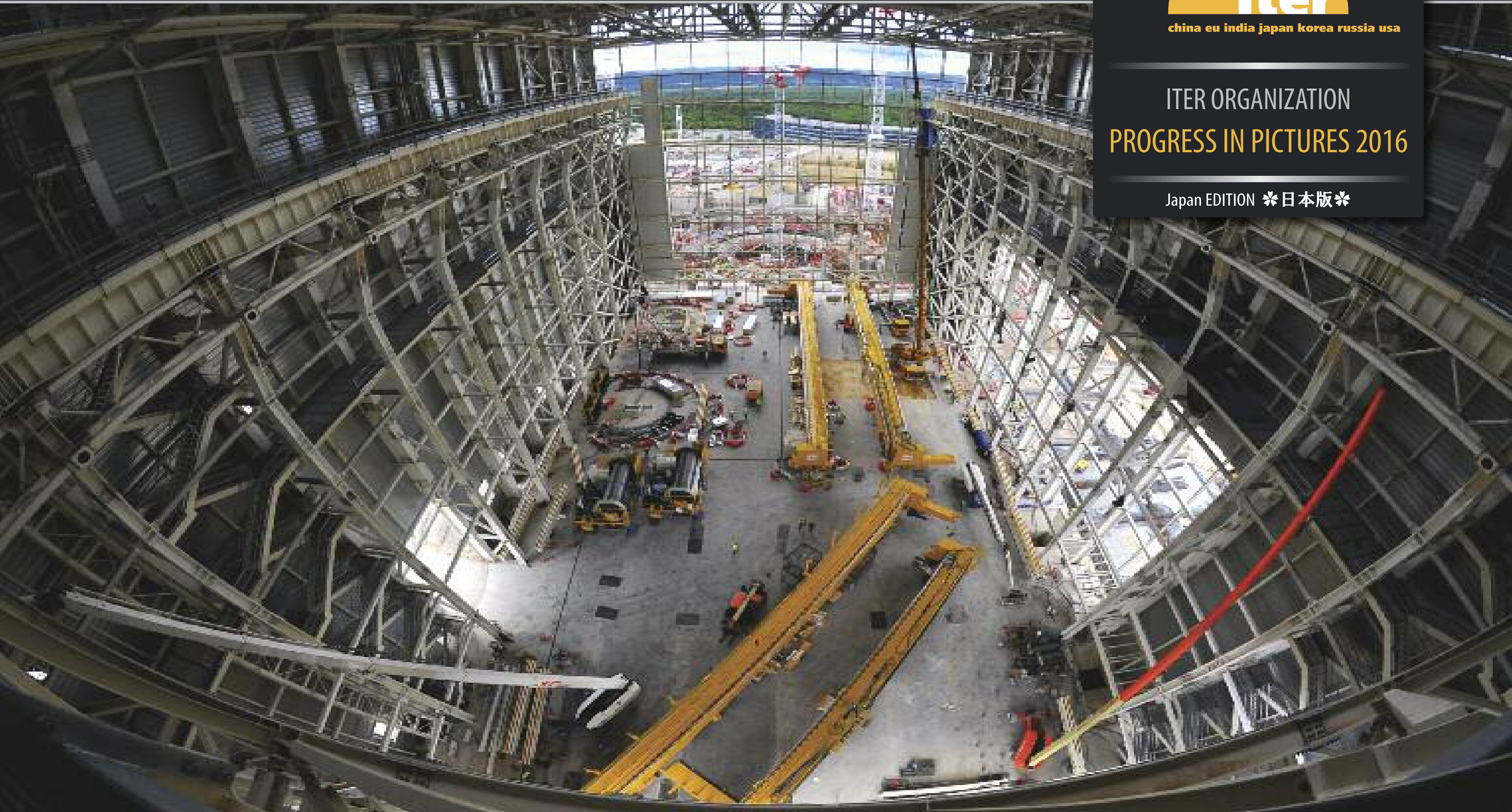

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ITER ORGANIZATION

PROGRESS IN PICTURES 2016

Japan EDITION ✲日本版✲


BRINGING
THE POWER
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ITER ORGANIZATION

PROGRESS IN PICTURES 2016

November 2016

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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.

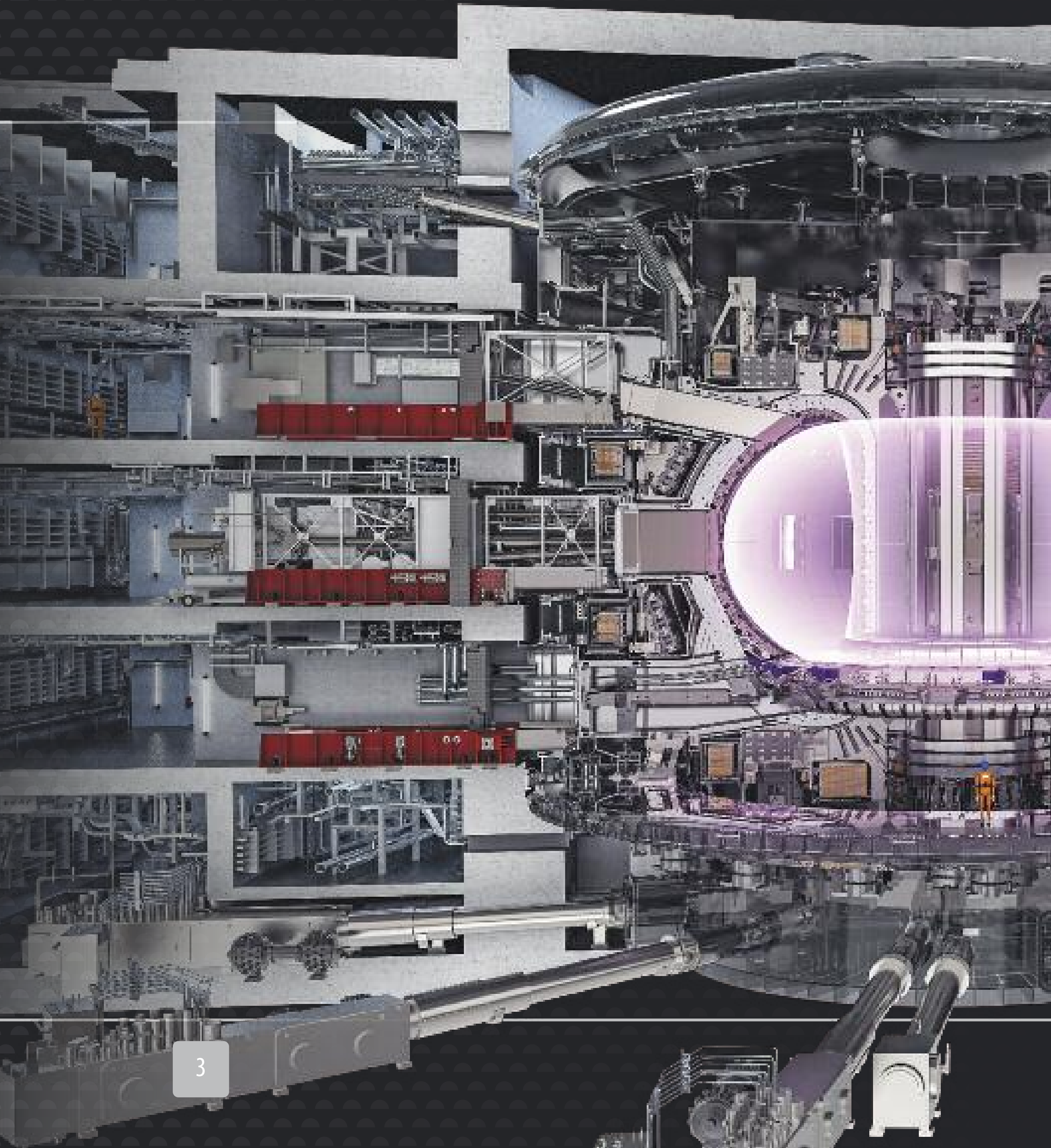
From a scientific and technological point of view, it will be one of humankind's historic achievements. The creation of an artificial star and the tapping of the tremendous amounts of energy produced could forever alter the course of civilization.

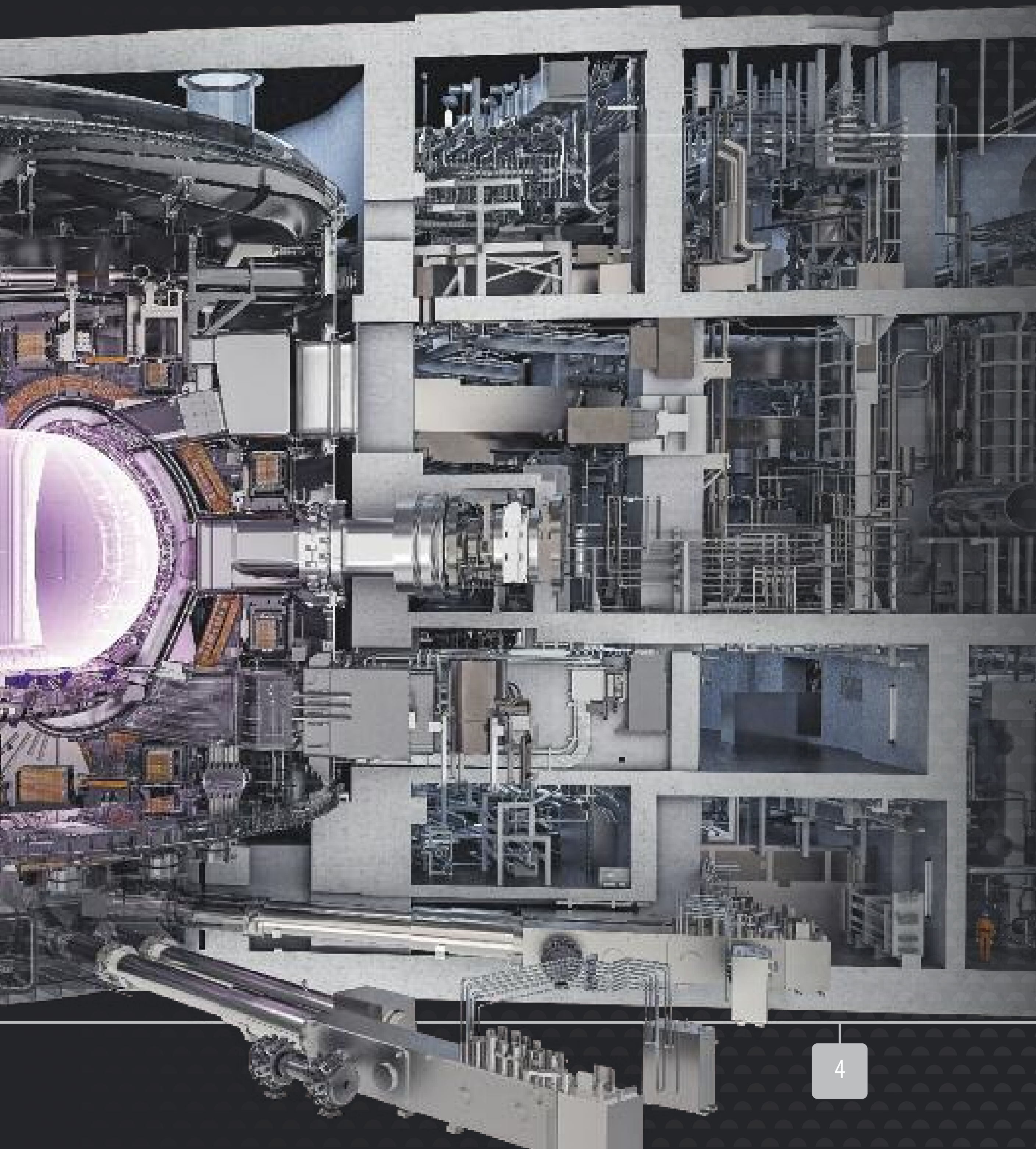
The ITER Project, an unprecedented international collaboration that brings together China, the European Union, India, Japan, Korea, Russia and the United States, is the culmination of decades of research and years of diplomatic negotiation. It has been the aspiration of three generations of physicists; 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

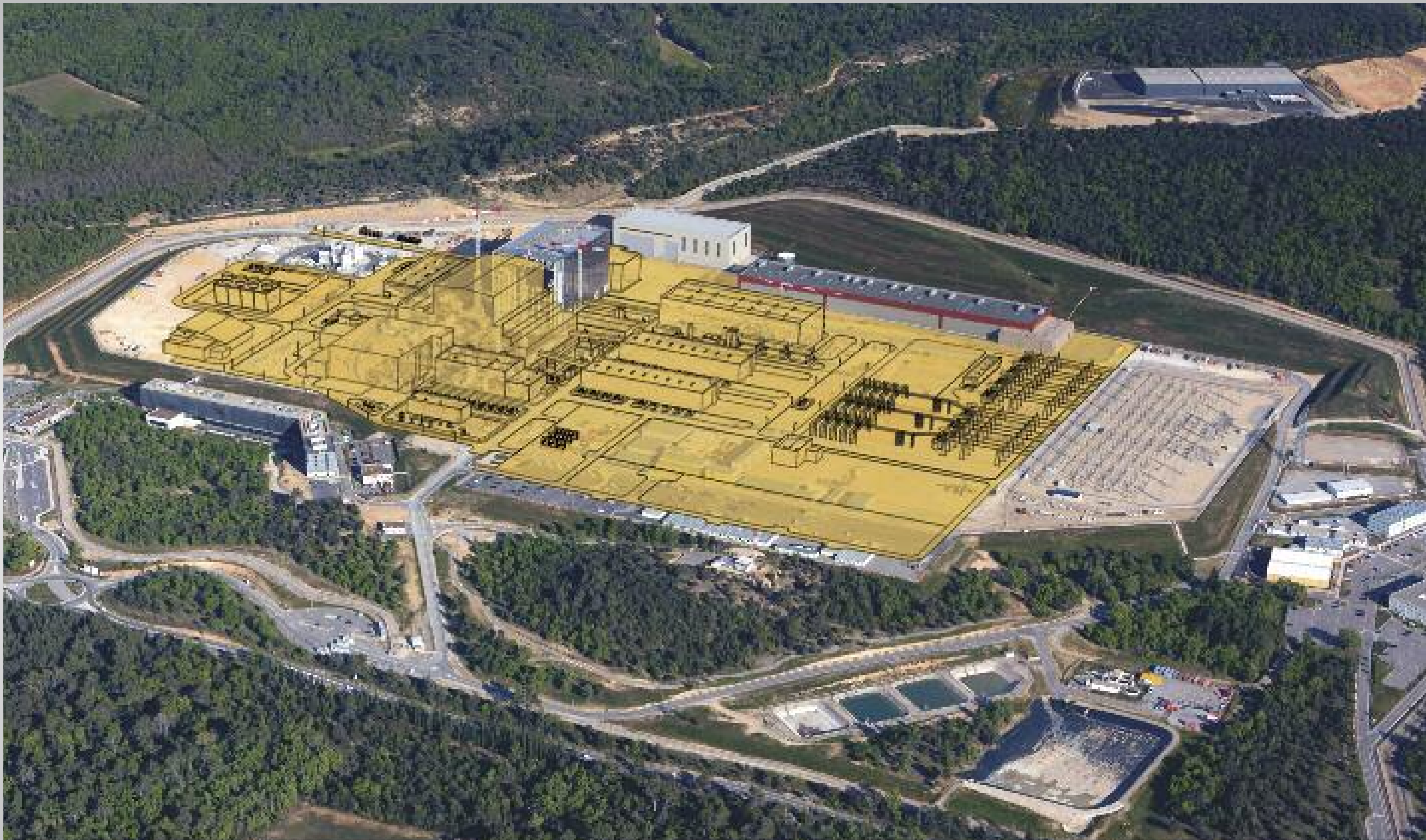
The ITER machine is a *tokamak*, the Russian acronym for Toroidal Chamber, Magnetic Coils. Tokamaks were developed in the 1960s at a time when nations were experimenting with all kinds of different systems to reproduce the nuclear reactions at work in the core of the Sun and stars.

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.

The heart of ITER

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*

The ITER site, looking northwest

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*

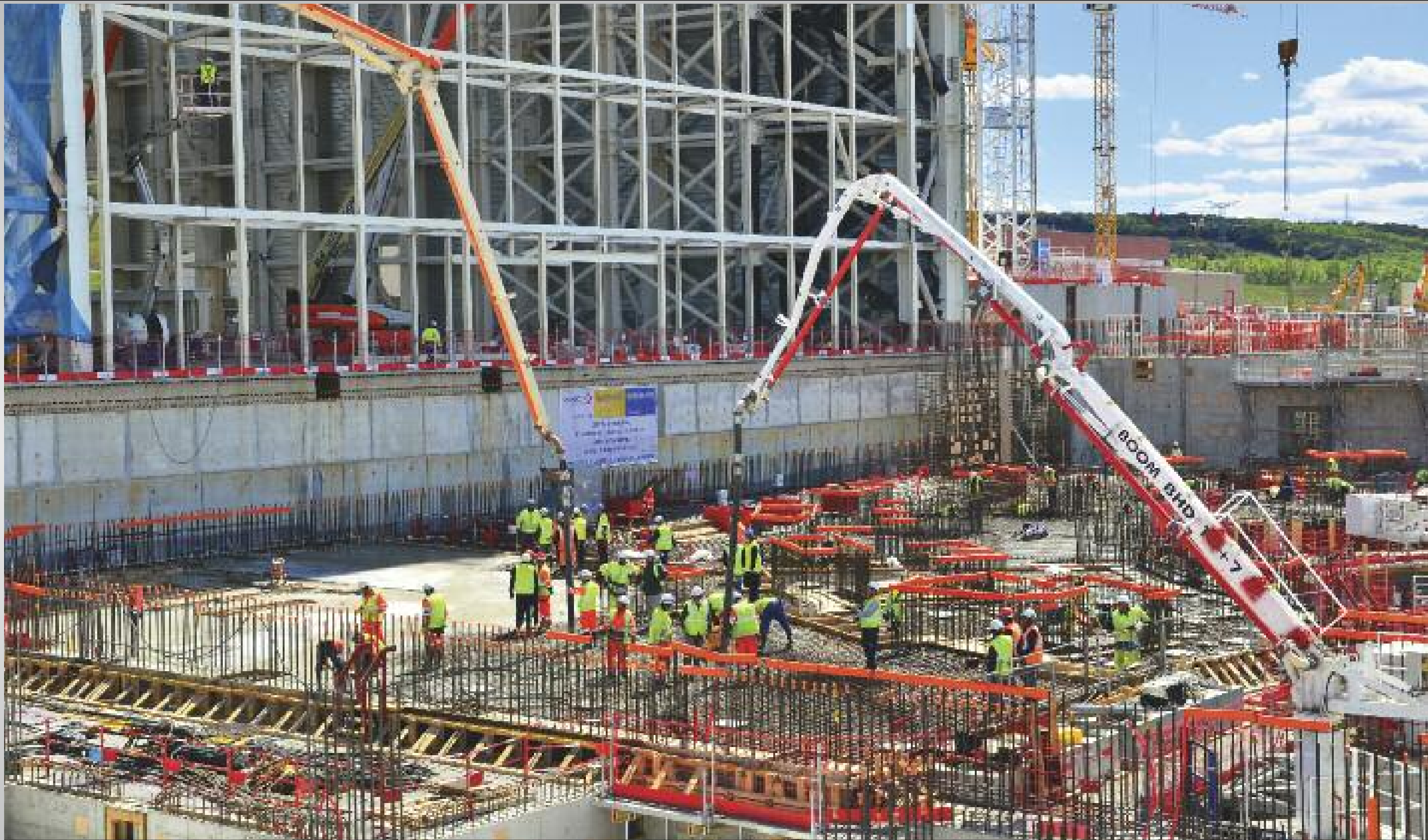
A spectacular backdrop

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*

Cladding completed

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*

Constructing the basement levels



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*

A perfect circle

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*

440,000 tonnes of building and machinery

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*

Deep in the Tokamak Pit

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*

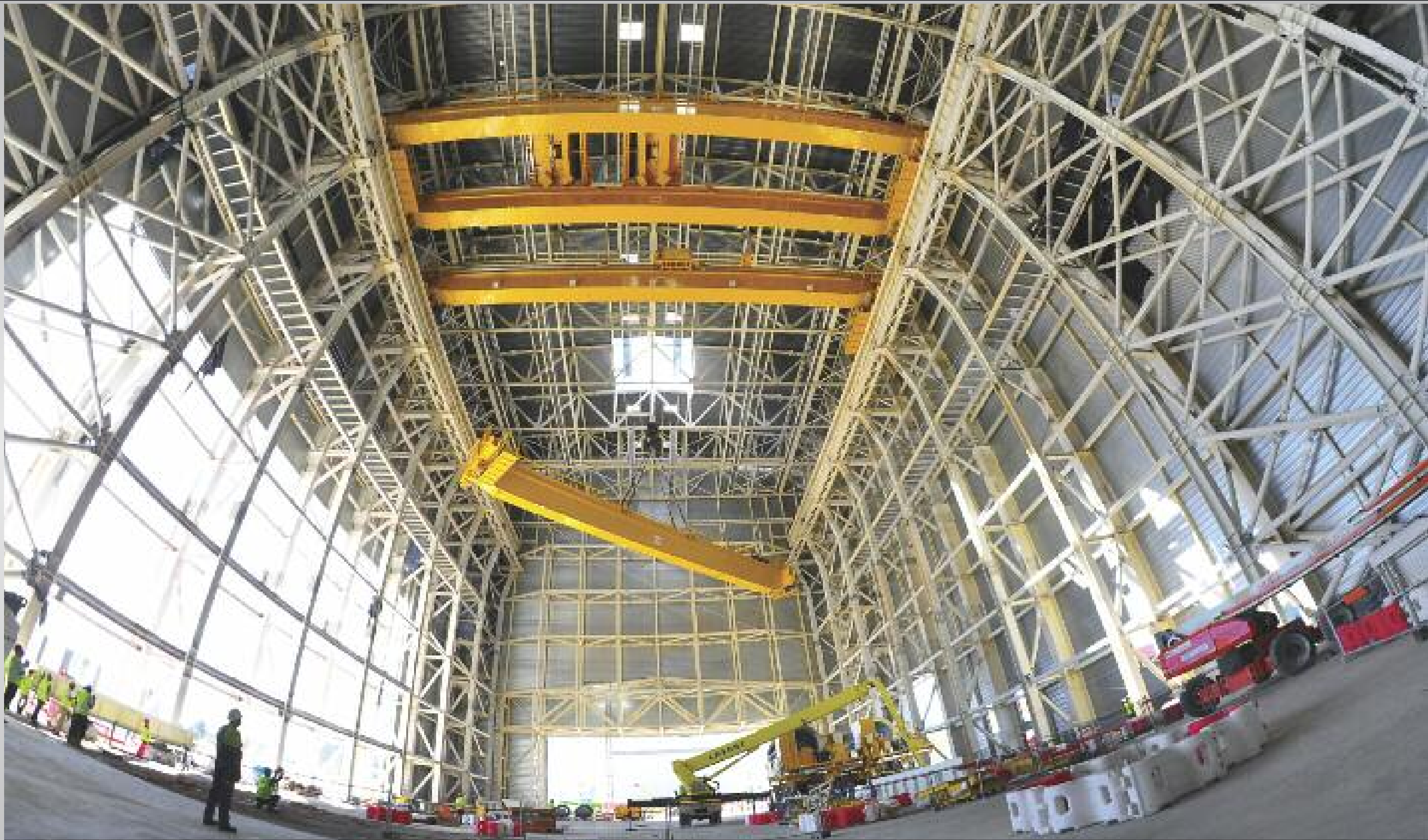
Cathedral-like space

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*

Cranes installed

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*

Assembly workhorses



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*

Winding qualification activities begin

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*

Cryoplant Building progressing

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*

World's largest single-platform cryoplant

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 cryoplant and distributed through a vast network of pipes, pumps and valves. *October 2016*

Deliveries accelerate

Large components like this cryoplant 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*

Barge and escort

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*

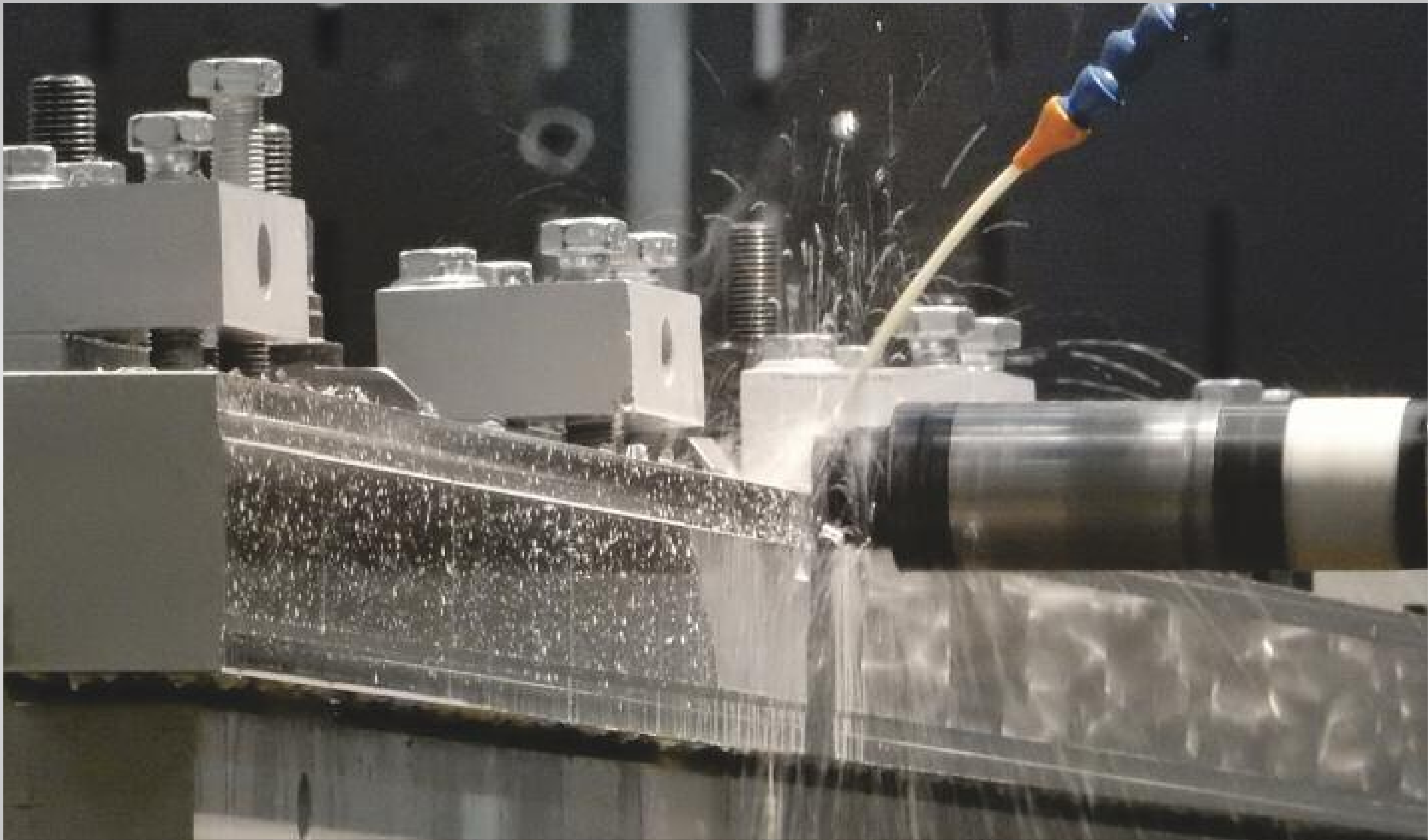
Approximately 1,500 workers are involved in the construction of the ITER scientific installation. The last daily shift ends at 10 p.m. *November 2016*

The challenge of cryostat assembly

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*

Cryostat welding begins

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

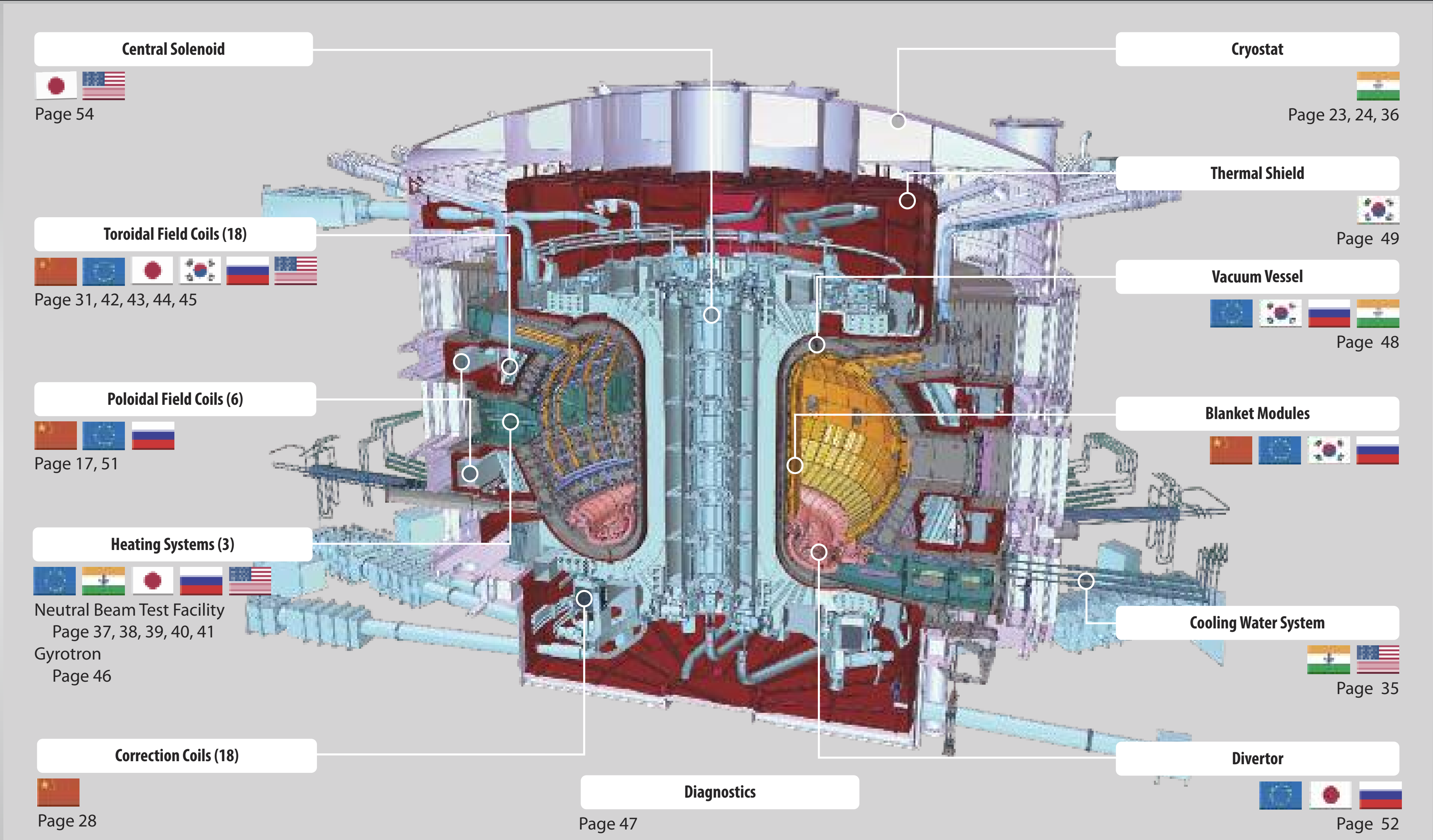
MANUFACTURING

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.

Qualifying correction coil fabrication

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.

Mega transformer

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.

Carrying a lot of current

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.

First toroidal field winding pack

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.

A small tank, but a large milestone

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.

Inner tank passes leak tests

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 m^3 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.

Cooling water pipes

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-factory inspections

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.

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china eu india japan korea russia usa

1MV insulating transformer's journey from Japan to the ITER NBTF site in Italy

Japan supplies the 1 MV dc high voltage power supply to be used in the Neutral Beam Test Facility at Padua, Italy, as part of the ITER project.
The 1 MV insulating transformer was manufactured at Kokubu Works of Hitachi Ltd..

Shipping the 1MV step-up transformers to the ITER NBTF site in Italy from Japan

A high voltage of 1 MV is generated from five step-up transformers connected in series delivering 200 kV each.
The transformers were transported from Kokubu Works of Hitachi Ltd. to Italy.

1 MV dc generator installed at the NBTF site in Padua, Italy

Diode stacks contained in pressure vessels were mounted on each step-up transformer to form what's called the dc generator, or DCG, to generate 200 kV dc.
Connected in series, the DCG delivers 66 A at 1 MV dc high voltage.

Contributing to the Neutral Beam Test Facility

Japan is supplying the high voltage power supplies and bushings for MITICA, a full-scale ITER neutral beam injector being installed at the PRIMA neutral beam test facility. Pictured are assembly tests of a 1MV bushing at Hitachi, Japan, before it was shipped and installed in the 1 MV insulating transformer.

Installation of 1 MV bushing for the insulating transformer at the NBTF

Negative ions of deuterium are first produced at 1 MV high potential, and then accelerated towards ground potential.
While the insulating transformer provides an electric power of 5 MVA for ion production at 1 MV high potential, the huge 16m-long bushing provides electric power at the top, ensuring 1 MV high voltage insulation.

Double pancake series production

Double pancakes for the ITER TF coils are first insulated with glass and polyimide tape, then impregnated with cyanate-ester and epoxy resins to harden the assembly.
Seven double pancakes for the first-of-series production – the building blocks of the toroidal field coils – have been insulated and impregnated at the Futami Plant of Mitsubishi Heavy Industries, Ltd./Mitsubishi Electric Co.

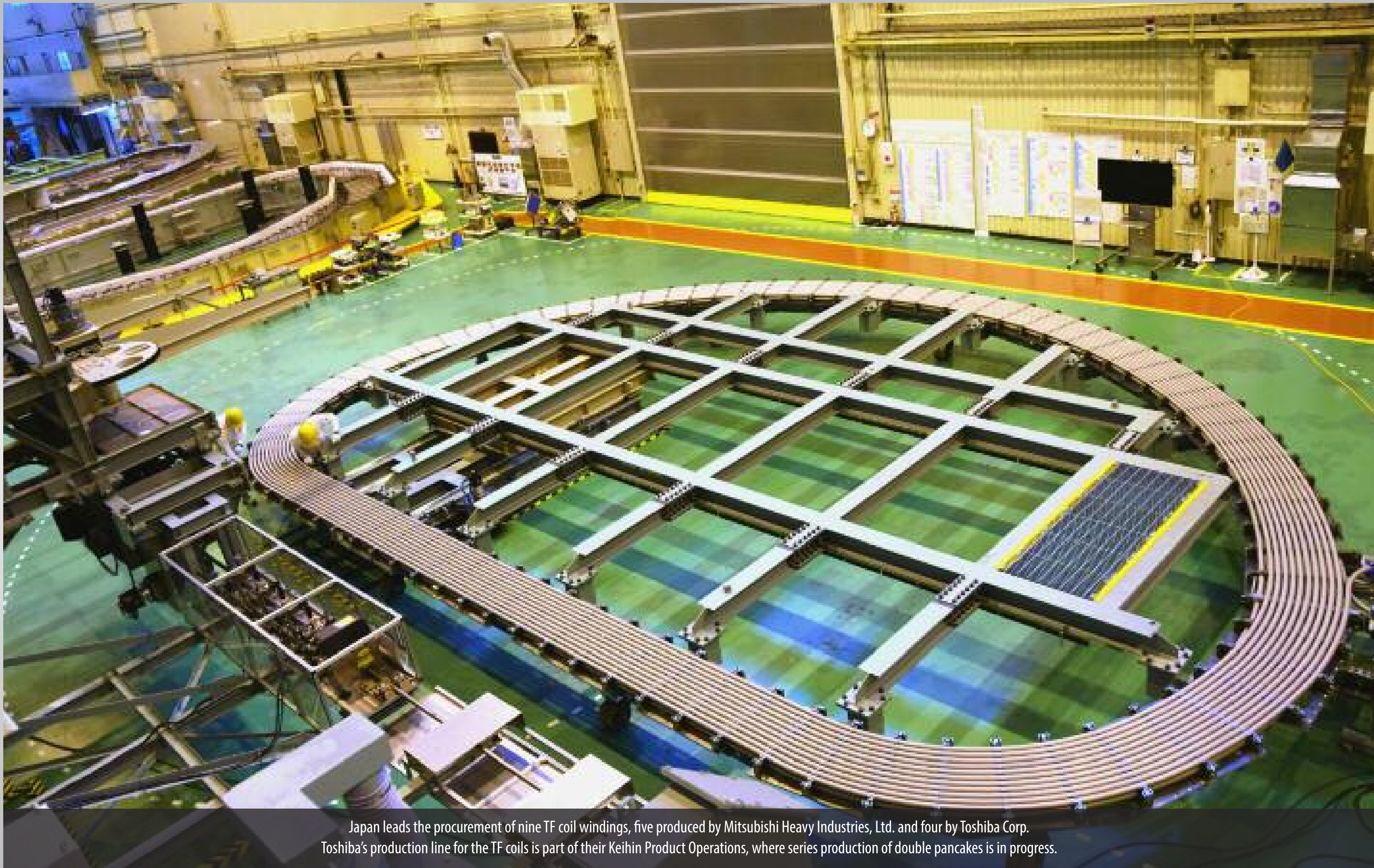
ITER Toroidal field coil structures now in series production

The inboard side structures for the ITER TF coil cases are now in series production at the Futami Plant of Mitsubishi Heavy Industries, Ltd..
The inboard side structures consist of a single long straight section in the center, and two curved parts at both ends. They are made of a special austenitic stainless steel and measure 16 m long.

Welding the TF coil winding cover plates

The TF coil conductor is wound into a D-shape and heat-treated to generate the superconducting Nb_3Sn compound in the conductor. The heat-treated conductor is then inserted into the grooves of a radial plate and cover plates are welded to seal the assembly. There are two cover plate welding stations at the Futami Plant of Mitsubishi Heavy Industries, Ltd./Mitsubishi Electric Co, each having two welding heads.

Second production line for TF coils is up and running



Japan leads the procurement of nine TF coil windings, five produced by Mitsubishi Heavy Industries, Ltd. and four by Toshiba Corp.
Toshiba's production line for the TF coils is part of their Keihin Product Operations, where series production of double pancakes is in progress.

First ITER gyrotron delivered to JADA for testing

The first gyrotron for ITER was manufactured at Toshiba Electron Tubes & Devices Co. Ltd., and delivered to QST's Naka Fusion Institute, where it will undergo performance testing at the RF testing facility.

Manufacture of MI cables for the Microfission Chamber System

Sealed at both ends, mineral insulated (MI) cables will deliver the signals from the micro fission chambers located near the plasma.
The microfission chamber system "counts" the neutrons during operation to measure fusion power.

Vacuum vessel fabrication in Korea

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.

Thermal shielding

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.

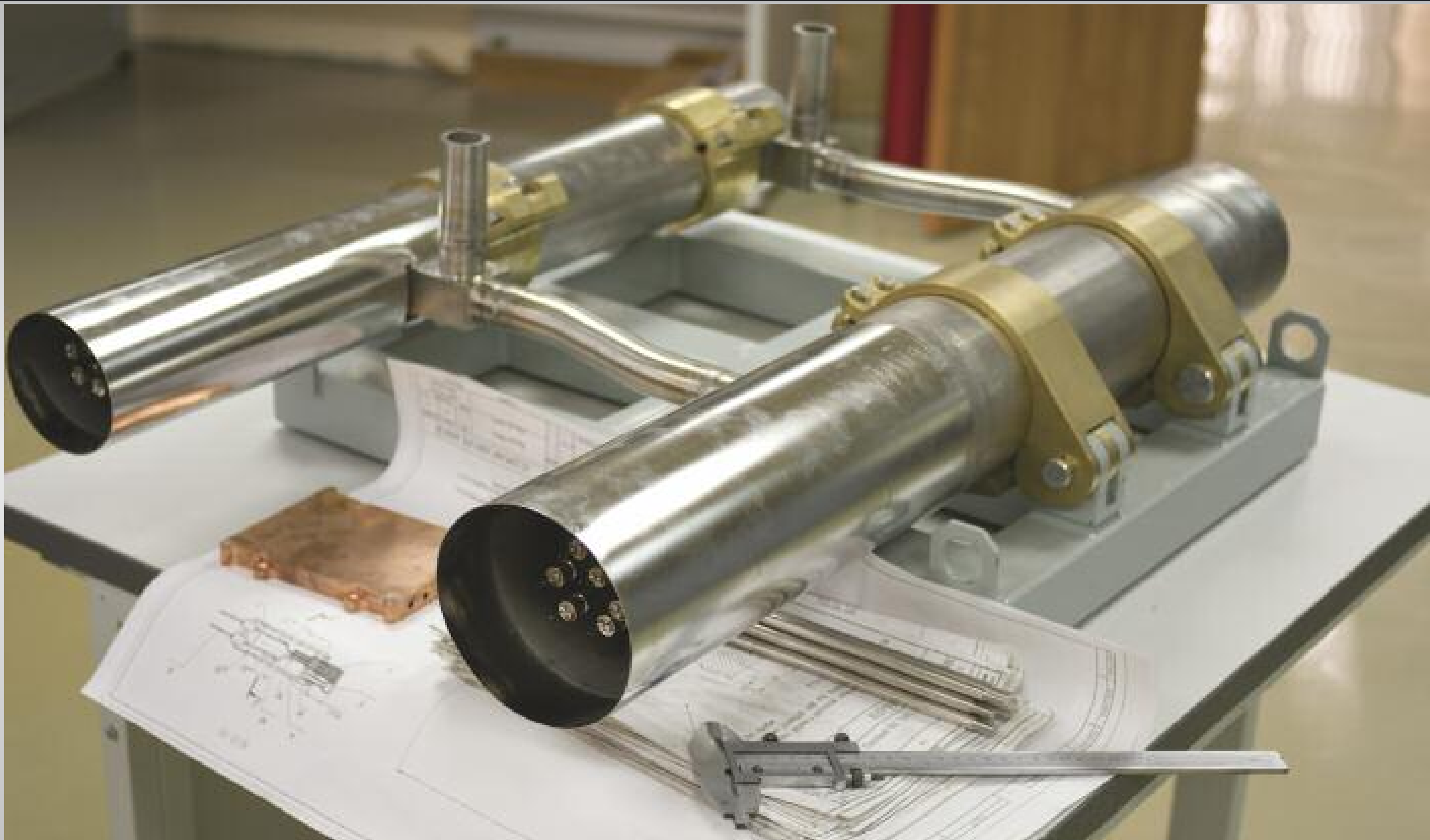
800-tonne assembly tool expected next year

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.

First of eight poloidal field coil windings

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.

Prototyping diagnostics

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.

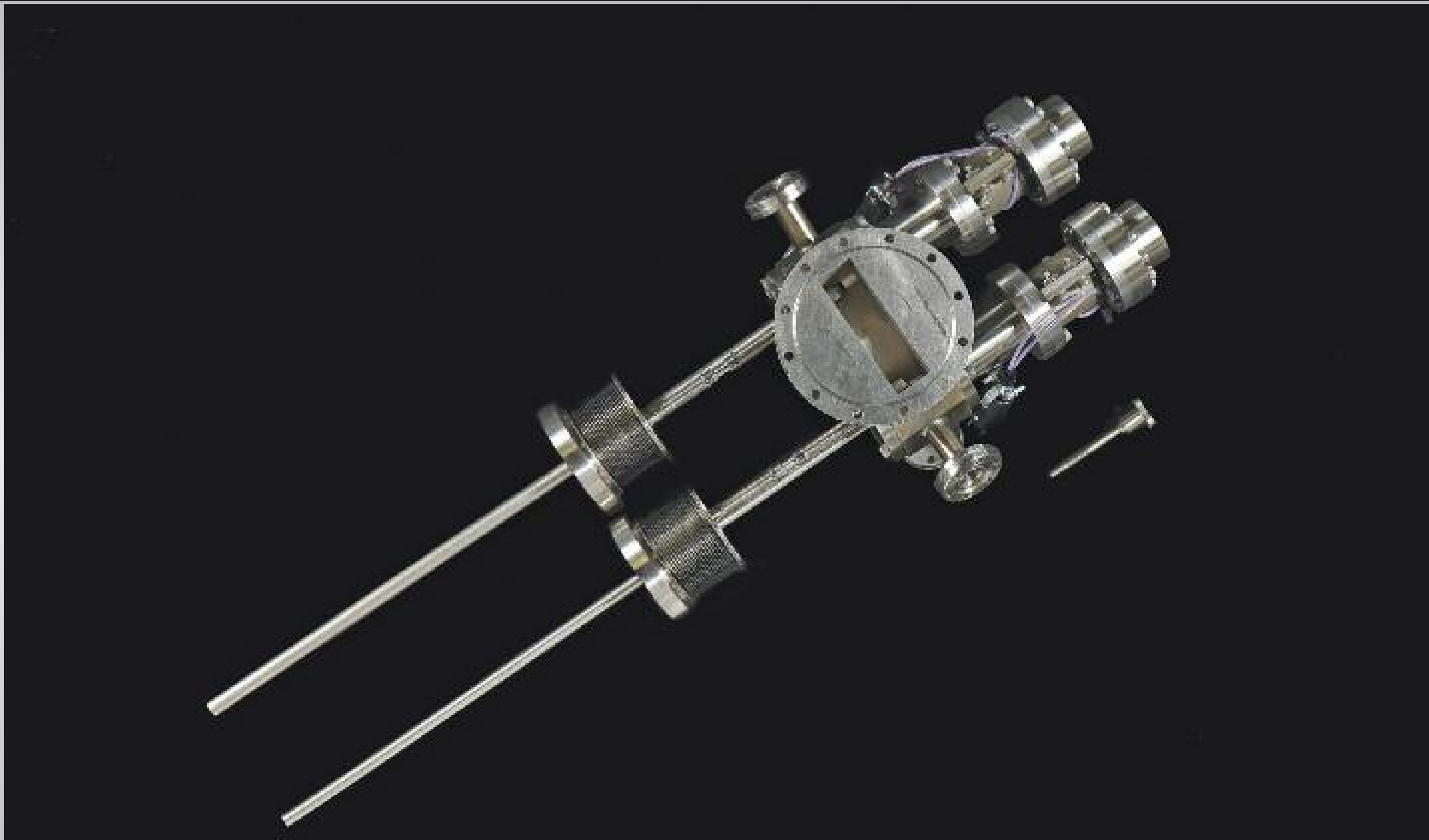
Central solenoid fabrication milestone

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.

Withstanding tremendous force

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.

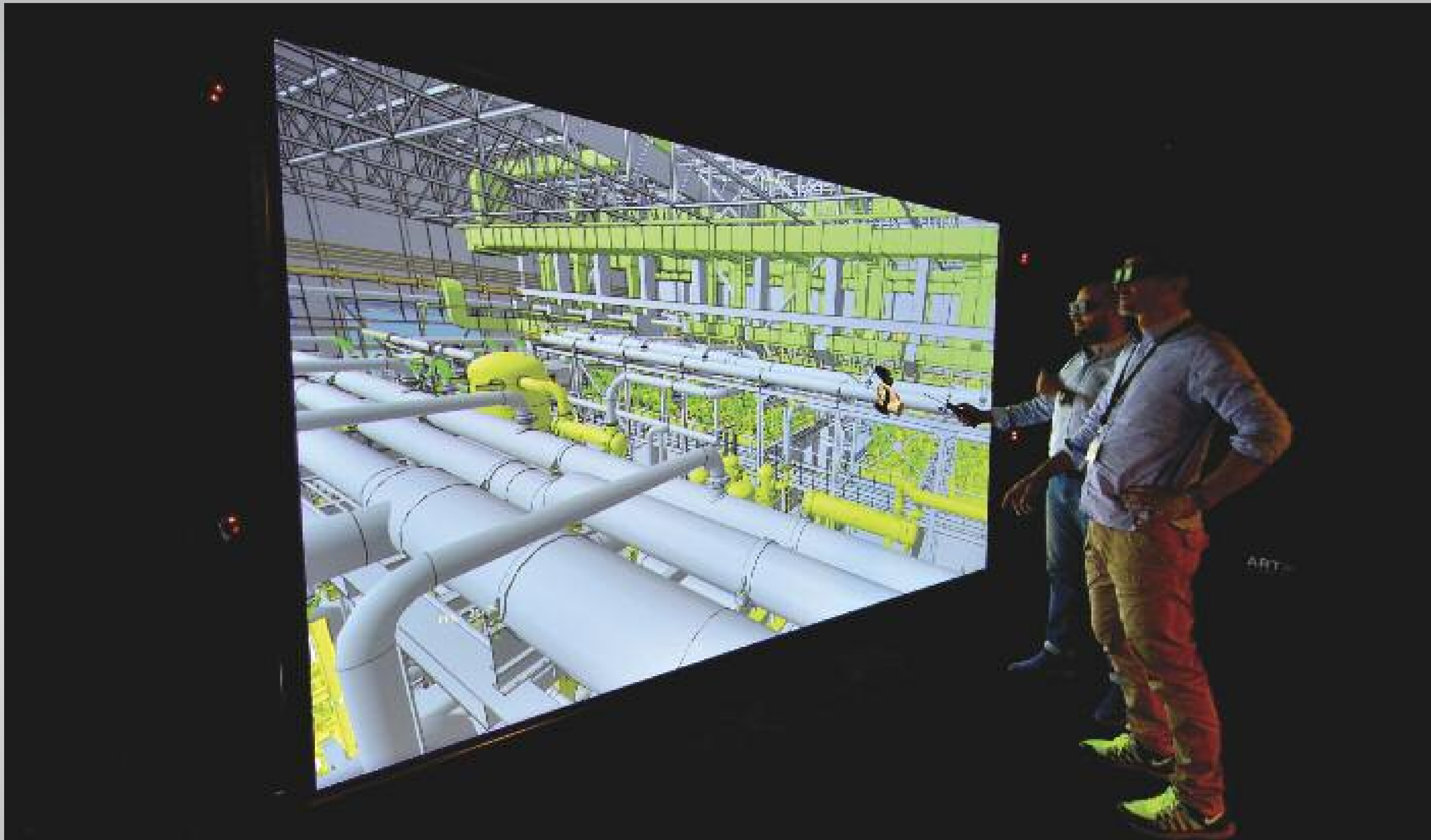
Shooting selected pellets



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.

Iranian delegation at ITER

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.

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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ITER Organization Headquarters
Route de Vinon-sur-Verdon
CS 90 046
13067 St. Paul-lez-Durance Cedex
France

Publications Director
Laban Coblentz
laban.coblentz@iter.org

Editors
Robert Arnoux
robert.arnoux@iter.org
Krista Dulon
krista.dulon@iter.org

www.iter.org

ITER Japan
Naka Fusion Institute
www.fusion.qst.go.jp/ITER/