-day event, more than 10 Business-to-Business (B2B) meetings took place and an interesting list of competences has been developed including instrumentation and control, wave length systems, image processing, real time monitoring and data acquisition.

Representatives from various SMEs and startups at the Big Science Partner & Industry Day, Institute of Nuclear Physics, Krakow, Poland

F4E Director strengthens ties with Japanese partners

As a step in maintaining and deepening working relationships with our Japanese colleagues, F4E Director Johannes Schwemmer visited Japan.

From left to right: S. Ohira (QST), J. Schwemmer (F4E), P. Cara (IFMIF/EVEDA), K. Sakamoto (QST) and S. Ishida (QST) standing right in front of the LIPAc.



From left to right: M. Hanada (QST), J. Schwemmer (F4E), S. Günter (IPP), Y. Kamada (QST) and S. Ide (QST) in front of the JT-60SA machine in Naka.

First stop: Rokkasho – the sites of the International Fusion Energy Centre (IFERC) project and the Engineering Validation and Engineering Design Activities for the International Fusion Materials Irradiation Facility (IFMIF/EVEDA). Johannes Schwemmer saw the progress of the projects, met European researchers and the management team of the Rokkasho Fusion Institute – Yoshitaka Ikeda (Director General), Shinichi Ishida and Shigeru Ohira (Deputy Director-Generals).

Travelling on to Naka and the JT-60SA site together with Prof. Sibylle Günter, Head of IPP Garching and during this visit representing EUROfusion, the F4E Director met with Dr Yutaka Kamada, JT-60SA JA Home Team Leader. The Director was notably impressed by the sheer size of the JT-60SA machine which will be the largest tokamak in the world once it starts operating. This year will be full of challenging assembly milestones. The meeting focused also on understanding more about key Japanese technologies for both ITER and JT60SA: the Electron Cyclotron/Gyrotron heating systems; Neutral Beam; and Blanket Remote Handling.

Kenkichi Ushigusa, Managing Director of the Fusion Energy Research and Development Directorate of QST, met with the F4E Director to discuss the strategy of Broader Approach phase II. In addition, F4E and QST will look for more involvement of accelerator and materials research communities from Japan and Europe to strengthen the team and future use of LIPAc. Prof. Sibylle Günter had a key role in these discussions regarding the research planning for the joint exploitation of JT-60SA.

In Tokyo, Johannes Schwemmer met with Dr Gediminas Ramanauskas, First Counsellor, Head of Science and Technology section at the Delegation of the European Union to Japan who demonstrated a strong interest in the BA and ITER research co-operation between Europe and Japan. Together with Makoto Sugimoto, Director of the ITER Department within the Fusion Energy Research and Development Directorate of QST, Johannes Schwemmer visited the Toshiba product operations in Kawasaki and Yokohama. He viewed the manufacturing activities for the huge stainless steel coil case components which will be used, partly by F4E, to build ITER's TF coils. At the Toshiba Keichi plant in Kawasaki, meetings were held with Toru Shibagaki, General Manager of the Keihin Product Operations, who assured Toshiba's commitment to quality and schedule.

European Parliament sets ITER as a tangible example of European added value

EU funding for ITER has generated growth and created new jobs.

The Budgetary Control Committee of the European Parliament, chaired by German MEP Ingeborg Graessle, organised a public hearing on the added value of EU funding on 21 January 2019. The hearing was moderated by its Vice-Chair, Czech MEP Martina Dlabajova who is also the rapporteur in the current discharge procedure of EU agencies and joint undertakings (including F4E) for the 2017 budget. In the framework of the competitiveness panel of the hearing, MEP Dlabajova invited the F4E Director to report on success stories that the EU contribution to the ITER project brings to many European companies and research centres involved in the manufacturing of the high-tech components for this big science project.

Johannes Schwemmer, F4E Director, kicked off the panel discussion with a short presentation on fusion and its benefits, and presented the international partnership to build ITER, one of the largest high-technology projects in modern history. The F4E Director explained the role of F4E, as the domestic agency for ITER, and highlighted the different projects underway to make fusion energy a reality.

Massimo Garribba, Director at the Commission's Directorate-General for Energy, picked up the torch to underline the key role of ITER in the European roadmap for the realization of fusion energy and the important milestone of 60% completion of the project in its drive to reach first plasma by the end of 2025. The Commission director insisted on the significant economic impact of ITER which over the period of 2008-2017 has produced almost 4.8 billion euro in Gross Value Added and almost 34 000 job years, through awarding over 900 contracts and grants in 24 EU countries worth 4.5 billion EUR. European companies report that working on ITER generates a new knowledge base, offers new business opportunities and increases their competitiveness and growth, helping to create additional jobs.

In order to highlight the role of EU industry in the construction of ITER and the benefits arising from their participation in such an international endeavour, two representatives shared their experiences.

Prof. C.J.M. Heemskerk from HiT, a small company in the Netherlands, presented an unexpected but important spin-off generated during the development of the remoting handling systems for the maintenance of ITER, which will be needed once the reactor becomes operational. The R&D in this area has led to a prototype robot ROSE (Remotely Operated SErvice Robot) providing home care support for elderly people and those in need. Prof. Heemskerk added that their involvement in ITER has given the company "an exposure to an international community" and has strengthened their competitiveness as "we have to be on our (their) toes" to fend off potential competitors around the world. In addition, the company has managed to gain contracts from international clients which would have not been possible "without our involvement in ITER".

Giovanni Grasso from ASG Superconductors, an Italian company specialized in superconducting magnet technology has worked for many big science organisations such as CERN and ITER. The superconducting technology which has been developed over the years for fusion has led to a number of spin-offs in sectors such as health (magnetic resonance scanners and health therapies). The most recent important spin-off from the ITER work consists of a superconducting cable which may be used for energy transmissions over last distances across Europe.

In the discussion that followed, a number of MEPs took the floor to highlight the benefits for European industry arising from their participation to the project. Italian MEP Flavio Zanonato underlined the important industrial investment realized in Padova in building a Neutral Beam Test Facility to develop the most challenging heating system for ITER.

In concluding the competitiveness panel of the European added value hearing, MEP Dlabajová thanked the participants and highlighted "the real and tangible added value" coming from the EU support of the ITER project.

Chairman of European Parliament Budget Committee visits the ITER Site

Jean Arthuis expresses his admiration for the project

Inside the ITER Cryostat, from left to right: Laurent Schmieder (F4E Manager for Site & Buildings), Jan Panek (Head of ITER Unit, European Commission), Jean Arthuis (Chairman of the Budget Committee, European Parliament), Bernard Bigot (ITER Director-General), Johannes Schwemmer (F4E Director).

Jean Arthuis, Chairman of the Budget Committee of the European Parliament visited the ITER site on 1 February. The French MEP, and former Minister of National Economy and Finance, was welcomed on the site by Bernard Bigot, ITER Director-General, Johannes Schwemmer, F4E Director, and Jan Panek, Head of the ITER Unit at the European Commission´s Directorate-General for Energy.

B. Bigot provided a detailed explanation of ITER, underlining the remarkable progress of the project in the last years pointing the way to first operations by the end of 2025. Johannes Schwemmer highlighted the role of Fusion for Energy (F4E) in delivering the EU contribution, and the significant benefits of investing in the biggest international research project in the field of energy. The manufacturing of the EU components represents a significant injection of EU funds in the industrial fabric of the Union generating growth and jobs for the economy and new business, lasting international partnerships and innovation for the participating companies.

The French MEP spent more than two hours on the site currently dazzling with activity, with stops at the Poloidal Field Coil factory to witness the progress of the gigantic poloidal field coils manufacturing and at the Cryoplant where Europe has installed the liquid nitrogen plant of the impressive cryogenic system needed to cool down the powerful magnets of ITER. The site tour continued with a visit of the Cryostat workshop where the Indian Domestic Agency is manufacturing the largest stainless steel high-vacuum pressure chamber ever built, inside which the ITER machine will be housed, before arriving at the towering Assembly Hall where some of the components will be pre-assembled before being installed in the adjacent Tokamak building, the heart of the ITER machine.

Following the visit of the ITER site, the Chairman of the Budget Committee expressed in his social media account (@JeanArthuis) his admiration and pride for ITER, "a project that epitomises what intelligence, science and technology have the audacity to undertake for the future of humanity."

Fusion for Energy
The European Joint Undertaking for ITER and the Development of Fusion Energy

C/ Josep Pla, 2
Torres Diagonal Litoral, Edificio B3
08019 Barcelona - Spain

Tel: +34 93 320 18 00
E-mail: info@f4e.europa.eu

www.fusionforenergy.europa.eu
www.youtube.com/fusionforenergy
www. twitter.com/fusionforenergy
www.flickr.com/photos/fusionforenergy

F4E News is a magazine published by Fusion for Energy (F4E)

Editor: A. Apollonatos
Design: M. Boulguy
Contributors: S. Arshad, B. Bellesia, T. Bonicelli, A. Bonito – Oliva, G. Calchi, F. Canadell Navarro, P. Carra, S. Chatzipanagiotou, S. Clement Lorenzo, C. Damiani, R. Darbour, S. Esque, P. Gavila, L. Guerrini, D. Gutierrez, R. Heidinger, G. Leidenfrost, M. Linjama, P. Lorenzetto, R. Martín Fernández, A. Masiello, M. Mendez, N. Mitchell, L. Mont Casellas, J-M. Pacheco, B. Perier, E. Ruiz Morales, H. Sairiala, J. Schwemmer, L. Semeraro, S. Shamsie, L. Siivonen, A. Teissier, C. Van Hille

For free subscriptions, please specify your requirements via e-mail: press@f4e.europa.eu

Printed by Bietlot in Belgium
ISSN 1831-5887 (Print)
ISSN 1831-8800 (PDF)

Publications Office

Fusion for Energy receives funding from the European Union budget

FU-AB-18-003-EN-C (Print)
FU-AB-18-003-EN-N (PDF)