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ITER ORGANIZATION
PROGRESS IN PICTURES 2016



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November 2016

A star will be born

A star will soon be born, a star unlike any other... a man-made star. ITER – the Latin word for “The Way” – will light up in the middle of the coming decade.

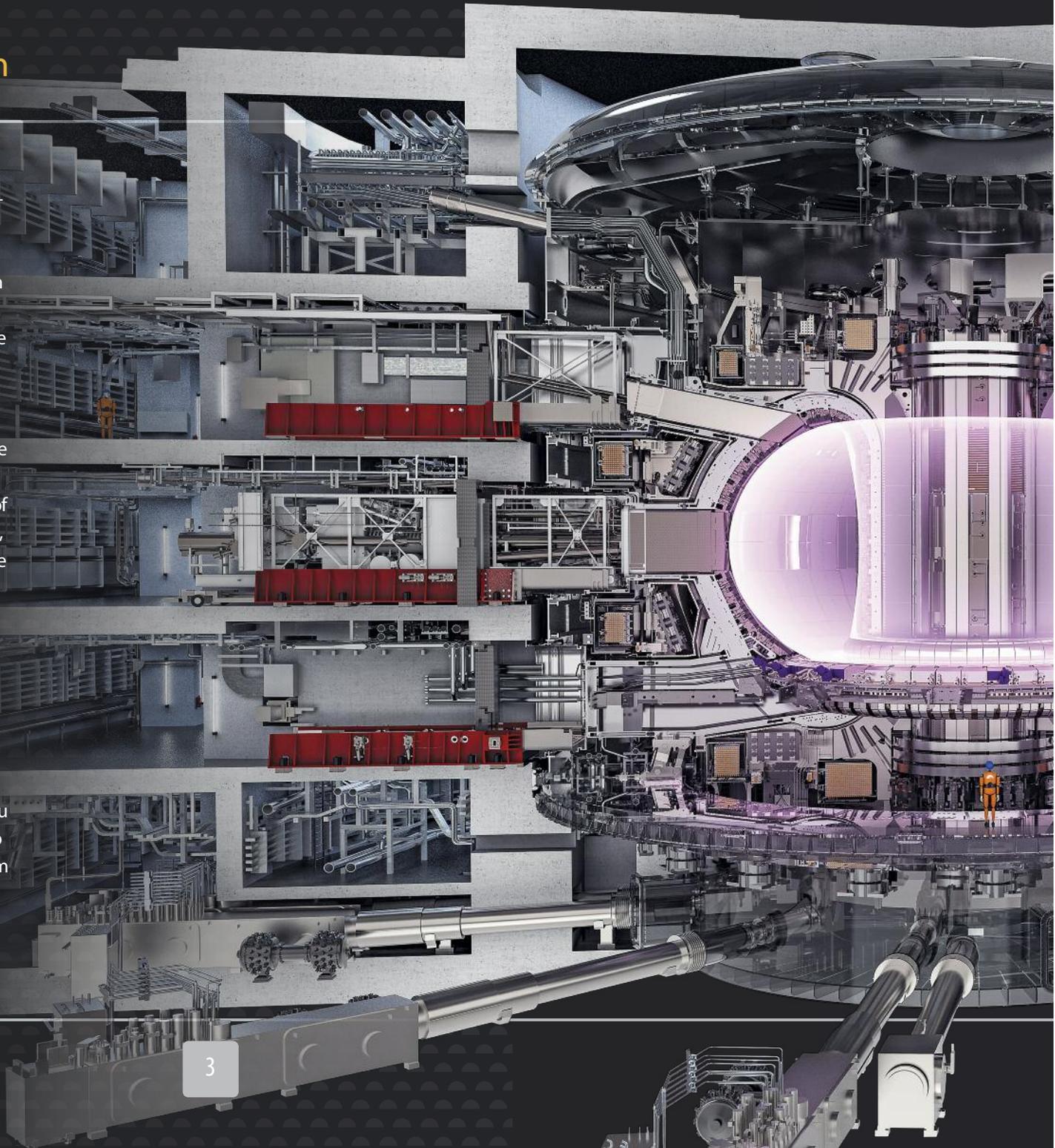
From a scientific and technological point of view, it will be one of humankind’s historic achievements. The creation of an artificial star and the tapping of the tremendous amounts of energy produced could forever alter the course of civilization.

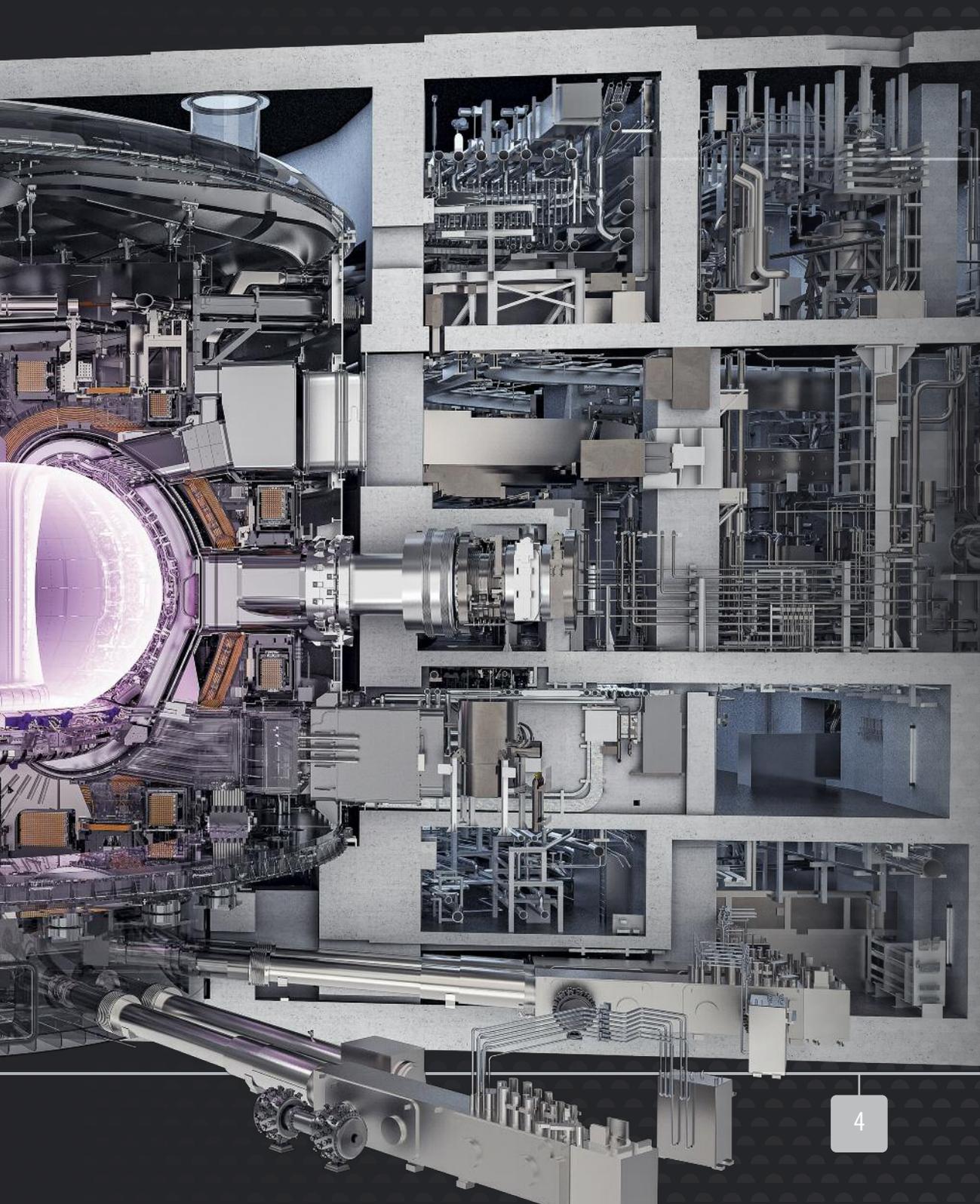
The ITER Project, an unprecedented international collaboration that brings together China, the European Union, India, Japan, Korea, Russia and the United States, is the culmination of decades of research and years of diplomatic negotiation. It has been the aspiration of three generations of physicists; it is now the reality of the hundreds of scientists, engineers and labourers working in southern France where the ITER installation is under construction.

The seven ITER Members, representing half the world’s population, share the responsibility for building the ITER machine and facilities. Every Member, essentially, is involved in every system.

As buildings rise on the ITER platform (pages 5 to 19), component manufacturing advances in ITER Member factories (pages 23 to 48).

This third edition of the ITER photobook aims to take you into the heart of ITER – from the rolling hills of Provence to factories on three continents, where men and women from 35 nations are bent on realizing one of mankind’s most enduring dreams: capturing the fire of the stars and making it available to humanity for the millennia to come.





The ITER Tokamak



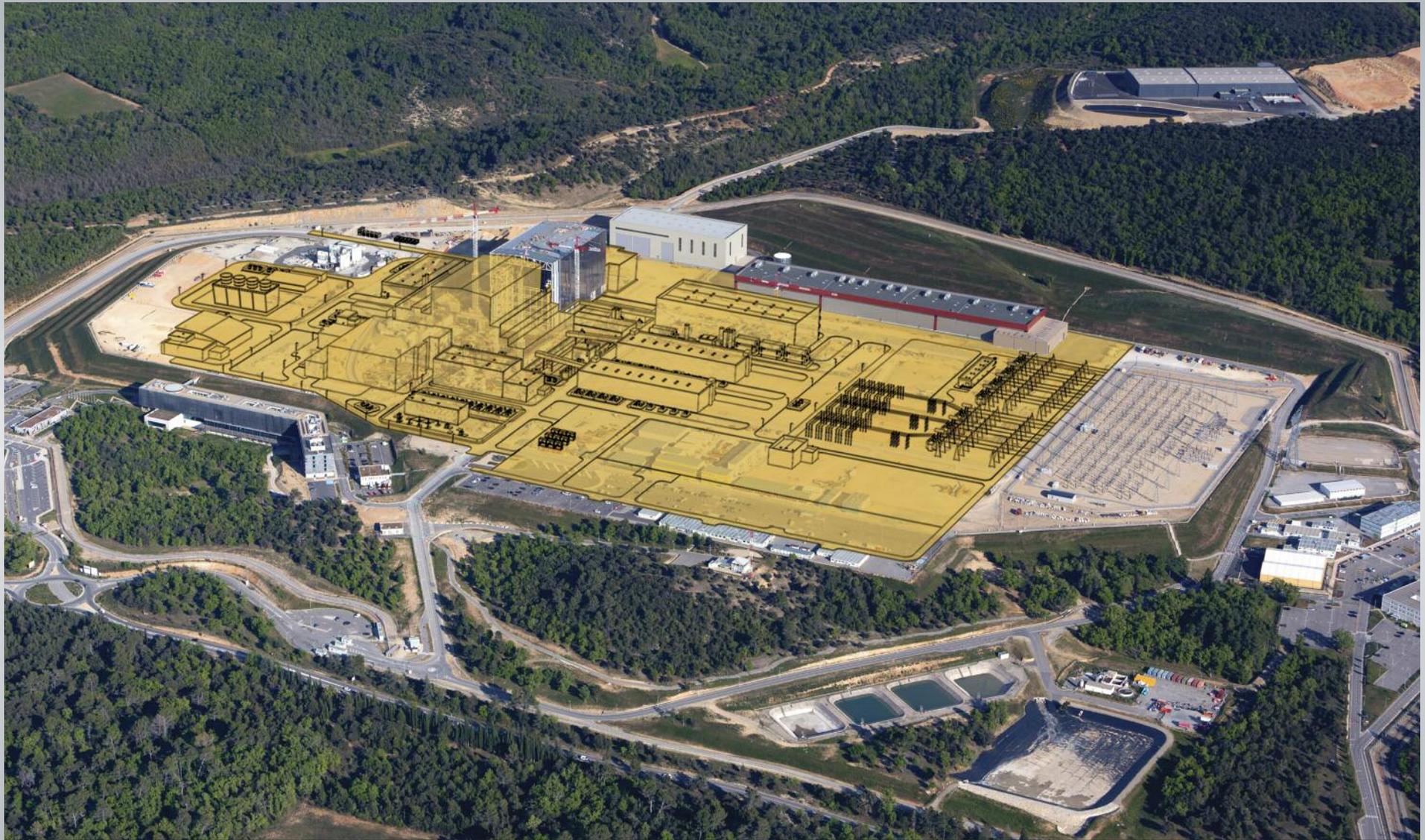
The ITER machine is a *tokamak*, the Russian acronym for Toroidal Chamber, Magnetic Coils. Tokamaks were developed in the 1960s at a time when nations were experimenting with all kinds of different systems to reproduce the nuclear reactions at work in the core of the Sun and stars.

A tokamak, like a star, is designed to fuse light atoms into heavier ones. A tokamak is a magnificent tribute to Albert Einstein's $E=mc^2$: the tiny loss of mass that results from the fusion process translates into a huge quantity of energy. One gram of fusion fuel (the hydrogen isotopes deuterium and tritium) generates as much energy as eight tonnes of oil.

ITER will be by far the largest and most complex tokamak ever built. Designed from the experience accumulated by hundreds of fusion machines throughout the world, it will demonstrate that fusion energy is scientifically and technologically feasible.

| | |
|----------------------------|--------------------|
| Weight | 23,000 tonnes |
| Height | ~ 30 metres |
| Diameter | ~ 30 metres |
| Plasma volume | 840 m ³ |
| Temperature at plasma core | 150,000,000°C |
| Fusion power | 500 MW |

Site map



The ITER Project is located approximately 75 kilometres north of Marseille, France, on a 180-hectare parcel of land in the Durance River Valley. Following three years of preparatory work to create a level platform for the scientific facility, building construction began in 2010.



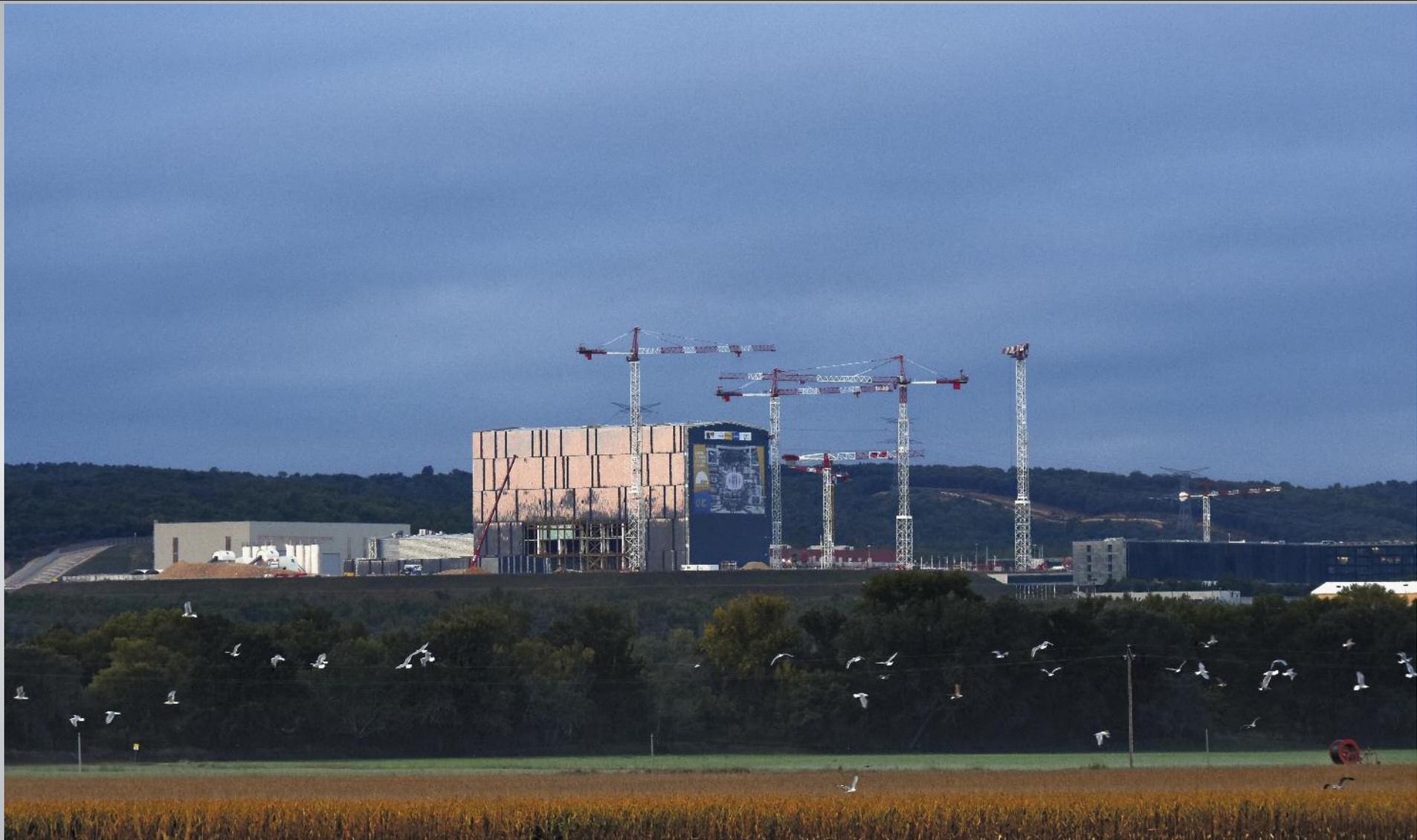
It took four years (2010-2014) to create the foundations of the Tokamak Complex, including the excavation, first-level basemat, retaining walls, seismic pillars and bearings, and second-level basemat. Now, the lowest levels of the Tokamak Complex are taking shape with – at their centre – a perfectly round “well” reserved for machine assembly. *April 2016*



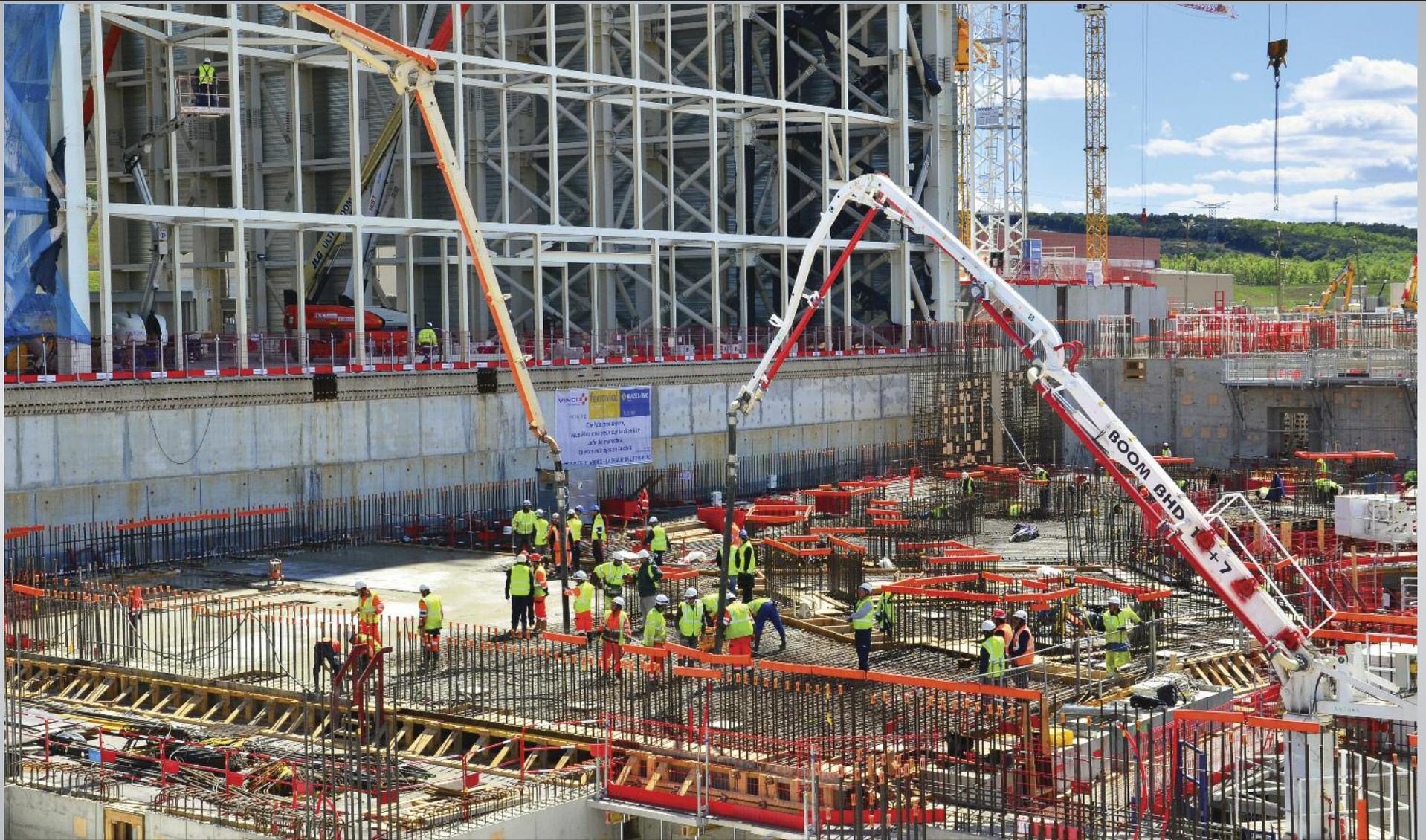
Industrial activity has kicked off in both of ITER's on-site manufacturing facilities: the vast winding facility for poloidal field coils (red trim) where European contractors have installed equipment and begun qualification winding activities; and the Cryostat Workshop (lower right), where Indian contractors have begun welding the cryostat base. *October 2016*



The ITER Assembly Building is now the most visible feature of the ITER site. This photo captures cranes on the ITER worksite as well as outlying buildings belonging to the CEA Cadarache research centre. *March 2016*



The Assembly Building will be equipped with specialized tooling to handle and pre-assemble Tokamak components. The building's mirror-like cladding, completed in 2016, will be reproduced on all the main buildings of the ITER facility. *October 2016*



The 17-metre-deep excavation for the Tokamak Complex has now disappeared under the reinforced walls and columns of the lower level basement (B2). As workers start on the B1 level of the Tokamak Building, only six metres remain before the construction reaches ground level. *April 2016*



The three-metre-thick ITER bioshield creates an inner circle, with spoke-like reinforcement set in place for the radial walls that will connect it to the cryostat crown. A wider circle is formed by 18 giant columns that will rise 30 metres to provide structural support to the Tokamak Building. *January 2016*



From the air, the three sub-projects of the Tokamak Complex (the Diagnostics Building, the Tokamak Building, and the Tritium Building) are clearly distinguishable. When completed and equipped, the Complex will weigh 440,000 tonnes. *June 2016*



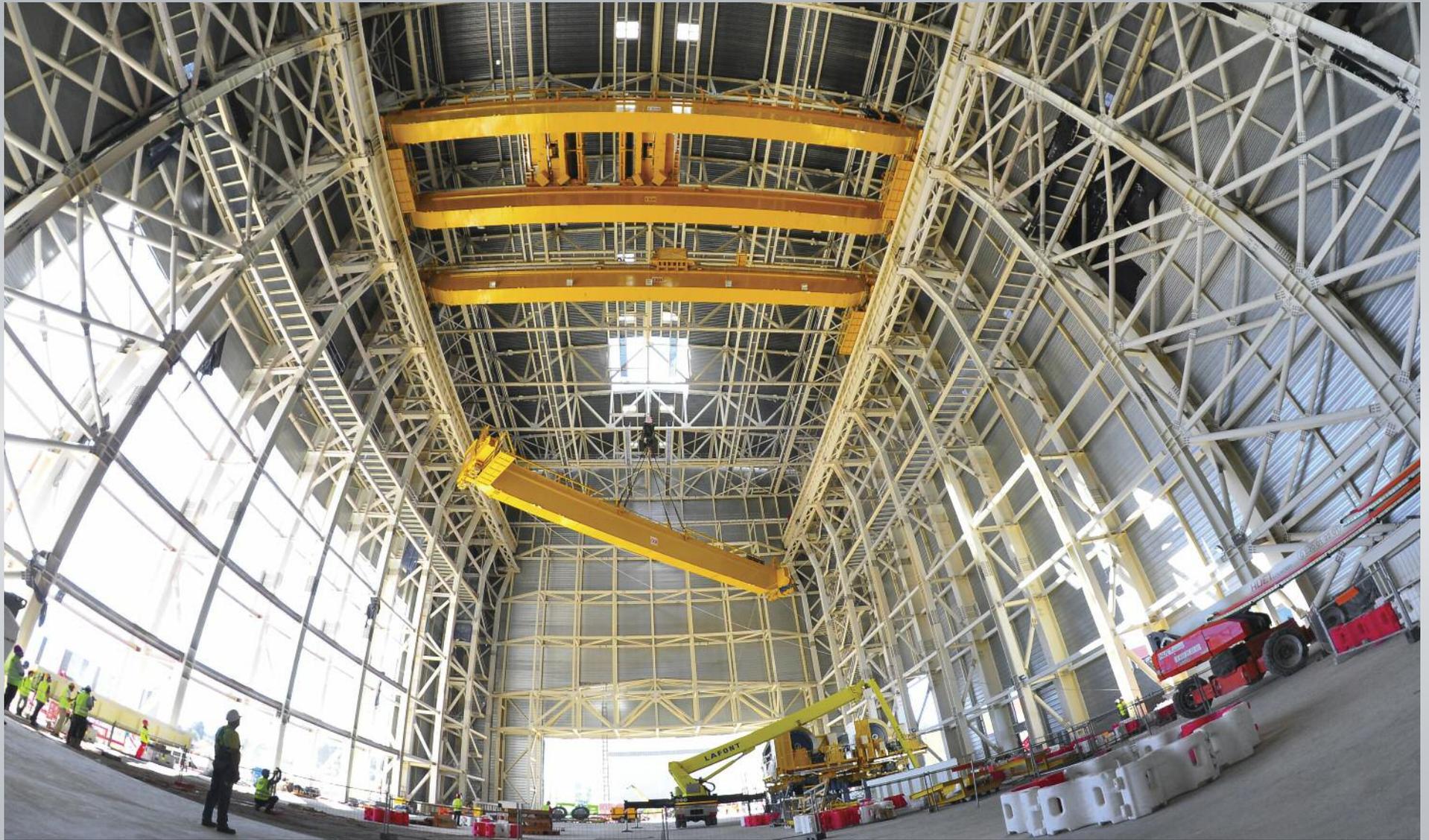
Machine assembly will begin here when the Tokamak Building is completed in 2018. At that point, the building will be as tall as the Assembly Hall. *October 2016*



The cavernous area in the basement of the Tokamak Building will completely fill up with pipes, cables, feeders and busbars as the Tokamak systems are installed. The equipment will be anchored to the embedded plates that can be seen in the floor, walls and ceiling. *October 2016*



A massive crawler crane raises the four metal girders of the Assembly Hall travelling cranes into position by passing hooks and cables through an opening in the roof. *June 2016*



Forty-three metres above the shop floor of the Assembly Hall, two travelling cranes will work in concert to lift loads of up to 1,500 tonnes. *June 2016*



Four of ITER's six ring-shaped poloidal field coils will be manufactured by Europe in this on-site facility. In 2016, activities to qualify tooling and processes were successfully launched. *November 2016*



The ITER Cryoplant Building is under construction now on the southeast portion of the platform. In parallel, cryogenic components (cold boxes, turbines, compressors . . .) have begun arriving on site. July 2016



Cryogenic technology will be used extensively at ITER to create and maintain low-temperature conditions for the magnet and vacuum pumping systems. The required cooling power will be produced in the cryoplat and distributed through a vast network of pipes, pumps and valves. *October 2016*



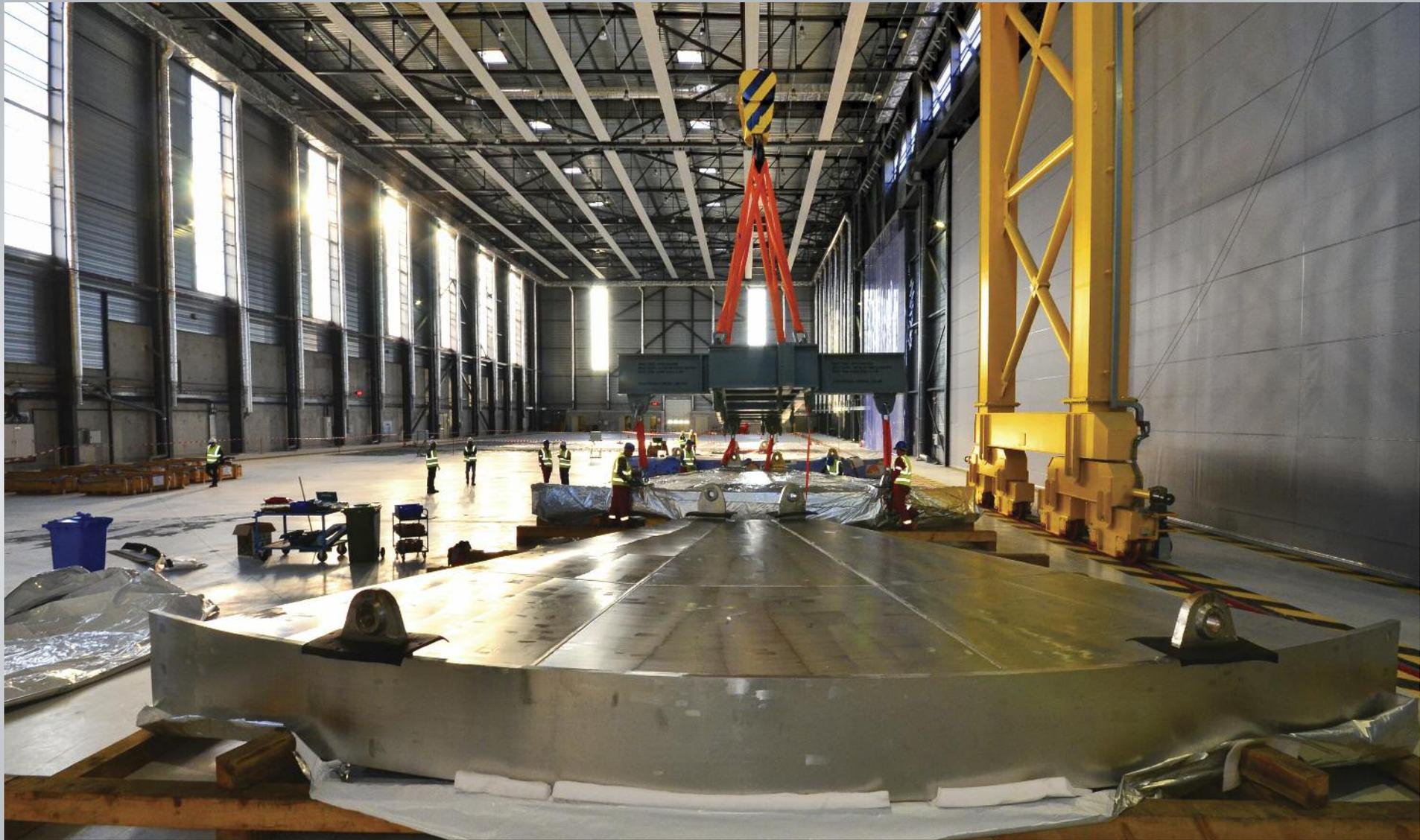
Large components like this cryoplat tank procured by Europe are shipped by sea to the Mediterranean port of Fos-sur-Mer before continuing along a specially adapted road itinerary to the ITER site. Approximately 10% of the "highly exceptional loads" scheduled to be delivered along the ITER Itinerary have already reached the site. *November 2016*



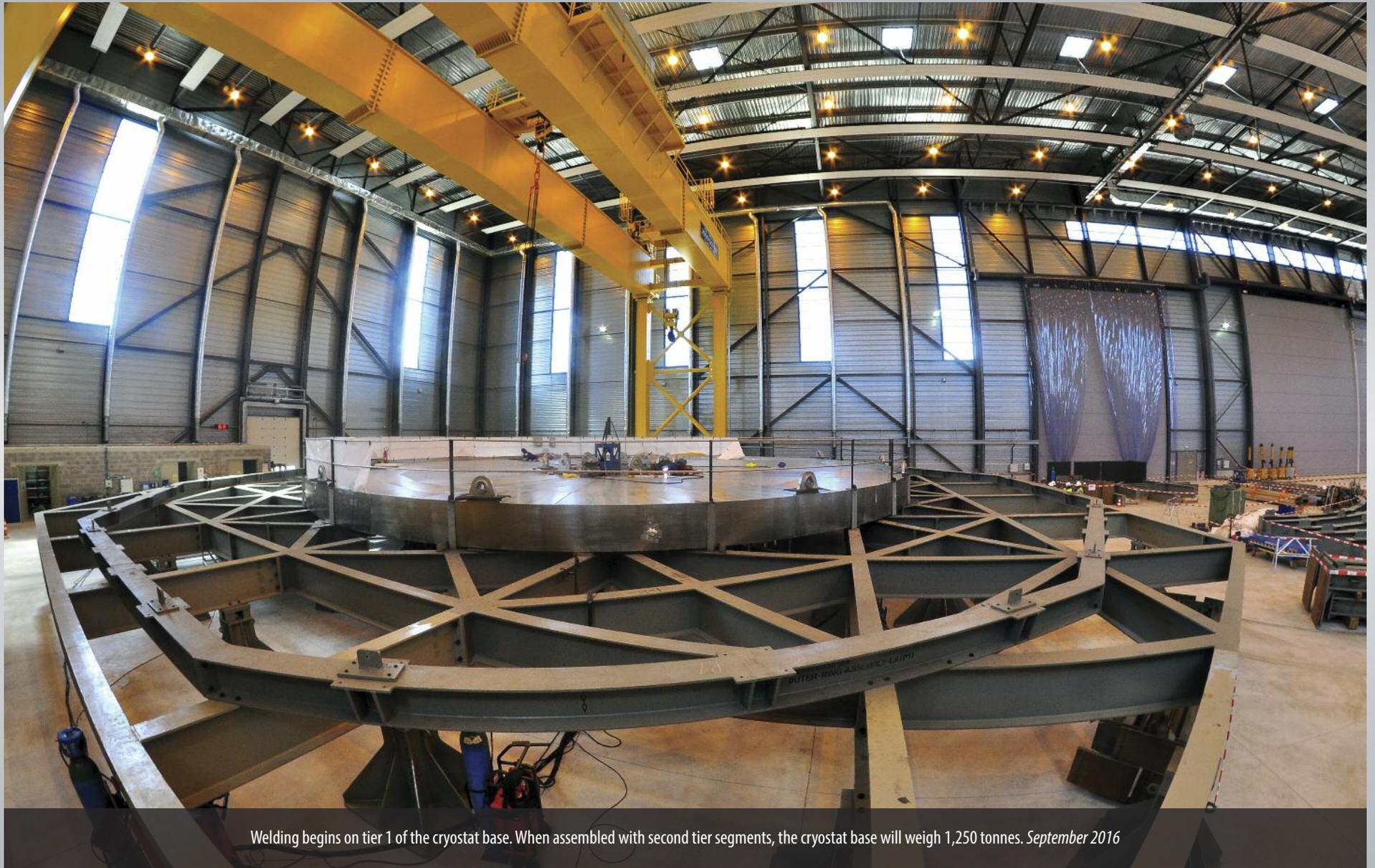
A 47-metre steel girder and its transport vehicle are ferried by barge across the inland sea Etang de Berre. When they dock, there will still be 104 kilometres to travel over land to the ITER site. *November 2016*



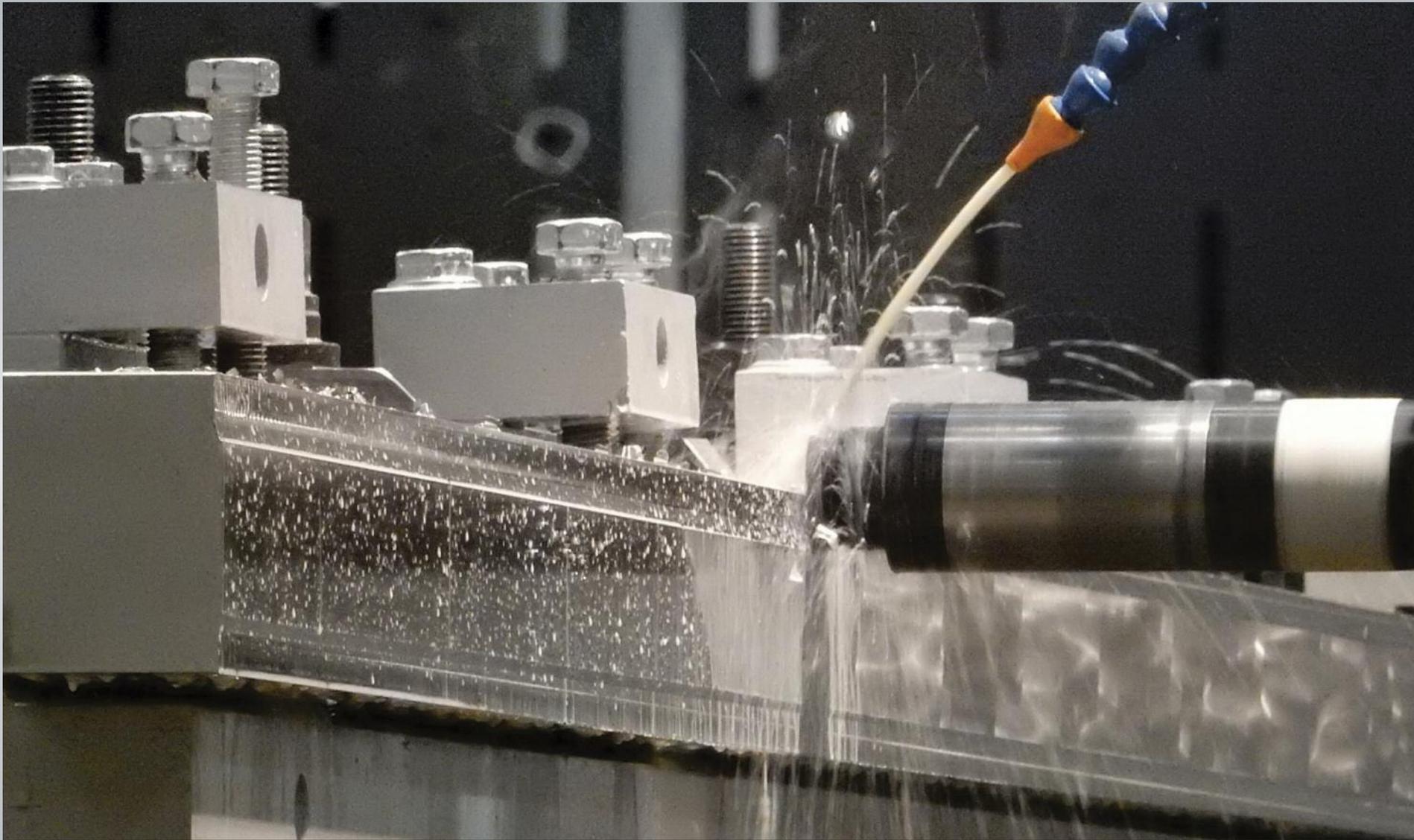
Approximately 1,500 workers are involved in the construction of the ITER scientific installation. The last daily shift ends at 10 p.m. *November 2016*



Advanced welding techniques such as automated, all-position narrow groove gas tungsten arc welding have been specially developed for the challenging assembly of 54 segments into the single largest component of the ITER machine. Pictured: two triangular segments for the cryostat base (tier 1) are stored in the Cryostat Workshop. *December 2015*



Welding begins on tier 1 of the cryostat base. When assembled with second tier segments, the cryostat base will weigh 1,250 tonnes. *September 2016*



By contributing to the construction of the experimental machine, the ITER Members are creating the technological and industrial basis for the commercial fusion reactors of the future.

ITER ORGANIZATION MANUFACTURING

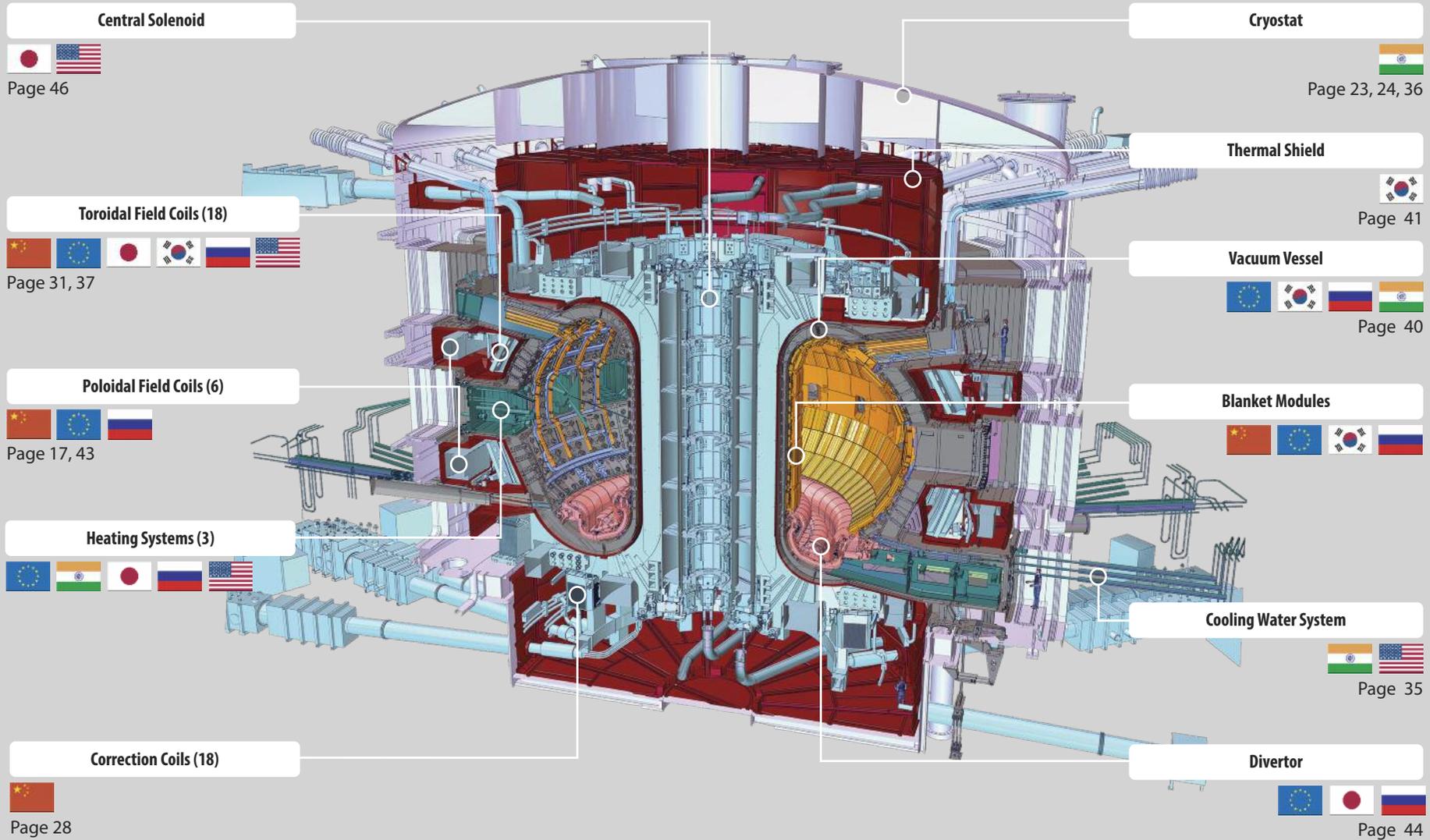
A unique aspect of ITER implementation is the in-kind procurement system that was established at the onset of the project. Instead of contributing purely financial resources, China, the European Union, India, Japan, Korea, Russia and the United States will be providing 90% of their contributions in the form of machine components, systems and – in the case of Europe – buildings.

Procurement packages are shared equally (~ 9% of the total value) between China, India, Japan, Korea, Russia and the United States; Europe's share, as Host Member, is ~ 45%.

The in-kind procurement arrangement is at the core of ITER's founding philosophy, offering the ITER Members invaluable experience in the manufacturing of components for a fusion installation.

By contributing to the construction of the experimental machine, the ITER Members are creating the technological and industrial basis for the commercial fusion reactors of the future.

Who manufactures what?



Not all systems (or contributions) are represented in this illustration.



Three sets of six correction coils will be distributed symmetrically around the tokamak to correct field errors. At the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP), the first-of-series, multiple-pancake bottom correction coil winding is prepped for the wrapping of ground insulation.



This 300 MVA step-down transformer is one of three that have successfully passed factory acceptance tests in China for ITER's pulsed power electrical network. The first transformer reached ITER in 2016; two others are expected next year.



High temperature superconductor (HTS) current leads will transfer large amounts of current from room-temperature power supplies to very low-temperature superconducting magnets. The 52 kA current lead prototype pictured (poloidal field and central solenoid type) has been successfully tested at ASIPP.



D-shaped toroidal field coils will create the magnetic field that confines the ITER plasma. In 2016, the first toroidal field “inner core” – called a winding pack – is successfully produced in Europe. Following testing, it will be inserted into a stainless steel coil case to form the final 310-tonne coil assembly.



This water detritiation tank being lowered into the Tritium Building is one of six that have since been installed at the B2 (lower basement) level.



A 23-metre storage tank for liquid helium, part of Europe's contribution to ITER's liquid nitrogen plant and auxiliary systems, has successfully passed leak tests. The 190 m³ stainless-steel tank will store liquid helium at -269 °C.

Thousands of in-wall shielding components



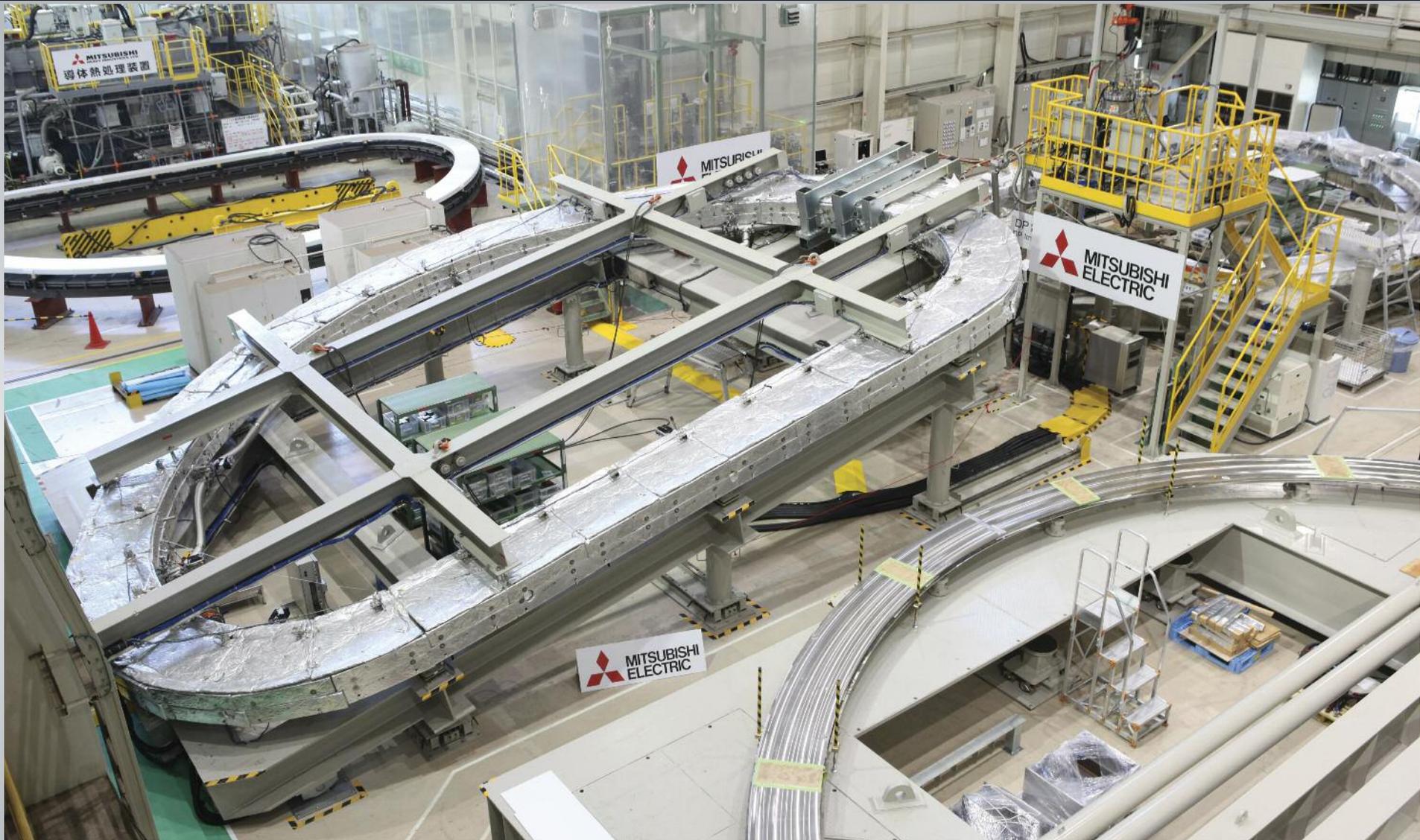
Approximately 55 percent of the space between the double walls of the vacuum vessel will be occupied by in-wall shielding blocks that protect ex-vessel components from neutron radiation. India is manufacturing close to 9,000 of these blocks and sending them in batches to vacuum vessel manufacturers in Europe and Korea.



Some 100 containers of piping are expected from India for ITER's component cooling water, chilled water and heat rejection systems. Deliveries are arriving regularly.



In the cryostat manufacturing facility in India, a segment of the pedestal ring (part of tier 2 of the base) is inspected before delivery to ITER. Responsible for the manufacturing design, fabrication and assembly of the 3,850-tonne ITER cryostat, India is shipping the cryostat to ITER in 54 segments for on-site assembly.



Toroidal field coil windings are first insulated with glass and polyimide tape, then impregnated with cyanate-ester and epoxy resins to harden the assembly. Thirty-five double-pancakes – the building blocks of the toroidal field coils – have been insulated and impregnated at Mitsubishi Heavy Industry's Futami factory.



Japan is supplying the high voltage power supplies and the high voltage bushing for MITICA, a full-scale ITER neutral beam injector under installation at the PRIMA neutral beam test facility in Italy. Pictured are assembly tests on the 1MV bushing at Hitachi, before the component is shipped and installed in the 1 MV insulating transformer.



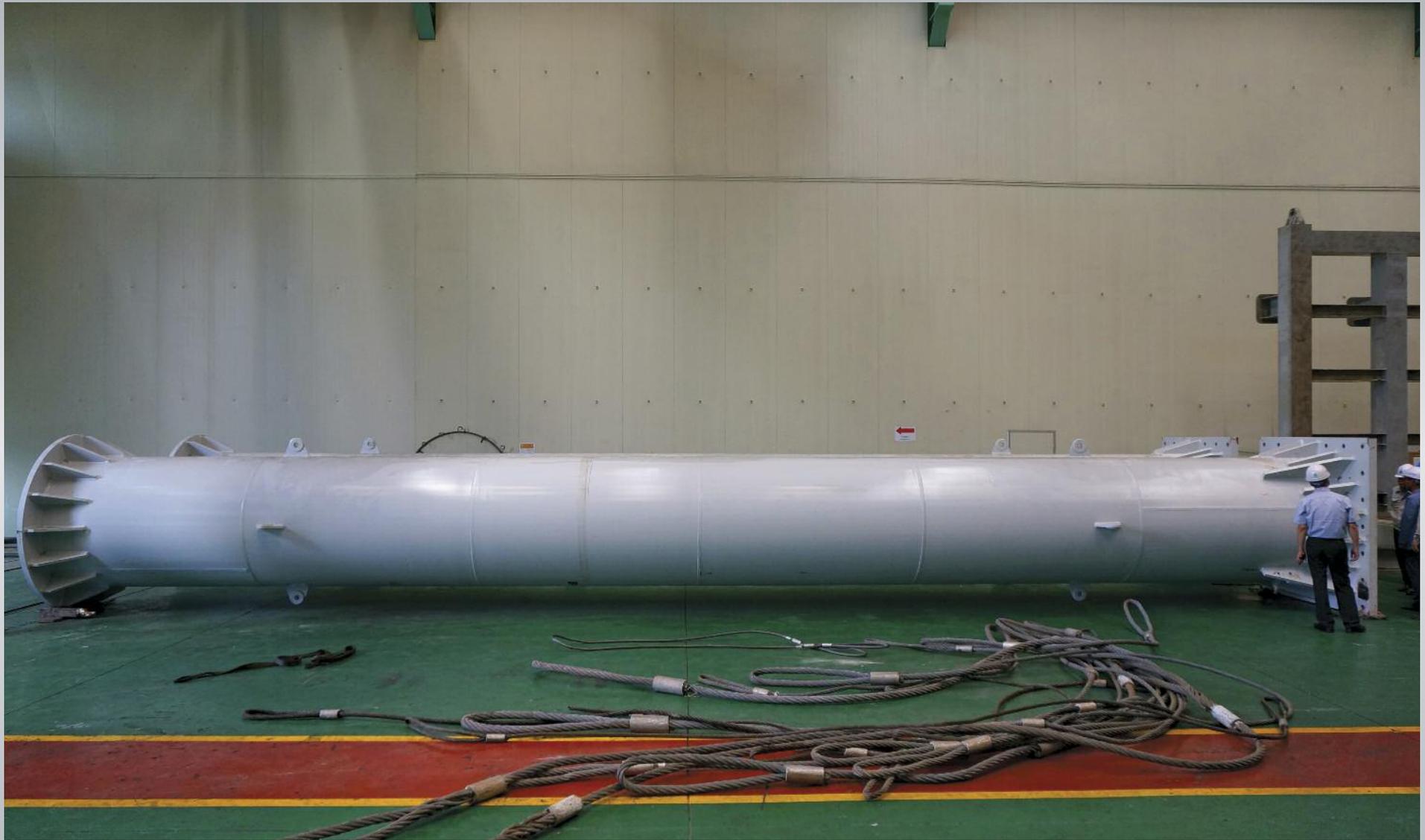
Mineral insulated (MI) cables have been manufactured by Toshiba Co Ltd under contract with QST. These MI cables will deliver signals from micro fission chambers which are located near the plasma to “count” neutrons during operation as a way to measure fusion power.



Each of the nine vacuum vessel sectors will be assembled from four segments (upper, lower, inner and outer). At Hyundai Heavy Industries, technicians carry out 3D dimensional inspection on the upper segment of sector 6.



A thin barrier of stainless steel (10-20 mm), actively cooled and covered with a low-emissivity coating of silver, will protect the magnet coils from thermal radiation. At SFA Engineering in Changwon, welding is underway on an outboard sector of the vacuum vessel thermal shield.

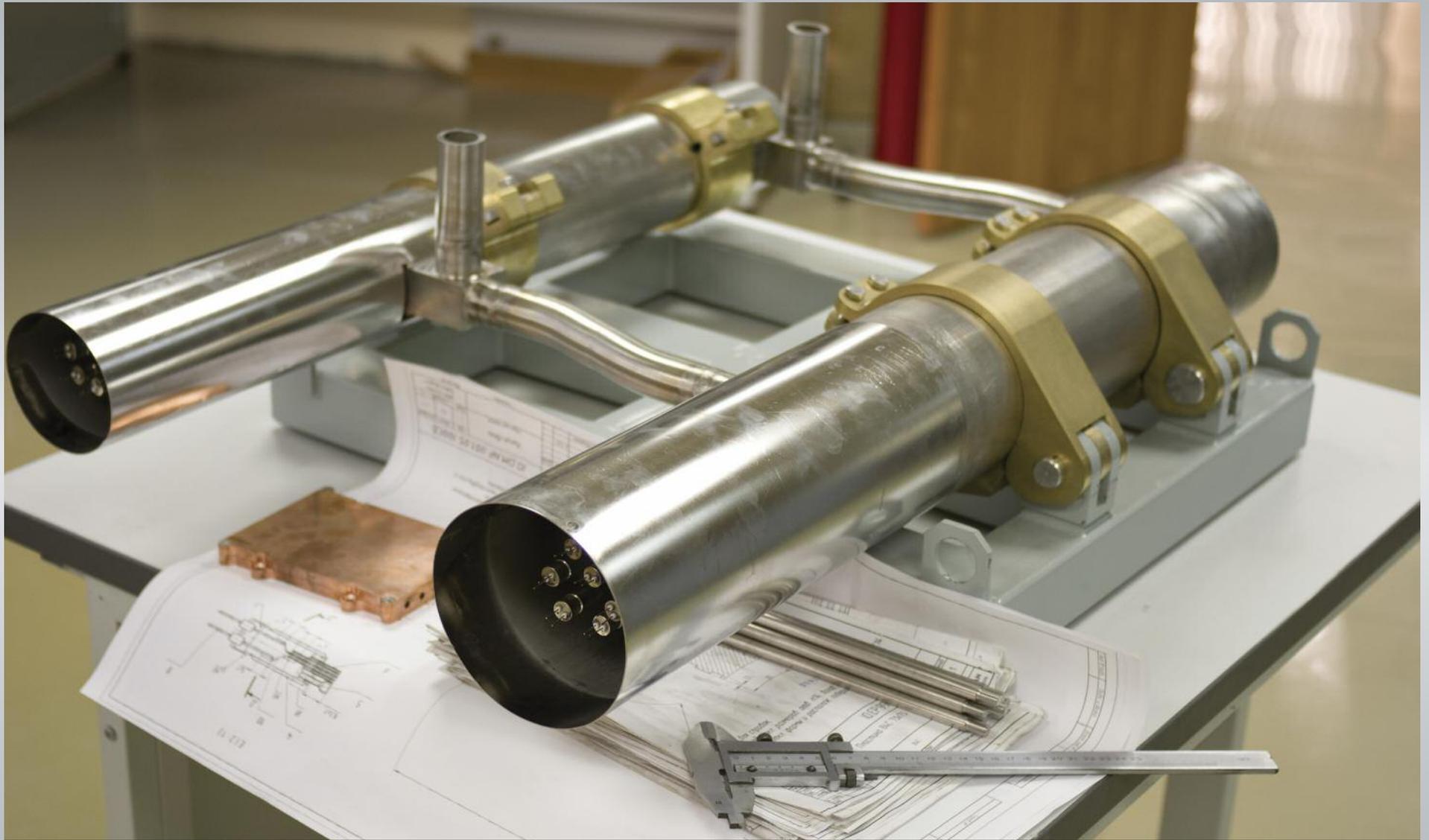


Staff inspects the outboard columns of the giant sector sub-assembly tool at Taekyung Heavy Industries in Changwon. Two sector sub-assembly tools – standing 22 metres tall and weighing 800 tonnes each – will suspend each vacuum vessel sector in the Assembly Hall while toroidal field coils and thermal shielding is installed.

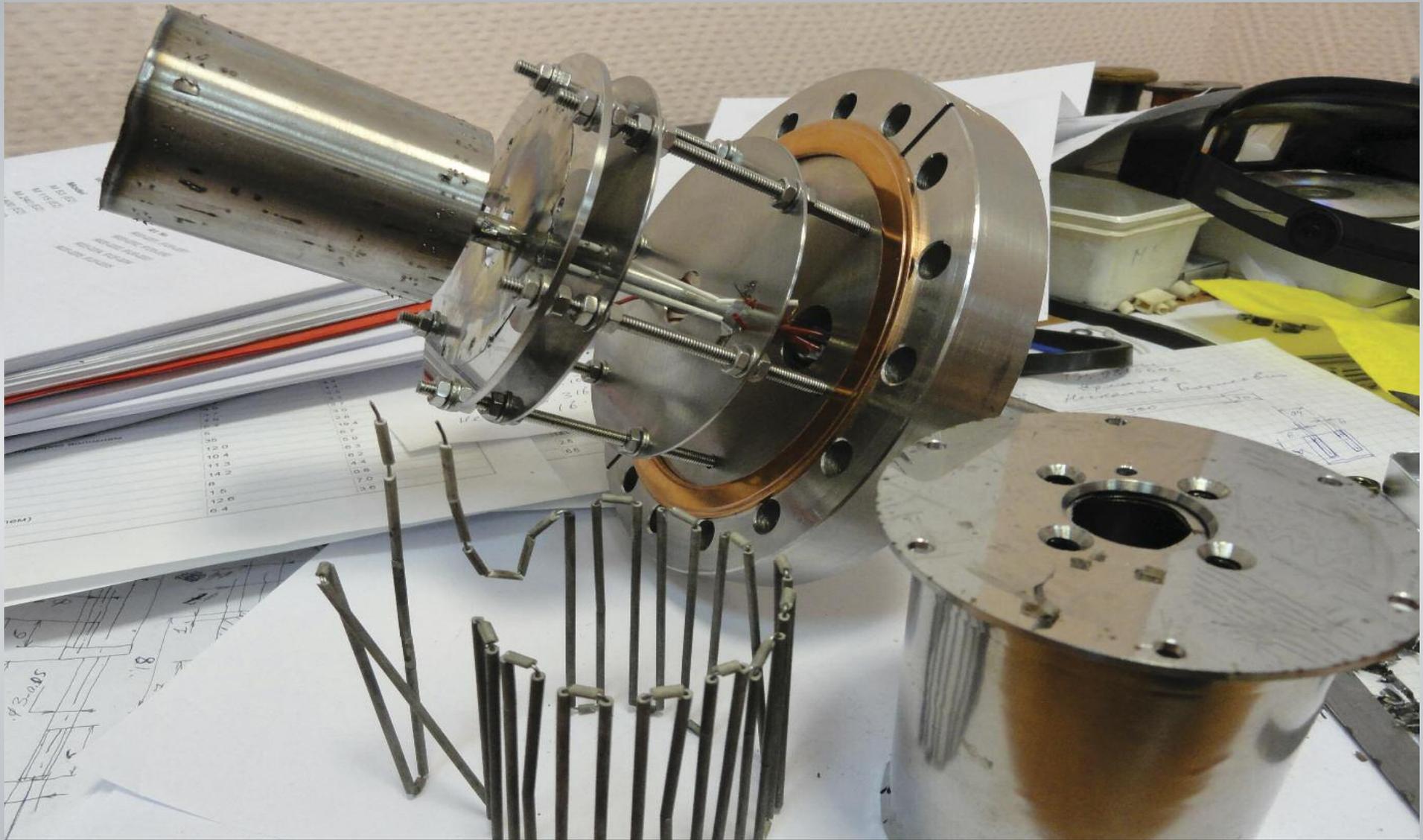


In St. Petersburg, specialists of the Efremov Institute and the Srednenevsky shipyard have completed the first poloidal field double pancake winding. Eight double pancakes will be stacked to form poloidal field coil 1, the smallest of ITER's ring-shaped magnets.

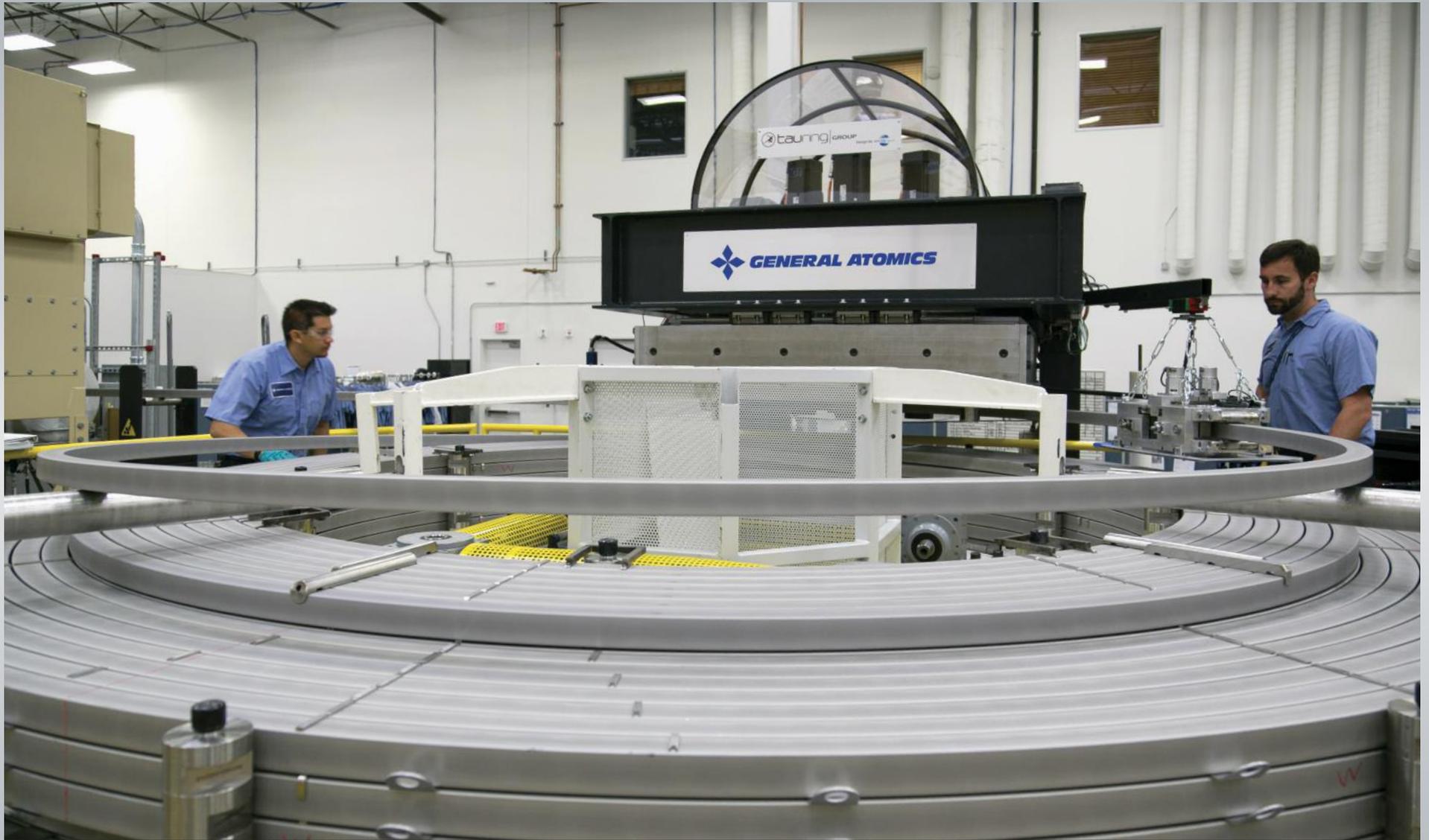
“Seeing” the neutrons from the divertor



The divertor neutron flux monitoring system – under development in Russia – will provide routine measurements of neutron emissions from a location at the bottom of the vacuum vessel.



The design, prototype manufacturing and testing of in-vessel components for the H-alpha spectroscopy diagnostic is underway. Mock-ups for the first mirror, the labyrinth mirror and a pneumatic shutter (pictured) have been successfully tested.



General Atomics technicians complete the winding of the first central solenoid module in April. Six modules – each made from approximately 6,000 metres of niobium-tin (Nb3Sn) superconductor supplied by Japan – will be stacked to form the 13-metre-tall central magnet.



Tie plates for the central solenoid undergo machining at Major Tool and Machine in Indianapolis, Indiana. These plates are part of a specially designed support structure that will hold the central electromagnet in place during operation despite thousands of tonnes of force.

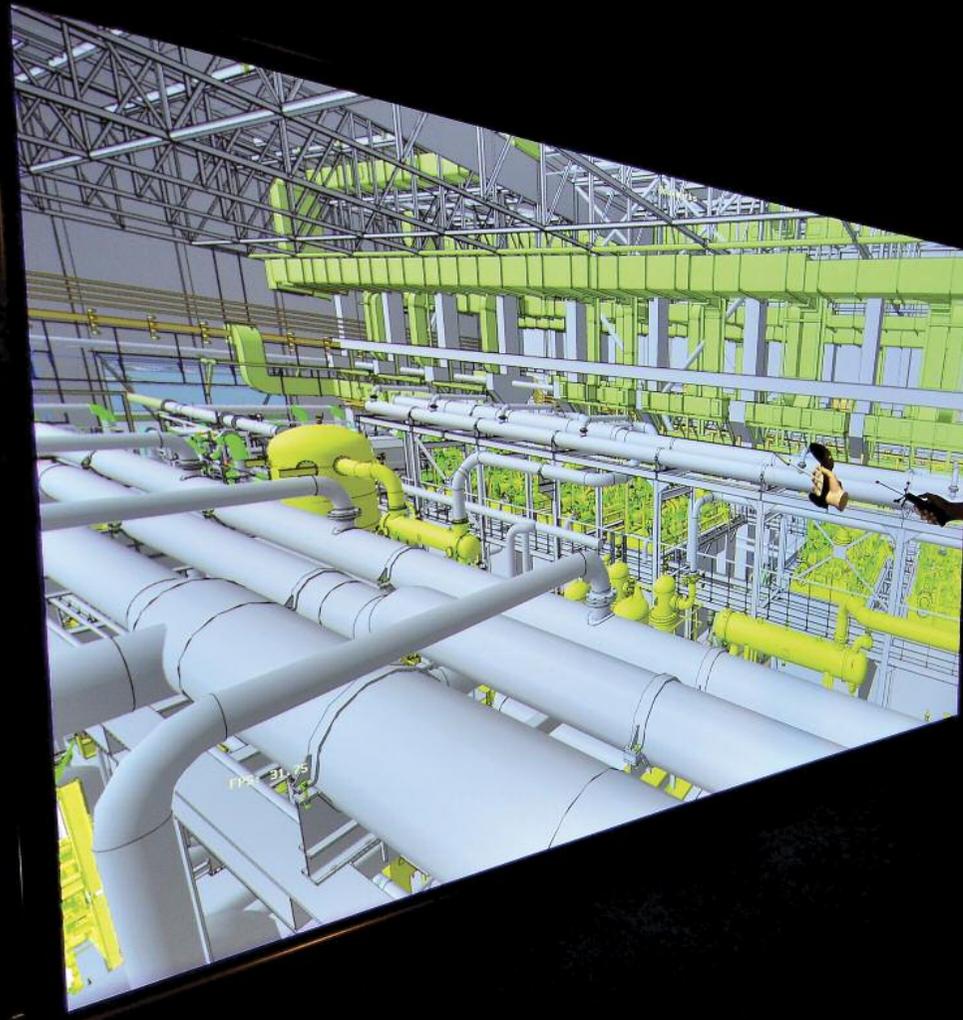


A high-speed injection system will be used to deliver pellets of fuel to the core of the plasma and “pace” plasma instabilities that may form on the edge. This dual nozzle developed at Oak Ridge National Laboratory will deliver both – selecting differently sized pellets for either fuelling or pacing.



Senior representatives from the seven ITER Members convene twice a year as part of the ITER Council – the ITER Organization’s top governing body.

3D rendering of ITER plant systems



The virtual reality room is used by technical responsible officers and configuration managers for design and engineering activities. The “immersion” experience (in this photo, the ITER cryoplant) facilitates the identification and resolution of integration challenges.

Welcoming the head of the IAEA



The Director General of the International Atomic Energy Agency, Yukiya Amano, considers that "ITER's impressive work is crucial to advancing research in [fusion]." His visit to the site in 2016 was the second in five years.



In July, a group of Iranian nuclear specialists and government officials visit to better understand the nature and scope of the project. Subject to the endorsement of all ITER Members, the ITER Agreement is open to any country that has the scientific, technological and financial commitment to contribute meaningfully to the project and its stated goal of demonstrating the scientific and technological feasibility of fusion energy for peaceful purposes.

Welcome Australia!



The ITER Organization concludes a technical cooperation agreement in September with the Australian Nuclear Science and Technology Organisation, ANSTO, representing the Australian fusion community. For this first technical agreement signed with a non-Member state, cooperation is foreseen in a number of strategic areas, including diagnostics, materials, superconducting technology, and fusion plasma theory and modelling.

Meeting the public



Held twice a year, ITER Open Door Days are the occasion to visit the construction site, meet ITER specialists and ask questions about the world's largest collaborative effort in science.

Scientist Fellow network launched



The first ITER Scientist Fellows gather at Headquarters in September. Nominated by heads of institutes in the ITER Members, these scientists have agreed to apply their expertise to solving some of ITER's high-priority research needs, particularly in the areas of simulation and theory.

The men and women of ITER



Approximately 500 of the ITER Organization's 730 directly employed staff members take part in a team photo in January, before the installation of the first assembly platform in the Cryostat Workshop makes gathering impossible.

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