# F4E NEWS

Fusion for Energy Newsletter

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The ITER Assembly Hall building

# The roof of the ITER Assembly Hall building has been lifted

An imposing steel structure standing like a giant has risen from the ground overlooking the Tokamak complex. It is no other than the Assembly Hall building where the high-tech components of the biggest-ever fusion device will be assembled.

It has taken approximately seven months to erect the 22 columns that weigh 6 000 tonnes upon which the 800 tonne roof relies. The operation had to be carefully planned in order to lift the load bit by bit and cope with the wind to position the roof exactly. The teams of F4E, ITER IO, the VFR consortium, Martifer, VSL and Apave have been preparing for this moment, which took nearly 36 hours to be completed, for some time. Under the watchful eye of 25 engineers and support staff, 22 hydraulic jacks, all connected to six hydraulic pumps, carefully lifted the roof from the ground.

Bernard Bigot, ITER Director-General, was also there to witness parts of the operation and highlighted the importance of the work stating that "without this building there would be no assembly, and without assembly there would be no machine and no project". For Laurent Schmieder, Head of Buildings Infrastructure and Power Supplies, and his team this has been an important milestone. "The challenge was to agree on a date with all parties taking also into consideration the weather forecast. Once this was agreed there was no turning back. Our goal was to coordinate the different contractors during the multiple stages of this operation in a seamless manner" he explains. We spoke to Gaël Nocenti working for VSL, the company responsible for the heavy lifting, to gain some insight into the logistics. "First we started lifting the roof 20 cm from the ground to check the jacks and tooling. Then we had to wait for the topographical surveys which lasted approximately 12 hours. The following day we continued lifting the roof, an operation that lasted 16 hours, until it reached a height of 60 meters. We are proud be a part of the ITER project and see it taking off".

The Assembly Hall building stands out due to its impressive size: 100 metres long, 60 metres wide and 60 metres high. Its construction started seven months ago with a workforce of 50 people who had to erect its steel structure. There was, however, a tricky challenge in all this: where would they assemble the massive roof? The decision was taken to erect the facades of the Assembly Hall and build the roof on the ground from where it would be eventually lifted. The team of engineers had to work round the clock so they could lift the roof and the facades on the same day, but not at the same time. To give you an example, the days and nights before they had to fix the more than 65 000 bolts. Thanks to this creative planning, the task has been completed three months earlier than foreseen.

As the roof was lifted and installed, there were signs of relief and satisfaction. This was an achievement that deserved a small symbolic celebration: 500 yellow and blue balloons, reflecting the colours of ITER and the EU, were released in the steel structure to reach the sun. The same source of energy that ITER aims to bring to earth.

View on F4E YouTube


The roof the Assembly Hall building has been lifted, ITER construction site, September 2015 - © ITER IO

# First European component for Neutral Beam Test Facility delivered

The first F4E component for the Neutral Beam Test Facility (NBTF), the SPIDER High-Voltage Deck (HVD), has been delivered and accepted at the NBTF at the Consorzio RFX site in Padua, Italy.

During the acceptance tests of the SPIDER High-Voltage Deck (HVD) at the Neutral Beam Test Facility (NBTF) at the Consorzio RFX site in Padua, Italy.

F4E have collaborated with the Italian company COELME in order to design, manufacture and install the HVD, a mechanical structure which will hold the set of power supply equipment weighing around 40 tonnes. The delivery and acceptance of the HVD marks the end of a four-month installation period. Each individual sub-component has undergone several checks and tests before performing the final electric tests for the whole HVD. Since the testing involved high voltage conditions (reaching up to 130 kV), it was important from a safety point of view to also ensure that the area was properly isolated and that all present at the testing were properly briefed about safety coordination.

"This is a major achievement", said Daniel Gutierrez, F4E Technical Officer. "We are especially pleased because we have not faced any major problems during installation or testing and everything has been carried out in accordance with our planned time schedule", he added. "The HVD is now ready to host the Ion Source and Extraction Power Supplies (ISEPS) which are necessary for feeding the ion source of the Neutral Beam injector".

The ion source produces ions (particles with electric charges – either positive or negative), from which neutral particles originate. The neutral particles will be injected in the ITER plasma in order for the plasma to obtain the temperature and conditions necessary for the fusion reaction to occur. The NBTF will house two independent test beds, namely SPIDER (Source for Production of Ion of Deuterium Extracted from Radio frequency plasma), where the first full-scale ITER ion source will be tested and developed with an acceleration voltage up to 100 kV; and MITICA (Megavolt ITER Injector and Concept Advancement) which will be the first 1:1 full ITER injector aiming at operating up to the full acceleration voltage of 1 MV and at full power (16.5 MW). F4E will supply the ITER machine with two neutral beam (NB) injectors (i.e. two similar injectors such as in MITICA).

The HVD is a vital component for the SPIDER experiment. It measures approximately 13 × 11 metres, the HVD is installed in a pit around 1 metre below ground-floor level, and is mounted on supporting insulators so that it can withstand the high 100 kV voltage of the power supplies. The HVD is covered by a closed aluminium screen which reduces electromagnetic interference that could have a negative effect on the equipment inside and the power supply.

The acceptance of the HVD is not the end of F4E's collaboration with COELME. The SPIDER Transmission Line (TL) is the component on which work will focus during the coming months. The TL will connect the power supplies installed inside the HVD to the SPIDER ion source and beam acceleration. Measuring around 30 metres in length, the Transmission Line uses unique double-screening sandwich panels which give extra protection against electromagnetic interference. The manufacturing stage of the TL will come to an end by November this year and its site installation is expected to start before the end of 2015.





# Successful completion of quench protection circuit procurement for JT-60SA

Work on JT-60SA is rapidly moving forward: the final acceptance tests of the quench protection circuit (QPC) for the superconducting coils have been successfully completed.

The quench protection circuit has an important safety function in the JT-60SA machine: superconducting coils are needed to confine the fusion plasma, but if, for whatever reason, the coils stop being superconducting, it is necessary to immediately discharge them to avoid damage from overheating. This protective function is performed in JT-60SA by the 13 QPC units that, when operated, allow rapidly dissipating the huge magnetic energy stored in the coils (>2.3 GJ in total) into a set of discharge resistors. The quench protection system applies an innovative hybrid mechanical-static circuit breaker technology to interrupt dc currents of more than 25 kA withstanding reapplied voltages of about 4.2 kV. Large design margin was taken to improve reliability and to further increase it an explosively actuated circuit breaker is included as back-up protection.

The QPC are procured by the Italian Research Council (CNR) acting through Consorzio RFX in Padua, Italy, within the frame of an "Agreement of Collaboration" with F4E. It is the first time such advanced hybrid circuit breaker technology has been used in industrial application for this high current and voltage ratings, and for this reason a dedicated R&D activity has been performed since 2007 in Padua.

In 2010, the contract for the QPC procurement (including design, manufacturing, testing, transportation, installation, commissioning and final test) was entrusted by Consorzio RFX to the Italian supplier Nidec ASI, which endorsed the innovative solution and launched an intense qualification process with the manufacturing and testing of two complete prototypes before starting the series production of the 13 QPC units in 2013.

The QPC installation in Japan started in December 2014, representing the first occasion of activities directly performed by European personnel for JT-60SA at the Naka site: a special VISA dedicated to Broader Approach activities has been issued by Japanese government for the European personnel involved in the QPC installation.

After the completion of commissioning activities, the final acceptance tests were successfully performed in June 2015, allowing the closure of the QPC procurement activities on 31 July 2015, according to the original schedule.

One of the 13 QPC units after installation in Naka, Japan.

# First heat exchangers for the ITER Liquid Nitrogen plant and auxiliary systems ready

Think of the ITER Cryoplant as a massive fridge that will produce and distribute cooling temperatures in the machine through different networks. Air Liquide, gas technology global leader, technologies and services for industry and health, has been entrusted with the manufacturing of the components that will perform this task.

F4E's Roger Martin with representatives from Air Liquide and Sumitomo Precision Products standing next to the first 80 K loop heat exchangers





The most advanced cryogenic technologies will be deployed to generate the extremely low temperatures needed for the ITER magnets, thermal shields and cryopumps. The magnets will be cooled with super critical helium to reach a superconducting state at 4.5 K, close to absolute zero, in order to confine the hot plasma that will reach 150 million ˚C.

Europe will provide the Liquid Nitrogen (LN2) Plant and the auxiliary systems that will cool down, process, store, transfer and recover the cryogenic fluids of the machine. Two nitrogen refrigerators will be manufactured along with two 80 K helium loop boxes, warm and cold helium storage tanks, dryers, heaters and the helium purification system.

F4E, ITER International Organization and Air Liquide are celebrating an important milestone with the successful factory acceptance testing of the first two heat exchangers for the 80 K loop boxes, which represent the first manufactured equipment for a contract signed in December 2013. These exchangers are aluminium plate fin type, brazed under vacuum in order to achieve high leak tightness internally and externally. They have been manufactured in Amagasaki, Japan, by Sumitomo Precision Products and they are on their way to Europe.

Six additional heat exchangers are being produced by the same company. Four of them, which are roughly 5 m long and with a cross-section of 1.5 m by 1 m, will ensure the main cycle exchanges for the LN2 Plants as well as the 80 K Helium loops. The two remaining ones, 3.1 m long with a cross section of 1.3 m by 1.1 m, will provide subcooling for the LN2 Plants. All six are expected to be delivered by the end of the year to be integrated into their respective cold boxes. Following the go-ahead that was received at the Preliminary Design Review of the Cryoplant in September 2014, the purchase orders for the heat exchangers were issued and manufacturing started a few months later.

The heat exchangers reflect the high performance requirements and strict quality and safety standards for the sophisticated operational system of the ITER machine. They are considered as “key components” due to the fact that are essential for the refrigeration of the cryogenic system. They have been designed and manufactured with the highest classification concerning quality requirements. The components have to comply with stringent leak tightness requirements, given the fact that once inserted into the perlite cold boxes they will no longer be accessible.

The brazed aluminium heat exchanger for the LN2 Plant at the workshop of Sumitomo Precision Products

# See the arrival of the first-ever European components to ITER

Europe, the biggest shareholder out of the seven parties contributing to ITER, the largest international scientific collaboration in the field of energy bringing together 80% of the global GDP and 50% of the world's population, has celebrated a symbolic milestone with the arrival of its first-ever piece of equipment to the project's seat in Cadarache, south of France.


View on F4E YouTube

Ensa makes history delivering Europe's first-ever equipment to ITER

F4E and Ensa, a Spanish company responsible for the design and manufacturing of six tanks that will be part of the fusion reactor's fuel cycle system, have made history the moment the equipment crossed the gates of ITER. The European contribution to ITER is in the range of 50%. In other words, Europe's industry, SMEs and laboratories will have the opportunity to develop and manufacture almost half of the components required through the contracts launched by F4E. Currently, Europe has signed more than 400 contracts reaching a cumulative value of 3 billion EUR with more than 250 companies and 50 laboratories.

The contract awarded to Ensa builds on the expertise of Empresarios Agrupados and GEA as subcontractors. It has taken roughly 20 months for the six tanks to be designed and manufactured, and their cost is in the range of 2 million EUR. Pietro Barabaschi, F4E's Acting Director, explained, "The arrival of this equipment marks the beginning of a long list of components that we, as Europeans, have the duty to manufacture and deliver to ITER – the biggest fusion energy project". Rafael Triviño, Ensa's Managing Director, stated "ITER is an impressive technological project and it has been a great honour to be the first European company supplying the first components".

**The scope of the contract**

The six large-sized tanks are part of ITER's water detritiation system. When ITER starts operating, the purpose of these tanks will be to collect the water containing tritium in order to recover it and subsequently use it in future fusion reactions. Four tanks, weighing approximately 5 tonnes and measuring 20 m³ each, will be part of this system. Two bigger tanks, weighing approximately 20 tonnes and measuring 100 m³ each, will be used for the tritium recovery phase in exceptional circumstances. The six tanks will be initially kept at a safe area, and once the Tritium plant is ready, they will be installed in the building. Ensa had to comply with a series of stringent safety and quality requirements that apply to ITER components.

**The role of the water detritiation system**

To get fusion going, two hydrogen isotopes- deuterium and tritium- need to collide at extremely high temperatures reaching 150 million °C. According to the sequence of actions of the ITER fuel cycle, the two hydrogen isotopes will be supplied in the machine through the Tritium plant. The two isotopes will travel through the pipes of the system to reach the core of the machine and fuse to release energy. What is left from the fuel of the fusion reaction, together with other gases produced, will return through pumps to the Tritium plant in order to recover the tritium and use it to start all over a new series of fusion reactions





# Europe achieves major technological milestone in ITER TF coils manufacturing

Europe is responsible for the manufacturing of 10 out of the 18 Toroidal Field (TF) coils of the ITER machine. The gigantic "D" shaped superconducting magnets will create a magnetic cage where the super-hot plasma will be confined.

Their main challenge will be to keep the 150 million °C plasma burning without touching the walls of the reactor's vessel. The double pancake is a large D-shaped disk that is 13 m long, 9 m wide and 0.1 m thick. It is composed of a stainless steel plate, known as the radial plate, with grooves machined on both sides and where a 450 m long insulated superconductor is located and impregnated.

A major part of the works linked to the TF coils manufacturing unfolds in the ASG facilities, located in La Spezia, Italy. It is where key processes such as winding, heat treatment, insertion of the superconductor inside the radial plate and laser welding of the radial plates-produced by SIMIC and CNIM, take place. Recently, an important milestone was celebrated in Europe: the first-ever double pancake prototype successfully passed a series of technically demanding tests. It is a reassuring result for Alessandro Bonito-Oliva, F4E's Project Manager for Magnets, and his team, as well as all the suppliers involved, all of whom have been working relentlessly towards this achievement. The technology they have opted for and the method of working have proved to be right. It is also important to mention the importance of the role played by the ITER International Organization TF coil Central Team and the respective team of the Japanese Domestic Agency. The excellent collaboration between the three teams, offering a dynamic exchange of technical reviews, expertise and information, has also played an important role towards the successful completion of this milestone.

Representatives of F4E, JADA, Toshiba, Mitsubishi, ASG Super Conductors, Iberdrola Ingeneria and Elytt Energy pose inside the first-ever completed Double Pancake

So what did the tests entail? In order to check the capability of the prototype to withstand the cryogenic temperatures of ITER, the double pancake was first cooled down to liquid nitrogen temperature, which is approximately -196 °C, and then, it was brought back to room temperature. Afterwards, the prototype went through a series of tests to check its response to High Voltage above 2 KV in air, and was also tested in Paschen conditions, considered as the most demanding electrical conditions due to the fact that even a tiny insulation defect would cause failure. Last, but not least, the prototype went through a leak test. All hurdles were passed without any problems. It is also worth highlighting the impressive dimensional tolerances achieved which indicated only a minute deformation of less than 1 mm in the prototype, in spite the 900 m long laser welding applied to the radial plate.

"This is an important technological step towards the manufacturing of one of the biggest and most complex superconducting coils ever produced. It is the result of the partnership established between F4E and ASG Superconductors, Iberdrola Ingeneria, Elytt Energy, CNIM and SIMIC", explains Alessandro Bonito-Oliva. The TF coils production series is moving at a galloping pace. 32 radial plates have already been produced by CNIM and SIMIC, 36 double pancakes have been wound, 30 of them have already been heat-treated, of which 11 have been transferred inside a radial plate.

# F4E awards one of the largest robotics contracts in the field of fusion energy

The ITER machine will consist of an unprecedented number of high-technology components that will require a vast range of bespoke devices for operation and maintenance. F4E has awarded one of the largest robotics contracts to date in the field of fusion energy to Amec Foster Wheeler, a UK innovation leader with a proven track record in energy.


(L-R) Carlo Damiani, F4E Project Manager for ITER Remote Handling Systems congratulating Ian Grayson, Boiler Spine Programme Director of AMEC Foster Wheeler

All activities ranging from design, manufacturing, factory testing, delivery, on-site integration, commissioning and final acceptance tests for ITER's Neutral's Beam remote handling system will be covered through this contract as it unfolds progressively. Its value is in the range of 70 million EUR and it is expected to run for seven years. Under the leadership of Amec Foster Wheeler, a group of laboratories and companies such as CCFE- the Culham Centre for Fusion, the UK's national fusion research laboratory, Reel SAS of France, Wallischmiller Engineering GmbH of Germany, Hyde Group of UK, Capula of UK, "KU Leuven-MaGyICs" of Belgium, VTT – the Technical Research Centre of Finland, and the Technical University of Tampere will share their expertise in robotics and contribute to the work.

F4E Acting Director, Pietro Barabaschi, explained that "thanks to this collaboration, leading innovators will be joining forces to deliver high-end engineering for ITER's maintenance system and will push forward know-how in robotics, a field with many applications". Clive White, President of Amec Foster Wheeler's Clean Energy Business, said: "This contract reinforces our company's strong expertise in remote handling and robotics, and more generally in taking a key role in the design and development of future fusion energy reactors".

**What is remote handling?**
Remote handling helps us to perform a task without being physically present where it is being carried out. For example, it is widely used in space exploration missions, underwater repairs or challenging maintenance works. The operations require extreme dexterity and milimetric precision. Technical staff will be specifically trained to use the equipment that combines inbuilt intelligence and intuition, together with advanced robotics, tooling and virtual reality platforms.

**Why ITER needs a remote handling system for the Neutral Beam Cell?**
ITER's superhot plasma will reach 150 million ˚C with the help of powerful injectors and heating systems. The confined space in the machine together with the weight of the tooling and the exposure of some components to radioactivity will require the use of remote handling systems during maintenance. The equipment in the Neutral Beam Cell falls under this category due to the nature of the tasks performed. A Diagnostic Neutral Beam Injector will measure the temperature, density and other properties of the plasma; two Heating and Current Drive Neutral Beam Injectors will fire high energetic particle beams in the plasma in order to raise its temperature.

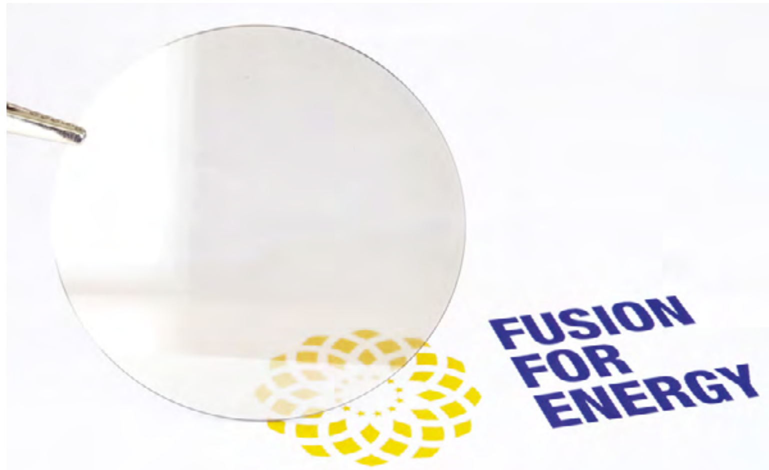
**How will the ITER Neutral Beam Cell remote handling work?**
A sophisticated repair hub will use a 90 m monorail that will spread over the Neutral Beam Cell, and will consist of transfer trolleys, beam line transporters and a variety of supporting beams that will operate in perfect coordination with tooling and manipulators. Some of the key tasks performed will include the maintenance work of the Neutral Beam Injectors, with the cutting and welding of myriads of pipes, and the transportation of heavy components coils to the Neutral Beam Cell storage area or to its main entrance for refurbishment and disposal.





# Diamonds for fusion

Its unbreakable, transparent nature and capacity to dissipate heat five times higher than that of copper, makes diamond, the hardest material on earth, and particularly useful for ITER's tokamak Electron Cyclotron (EC) heating system.




An example of the diamond disc prototype currently being produced

The EC system, will heat the plasma up to 150 million °C by transferring the energy from electromagnetic waves into the electrons of the plasma which is necessary for the fusion reaction to occur, by injecting an unprecedented 1 to 2 MW of power up to 56 beam-lines (tubes that guide the power). This very high power has to be transmitted safely and efficiently across the 80 mm diameter diamond disk, for durations of up to 3 000 seconds.

The power supplies of the EC system convert the electricity from the grid to provide the correct current and voltage to the source of the EC waves (gyrotrons) that in turn generate the electromagnetic waves. The gyrotrons are located some 100 metres away from the tokamak in order to avoid perturbations from its magnetic field. The beam-line leads the electro-magnetic waves from the gyrotron to the ITER vacuum vessel through an antenna which transmits and directs the waves to the electrons inside the plasma chamber. Since both the gyrotrons and the chamber have to remain vacuum tight, and since the radiofrequency waves propagate in a manner similar to light, the only way to get them out of the gyrotrons and into the chamber is through a window — a diamond window – and F4E is responsible for procuring 60 such windows.

The core of the window is the diamond disc, and in collaboration with ITER IO and Karlsruhe Institute of Technology (KIT), F4E has entrusted the manufacturing of two prototypes diamond disks to a German SME named Diamond Material which is based in Freiburg. Manufacturing of the diamond disc, the 1.1 mm thick part of the window where the electro-magnetic waves will travel, is currently under way and is the result of some 10 years of development at KIT and the Fraunhofer Institute (IAF) where the owners of Diamond Material previously worked.

"The diamond disc will be integrated into a mechanical structure which needs to be extra robust and mechanically stable in order to withstand the harsh ITER tokamak environment and ensure that the diamond window does not fail. Vacuum-tightness is also of upmost importance since the window will confine the tritium gas used for fuelling the ITER plasma and thus the disc is key element for the confinement", explains Gabriella Saibene, F4E Project Team Manager for Antennas and Plasma Engineering.

How exactly is a diamond window produced? The production of the disc is a slow industrial process: chemical vapour deposition (CVD) is the method by which diamond can be 'grown' from a hydrocarbon gas mixture. The CVD growth involves substrate preparation, feeding varying amounts of gases into a chamber and energising them. By controlling the pressure and temperature of about 800 °C in the growth chamber, the hydrocarbon gas is ionized into chemically active radicals using microwave power. During the 'growth', the gas in the chamber is ionised, (a plasma is formed), the molecules are broken off and they deposit very slowly on the substrate (about 1 micron per hour) and incorporated in the diamond thus making it 'grow'. After weeks of this process, the diamond disc has grown to its required thickness, so that it can be polished, measured and then mounted into a metallic structure to make a 'window'.

"Thanks to the very successful collaboration between F4E, ITER IO and KIT and Diamond Material, we have been able to progress exceptionally well", enthuses Gabriella Saibene. "The next step will to carry out optical and mechanical testing, as well as check how the disc will resist fractures (fracture toughness) and how well it brazes (joins with metal) as it needs to be attached to a copper mechanical structure. Conclusion of the testing and the conclusion of the entire two diamond window prototypes is expected in less than one year's time", she adds.

# DAHER signs a multimillion contract for global logistics

F4E has entrusted DAHER, a French company counting more than 150 years of experience in the fields of manufacturing and integrated logistics, with the transport of its share of components. The prestigious deal signed between the parties is in the range of 100 million EUR and is expected to run for at least two years.


From now on in all future F4E contracts, DAHER will be named Europe's exclusive logistics service provider. Its mission will be to deliver F4E's impressive share of ITER components to the project site, in Cadarache, from many different international locations. As host, Europe will pick up the bill for the services of DAHER used by the other ITER parties – China, Japan, India, the Republic of Korea, the Russian Federation and the US – to transfer their components from Marseille's Marignane airport or Fos-sur-Mer, its sea port, to Cadarache. The condition, however, is that the other ITER parties will have to use DAHER as logistics provider to ship their equipment to France. Bringing together the different contributions is putting together the pieces of the biggest energy puzzle. Rigorous planning, adaptability and excellent co-ordination between ITER parties, suppliers and French authorities will underpin the implementation of this contract and will reinforce the image of Marseille as an international hub.

**The scope of the contract**

Approximately 4 000 European loads will be transported through this contract, which will be divided between exceptional loads, as it was the case for the delivery of the water detritiation tanks earlier this month, and conventional loads, such as pumps or more conventional equipment that could fit in containers. In addition, 220 highly exceptional loads will also be transported through this contract. These are components that due to their exceptional weight and size will need to be transported at night, following a specific itinerary, and accompanied by representatives from the forces of the gendarmerie so as to minimise any disturbance that may be caused to locals. Two successful convoy rehearsals have already been conducted in September 2013 and April 2014 for the transportation of such loads. They were carried out by DAHER in collaboration with F4E, ITER International Organization (IO), Agence ITER France and the French local authorities. The arrival of the US transformer in January 2015 made history being registered as the first real highly exceptional load entering the ITER site.





# F4E signs contracts for the pre-qualification for the Divertor Inner Vertical Target

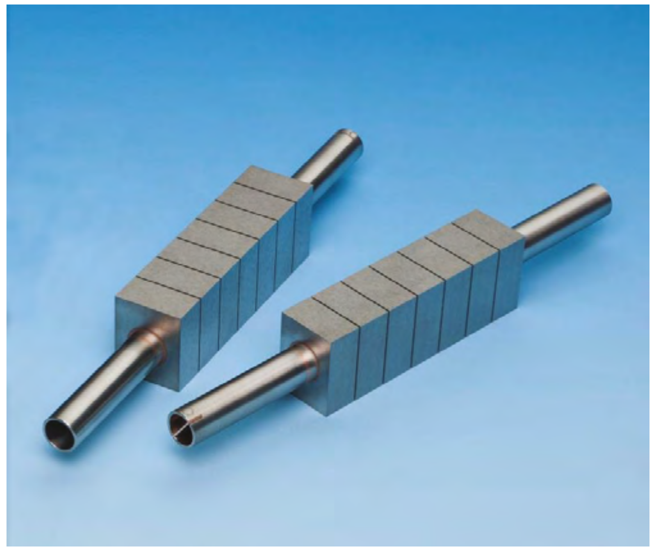
With the objective of fostering competition, F4E has signed framework contracts for the manufacturing of divertor inner vertical target (IVT) prototypes with the two French consortiums ALCEN-ATMOSTAT and CNIM-TPI, as well as the German company Research Instruments.
These three contractors join the already existing approved contractor Ansaldo Nucleare in their bid to pre-qualify as F4E suppliers.

The multiple framework contract involves two stages: The first (pre-qualification) stage entails each of the contractors validating the fabrication technologies they have proposed by manufacturing and testing small-scale mock-ups of the IVT. Contractors who submit small scale mock-ups that pass F4E's acceptance tests can then re-compete for the second (qualification) stage of the framework contract, namely the manufacturing of full-scale IVT prototypes.

With different companies contracted, F4E ensures that competition is healthy and fair. An additional advantage is that different technologies will be developed that mitigates technical risks. "We are working to find the right compromise – we need enough different contractor companies for the pre-qualification stage in order to have enough competition when we then get to the qualification stage", explains Patrick Lorenzetto, Project Team Manager of F4E's In Vessel Team. "All these companies will be able to develop their skills and technologies while manufacturing the small scale mock-ups which will make them valid possible contenders for winning the second stage of the contract for the full-scale version. That we use resources at this first stage will help us mitigate risks and additional costs later on during the series production stage, when the actual components for the ITER machine will be manufactured", he adds.

Located at the very bottom of the vacuum vessel, the ITER divertor is made up of 54 remotely-removable cassette bodies, each holding three plasma-facing components (namely, the inner and outer vertical targets and the dome). The technical design will enable the targets, in their lower part, to intercept the magnetic field lines, and therefore divert (thus the name 'divertor') the high particle heat flux load coming from the plasma. F4E is responsible for providing the inner vertical target, the cassette bodies and the mounting of all the plasma-facing components, together with the required diagnostics and instrumentation, on the cassette body. The Japanese and Russian Domestic Agencies are responsible for providing the outer vertical target and the dome respectively.

With the framework contract signatures now in place, the companies will have approximately 18 months for the manufacturing of the IVT small-scale mock-ups. The second stage of the competition, the manufacturing of the full-scale prototypes, is scheduled to be launched by the end of 2016. This latter stage should last about two and a half years after which the Call for tender for the series production will be launched.



Examples of how the small-scale mock-ups of the Inner Vertical Target (IVT) could look when completed.

# Ferrovial collaborates with F4E to heat up ITER's mega plasma

The progress of the civil engineering works on the ITER construction site is visible. Key buildings like the Tokamak complex, where the biggest-ever fusion device will be located, and the Assembly Hall, where hundreds of bulky high-tech components will be assembled in order to be fitted correctly in the ITER machine, are constantly evolving.
A new chapter is about to begin on the site with the development of infrastructure that will supply ITER and its different systems with electricity.

Two new substations where high voltage electrical networks, including seven transformers, will be installed in order to supply the ITER machine and some of its systems with power, are to be delivered through a contract signed between F4E and Ferrovial Agroman. The works are expected to be completed in six years and will reach a value of approximately 30 million EUR. The design, installation, commissioning and maintenance of the electrical networks, combined with civil engineering works of the buildings that will host the electrical devices, will materialise through this contract. For Pietro Barabaschi, F4E Acting Director, "This contract sets the foundations of the power supply that ITER will require in order to demonstrate the viability of fusion energy at this scale". Alejandro de la Joya, CEO of Ferrovial Agroman, explained that "Thanks to this contract, Ferrovial Agroman has the opportunity to be further involved in ITER and establish itself as one of the most committed contractors. We are extremely proud to be part of the most ambitious international energy project".

**The ITER site:**
The size of the ITER platform is 42 hectares and Europe is the party responsible for the delivery of the 39 buildings and areas that the ITER platform will host. Currently, the personnel directly involved in construction counts 400 people. One of the key challenges will be to accommodate the needs of the rapidly growing workforce and to guarantee an optimal use of space to the different companies operating on the ground, in order to carry out the construction of all infrastructures in parallel and on time.

**The ITER electrical network:**
A total power of 1 200 MVA will be made available through a Pulsed Power Electrical Network (PPEN) and a Steady-State Electrical Network (SSEN). For example, the AC/DC converters, the Heating and Current Drive systems, and the Reactive Power Compensation will be supplied through the PPEN, whose high voltage components will come from China. Thanks to this electrical network, the ITER plasma will be heated and the powerful superconductive magnets will operate in order to confine it. Meanwhile, the major consumers of the SSEN, whose high voltage components will come from the US, will supply with power the cryogenic and cooling water systems, the tritium plant and the general infrastructures. This network will provide the power needed to generate the low temperatures for some of the components in the machine.

**The scope of the contract:**
Through this contact, apart from the electrical equipment that will be provided such as substations containing circuit breakers, lines, disconnectors, transformers, and medium and low voltage load centres, it is envisaged that infrastructure works will be carried out and one building will be constructed.





# Final Works Acceptance of the JT-60SA gaseous helium storage vessels successfully completed

On 5 February the Final Works Acceptance tests of the six helium pressure vessels to be provided by Europe for the JT-60SA cryogenic system were successfully completed.

Side view of one of the six vessels for which the Final Works Acceptance tests have now been concluded.

The cryogenic system can be described as a large plant for cooling helium to very low temperatures with an equivalent refrigeration capacity of 9 kW at 4.5 K (-269 °C). The plant will provide helium at 80 K to the thermal shields, at 50 K to the current leads, at 4.4 K to the superconducting coils, and at 3.7 K to the cryopumps of the JT-60SA Tokamak. The JT-60SA Tokamak, is being constructed in Japan under the Broader Approach Agreement between Japan and Europe.

The Final Works Acceptance tests of the six vessels, which consisted of verifications to ensure that the components conform to international standards and to ensure that there are no defects, was carried out during a period of seven days each. Their completion is an important milestone and brings the operation of the JT-60SA machine one step closer.

In total, the six pressure vessels will store 3.6 tonnes of gaseous helium. Each pressure vessel is 22 metres long, has a diameter of 4 metres and a 250 $m^3$ volume, and weighs about 73 tonnes. As the vessels will store pure helium, the tightness and cleanliness requirements are demanding.

If a fast discharge of the current in the superconducting coils is necessary, one of the vessels is also designed to receive cold helium (-254 °C) discharged from the coils through the cryogenic system quench line. F4E has performed a fluid dynamic study of the impact of this event on the quench line and this pressure vessel. The results have shown that the use of a special 18 metres long helium diffuser system and of a thermal barrier connector at the quench line flange avoids local chilling of the vessel wall below the minimum allowed temperature of the material. The procurement of these components has been added to the supply contract during the contract execution without impacting on its deadline.

The contract for the supply and transport to Japan of the pressure vessels and their equipment has been awarded by F4E to A. Silva Matos Metalomecanica SA (ASMM) (Portugal). Collaboration has been very efficient and successful – the project has run on budget and on time with the earliest delivery date (two months ahead of the contractual date), in spite of the very stringent schedule. In less than nine months from the kick-off meeting, the detailed design, manufacturing and testing of these large components have been completed according to the ASME VIII div. 1 rules (particular requirements standards with regards to quality control).

The six helium pressure vessels will now be shipped to the Hitachi port in Japan. The last difficult operation will be the road transport of the vessels from the port to Naka and their installation on site, which is planned to be executed before the end of June 2015.

The Works Acceptance team consisting of representatives from F4E and ASMM

# The EU design of the gyrotron for ITER is pre-validated by F4E

F4E's work on the gyrotron, a part of ITER's Electron Cyclotron (EC) heating system, is progressing well and the EU design of the gyrotron has been pre-validated.

Fabrication and testing is currently being carried out on the short-pulse gyrotron.

It is the EC heating system that will heat the plasma in the ITER machine to the sweltering temperature of 150 million °C necessary for the fusion reaction to occur by transferring the energy from electromagnetic waves into the plasma electrons. These radiofrequency (RF) waves are generated by devices called gyrotrons located some 100 metres away from the tokamak. The RF waves are guided to the launchers attached to port plugs of the vacuum vessel for injection into the plasma, so that they can transmit their energy to the electrons.

Responsible for providing six of the ITER gyrotrons (the remaining 18 gyrotrons will be delivered by the Russian, Japanese and Indian ITER Domestic Agencies), F4E is working on the development of the final gyrotrons for ITER which will exude radio frequency waves of 170 GHz – the work is being carried out step-by-step on various different gyrotron prototypes. In collaboration with the European Gyrotron Consortium (EGYC) (which consists of several European Fusion Laboratories, namely KIT - Germany, CRPP - Switzerland, HELLAS - Greece, CNR - Italy, and USTUTT - Germany, and ISSP - Latvia as third parties) and Thales Electron Devices (TED), a French company, fabrication and testing is being done on short-pulse gyrotrons (where the radio frequency of 1 MW is typically produced for a few milliseconds, and where the gyrotron has a very limited active cooling so it is especially adequate for testing different subassembly configurations). In parallel, a long pulse Continuous-Wave (CW) industrial prototype, which will produce a radiofrequency wave of longer duration of several minutes, is being manufactured and will be delivered during the autumn.

Also, a mock-up of the cavity, the gyrotron subassembly where the radio frequency waves at 170 GHz will be generated, is currently being developed by TED and F4E and tested at the FE200 high heat flux test facility of AREVA, a company based in France. The inner walls of the gyrotron cavity, a small cylinder with a diameter of 40 mm and a length of 15 mm, made out of a Glidcop Copper-based alloy (which is especially adequate to withstand high temperatures while maintaining a high electrical conductivity), is the most critical in terms of heating. During the generation of the radio frequency waves, some energy will be lost and will heat the walls of the cavity with more than 20 MW/m$^2$. Pushing the limits of the technology of today, these high thermal heat loads will be dissipated using a specific water cooling technique. In order to verify the capabilities of this cooling technique, detailed computational fluid dynamic analysis has been performed by the Polytechnic School of Turin.

The work on the gyrotron prototypes and cavity mock-up follows a development programme which specifies project goals in order to reduce the technical risks and monitor progress. The first project goal was reached in the holding of a meeting to carry out the pre-validation of the gyrotron – this entails validating the most critical components and the scientific design of the gyrotron, i.e. all the R&D aspects contributing to the generation of the required amount and quality of radio frequency power. The meeting was held in April and attended by representatives from F4E, EGYC, TED and ITER IO. The results which were presented during the meeting have been highly encouraging – all activities are considered to be fully successful and the short-pulse gyrotron is producing an exceptionally good output beam of more than 1 MW at the right 170 GHz frequency (up to 1.4 MW has been achieved) in a broad operational domain. The second milestone, which is the full validation of the gyrotron technical design, is expected during the first half of 2016.





# Turning point for European Test Blanket Module Systems

ITER will give a one-of-a-kind opportunity to different scientists around the world to test a range of technologies in unprecedented conditions. Without a doubt, the lessons drawn will have significant implications towards the design of future fusion reactors like DEMO.

Experts and representatives from F4E and ITER IO during the Conceptual Design Review of the European Test Blanket Module Systems

Experts working in the area of Test Blanket Modules Systems (TBMS) are among those who will use ITER to understand how tritium can be continuously bred in order to keep the fusion reaction going. In essence, they will be generating a new nuclear system and licensing it using advanced materials and top fabrication techniques.

Europe has developed two blanket concepts: the Helium-Cooled Pebble-Bed (HCPB) and the Helium-Cooled Lead Lithium (HCLL). The key difference lies in the type of materials used for the tritium breeder. In order to choose which way to go for DEMO, it has been decided to test both European concepts simultaneously in ITER by placing the TBMS in an equatorial port of the machine. Under the leadership of F4E, companies like IDOM, Atmostat, AMEC Foster Wheeler, Empresarios Agrupados, Assystem, Iberdrola, and European fusion laboratories such as KIT, CEA, ENEA, CIEMAT, UJV, KFKI, NRG, have been collaborating extensively to push the R&D frontiers further.

Years of hard work and a documentation exceeding 1 500 pages of engineering reports have come to crunch during the Conceptual Design Review (CDR) meeting, organised jointly by F4E and ITER International Organization on 8-12 June in Barcelona, gathering 30 distinguished experts from this field in order to review and assess the progress so far. In a nutshell, the main objectives of the meeting were to check how the requirements of the systems have been properly taken into account in the design, how risks have been taken into consideration and have been minimised, and whether all boundaries of the system in ITER have been established and secured. For Yves Poitevin, F4E's Project Manager for European TBMS, and his team, "This has been a turning point for the field because years of R&D work have taken shape and evolved into an engineering design that one day will be a system in ITER".

The assessment of the CDR panel was overall positive praising the high quality of work and making some recommendations. This has been a big deal for those involved in this system the last 15 years, witnessing its transformation from the early concepts elaborated in European fusion laboratories to engineering design and standardised manufacturing procedures developed in collaboration with industry.

# Discover the ITER Divertor Remote Handling System

**The biggest-ever fusion device will be bringing together a vast range of technologies defining to a great extent the design and operation of the future fusion reactors. Remote handling will be one of the technology fields that will generate a lot of enthusiasm and interest due its futuristic mix of tools such as high-tech robotics, high-speed networks and virtual reality platforms.**

One of the most fascinating aspects of ITER is the way high-tech robotics, virtual reality and the transportation of heavy-load equipment within a tightly confined space, will be inter-connected in a seamless manner to deliver the remote handling systems of the biggest-ever fusion device.

Such systems are needed because it is either dangerous or impossible to be physically present and perform inspections or maintenance works. Think for instance of the Mars rover space mission or underwater operations that had to rely on this mix of technologies. In the case of ITER, the components of the divertor will need to be installed, inspected and replaced when the 150 million °C of the super-hot plasma is switched off. All these tasks can only be performed through remote handling.

At VTT, Finland's Technical Research Centre, in collaboration with the University of Tampere, they have been proudly hosting a facility known as the Divertor Test Platform (DTP2) over the last six years. A team of experts has been relentlessly working together with F4E in order to test the movement and transportation of one real size component mock-up in order to draw lessons and use this knowledge at the final stage of manufacturing of the systems. A dark piece of metal weighing roughly 10 tonnes and measuring 3.3 m x 2.3 m x 0.8 m is in full contrast to the white rails upon which it is resting. To those not familiar with ITER it may look like a massive snail. To others who know the project inside out it is what we call in ITER jargon – a divertor cassette. The machine will have 54 cassettes in total and they will form the ITER divertor. This component will absorb a significant amount of the heat during operation and shield the lower part of the vacuum vessel and magnets from the neutrons. How will this work? In practice, the powerful magnets will divert part of the hot plasma together with the "ashes" and impurities from the walls of the vessel and direct them to the massive ashtray formed by the divertor cassettes.

For Carlo Damiani, F4E's Project Manager for Remote Handling systems, and his team, this is a big day. They have arrived to Tampere, where DTP2 is located, to witness the demonstration of the central cassette mock-up being installed and removed. There is an unusual buzz in the facility and every protocol needs to be respected. The remote handling operators take positions in front of the big screens in order to perform the test with extreme precision and dexterity. All eyes are glued on the monitors as the 10 tonnes start moving gracefully on the rails. Different parameters are rolling in front of our eyes indicating speed, angles and the time left to complete the task. On the screens we see the cassette emerging, slowly and subtly lifted and finally locking. They did it! For Salvador Esqué, following this project on behalf of F4E, it is a feeling of relief and excitement. "It's almost like a camel going through the eye of a needle. Can you imagine the millimetric precision that is required and the weight that we are lifting and transporting? It's really impressive".

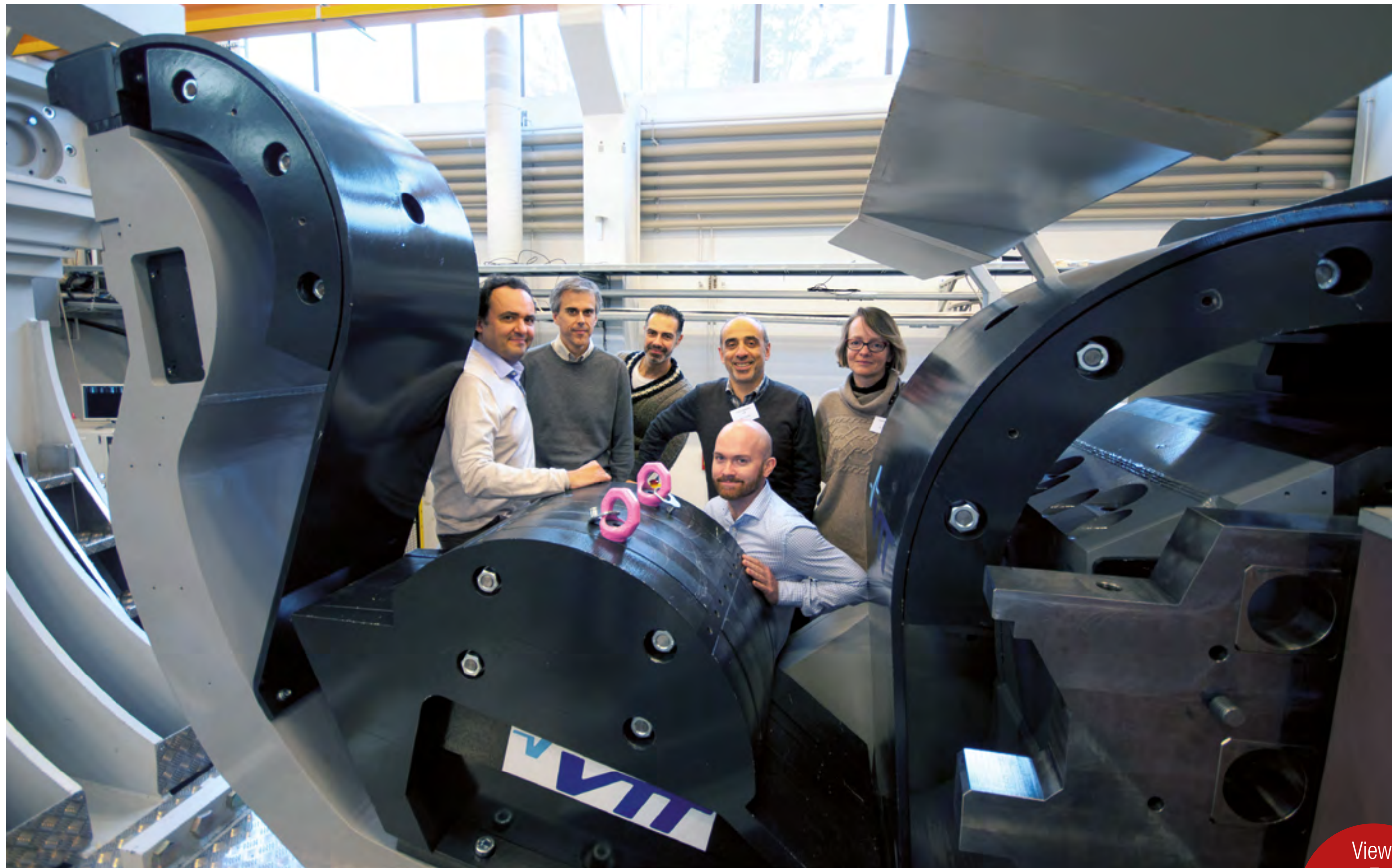
The test is successfully concluded and Carlo Damiani is already thinking of the next steps. "What you have just seen is the beginning of a brand new technology chapter written thanks to ITER. We need to design and manufacture remote handling systems that are resistant, agile and precise. It's an opportunity for industry, SMEs and laboratories to think out of the box, innovate in engineering and shape the future fusion reactors". Europe's contribution to ITER's remote handling systems is in the range of 250 Million EUR. F4E and its suppliers will have to deliver the divertor and Neutral Beam Remote Handling systems, the Cask Transfer system and the In-Vessel Viewing and Metrology system.

Jouko Suokas, VTT Executive Vice President for Smart Industry and Energy Systems, is also present at the demonstration and after thanking his team he explains that "playing a role in this big-science project has helped us to generate new know-how. To give you an example, we have developed new expertise in areas like mechanical engineering, manipulator arms, special tooling, control system software, virtual reality and so on… The potential spin-offs and expertise are some of the key reasons of our involvement. The possible industrial applications are widespread in the field of industry, such as in off-shore movable machine manufacturers, power plants or the manufacturing industry".

The R&D that started in the DTP2 facility has successfully found a niche in the partnership of companies and laboratories led by Assystem UK, a leader in innovation and engineering consultancy, for the design, manufacturing, delivery, on-site integration, commissioning and final acceptance tests for the ITER Divertor Remote Handling system. The value of the contract, awarded by F4E, is in the range of 40 million EUR and brings onboard some of the pioneers from the area of remote handling in Europe such as the UK's Culham Centre of Fusion Energy (CCFE) and Soil Machine Dynamics Ltd (SMD) together with the Tampere University of Technology (TUT) and VTT. Through this contract, the complete set of cassette movers, manipulators and tools will be designed and manufactured.








The F4E team behind the ITER divertor cassette mock-up before the tests begin.

View on F4E YouTube


The ITER divertor cassette mock-up. Its weight is 10 tonnes and measures 3.3 m x 2.3 m x 0.8 m.


F4E and VTT representatives following the tests from the remote handling room.

# F4E concludes final design review for its contribution to ITER Cryoplant

To achieve fusion energy the ITER device will have to cope with extreme temperature fluctuations. The fusion fuel will need to be heated at 150 million ℃ to obtain the biggest-ever plasma reaching 840 m³. Meanwhile, the powerful magnets will need to be cooled with super critical helium to reach a superconducting state at 4.5 K, close to absolute zero, in order to confine the hot plasma. The magnets, thermal shields and cryopumps will have to be cooled down and maintained at operating temperatures with the help of cryogenic fluids that will be produced in the most advanced cryoplant to date.

F4E has signed a contract with Air Liquide to supply the Liquid Nitrogen Plant (LN2) and Auxiliary Systems which will cool down, process, store, transfer and recover the cryogenic fluids of the machine. Two nitrogen refrigerators will be delivered along with two 80 K helium loops, warm and cold helium storage tanks, dryers, heaters and the helium purification system.

In order to ensure a thorough, in-depth and independent assessment of the design, F4E has structured a design review process relying on two main bodies: the design review panel and the steering committee. The former brings together highly qualified experts from external organisations, F4E and ITER IO, willing to share their expertise by assessing the work performed, raising issues and making recommendations. The latter has the final say endorsing or amending the conclusions of the review panel.

In less than one year after the preliminary design review of the LN2 Plant and Auxiliary Systems, F4E has concluded a major milestone on time and hosted the final design review on 15-17 July 2015. The meeting gathered more than 50 participants, members of the review panel and staff from Air Liquide and GTD Sistemas, the ITER International Organization, India's ITER Domestic Agency and F4E.

Prior to the meeting and during its course, participants were given the possibility to evaluate the requirements, review the different solutions presented by the design project team and identify outstanding issues. The panel invited attendees to propose suggestions for improvement and to screen all processes of the specific cryoplant components. All pending issues were discussed at length giving further confidence to the overall design. The review panel concluded the meeting praising the level of commitment and technical competence of the design project team. The steering committee is expected to transmit its final decision towards early September so that manufacturing enters a decisive phase.

That being said, some pieces of equipment have already started being produced. F4E and Air Liquide have recently celebrated an important milestone with the successful factory acceptance testing of the first two heat exchangers for the 80 K loop box.

Experts reviewing the final design details of Europe's contribution to the ITER Cryoplant





# Stuart Ward steps down as F4E Governing Board Chair

During the latest Governing Board (GB) meeting on 8-9 June, the GB Chair, Stuart Ward, submitted his resignation due to personal reasons.
All GB members expressed their appreciation for his important contribution to F4E over the previous four years as Chair. "Stuart has been an excellent chair of the GB and has supported F4E in many ways – he has an impressive ability to steer the discussions in the GB towards a consensus and constructive conclusion", said F4E Acting Director Pietro Barabaschi.

Stuart Ward

Joaquín Sánchez

Chair of the Governing Board since 2011, Stuart Ward was previously the GB representative for the United Kingdom since F4E was created in 2007. His background in physics and experience as Director of Corporate Services at the UK's Engineering and Physical Sciences Research Council, was well-suited to the mission of F4E. His calm and collected nature has been appreciated by F4E staff and European colleagues alike. "I have been impressed with Stuart Ward's level of commitment as a Chair of the Governing Board. I have rarely worked with a Chairman as engaged and thorough", said Robert-Jan Smits, Director-General, Directorate-General for Research & Innovation of the European Commission. Professor Henrik Bindslev, former Director of F4E said "It was a pleasure to serve together with Stuart Ward in the GB when founding F4E, in the following years in forming the organisation and finally as F4E Director reporting to Stuart as the GB Chair".

Joaquín Sánchez has been appointed as the Acting GB Chair until the end of 2015. "It was a pleasure and a privilege to work together with Stuart in the GB. He had a key role not only during the meetings, where with his bright and effective style he was able to reach consensus in nearly every case, but also in the preparation phase between meetings, with an intensive and effective work in multilateral contacts with all the relevant stakeholders. I am honoured to take over as GB chair and I know I will have to work hard to stay at Stuart's level", said Dr Sánchez.

Propping and formworks installation for the realisation of the slab, July 2015

# ITER Diagnostics building starting to take shape

Among the 39 buildings under construction in the vast 42 hectare ITER platform, where the equipment of the most ambitious fusion energy facility will be housed, the Tokamak complex is the one of critical importance because it holds the key to success.

Without a doubt it is the most emblematic construction area of the project. It consists of the Tokamak building, where the ITER machine will be located, with two adjacent buildings where the fusion fuel will be stored and treated known as the Tritium building, and the Diagnostics building, where the information received by the instruments acting as the eyes and ears inside the machine will be interpreted, analysed and processed. The works are being carried out by the VFR consortium (Vinci Ferrovial Razel) as part of the contract that was awarded by F4E in December 2012.

Almost a year ago the ITER project celebrated an important milestone with the completion of the first floor of the Tokamak complex known as the B2 slab. Works on the site have further advanced and on June 23 the propping works for the level above, which measures 9 300 $m^2$, have started. Today the Diagnostics building has started to take shape and it is estimated that 800 $m^3$ of concrete and 110 tonnes of steel will be used for the construction of its slab. The concrete will be poured in three lots to cover its 1 600 $m^2$ surface and works are expected to last three months mobilising 40 workers.

One of the biggest construction challenges of the Tokamak complex is the installation of the embedded plates. These are thick steel plates onto which several steel studs with rounded heads are welded. They are anchored deep into the concrete and positioned with accuracy to match the location of the ITER equipment that will be installed. More than 80 000 embedded plates will be installed in the Tokamak complex.

The installation of one type of embedded plates, known as the “shear lugs and skirts”, which are the finishing points of the Tokamak machine into the concrete structure, will be particularly challenging. They will have to be placed with an accuracy of 10 mm, which is remarkably tight considering that they weigh approximately 3 tonnes each. It would be like loading a truck into a container with a 5 mm margin.

Meanwhile, the reinforcement works on the 3.5 metre-thick bio-shield wall that will surround the Tokamak machine are ongoing.



# F4E hosts first Diagnostics Workshop

For the first time, engineers and scientists from 20 European fusion laboratories and companies from 12 different countries, colleagues from the ITER IO Central Team, the US Domestic Agency, and F4E all came together for two days at the F4E Barcelona offices to discuss the progress being made on the development and integration of the ITER Diagnostic Systems currently being developed by the EU.

The participants of the Diagnostics Workshop at the F4E office

The diagnostics on ITER will monitor the plasma during the operation of machine. F4E is responsible for contributing with 11 Diagnostic Systems (which corresponds to approximately 25% of the ITER Diagnostics Set) and works in collaboration with several large design teams made up of engineers and scientists from the European fusion laboratories and companies in order to develop and integrate the diagnostic systems. Each design team was represented at the meeting.

After a welcome introduction from Pietro Barabaschi, F4E Acting Director, the workshop was organised into a number of blocks addressing topics such as technical progress, project and contract management, systems engineering and management of requirements, the design review process, prototyping and testing, and port integration. Presentations by the fusion laboratories and companies were the core of the workshop, complemented by specific presentations by the ITER IO Central Team, the US Domestic Agency, and F4E. At the end of most presentation blocks, moderated discussion sessions identified good practices, issues and synergies, which proved to be very useful for drawing conclusions from the workshop.

The presentations at the workshop demonstrated the capabilities of the design teams, all of which are moving full steam ahead with the diagnostic development for ITER. The workshop proved to be a good forum for fostering closer collaboration and exchanging good practices. One of the positive outcomes is that, on the basis of feedback received during the workshop, F4E is taking action to streamline a number of contractual aspects and improve further decision-taking and the information flow within an integrated team approach. Given the outcome and positive feedback received, future similar workshops are currently being planned.

# F4E invites ITER Remote Handling community to develop an industrial culture for fusion reactors' maintenance

**During a two day workshop organised on 17-19 June in Barcelona by F4E, ITER IO, Japan's ITER Domestic Agency more than 50 experts have met to exchange know-how and explore further collaborations in this field.**

Remote Handling (RH) is one of the most fascinating ITER systems encompassing a vast range of technologies that cross-cut the functions of the biggest-ever fusion device. High-tech robotics operating with extreme dexterity and millimetric precision will be used to carry out from a distance a sequence of complex tasks. A fine-tuned choreography where cranes, tooling and manipulators will be moving impressive weights like in the case of the installation and replacement of the ITER divertor cassettes or the maintenance of the Neutral Beam Injector system.

In spite of the fact that virtual reality platforms play a significant role in this system, the two-day workshop organised on 17-19 June in Barcelona by F4E, ITER IO and Japan's ITER Domestic Agency, was all about bringing together more than 50 experts working in this field under the same roof. Participants met together for the first time and reported on the current progress of their work; recent technology breakthroughs and areas of mutual collaboration. This first-of-a-kind workshop went beyond the conventions of a business networking event. It laid the foundations for a technology cluster consisting of pioneers working in this domain.

Carlo Damiani, F4E's Project Manager for ITER Remote Handling systems, and his team have been working hard during the last couple of months to see this idea through. This has been an important achievement because it can be considered as a first step towards the development of an innovation community where participants could all learn from one another and evolve. "Now that we have a critical mass of big industries, SMEs and fusion laboratories contributing to ITER's RH system through contracts and grants, we have started to form an integrated team. With more business opportunities in the horizon, this community is expected to grow in size and expertise. The sooner we bring the different parties together the better, so that they benefit from each other's expertise. This initiative will also help F4E, ITER IO and Japan's ITER Domestic Agency to develop a better understanding of the field and have a strategic overview" he explained.

Jim Palmer, Acting Section Leader of ITER IO Remote Handling and Hot Cell Complex, confirmed that "the open and frank exchanges created a team spirit that helped people to see beyond their sub-system. It gave them a sense of the big picture and of the impressive industrial potential stemming from their design and R&D". Part of the ITER Remote Handling system will be manufactured in Japan which is why Nobuzaku Takeda represented Japan's ITER Domestic Agency at the workshop. In his view "there is a clear industrial potential that will mature with time. To give you an example, we will be developing special cameras fit to sustain the harsh environment of the Tokamak machine that could be of use in other industrial applications".

During the workshop we met with some of the participants to learn how they contributed to the different thematic sessions and what sort of challenges they identified.

Bryn Thomas, Head of Civil Nuclear Power working for Assystem UK, offered a progress report regarding the contract for the Divertor Remote Handling system awarded by F4E. "Thanks to this workshop we became aware of some very useful developments in electronics and camera systems that may yield potential benefits across all remote handling systems. Some of the challenges that we face are linked to the management of interfaces between systems and components; the maturity of technologies in manipulators, cutting, welding and hydraulic systems" he explained.

Participants discuss the latest developments in ITER Remote Handling systems

For Ian Grayson, Boiler Spine Programme Director for AMEC Foster Wheeler, managing the contract for the Neutral Beam Injector Remote Handling system that was recently awarded by F4E, "sharing our thoughts on some technical problems and identifying ways to solve them has been extremely useful. We are in the process of preparing the first task order of our contract to review the existing design concept. Any unexpected changes in the different components manufactured around the world will have an impact on the system. We would therefore need to test the mock-ups off-site in facilities on the basis of the specifications we get".

Apart from tooling, RH systems require sophisticated software solutions that will enable the equipment to run smoothly. Héctor Novella, GTD Project Manager for Energy and Science, has been working on the development of a GENROBOT, a generic low level control system software controller for the RH Control System. "This workshop helped us to get in touch with the ITER RH community and we developed an understanding of who does what and how. This is extremely useful for a company like ours which has a proven track record in critical systems but we are newbies in robotics" he stated.

This innovation cluster, however, is not only for big players. This is a technology area that requires flexibility and creative thinking in order to integrate niche skills that mostly SMEs master. Amada Engineering, an Italian company working in the field of engineering solutions, is contributing to the GENROBOT project, under the supervision of GTD, providing technical support in design and testing of software for RH systems. "Some of the main challenges that we face are about the definition of standards and the identification of the right interface" said Marco Ricci.

From such a workshop, European fusion laboratories could not be absent given the fact that they are vital motors of most of the R&D that is subsequently passed on to industry. And the best way of making this point was by inviting Tony Loving, Chief Fusion Technologist from the UK Atomic Authority, working on remote systems of DEMO in order to raise awareness about the post-ITER era where a more powerful machine will come to play. Minimising shut down for maintenance and maximising overall operation summarise the main challenges that RH systems will have to face in future. "There will be many parallels with ITER, for example: maintenance of power plant sub-systems, transportation of activated and contaminated components, decontamination and detritiation. This said, any future fusion device to be realised will have to take advantage of the technology investment within the ITER programme", he explained.

This first attempt of gathering F4E's RH systems contractors was extensively praised and has led the organisers to plan a follow-up in 2016 where future contractors will also be invited. It has also led F4E, ITER IO and Japan's ITER Domestic Agency for ITER to the decision of holding a monthly co-ordination meeting, on top of the regular bilateral meetings, to address the progress of technical issues in a more integrated manner. Last but not least, it has raised awareness across the suppliers about the available expertise in this field and the possibilities of future partnerships.

# F4E hosts ITER divertor meeting

Representatives from F4E, the Japanese and Russian Domestic Agencies (DAs), and ITER IO gathered together to share information and discuss the status of the divertor procurement, on-going R&D and future plans.

The participants of the divertor meeting

This annual divertor meeting was hosted by F4E at its offices in Barcelona. Around 35 attendees were present at the three-day meeting which apart from including plenary sessions about the status of the work at ITER IO and in the DAs, also offered bilateral sessions for detailed technical discussions. Among others, topics such as the merging together of the divertor's different components (divertor integration activities) and the specific issues regarding the tungsten material to be used in the divertor (armour design and tungsten performance) were discussed.

Located at the very bottom of the vacuum vessel, the ITER divertor is made up of 54 remotely-removable cassette bodies, each holding three plasma-facing components (namely, the inner and outer vertical targets and the dome). The technical design will enable the targets, in their lower part, to intercept the magnetic field lines, and therefore divert (thus the name 'divertor') the high particle flux coming from the plasma. F4E is responsible for providing the inner vertical target, the cassette bodies and the mounting of both types of targets and the dome on the cassette body. The Japanese and Russian Domestic Agencies are responsible for providing the outer vertical target and the dome respectively.

Full-size prototypes for the cassette bodies, the inner and outer vertical targets and the dome are currently being developed within all DAs and there have been some remarkable results in terms of thermal fatigue testing. Indeed, preliminary test results show that the divertor system will be able to sustain the thermal load it is expected to be exposed to when functioning in ITER.





# First training in metrology techniques takes place at F4E

Metrology, the science of measurement, plays a vital role in F4E's work of procuring components for the ITER machine. In the case of ITER, all components must be measured before they are delivered to the ITER site in Cadarache.


The participants of F4E's first-ever metrology training

This for two reasons: firstly, in order to ensure performance (that the components fulfil their tolerance specifications), and secondly, to ensure that the components, which are being produced all over the world by the different ITER Domestic Agencies will all fit together during assembly. Metrology measurements are carried out using different combinations of tools and software applications and it is necessary to take metrology aspects into account from the design phase up to manufacturing and assembly.

F4E's Metrology Group exists within the Technical Support Services Unit and plays an ever more important role with the increasing amount of F4E manufacturing contracts being signed and the fact that more and more components are currently being produced. In the interest of increasing efficiency and reducing the risk for errors, F4E has now started to train partners and suppliers with which the organisation works, so that they are trained to use the same tools and the same procedures.

Held for two days, this first metrology techniques training consisted in theoretical sessions and a practical session which involved using the actual metrology equipment. Attendees came from European Fusion Laboratories and industry, as well as scientific organisations such as CERN. Led by the members of the F4E Metrology Group who all have a background in mechanical engineering but also specialist knowledge in the ever-evolving state of the art metrology equipment, the training was very much based on first-hand experience from working on the ITER project. "We have now noticed that our suppliers and partners now have a better understanding of the importance of a correct metrology inspection – we now speak the same language and the documentation produced by them now starts to comply to the required standards and specifications, without any necessary additional intervention from F4E"", said Luigi Semeraro, Head of F4E's Metrology Group. "All in all, we see that sharing a common metrology culture on metrology has greatly improved the efficiency of the ITER component acceptance process. We plan to continue training sessions and share updates on this ever-advancing technology on a regular basis", he added.

# F4E kicks off collaboration with British SME for gyrotron superconducting magnet prototype production

With the objective of producing a first-of-its-kind European superconducting magnet, F4E and British SME Cryogenic Limited have now started work together. This collaboration encompasses the design, manufacturing and assembly of a superconducting magnet (SCM) for the EU 1 MW gyrotron prototype.

Representatives from F4E and British SME Cryogenic Limited at the kick-off meeting





The superconducting magnets will together with the gyrotrons form the source of power of ITER's Electro-Cyclotron (EC) heating system which is responsible to generate the radiofrequency (RF) waves which will heat the plasma to the 150 million °C necessary for the fusion reaction to occur. The gyrotron is inserted in the vertical hole in the middle of the cylindered SCM, and the role of the SCM is to produce a very high magnetic field in order to allow the gyrotron to generate the RF power.

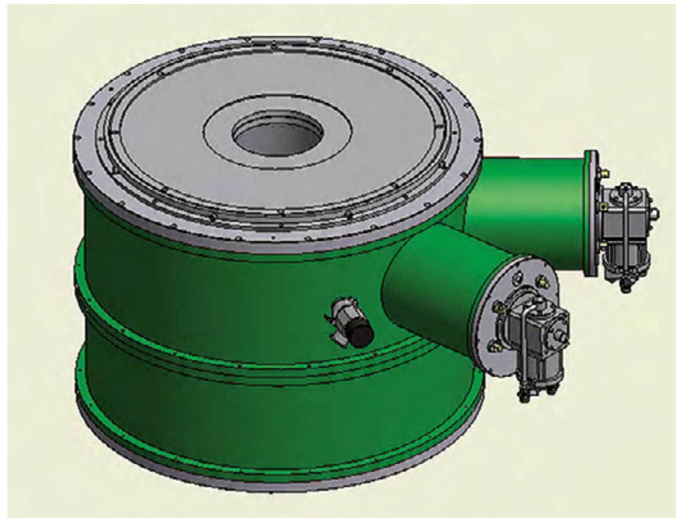
In order to produce this magnetic field, the coils of the SCM must be superconducting and work at cryogenic temperatures (of around -269 °C). Until now, European industry has been producing a type of SCM which uses a bath of liquid helium (called 'wet' magnets) that flows through the magnet system and through convection, cools down the coils to extremely low, cryogenic temperatures. However, F4E and Cryogenic Limited will use an innovative cryogen-free, 'dry' magnet technology which until now has never been used in Europe: rather than relying on cold liquid helium to flow within, the SCM will be cooled down by heat conduction by extracting the heat through strips of solid material.

The SCM will measure a maximum 820 mm in height and the cylindered hole where the gyrotron will be places measures 240 mm in diameter, meaning that the supplier needs to keep the design of the magnet system very compact. The maximum value of the magnetic field on the SCM axis will be 6.77 Tesla, a significantly high value for this type of magnet. Furthermore F4E has specified in the contract that the magnetic field produced by the SCM should only vary 0.1 % of the required value. The reason for this tight requirement is that the gyrotron will not operate unless the magnetic field is within this range and necessitates that the design and mechanical construction of the coils of the SCM must be exceptional.

"This is the first-ever magnet of this kind in Europe in terms of the precision of the magnet construction and the mechanical tolerances of the magnetic field", explains Fabio Cismondi, F4E Technical Officer dealing with the SCM system. "The strict requirements on the magnetic field axial profile and magnetic axis position make the design and assembly of a 'dry' SCM for the gyrotron operation very challenging. The positioning of the magnetic field which is produced by the SCM in the gyrotron is very important: if the magnet is not aligned properly, the production of the RF power is compromised".

The final design of the SCM is scheduled to be concluded in October of this year. In parallel, the material and superconducting wires procurement will start. The manufacturing and assembly of the SCM is foreseen to be ready during the Autumn of 2016. After installation and acceptance tests, the SCM will be used to operate the 1 MW CW gyrotron prototype (presently being procured by Thales Electron Devices) in the European EC Test Stand at the European Fusion Laboratory CRPP (Lausanne, Switzerland).

Within the framework of the ITER in-kind contribution, Europe will have to provide 6 gyrotrons sets, i.e. 6 gyrotrons equipped with 6 SCMs (the additional 18 gyrotron sets will be provided by the Russian, Japanese and Indian ITER Domestic Agencies.



The superconducting magnet (SCM) for the EU 1 MW gyrotron prototype will be produced using a technology which until now has never been used in Europe.

# Europe and Japan celebrate achievement of important JT-60SA milestones

The concurrent achievement of several important milestones of the JT-60SA project was celebrated by some 200 high-level European and Japanese guests at the JT-60SA project site in Naka, Japan, on 20 April. The JT-60SA project is a "satellite" to the international ITER project and aims to model proposals for optimising plasma operation and investigate advanced plasma modes that could be tested on ITER or used later on DEMO.

This satellite tokamak programme was established in 1997 as one of three joint projects between Europe and Japan within the Broader Approach Agreement.

Hosted by the Japanese Atomic Energy Agency (JAEA), the Japanese Implementing Agency for Broader Approach activities, the event was in celebration of the excellent progress achieved to date, with the coincidence of four major achievements. Interest in the project was clearly high – the celebration and the reasons behind it were also covered in several print, online and audio-visual media reports.

Yutaka Kamada, the Japanese home team project manager and Pietro Barabaschi, the European home team project manager and Acting Director of Fusion for Energy, welcomed the guests and acted as masters of ceremony. Addresses by high-ranking representatives of the Japanese government, European Embassies and the European Commission expressed satisfaction with the contributions of all institutions involved, and drew attention to the mutual trust that had developed between the partners. Finally the Project Leader of JT-60SA, Hiroshi Shirai, gave an overview of the state of the project. After a tree planting ceremony, guided tours of the site offered visitors the opportunity to see for themselves the state of technical achievements in the different areas.

The first achievement concerned the assembly of 17 out of 18 sectors of the plasma vessel (the double-walled vacuum vessel which will enclose the 100 million °C hot plasma). This large vessel 6.6 m high and 10 m in diameter was manufactured by Toshiba as part of JAEA´s contribution to the JT-60SA project. All stringent pressure and leak tests have been passed successfully and all tight manufacturing tolerances have been maintained.

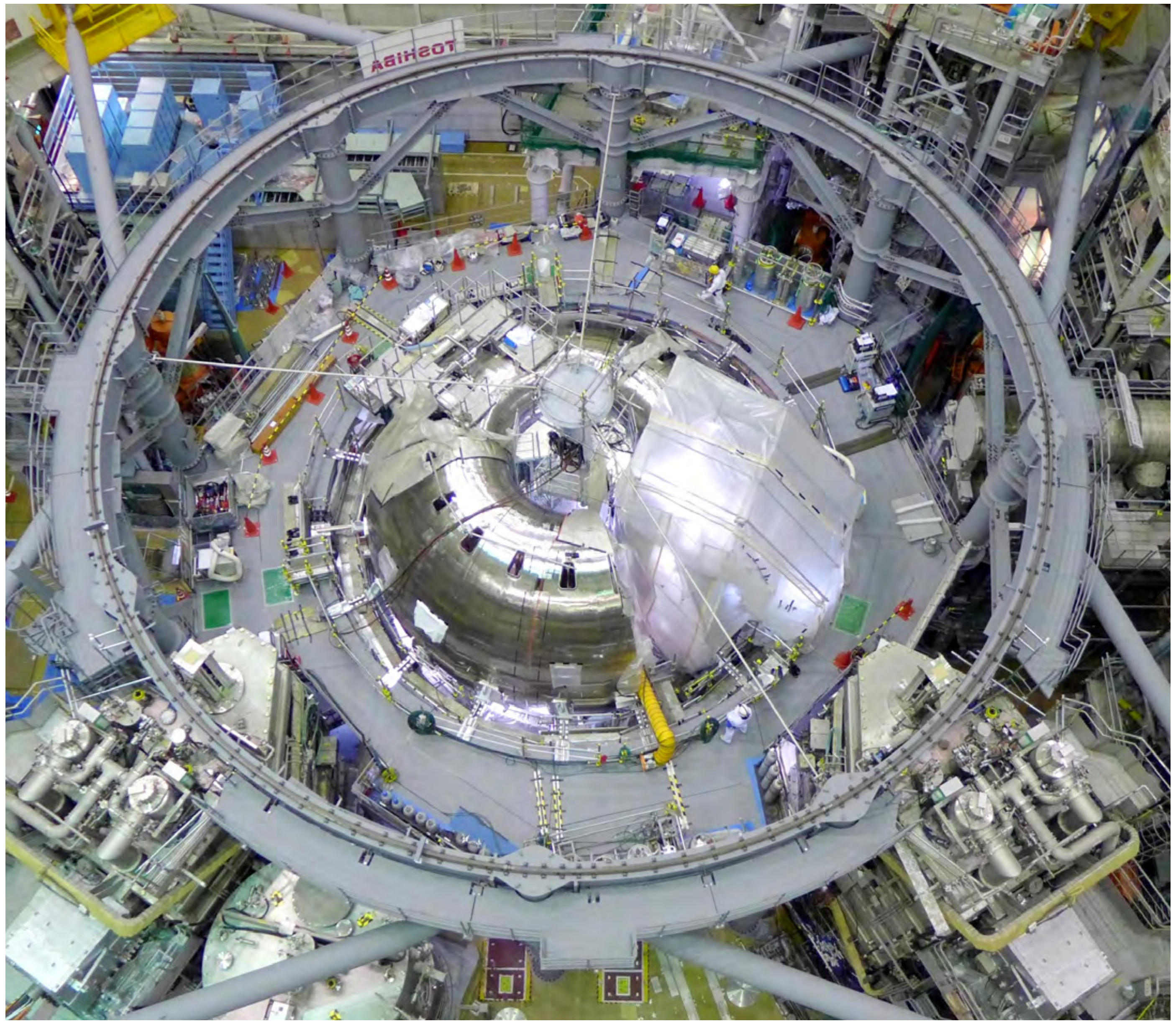
The second achievement was the completion of the installation and testing of the quench protection system for the superconducting coils, which create a magnetic bottle to confine the plasma for the fusion reaction. If, for whatever reason, part of the coils stop being superconducting, the quench protection system avoids overheating of the coils by immediately discharging their stored electromagnetic energy into a set of resistors. The system is composed of 13 units applying the most advanced hybrid mechanical-static circuit breaker technology to interrupt currents of more than 25 kA at voltages of about 5 kV. It was procured by Italian CNR acting through Consorzio RFX in Padua. The contractor was Nidec ASI company. The system has just been installed and commissioned at JAEA, and the acceptance tests are being completed in April according to the agreed schedule before ownership is transferred to JAEA.

The third achievement was the arrival of the main subsystems of the cryogenic system on site. The cryogenic system is a very powerful fridge able to reach temperatures close to absolute zero (-269 °C). This system is provided by the French CEA Grenoble through their contractor Air Liquide Advanced Technologies. The main duty of the cryogenic system is to maintain the magnetic coils in a superconducting state. At the end of March all subsystems of the cryogenic system arrived in Japan and are now being assembled and commissioned. Just beforehand, again on schedule, JAEA finished construction of a new compressor building and the refurbishment of an existing hall for the refrigerator coldboxes.

The electrical connection between the warm power cables of the magnet power supply and the cold superconducting electrical network of the coils is realised by special helium-cooled connectors, so-called current leads. Twenty-six such current leads are being developed, manufactured and tested in a dedicated test facility by Karlsruhe Institute of Technology (KIT) in Germany. The current leads use high-temperature superconductor (HTS) tapes to reduce the resistive losses while creating a thermal barrier to reduce the heat flow to the very cold electrical networks. After their successful test at nominal operation conditions, KIT delivered the first two HTS current leads very recently to JAEA – the fourth achievement. The remaining current leads are in different advanced stages of construction and testing and will be delivered subsequently.








On top: The 17 out of 18 sectors of JT60-SA's plasma vessel (the double-walled vacuum vessel which will enclose the 100 million °C hot plasma) have been assembled. (Image courtesy of JAEA).
Several important milestones of the JT-60SA project was celebrated by some 200 high-level European and Japanese guests at the JT-60SA project site in Naka, Japan.
On the right: The first two HTS current leads delivered by KIT.

# MEP Martina Dlabajová visits ITER site to see progress

Martina Dlabajová, MEP of the Group of the Alliance of Liberals and Democrats for Europe and Vice-Chair of the Budgetary Control Committee of the European Parliament, visited the ITER site in Cadarache to receive an update on the overall progress of the ITER project and in particular on Europe's contribution.

MEP Martina Dlabajová (fourth from the left) visiting the ITER site.

MEP Martina Dlabajová received an update on the overall progress of the ITER project and on Europe's contribution from F4E and ITER IO representatives.

After a tour of the challenging construction being carried out on the ITER site, Martina Dlabajová engaged in a lively discussion with a group of representatives from F4E and ITER IO which included Glenn Counsell, Deputy Head of the F4E ITER Department, and Ioan Cruceana, Head of Cabinet of the ITER IO Director General. Points discussed included the manufacturing of components for the ITER machine that F4E is responsible for delivering. For instance, the completion of the fabrication of the ITER Magnets, the development of the full-scale prototype of the Divertor Remote handling system and the work related to the ITER Electron Cyclotron and Neutral Beam Heating Systems, are just some examples that demonstrate F4E's ambitious contribution to the ITER project. Another point of discussion was the F4E contracts and grants with European industry and research laboratories, and how the production of components and the potential technological transfers stemming from ITER boost Europe's growth and competitiveness.

Martina Dlabajová thanked F4E and ITER IO for the site visit and the informative discussion which allowed her to gain an insight into the project. F4E and ITER IO, in turn, expressed their gratitude to the MEP for her keen interest and support to the ITER project.

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

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