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DECEMBER 2017

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A star is born

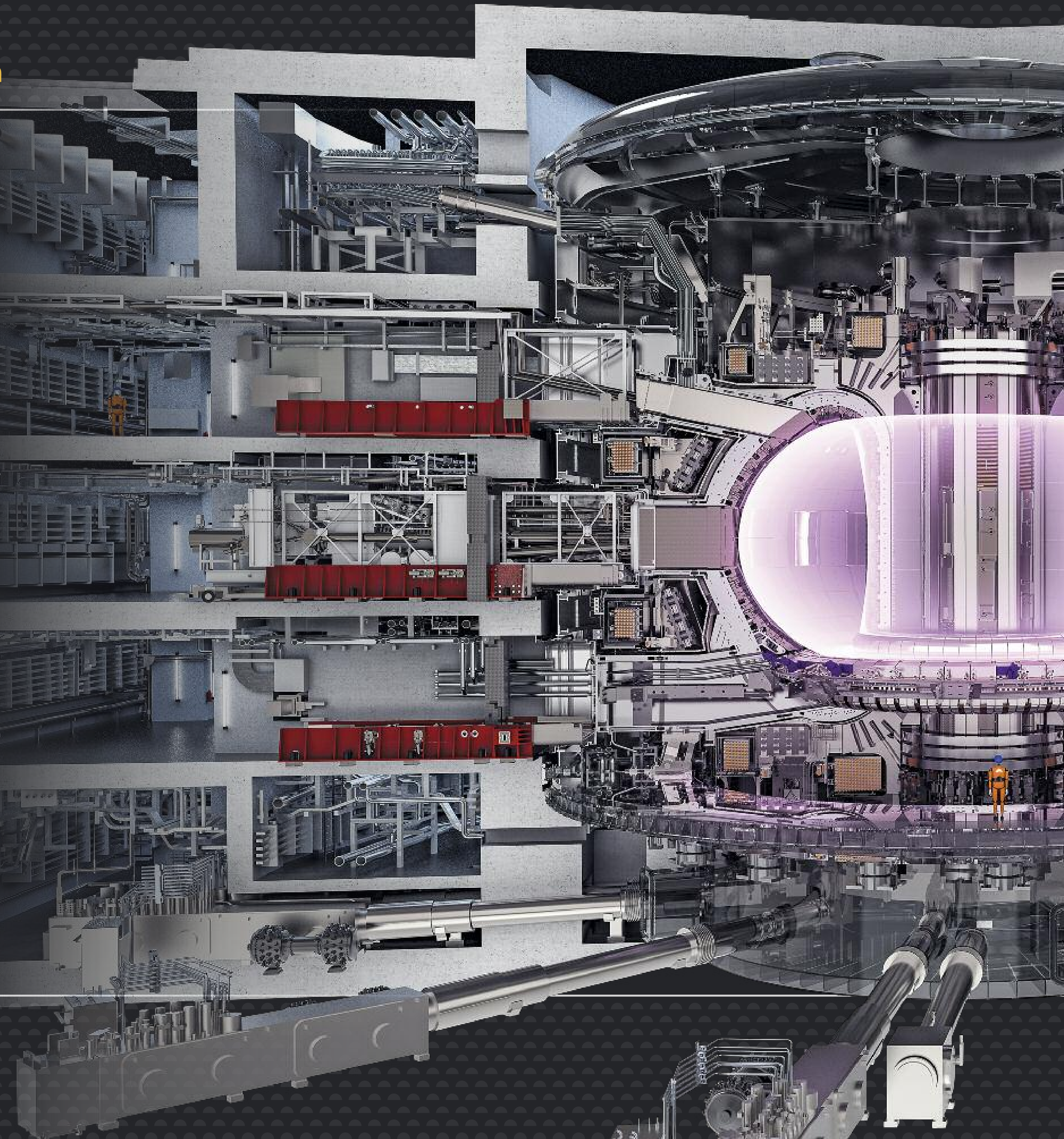
A star will soon be born, a star unlike any other ... a man-made star. ITER – the Latin word for "The Way" – will light up in the middle of the coming decade.

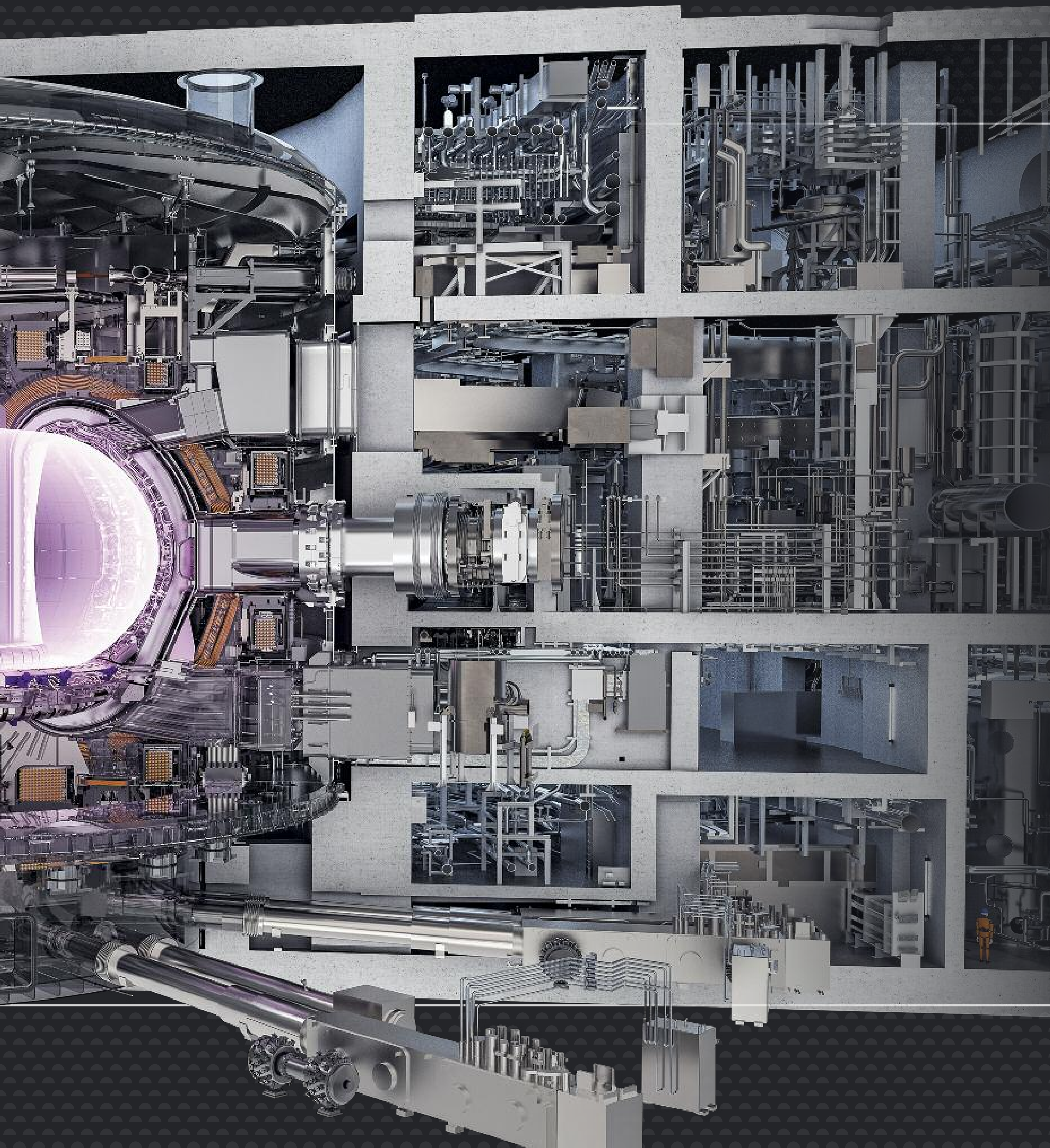
From a scientific and technological point of view, it will be one of humankind's historic achievements. The creation of an artificial star and the tapping of the tremendous amounts of energy produced could forever alter the course of civilization.

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 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.

This fourth edition of the ITER photobook aims to take you into the heart of ITER – from the construction site in Provence (pages 5 to 30) to factories on three continents (pages 31 to 54), where men and women from 35 nations are bent on realizing one of humankind's most enduring dreams: capturing the fire of the stars and making it available 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, fuses 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 gramme 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 in 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

An unprecedented collaboration

As signatories to the ITER Agreement, ITER Members China, the European Union, India, Japan, Korea, Russia and the United States are sharing in the cost of project construction and operation and also in the intellectual property and experimental results generated by the project. *April 2017*

Boomtown ITER

ITER is located approximately 75 km 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. *August 2017*

One kilometre of construction

As part of commitments as project host, Europe is building nearly all of the buildings and site infrastructure. The most complex project underway is the Tokamak Complex (left, foreground) and its perfectly circular "well" for the ITER machine; the rest of the 42-hectare platform is reserved for auxiliary plant buildings. *June 2017*

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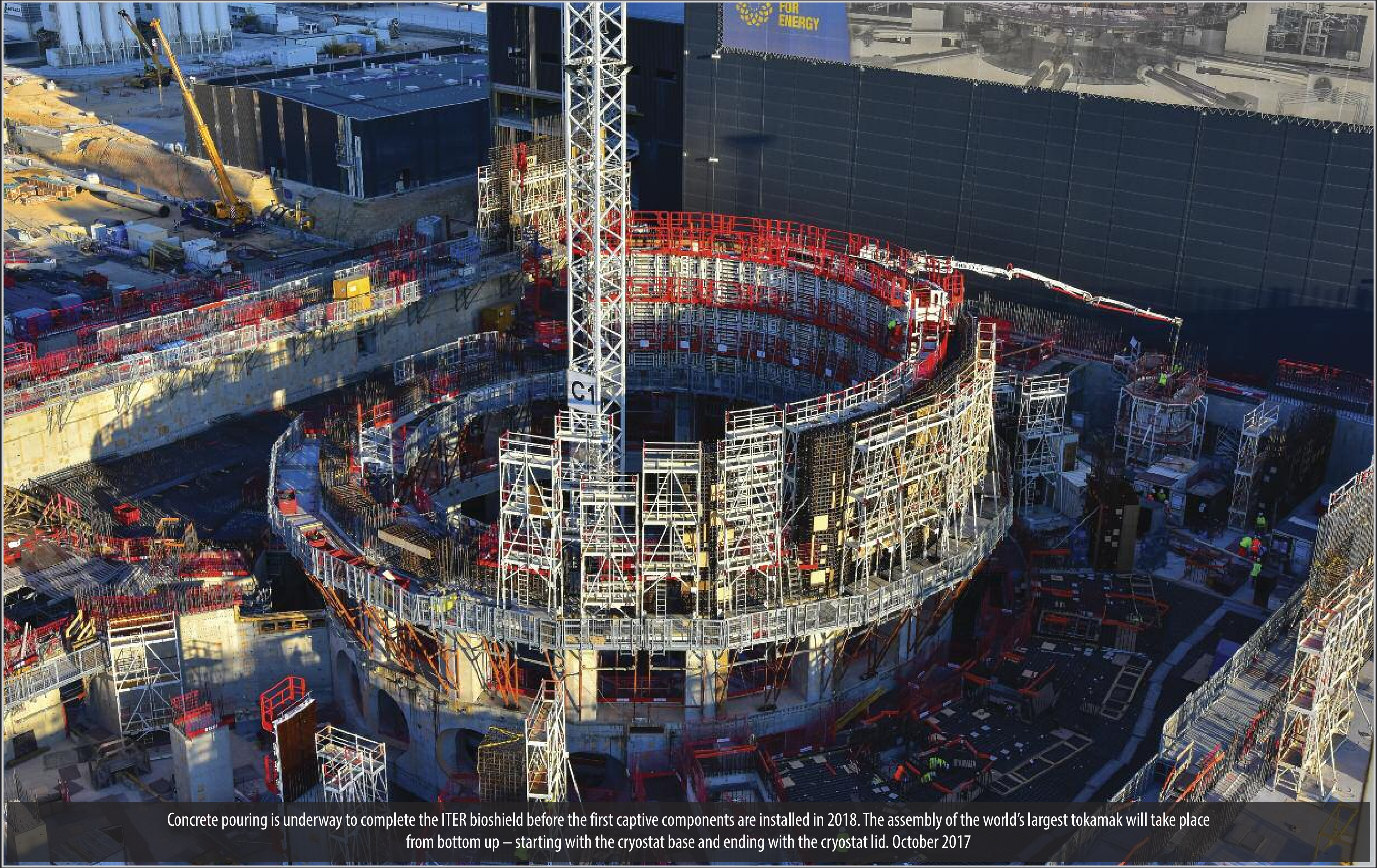
Night shift

Approximately 1,700 workers are involved in construction in two shifts. The last daily shift ends at 10:00 p.m. *February 2017*

Assembly arena



Concrete pouring is underway to complete the ITER bioshield before the first captive components are installed in 2018. The assembly of the world's largest tokamak will take place from bottom up – starting with the cryostat base and ending with the cryostat lid. October 2017

The golden hour

Late afternoon light reflects off of the ITER Assembly Hall, currently the tallest structure on site. The Tokamak Building, going up in the circle formed to the left by the cranes, will be identical in height and length. *March 2017*

Spaceport ITER

At nightfall, when buildings, work areas, roads and parking lots light up with the yellow glow of sodium lights, the ITER site resembles an alien spaceport. *January 2017*

Upon an Alpine backdrop

In the space of one year, the Tokamak bioshield has risen 20 metres. The circular structure, as thick as 3.2 metres in some areas, is designed to protect workers and the environment from radiation generated by the fusion reaction. *March 2017*

World's largest single-platform cryoplant

Cryogenic technology will be used extensively to create and maintain low-temperature conditions for the magnet, vacuum pumping and thermal shield systems.
Inside the ITER cryoplant (nearly completed, middle) component installation and testing has begun. *October 2017*

Cooling tower zone

ITER's cooling water system will dissipate the heat generated during plasma operation. Through a cascade of cooling loops the water will be transferred to the heat rejection zone (pictured, under construction), where it will be cooled using an evaporative process. *November 2017*

The ring factory

Four of ITER's ring-shaped poloidal field coils will be manufactured by Europe in this on-site facility. In 2017, fabrication began on the first coil – PF5. *January 2017*

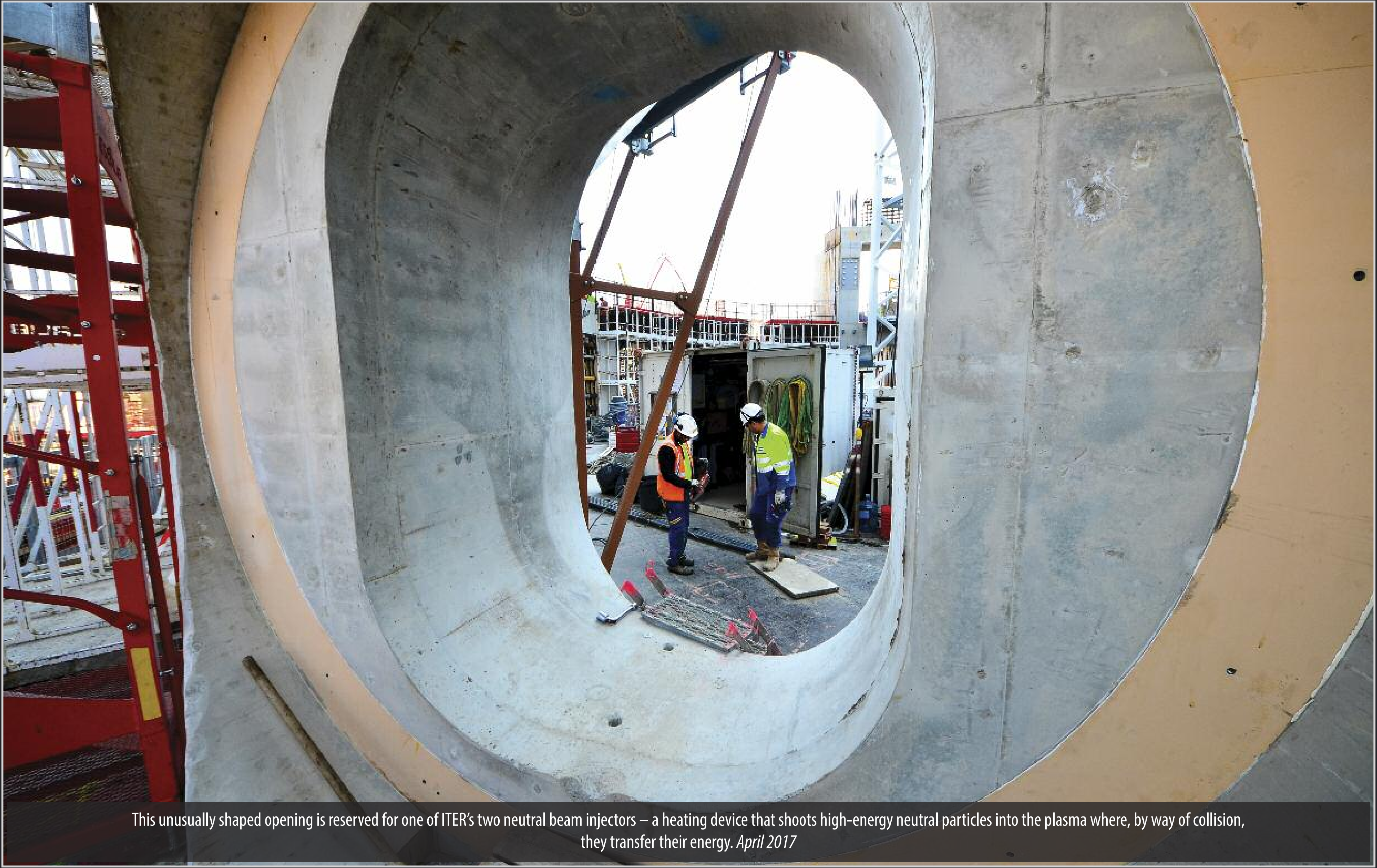
The steel-and-concrete fortress

During the machine assembly phase, the circular bioshield will support the beams of the in-pit assembly tool as nine 440-tonne steel vacuum vessel sectors are aligned and welded. *March 2017*

The ITER colosseum

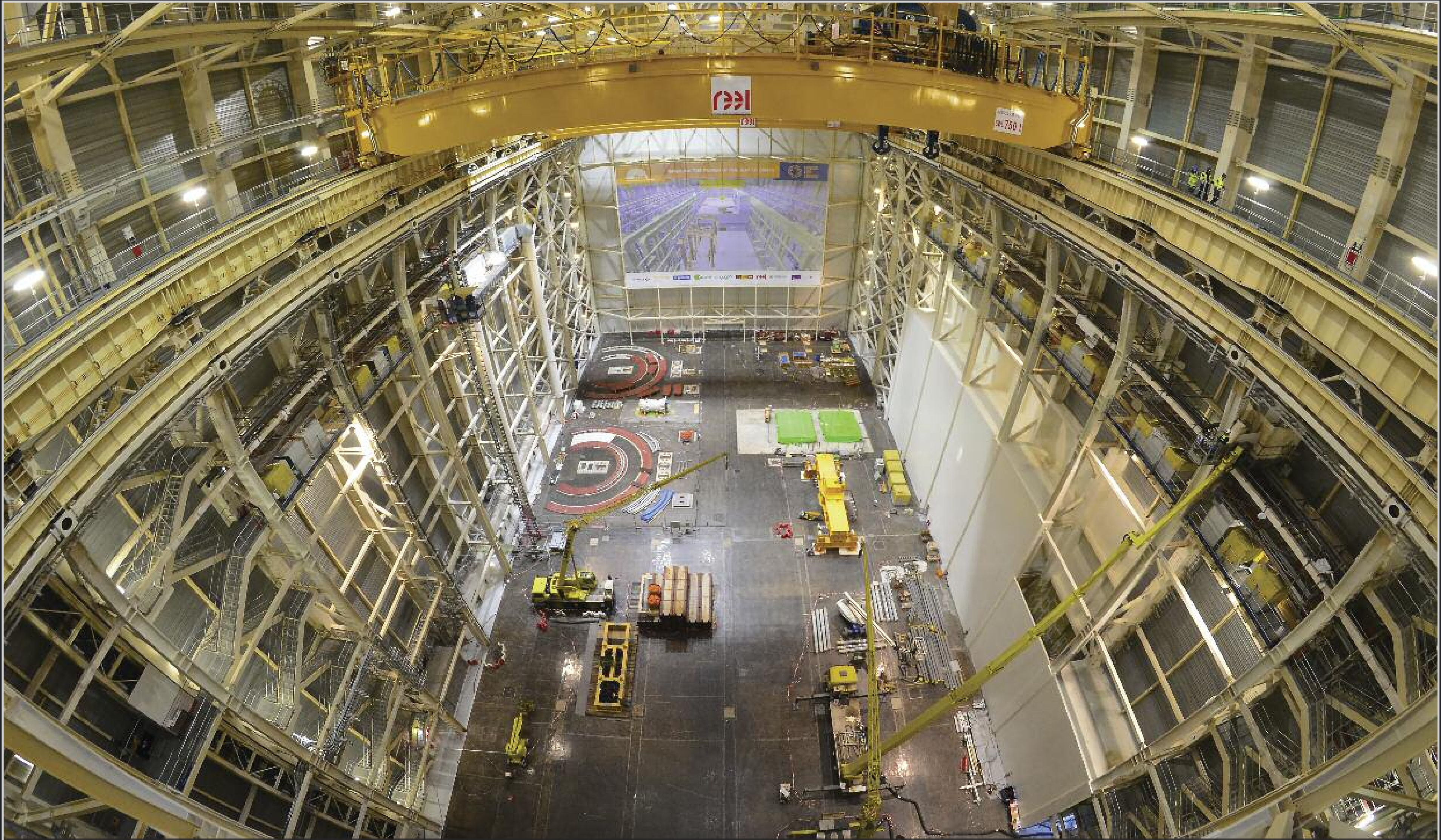
Only two levels remain to be realized before the bioshield is complete. Each opening in the circular wall will provide access for systems and equipment. *July 2017*

Through a Hobbit hole



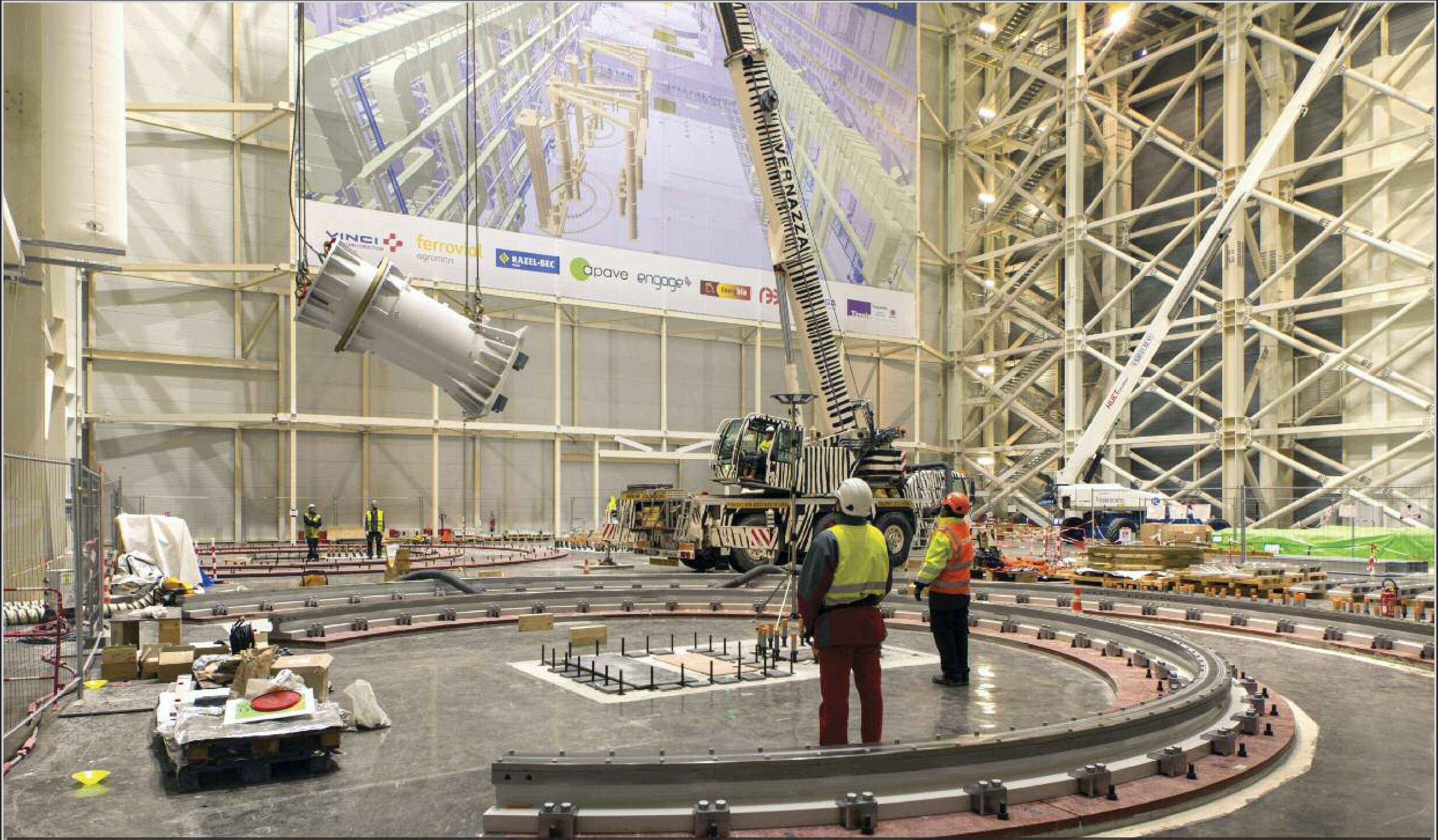
This unusually shaped opening is reserved for one of ITER's two neutral beam injectors – a heating device that shoots high-energy neutral particles into the plasma where, by way of collision, they transfer their energy. *April 2017*

Antechamber to the Tokamak



The ITER Assembly Hall is the space for the pre-assembly of all main machine components. As shown in the poster, once the temporary wall is removed the overhead cranes will travel into the Tokamak Building to deposit their loads. The cranes can carry 1,500 tonnes. *November 2017*

A Titan's foot



Two large assembly tools – the vacuum vessel sector sub-assembly tools seen in yellow on the poster – will be erected at the far side of the Hall.
The rails are in place and the first vertical elements of tool #1 have been positioned. *November 2017*

Quite a hook

Big, powerful cranes need big, powerful hooks. This is one of four that belong to the double overhead bridge crane installed 43 metres above the basemat of the Assembly Hall. *October 2017*

Housing the mega converters

Located between the electrical switchyard (background) and the Tokamak Complex, the Magnet Power Conversion buildings will furnish DC current to 10,000 tonnes of superconducting magnets. *September 2017*

On the road to ITER

A segment of the cryostat is transported to ITER. Large components for the machine or plant are shipped by sea to the Mediterranean port of Fos-sur-Mer before continuing along a specially adapted road itinerary to the site. *April 2017*

Mirror, mirror on the platform ...

Mirror-like cladding, evocative of the high-tech nature of ITER, is the architect's choice for all the main buildings of the ITER installation.
From left to right: the Cleaning Facility, the Assembly Hall, and the Radiofrequency Heating Building. *July 2017*

Cold boxes reach home

This helium "cold box" – installed with two others in the cryoplant during the year – will provide insulation for the key components of the liquid helium plant. *June 2017*

In the autumn light

The ITER construction platform seen from the air, with the Tokamak Complex under construction on the left, the Assembly Hall in the background, and plant system buildings to the right. The poster on the Assembly Hall shows the ITER Tokamak at 70% of its actual size. *October 2017*

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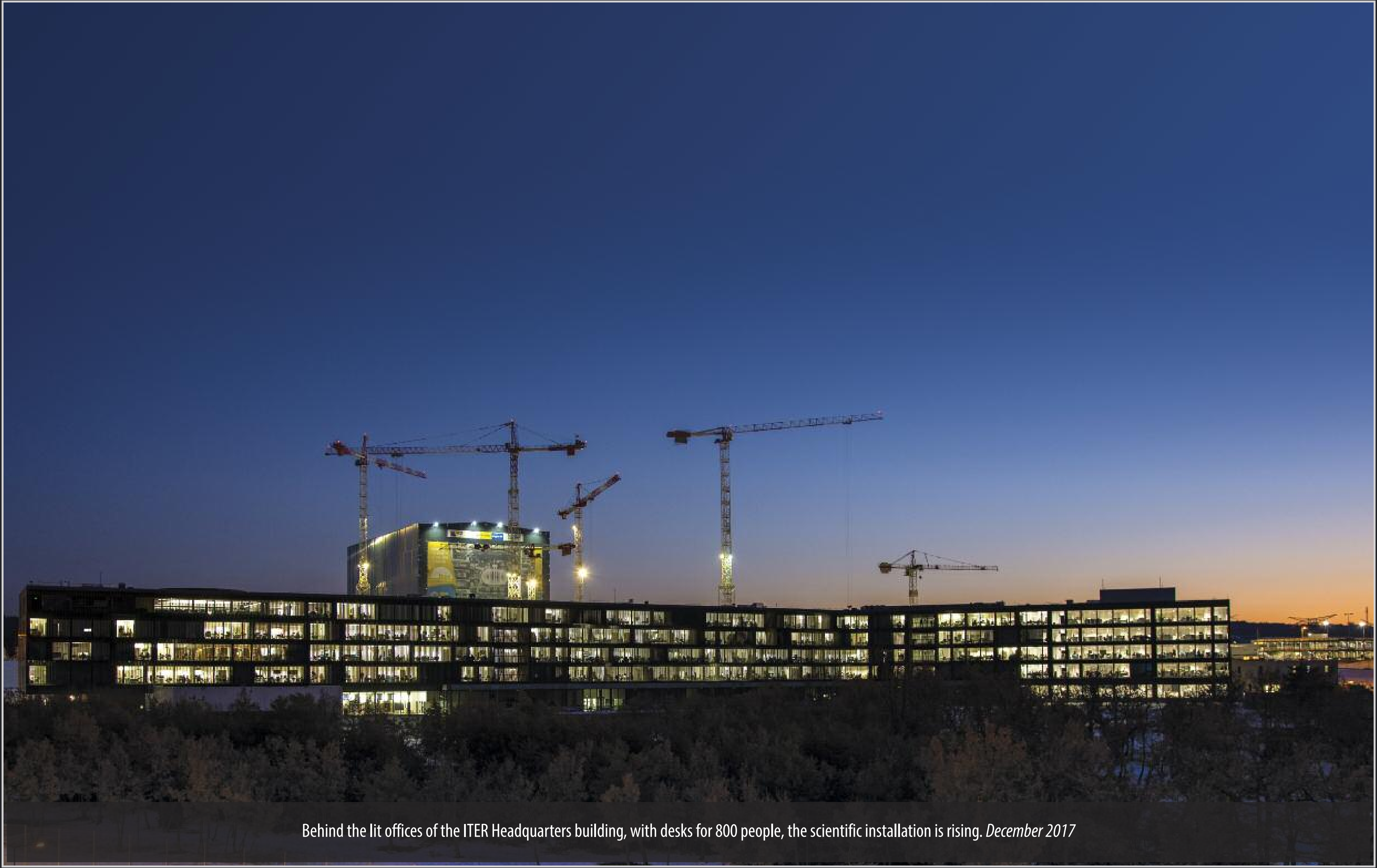
One December evening

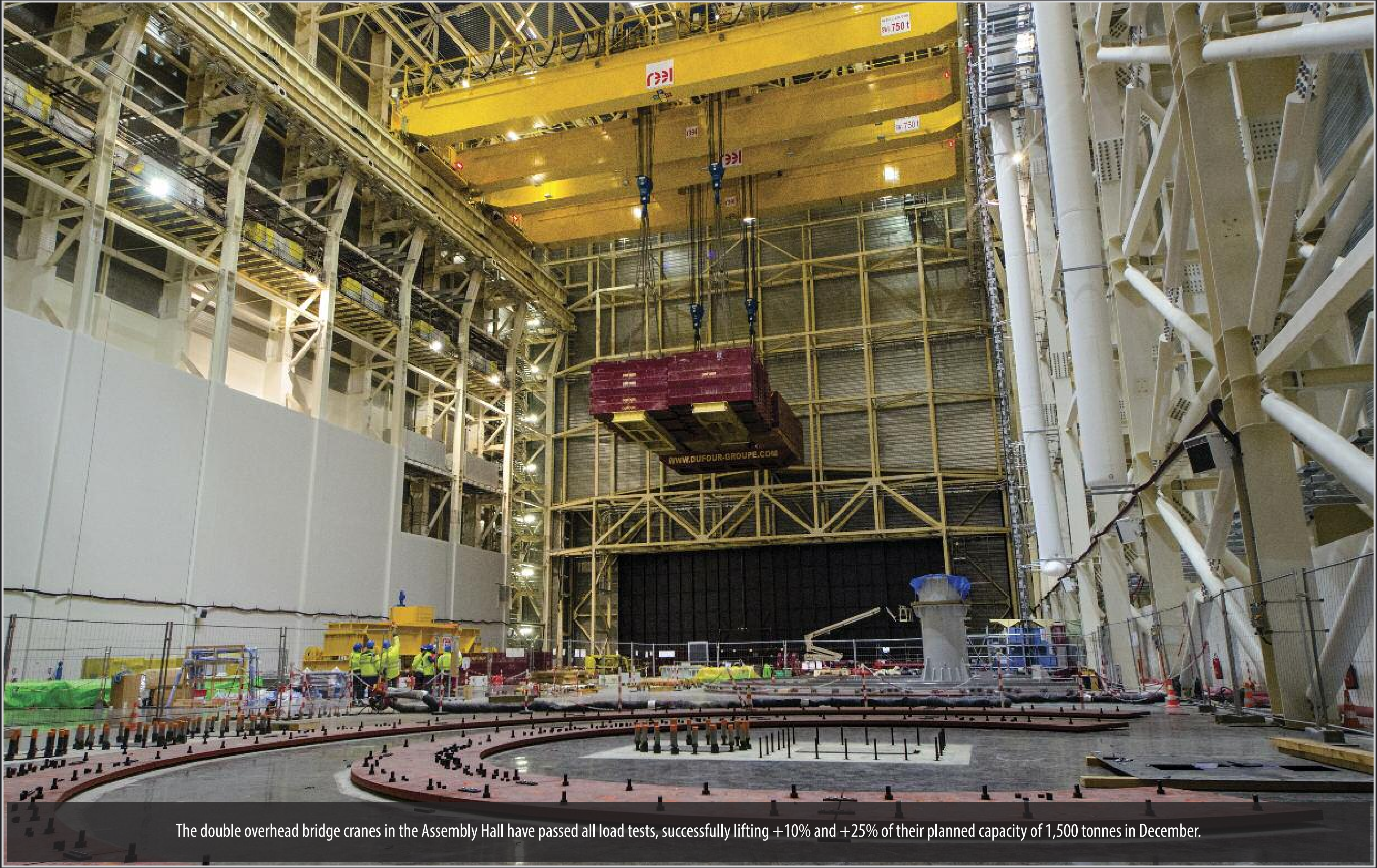


Behind the lit offices of the ITER Headquarters building, with desks for 800 people, the scientific installation is rising. *December 2017*

Huge and leak-tight

The ITER cryostat – the leak-tight vacuum container that will act as a thermos to insulate the ultra-cold superconducting magnets from the outside environment – is being assembled in a dedicated facility on site by contractors to the Indian Domestic Agency. These lower cylinder segments give a good sense of the size of the ITER machine. *October 2017*

Testing the cranes



The double overhead bridge cranes in the Assembly Hall have passed all load tests, successfully lifting +10% and +25% of their planned capacity of 1,500 tonnes in December.

A pedestal for the machine

Part of the cryostat base, these pedestal segments have been positioned on pillars for welding. The completed base section, at 1,250 tonnes, will be the heaviest single component of the ITER machine. *October 2017*

ITER ORGANIZATION
MANUFACTURING

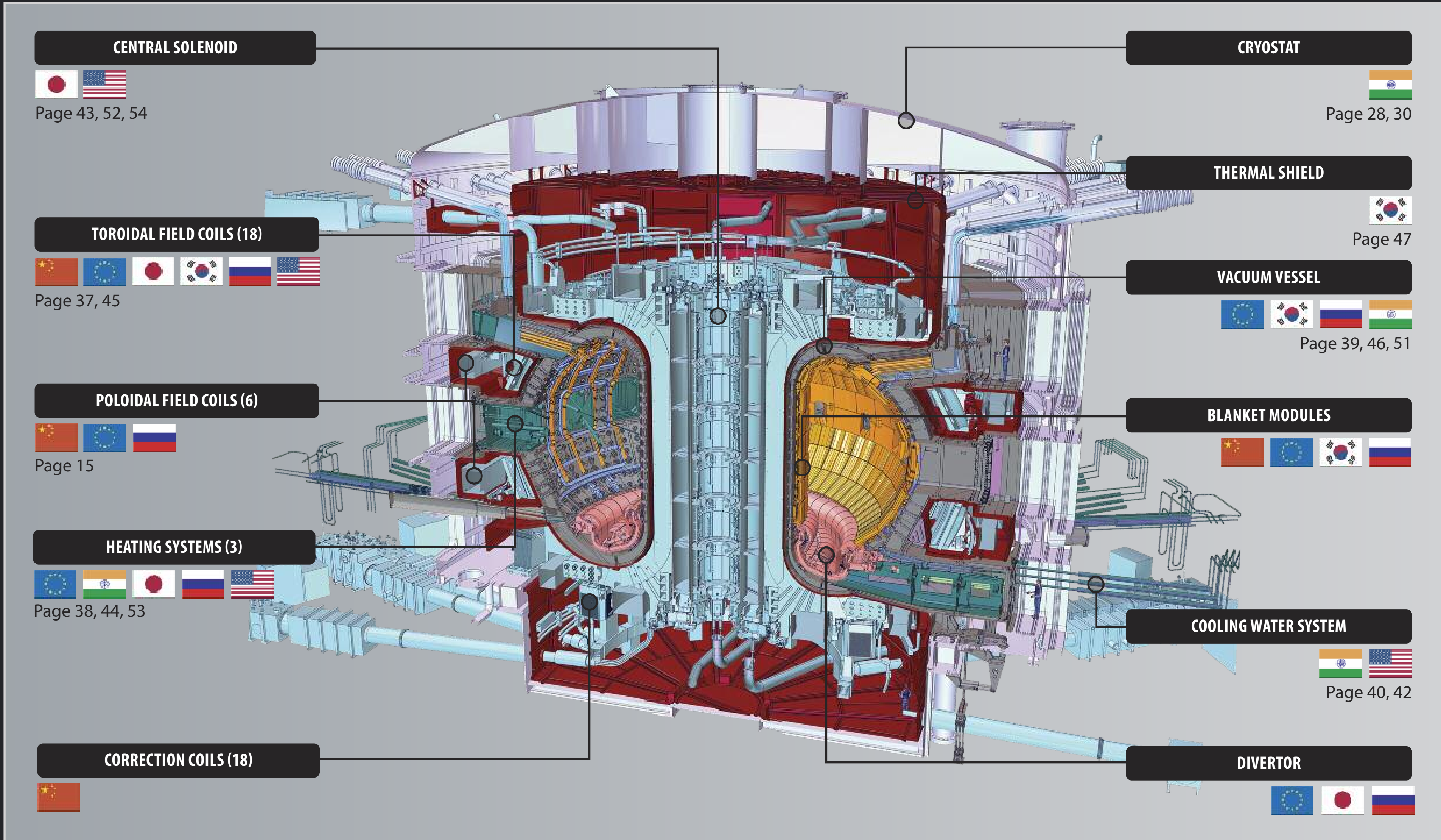
A unique aspect of ITER implementation is the in-kind procurement system that was established at the onset of the project. Instead of contributing purely financial resources, China, the European Union, India, Japan, Korea, Russia and the United States will be providing 90% of their contributions in the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

The project is also spurring developments in other industries, as companies apply expertise acquired in the fabrication of ITER's cutting-edge components and systems to other applications and technologies.

Who manufactures what?

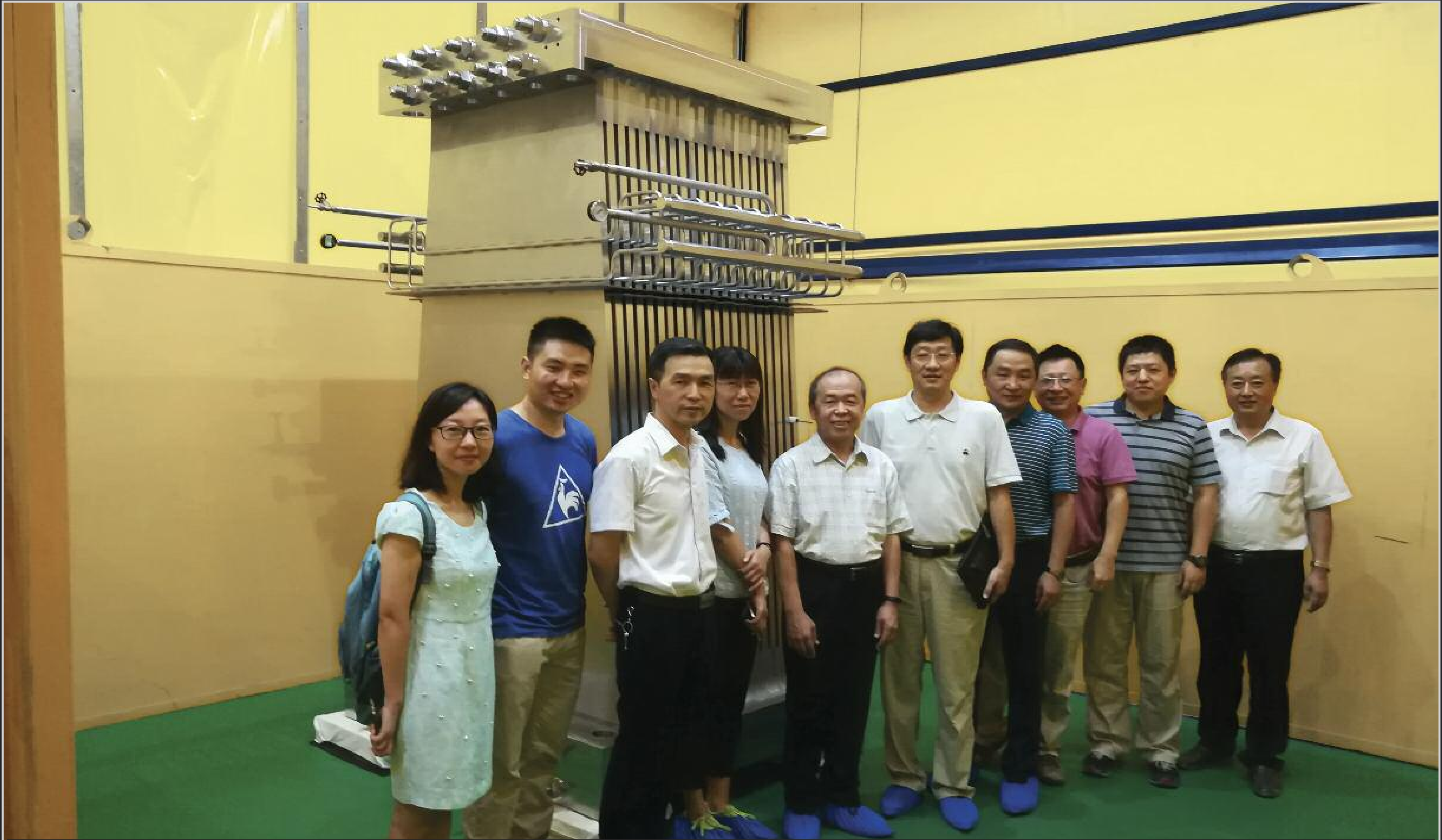


Not all systems (or contributions) are represented in this illustration.

Fast-acting reactive power compensation

One of the largest reactive power compensation and harmonic filtering systems in the world is being manufactured and tested at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP).

A full set of magnet supports



The Chinese Domestic Agency is procuring the full set of magnet supports for ITER, representing more than 350 tonnes of equipment. This first-of-series toroidal field coil gravity support is now ready for acceptance testing.

First magnet component reaches ITER

Despite a simple outward appearance, this elbow-shaped feeder segment is packed with a large number of advanced technology components (high-temperature superconductor current leads, cryogenic valves, superconducting busbars, and high voltage instrumentation hardware). Delivered in October, it is the first completed magnet component to reach ITER.

D-shaped winding packs ready for their case

Eighteen toroidal field magnets – each made up of a 110-tonne winding pack and stainless steel coil case – will surround the vacuum vessel to confine the particles of the ITER plasma.
The first of 10 winding packs under European responsibility has left the ASG consortium in La Spezia, Italy.

Futuristic high voltage testing

Six metres above floor level, the mockup of a high voltage deck is tested successfully in a laboratory at HSP GmbH, Germany. The cube is 1/15th of the size of the deck that will be integrated into the MITICA testbed, currently under construction at the ITER Neutral Beam Test Facility in Padua, Italy.

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Complexity on a large scale

Five thousand tonnes of steel, dozens of "port" openings at three levels, interfaces with nearly every major system ... ITER's steel vacuum vessel is one of the largest-scale and most complex of the ITER "objects" to manufacture. In Europe, the AMW consortium is manufacturing five of the nine sectors (pictured: a sub-segment for sector #5).

Cooling water components

Work is underway in India to procure the components of ITER's component cooling water, chilled water and heat rejection systems. This large-capacity water-cooled chiller (one of eight required by the chilled water system) has successfully passed pre-shipment inspection at Kirloskar Chillers (Pune, Maharashtra).

Not just piping

Large-diameter cryogenic lines and multi-process pipes leave the Inox India Limited factory in Gujarat. Nearly 25 tonnes of liquid helium – at minus 269 °C – will circulate in ITER through a five-kilometre network of pipes, pumps and valves.

Heat dissipation technologies

Destined for ITER's component cooling water system, this 40 MW plate-type heat exchanger has passed factory acceptance tests at Kelvion India (Pune, Maharashtra).

Central solenoid conductor completed

Japanese contractors have successfully completed the fabrication of 43 kilometres (700 tonnes) of niobium-tin cable-in-conduit superconductor for ITER's central solenoid magnet. The last conductor unit length, of 49, is pictured at the Wakamatsu factory of Nippon Steel and Sumikin Engineering Co., Ltd. in Kitakyushu.

Powerful waves

Powerful radio-frequency-generating devices called gyrotrons will generate microwave beams over a thousand times more powerful than a traditional microwave oven.
The first device has been manufactured by Japan and is now undergoing factory acceptance testing.

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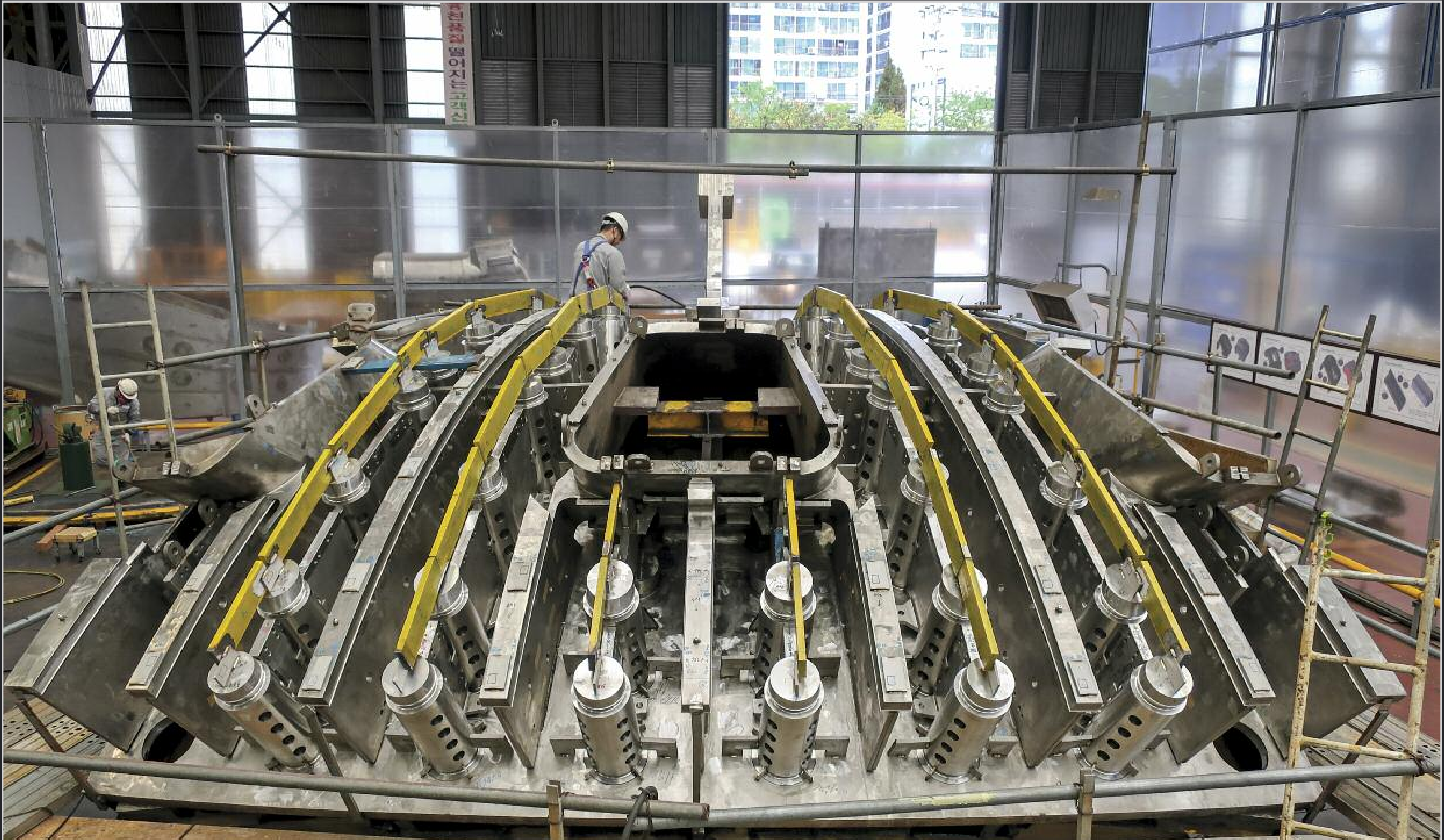
Impregnated in resin

Resin impregnation has been carried out on the superconducting winding pack for toroidal field coil #12 – the first magnet coil expected at ITER and one of nine under fabrication in Japan. This winding pack will be inserted into a heavy steel case and welded shut before shipment.

Sub-elements of all shapes and sizes



Vacuum vessel manufacturing is time-consuming and labour intensive due to the sheer volume of sub-elements, and their unconventional shapes and size. At the end of the process, each sector will measure 6.5 metres in height; 3 x 6 metres in width and depth; and weigh between 400 and 500 tonnes. (Pictured: a sub-element of sector #6.)

Stopping thermal radiation

Two layers of thermal shielding procured by Korea will be interposed between the vacuum vessel and the cryostat to minimize heat loads transferred by thermal radiation. The thermal shield is coated in low-emissivity silver and actively cooled with gaseous helium at 80 K.

The largest tool in the kit

The first sector sub-assembly tool stands assembled at Taekyung Heavy Industries in Changwon. After demonstrating all functional performance, the largest tool in ITER's assembly kit (23 metres tall, 24 metres wide, 800 tonnes) shipped to ITER.

A five-kilometre aluminium snake

The first batches of these large water-cooled DC busbars, which will feed power to ITER's superconducting magnet coils, have already been received at ITER. Russia's Efremov Institute has contracted to manufacture and ship 5.4 km of these high-tech components for a total weight exceeding 500 tonnes.

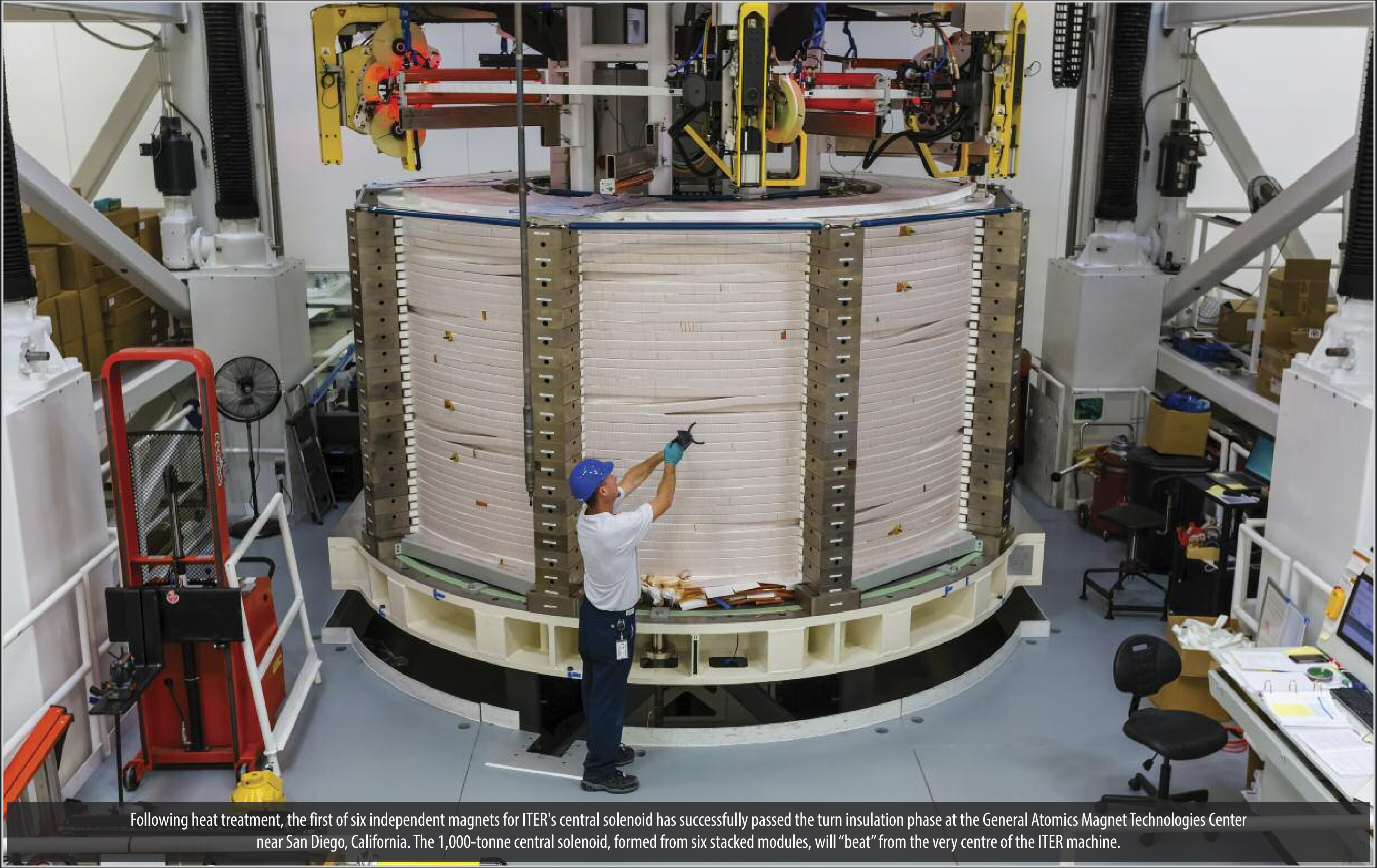
Key power supply elements tested

Russia is responsible for procuring a wide variety of electrotechnical components, many of them designed specifically for ITER. Key elements of the switching network, fast discharge unit, and DC busbar procurement package are shown in testing at the Efremov Institute in Saint Petersburg.

Verifying the performance of the plugs

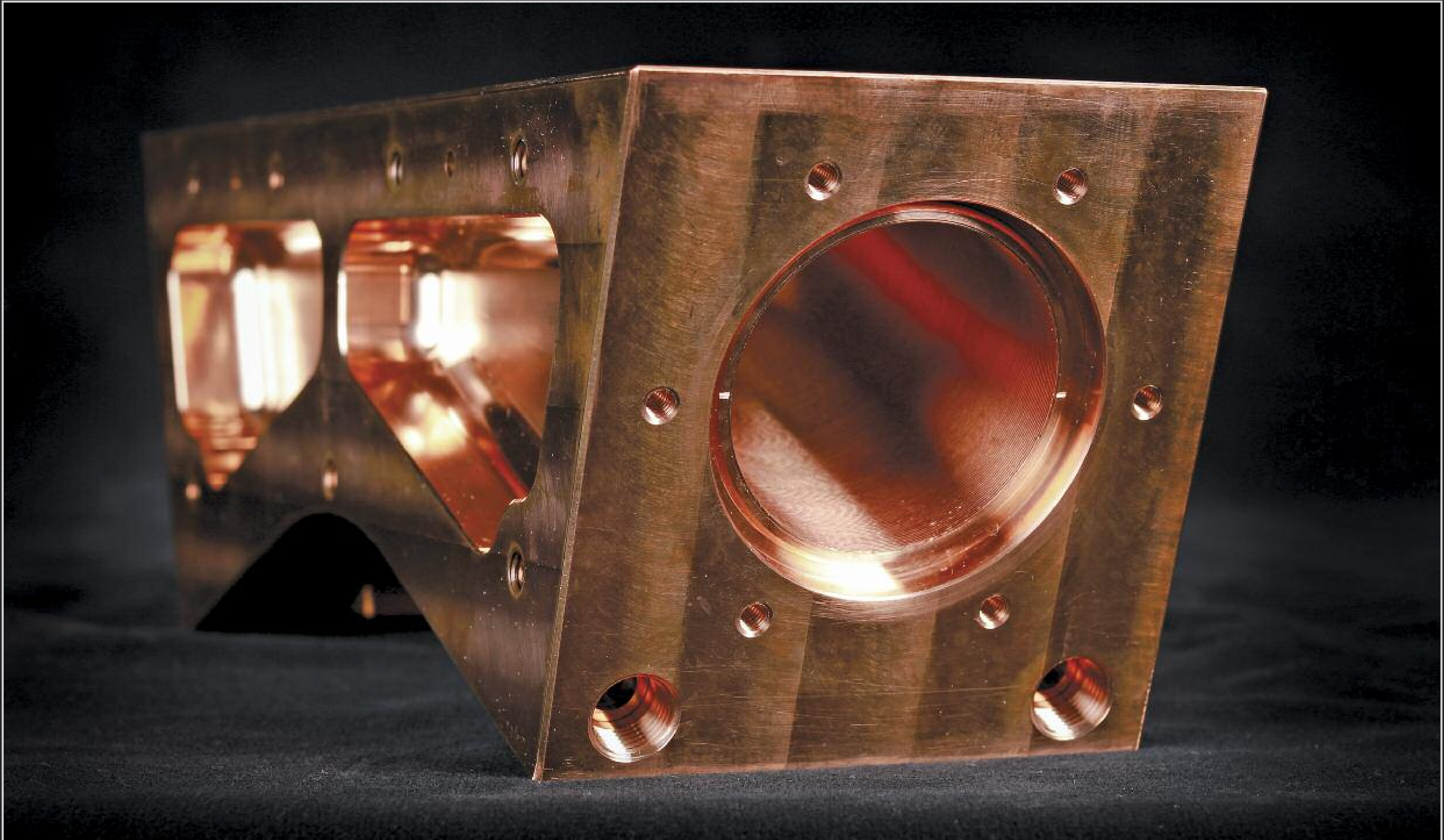
Test stands will verify the performance of ITER's port plugs – critical components that seal the openings of the plasma chamber – before their installation on the machine. A multiyear development program is underway at the Cryogenmash facility, near Moscow.

Creating the "beating heart" of ITER



Following heat treatment, the first of six independent magnets for ITER's central solenoid has successfully passed the turn insulation phase at the General Atomics Magnet Technologies Center near San Diego, California. The 1,000-tonne central solenoid, formed from six stacked modules, will "beat" from the very centre of the ITER machine.

Routing the beams to deliver power



The role of the electron cyclotron transmission lines is to route microwave beams from the Radio Frequency Building to the Tokamak, where they will deliver 20 MW of heating power to the ITER plasma. Transmission line R&D, design and fabrication is under the responsibility of the US Domestic Agency. (Pictured, a "mitre bend" waveguide prototype.)

Testing the central solenoid

The 110-tonne central solenoid modules will be manufactured and tested in the US before shipment to ITER for assembly. (Pictured: the power supply of the 4 K test station.)

ITER ORGANIZATION **HIGHLIGHTS**

In the last months of 2017, ITER passed a symbolic milestone. Based on the stringent metrics that measure overall project performance, 50 percent of the "total construction work scope through First Plasma" (a category that includes all design work; construction and manufacturing; delivery; assembly, installation and commissioning) is now complete.

First Plasma, scheduled in 2025, will be a decisive step in the making of the man-made star that will demonstrate that fusion energy can produce electricity on an industrial scale.

Welcome Kazakhstan!

Representatives of Kazakhstan visit ITER in February 2017 to evoke the possibility of a cooperation framework that would enable the ITER Organization to access the Republic's KTM tokamak for the testing of plasma-facing materials. Four months later, a technical cooperation agreement is concluded between the ITER Organization and Kazakhstan's National Nuclear Center.

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Doing business in the palace of the Popes

Business and industry leaders from all over the world meet in March in Avignon, France, to be informed about upcoming tender opportunities. Close to 450 companies, laboratories and institution from 25 countries are represented at the 2017 ITER Business Forum, which is held in the Palace of the Popes.

4 days and 40,000 Lego bricks

These Master's students from Kyoto University, Japan, were able to build a 1:40-scale, 40,000-piece ITER model in four days. The model is now a permanent exhibition in the lobby of ITER Headquarters.

A growing family

ITER staff members, now numbering 800, gather for a "family photo" on the edge of the construction site in October.

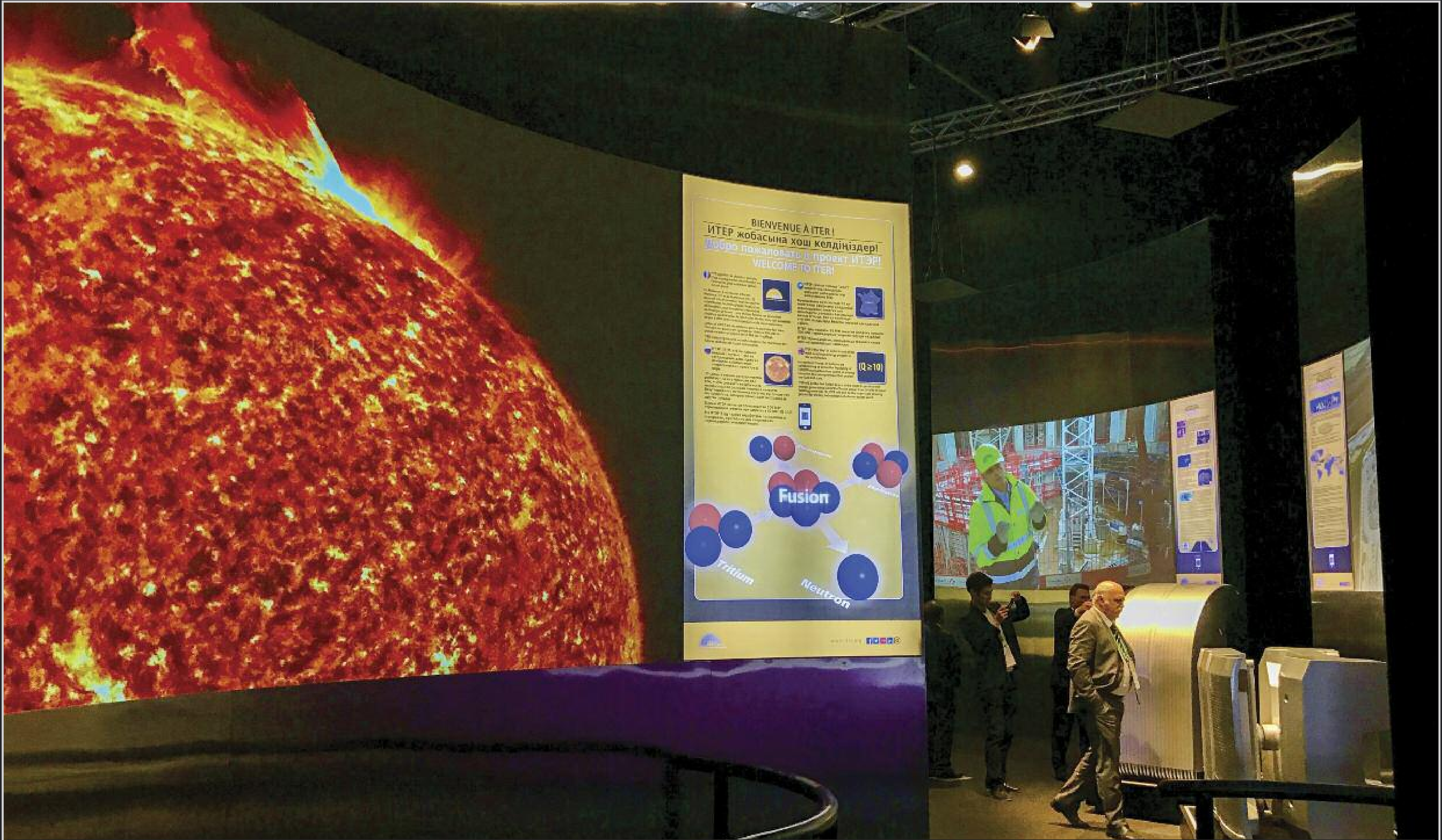
Small robots for future engineers

Six hundred students participate in the sixth edition of the ITER Robots contest. Drawing inspiration from the robotic challenges that ITER engineers will face during installation or maintenance, organizers ask participants to design Lego robots capable of lifting and depositing objects, and travelling along precise trajectories.

Something for all ages

Twice a year, ITER's doors are opened to the public. Visitors of all ages have a chance to visit the construction site, meet ITER specialists and ask questions about the world's largest collaborative effort in science.

Going to the World's Fair



The project is presented from June to September at the 2017 World's Fair in Astana, Kazakhstan. The theme of the Fair – "Future Energy" – is a topic that resonates directly with the mission and vision of ITER.

ITER at 10

The ITER Organization, established by international agreement in November 2006, formally came into existence eleven months later as ratification procedures were concluded by all Members.
In November 2017, 10 years later, a birthday celebration is held at ITER Headquarters.

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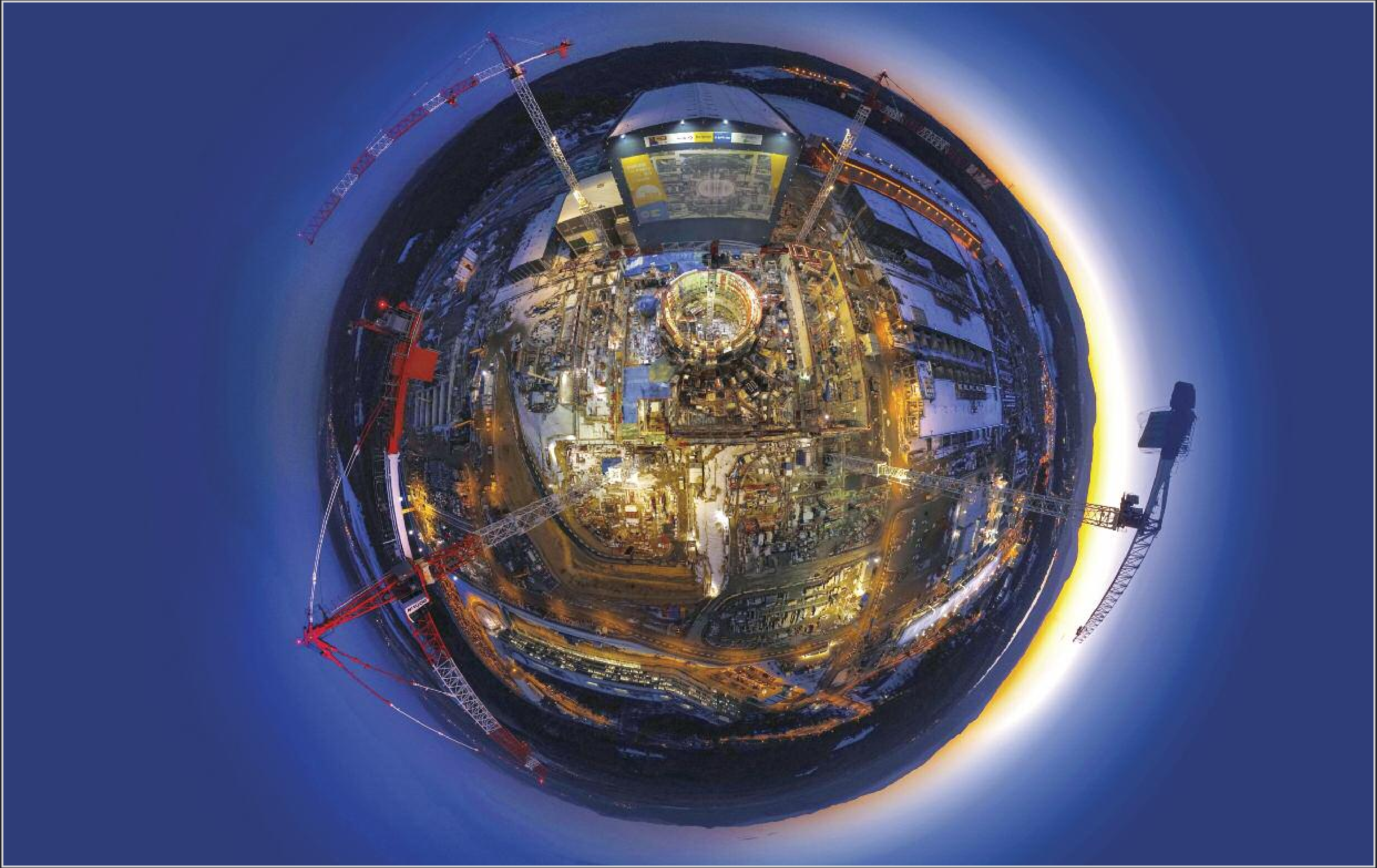

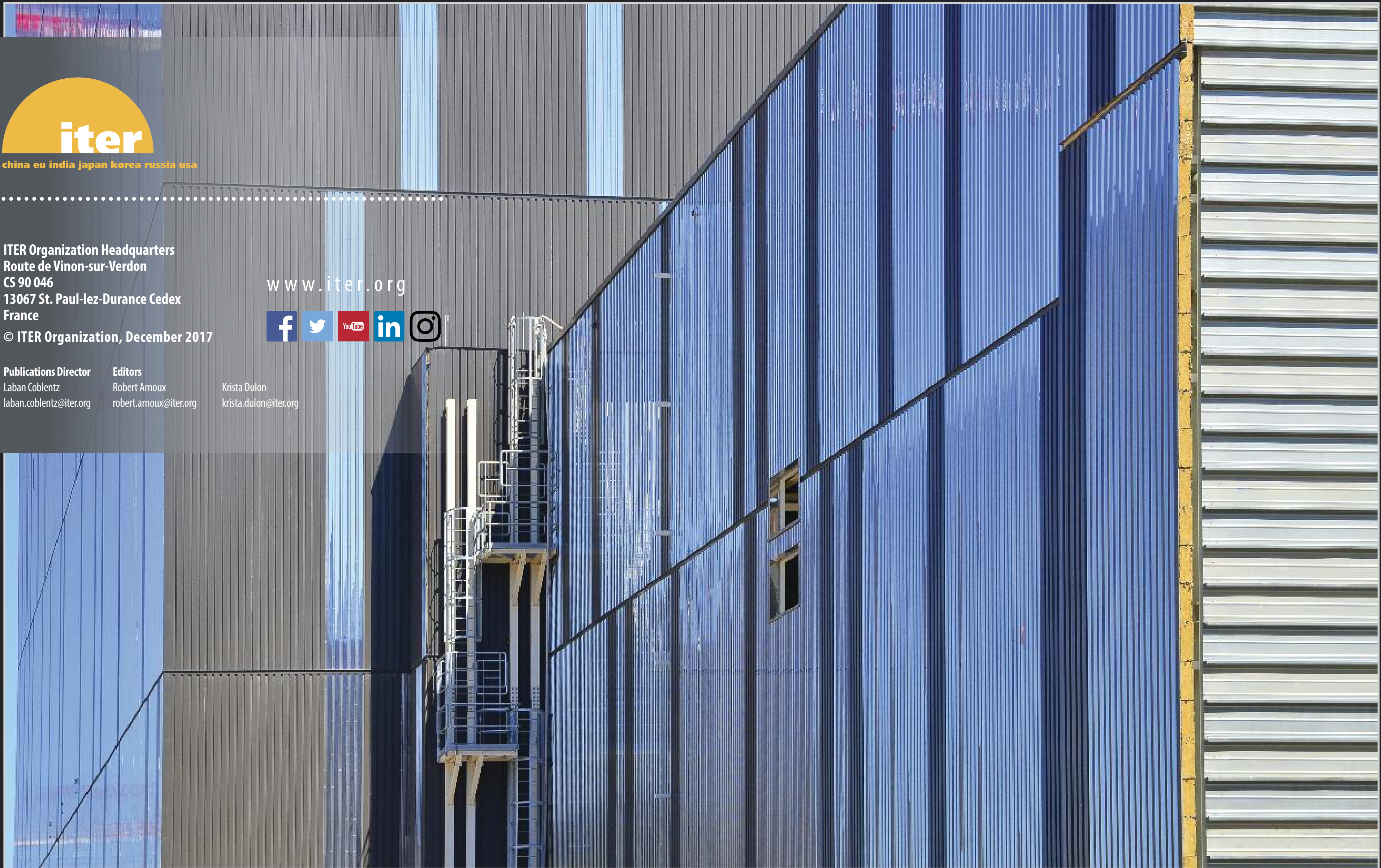

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