ITER ORGANIZATION

Progress in Pictures 2019

Japan EDITION ✿日本版✿

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2019

A star is born

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

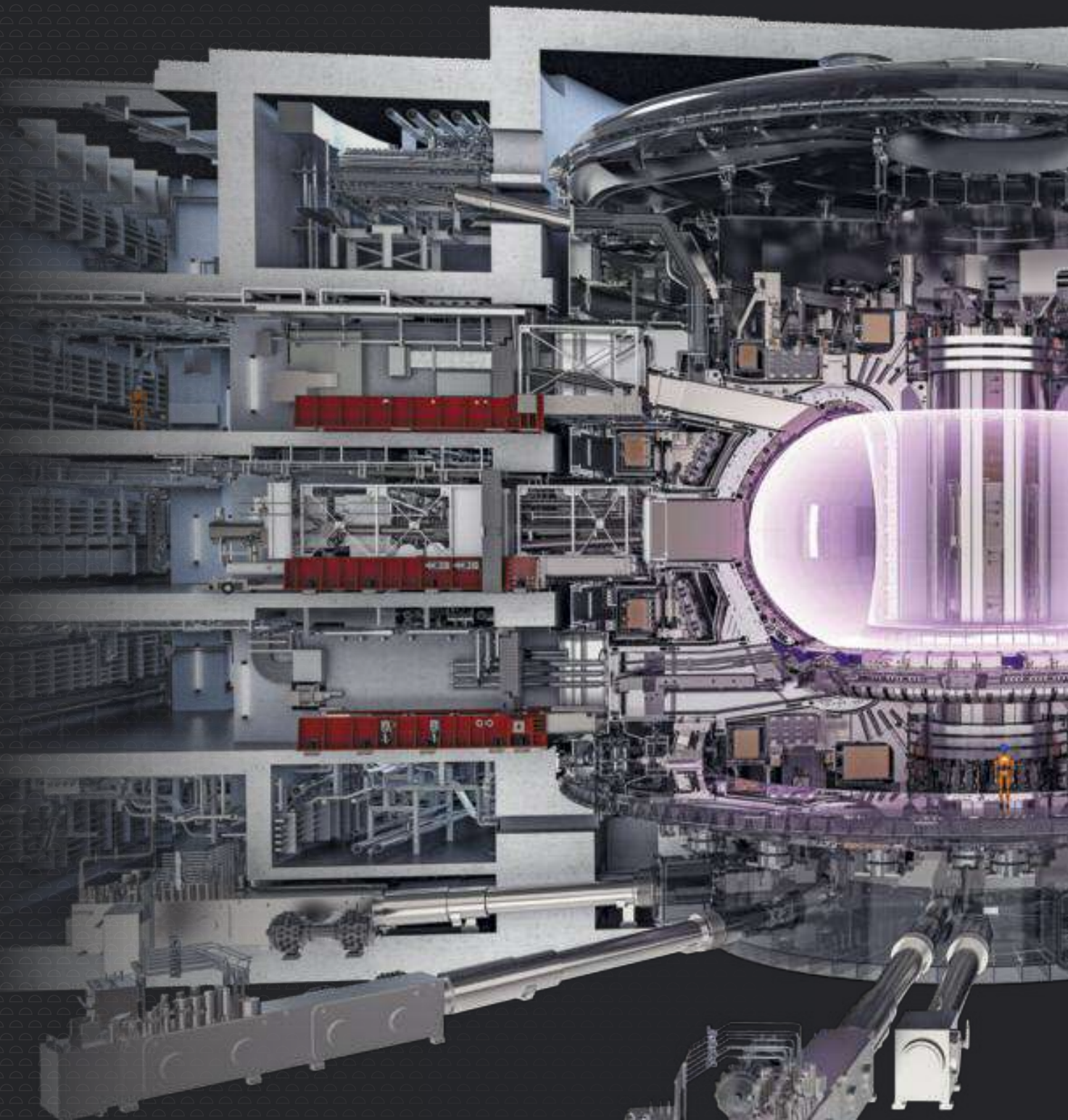
From a scientific and technological point of view, it will be one of humankind's historic achievements. The creation of an artificial star and the tapping of the tremendous amounts of energy produced could forever alter the course of civilization.

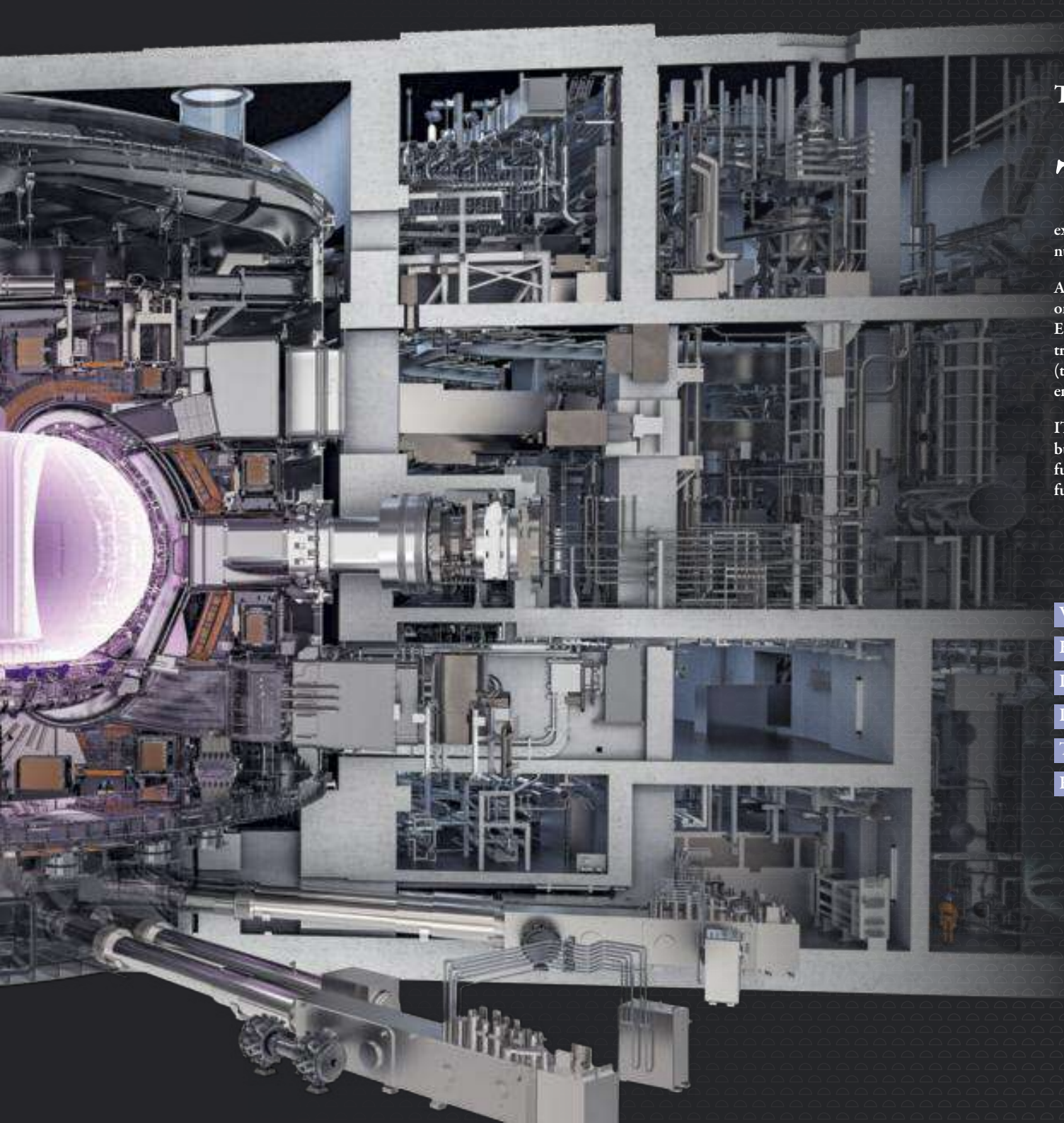
The ITER Project, an unprecedented international collaboration that brings together China, the European Union, India, Japan, Korea, Russia and the United States, is the culmination of decades of research and years of diplomatic negotiation. It has been the aspiration of three generations of physicists;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

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 33), component manufacturing is advancing in ITER Member factories (Pages 34 to 57) and preparations are underway for the machine assembly phase.

This sixth 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 humankind'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=mc2: 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 in hundreds of fusion machines throughout the world, it will demonstrate that fusion energy is scientifically and technologically feasible.

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

ITER collaboration

As signatories to the ITER Agreement, ITER Members China, the European Union, India, Japan, Korea, Russia and the United States share in the cost of construction, the planning for operation, and the overall governance of the project. *November 2019*

The construction platform

Building started on the 180-hectare site in southern France in 2010. Six years remain until First Plasma. *October 2019*

Assembly arena

The ITER machine will be completely integrated into the Tokamak Building, assembled within the central "well" visible in this image – the bioshield – that is 30 metres deep. *April 2019*

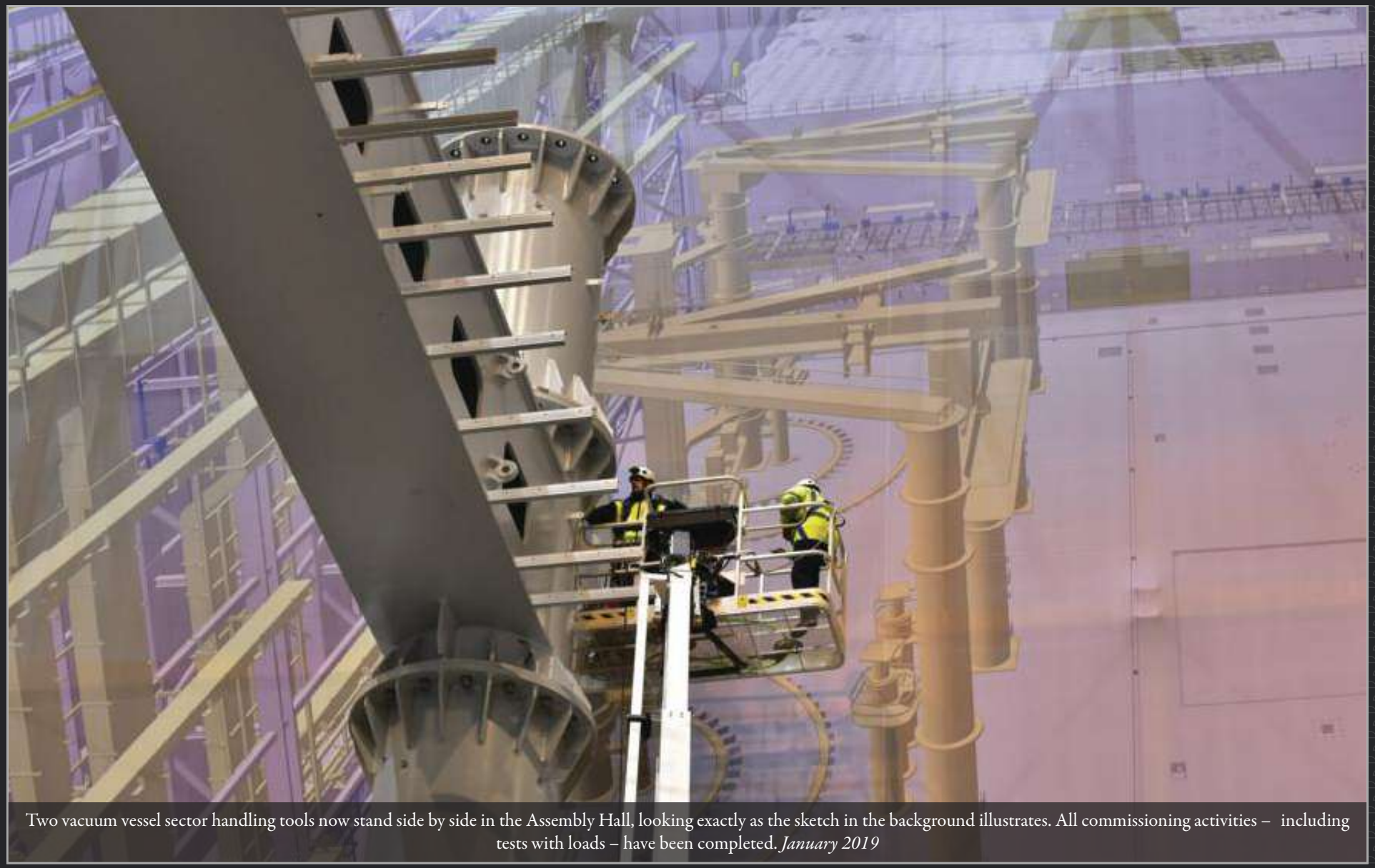
From the highest perch

Sitting in their cabins 70 or 80 metres above the platform, worksite crane operators enjoy some of the most spectacular views of the ITER construction site. *June 2019*

Autumn mist

Early one autumn morning, mist from the Durance River partially obscures the construction site. ITER is nestled in the hills of Provence, about one hour north of Marseille. *October 2019*

Fine tuning the giant tools



Two vacuum vessel sector handling tools now stand side by side in the Assembly Hall, looking exactly as the sketch in the background illustrates. All commissioning activities – including tests with loads – have been completed. *January 2019*

A frame for "upending"

A second built-to-purpose assembly tool (right) arrives from Korea in November. This "upending frame" will be used to raise some of the largest machine components from their horizontal delivery positions to vertical for subsequent handling. *November 2019*

Dedicated to heat removal

Europe has provided the physical infrastructure, India is contributing the equipment, and the ITER Organization is managing the installation tasks for the 6,000 m^2 heat rejection zone on the northern edge of the platform. *November 2019*

Cryolines

Cooling fluids produced in the cryoplant are delivered to the machine through high-technology cryolines developed by India. Looking from the outside like ordinary steel pipes, each section can host up to seven individually insulated lines. *October 2019*

All that power

Fusion for Energy, the European Domestic Agency, has officially transferred the twin magnet power conversion buildings (centre) and a small building for reactive power compensation (left) to the ITER Organization for the start of equipment installation. *February 2019*

After five years

On either side of the Tokamak assembly pit, the tallest reaches of the Tokamak Building are completed in 2019 (Level L5). The end of five years of construction is approaching for the building that will house the ITER machine. *May 2019*

Next phase: machine assembly

The European Domestic Agency works throughout 2019 toward an important milestone – progressing the Tokamak Building to the point where the roof structure can be erected and the assembly cranes extended out over the Tokamak pit. The building must be ready in March 2020. *June 2019*

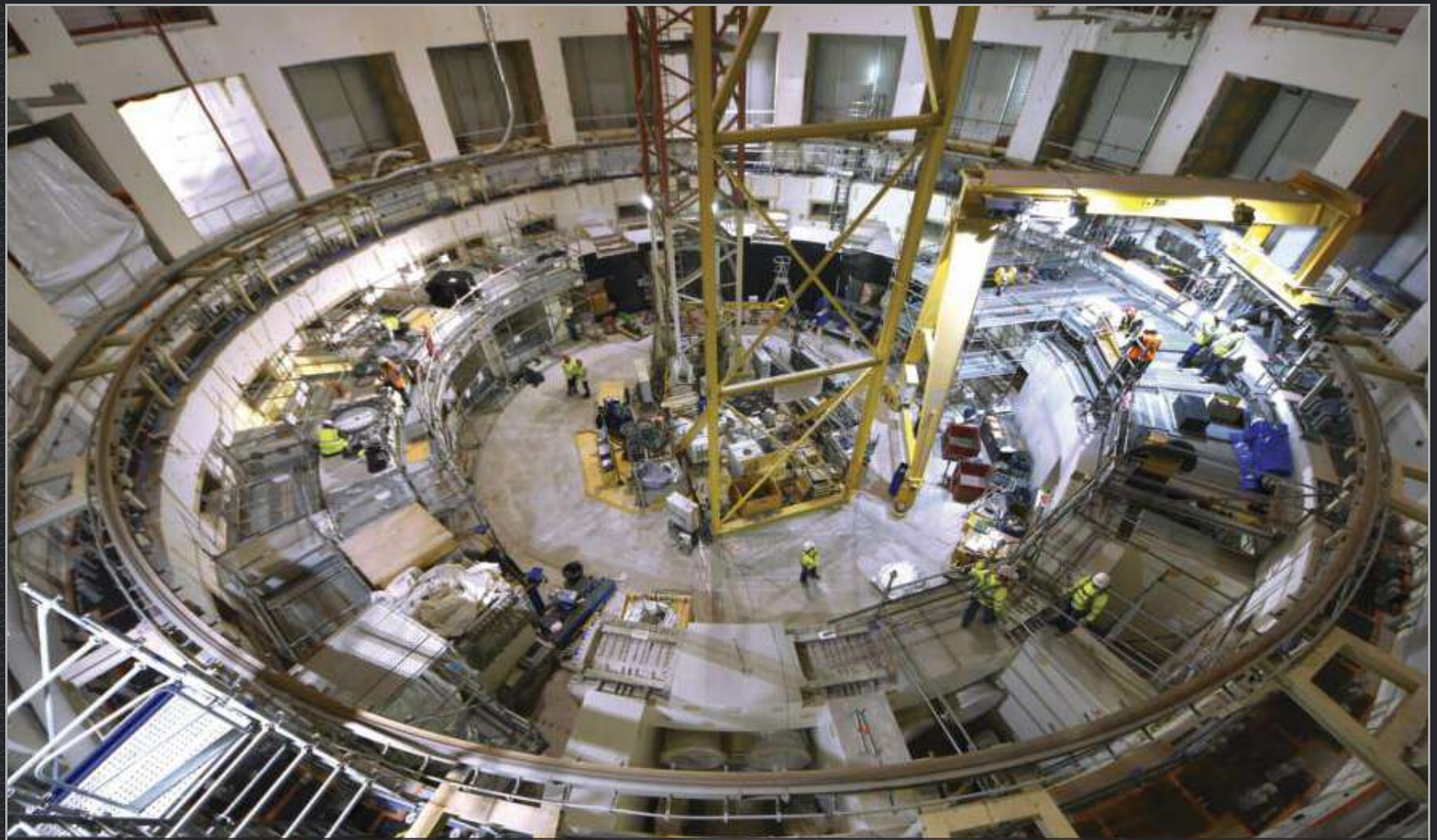
Cooling water

Heat generated by the machine is collected by the Tokamak's cooling water system and transferred through the component cooling water loops to the heat rejection system. The largest piping is 2 metres in diameter. *September 2019*

3 weeks, 2,000 kilometres

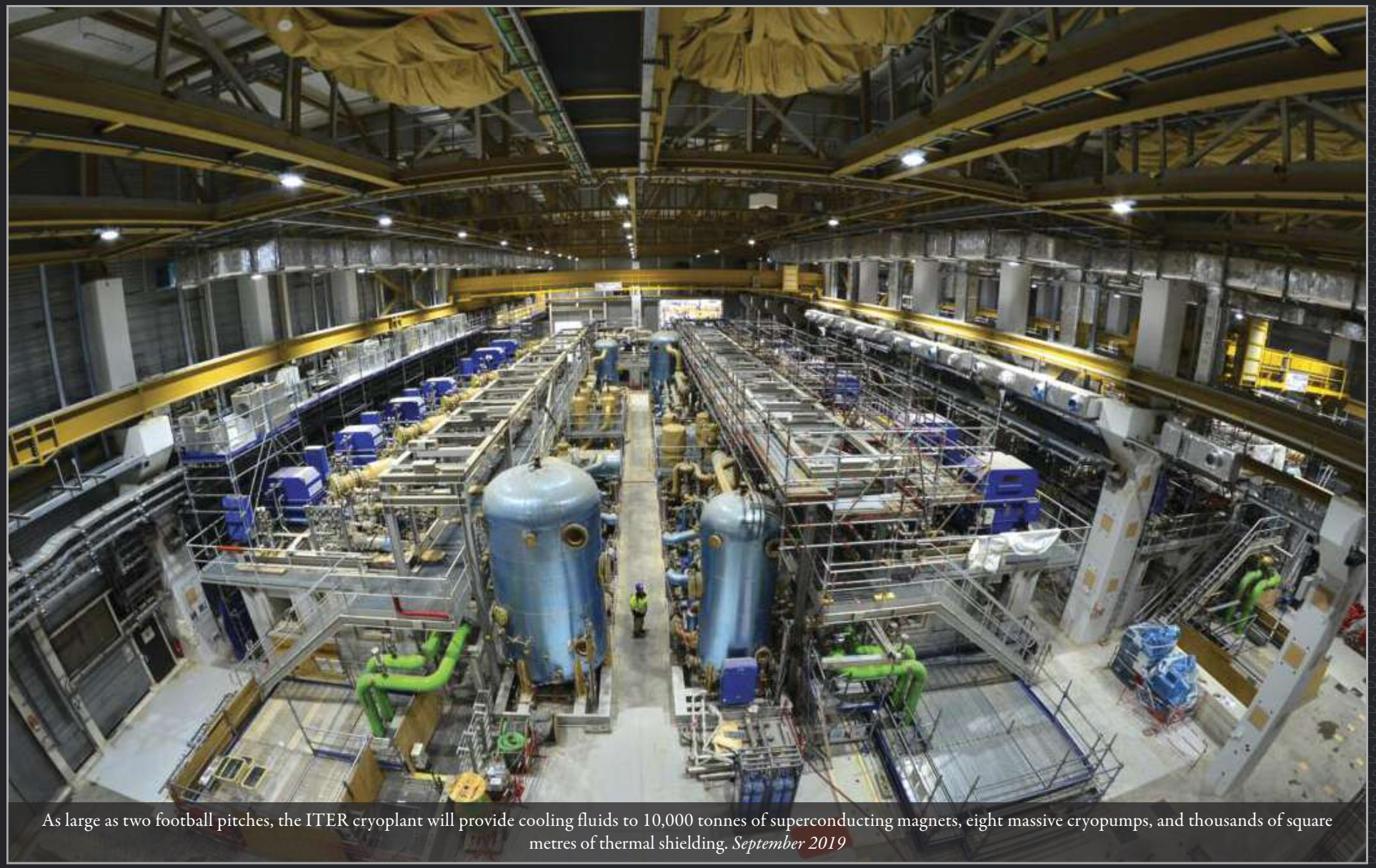
ITER components are arriving by sea, air, road ... and even canal. This cryogenic termination box procured by India in Switzerland is heading for the Rhône river valley through a network of small-gauge canals dotted with locks and tunnels. *February 2019*

Bearing the forces



Between the concrete pedestal at the bottom of the Tokamak pit and the cryostat base, 18 spherical bearings will act as ball-and-socket joints to permit the machine to "breathe" during operation. Installation is underway. *September 2019*

Inside the cold factory



As large as two football pitches, the ITER cryoplant will provide cooling fluids to 10,000 tonnes of superconducting magnets, eight massive cryopumps, and thousands of square metres of thermal shielding. *September 2019*

Under wrap

The 490-tonne lower cylinder of the cryostat has been safely "cocooned" and stored outside of the Cryostat Workshop to wait for its turn in the machine assembly sequence. *April 2019*

Magnets: proceeding step by step

This segment ofmockup coil faithfully mimics poloidal field coil #5 (PF5) and its eight stacked double pancakes. It is used in 2019 to test winding pack impregnation, before the operation is carried out on the production coil. *March 2019*

Tool commissioning completed

Test loads of 360 tonnes were placed on the wings of the sector sub-assembly tools to demonstrate all specified functional requirements. Both passed the tests with flying colours. *July 2019*

First pillar

Twenty tall pillars will support the roof of the crane hall and the weight of the bridge cranes as they are extended from the Assembly Hall into the Tokamak Building. The first pillar is installed in September; by December the full structure, including roof modules, is in place. *September 2019*

Tokamak Building: civil works completed

On 13 November, the ITER Organization joins Fusion for Energy, the European Domestic Agency, and its main contractor, the VFR consortium, at the top of the Tokamak Building to celebrate the last concrete pour ... and five years of intense work and commitment. *November 2019*

As dawn rises

Over nine days in December, five pre-assembled modules for the roof of the crane hall are lifted into place. The first operation takes place very early in the morning. *December 2019*

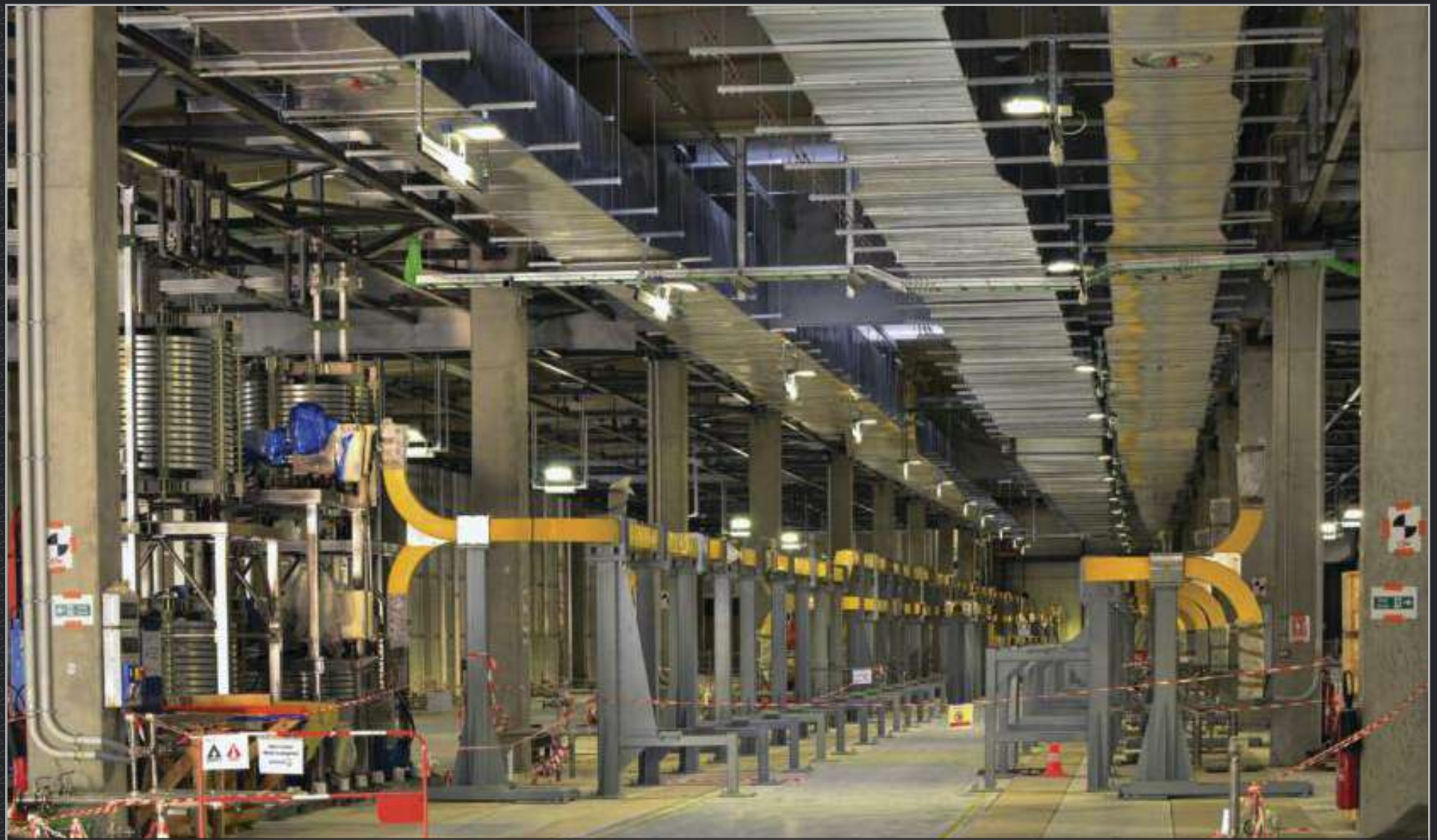
Six-tonne shafts

As part of the heat rejection process, 13 vertical turbine pumps will take cooling water from deep in the hot basins and circulate it to the cold basin through the heat exchangers. The six-tonne vertical shafts (pictured) must be perfectly positioned and balanced to withstand the force of the water and the rotating impellers. *September 2019*

A break between sessions

Working as an integrated team, the ITER Organization and seven Domestic Agencies are continuing to meet the project's demanding schedule to First Plasma. By the end of the year, project execution to First Plasma stands at 67%. *June 2019*

Five-kilometre aluminium snake



Large water-cooled DC busbars supplied by Russia will feed power to ITER's superconducting magnets. The first elements have been installed on site in the twin buildings for magnet power conversion. *December 2019*

The temple of the Sun ...

Raw concrete in the Tokamak assembly pit has given way to the smooth shiny surface of many layers of white paint. The vast volume of the pit (25,000 m^3) is nearly ready to receive the first major machine components. *July 2019*

And now, the upper cylinder

The assembly of the 430-tonne upper cylinder is underway in India's on-site Cryostat Workshop. Contractors Larsen & Toubro (fabrication and assembly) and MAN Energy Solutions (welding) are in charge of carrying out the assembly activities. *October 2019*

Clockwork precision

Each of the 18 cryostat bearings rests on a steel transition piece that is half embedded in the concrete crown. A high-strength top plate (3.5 tonnes of steel) is positioned on the transition piece to receive the bearings with a mechanical blocking mechanism worthy of a Swiss watch. *September 2019*

Last pour for the Tokamak Building

On 7 November, Fusion for Energy, the European Domestic Agency, and its contractors carry out the last concrete pour for the Tokamak Building. In all, six million work hours, performed by 850 people, were required for this project "of unusual technical complexity," according to consortium leader Vinci Construction. *November 2019*

Equipment expected soon

In one of the yet unpainted galleries of the Tokamak Complex, teams meet to discuss the day's work program. The vast galleries like this one that surround the central machine well will be completely filled with equipment as time progresses. *November 2019*

2019

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 provide 90% of their contributions in the form of machine components, systems and – in the case of Europe – buildings.

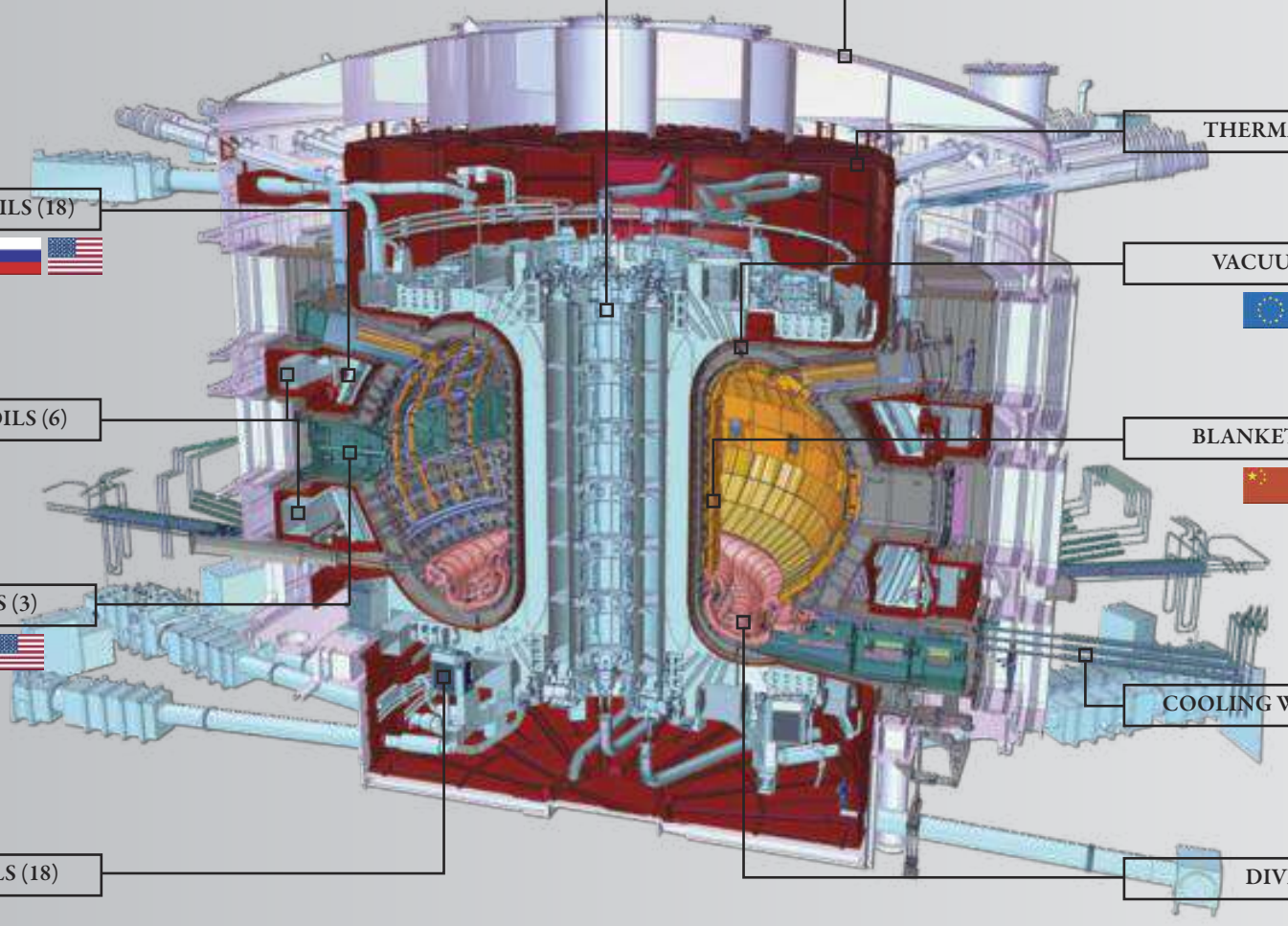
Procurement packages are shared equally (~ 9% of the total value) between China, India, Japan, Korea, Russia and the United States; Europe's share, as Host Member, is ~ 45%.

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 fields, as companies apply the expertise acquired in the fabrication of ITER's cutting-edge components and systems to other applications and technologies.

Who manufactures what?



CENTRAL SOLENOID

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TOROIDAL FIELD COILS (18)

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POLOIDAL FIELD COILS (6)

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HEATING SYSTEMS (3)

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CORRECTION COILS (18)

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CRYOSTAT

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THERMAL SHIELD

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VACUUM VESSEL

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BLANKET MODULES

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COOLING WATER SYSTEM

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DIVERTOR

Page 41

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

First correction coils

Production is underway at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP) on the correction coils that will enable small magnetic field adjustments. Four bottom correction coils will be delivered in early 2020.

Manifold inputs

Different gas species from the Tritium Plant will be delivered to the fuelling, neutral beam and disruption mitigation systems via a gas distribution manifold system. The assembly of the first manifold spool is ongoing, including the process pipes, guard pipe, evacuation pipe and inner supports.

Late-night transport

Several large semi-circular components have been delivered for the magnet feeder system that will transport cryogens and electrical power to the bottom correction coil magnets. These feeder sections will be installed inside the cryostat base.

Successful coil insertion

SIMIC successfully carries out the first insertion operation of the toroidal field coil program, placing a winding pack manufactured at ASG Superconductors (Italy) into the coil case provided by the Japanese Domestic Agency. The next step is welding the cover plates along the inside surfaces of the D-shaped coil.

Divertor cassette bodies

Divertor cassette bodies are the "chassis" of the divertor assemblies – eight-tonne structures that will support plasma-facing targets, diagnostics, operational instrumentation and cooling. Pictured is a real-size prototype manufactured by Water Tosto.

The shape of ITER

Fusion for Energy, the European Domestic Agency, is delivering five of ITER's nine vacuum vessel sectors. The first to come off the production line will be Sector #5. (Pictured, the lower poloidal segment of Sector #5 as it enters a facility for radiographic tests.)

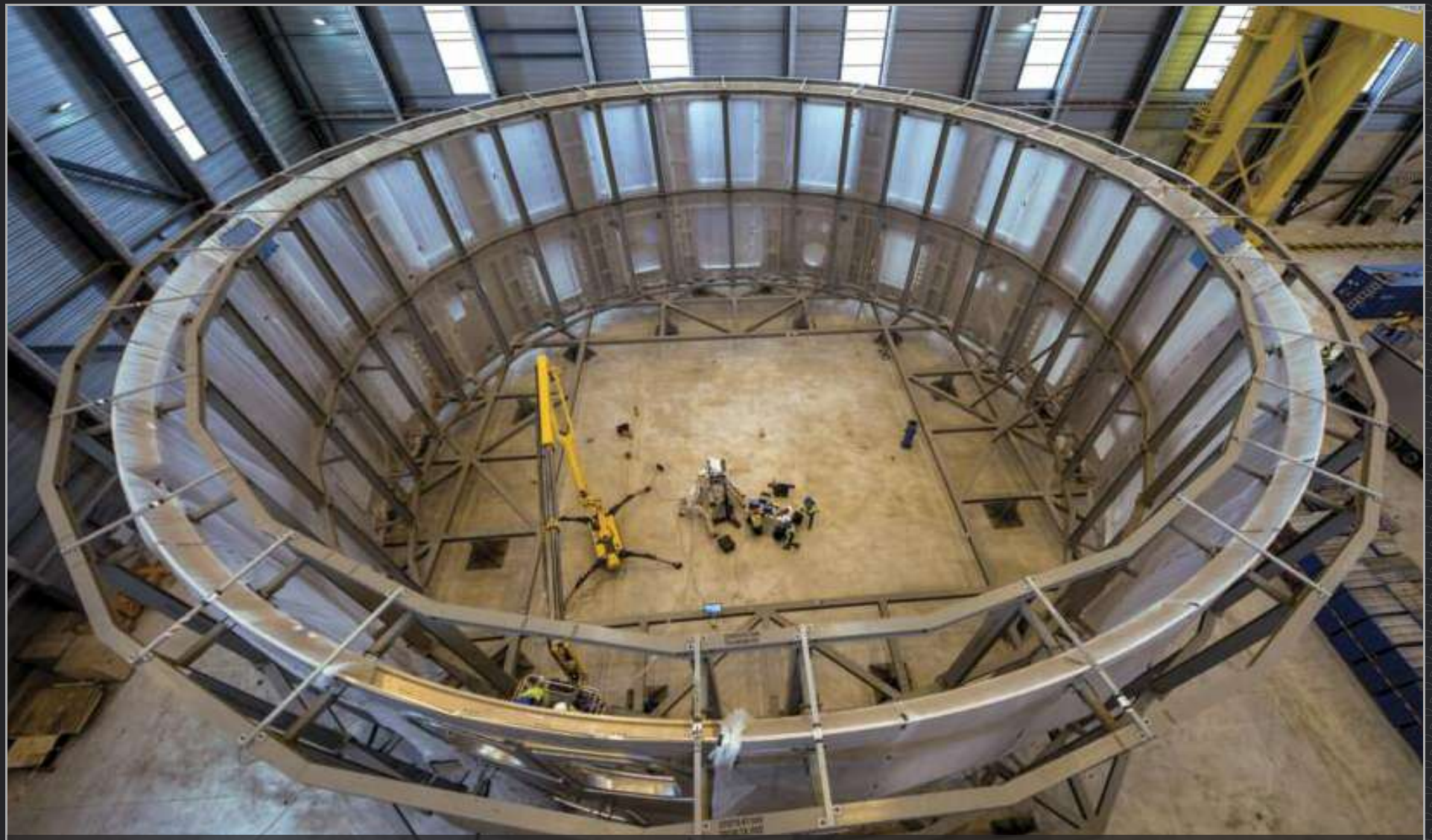
Cryostat top lid

At the Larsen & Toubro factory in Hazira, India, the elements of the top lid of the cryostat are in fabrication. When completed they will be sent to the Indian Domestic Agency's assembly workshop at ITER.

Apertures galore

All of the components of ITER's diagnostic neutral beam system will be tested in advance of shipment at a dedicated facility in Ahmedabad, India. These plasma grid segments were produced by first-of-a-kind angled-grid machining.

Completed this year

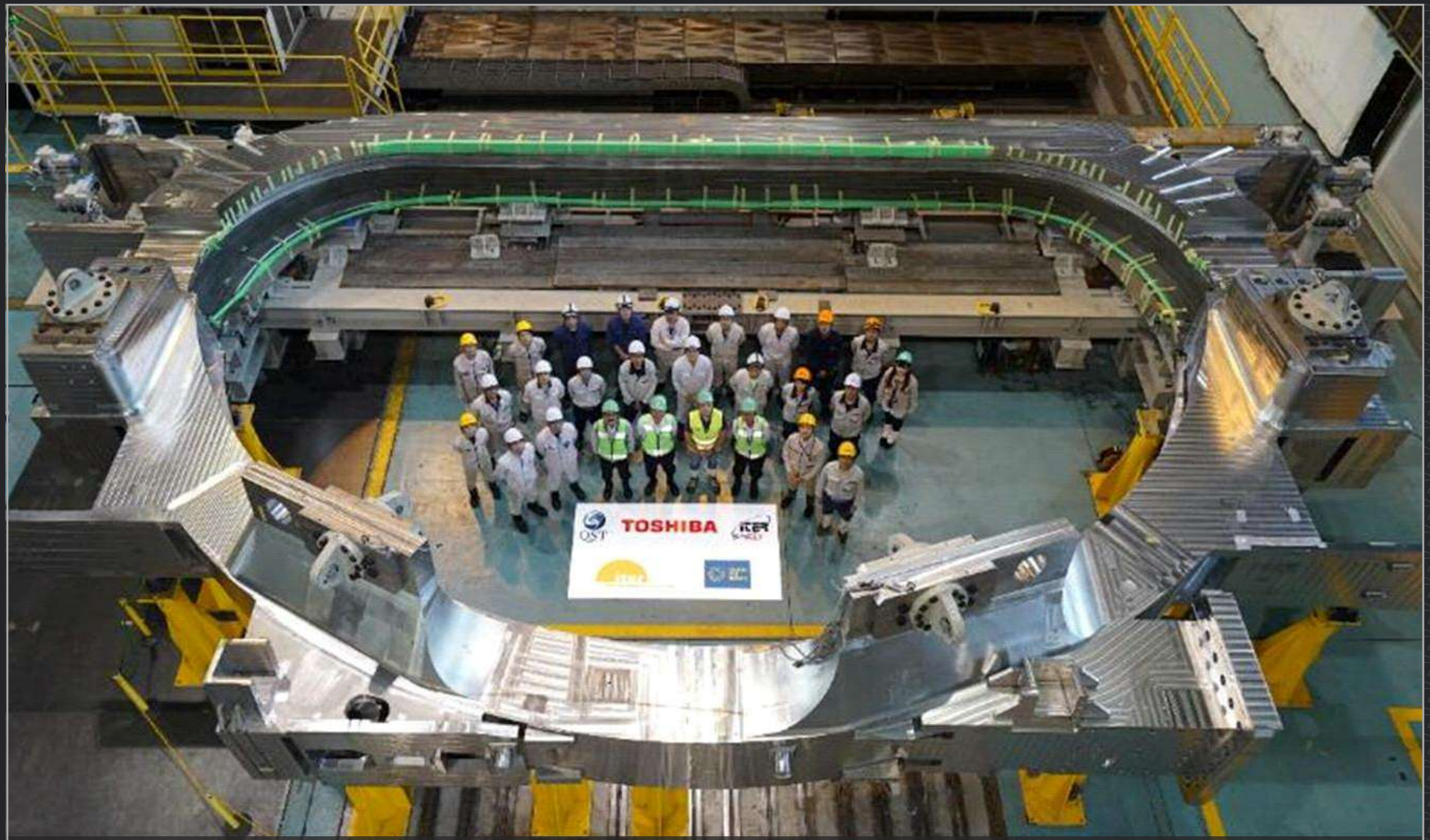


The Indian Domestic Agency delivers half of the ITER cryostat in 2019 – the 490-tonne lower cylinder (pictured) and the 1,250-tonne base. The lower cylinder has since been removed from the workshop on its platform and stored in order to make room for the assembly of the upper cylinder.

Successfully inserted

Contractors are carrying out the final fabrication steps on the first Japanese production coil. In 2019, the winding pack is successfully inserted into its coil case vertically, in a joint effort between Mitsubishi Heavy Industries and Mitsubishi Electric Corporation.

Completion of the Fourth TF Coil Case for the EU



Sub-assemblies AU and BU for TF03 (EU06), which is the 4th TF Coil Case for the EU, passed its final fitting and acceptance tests.

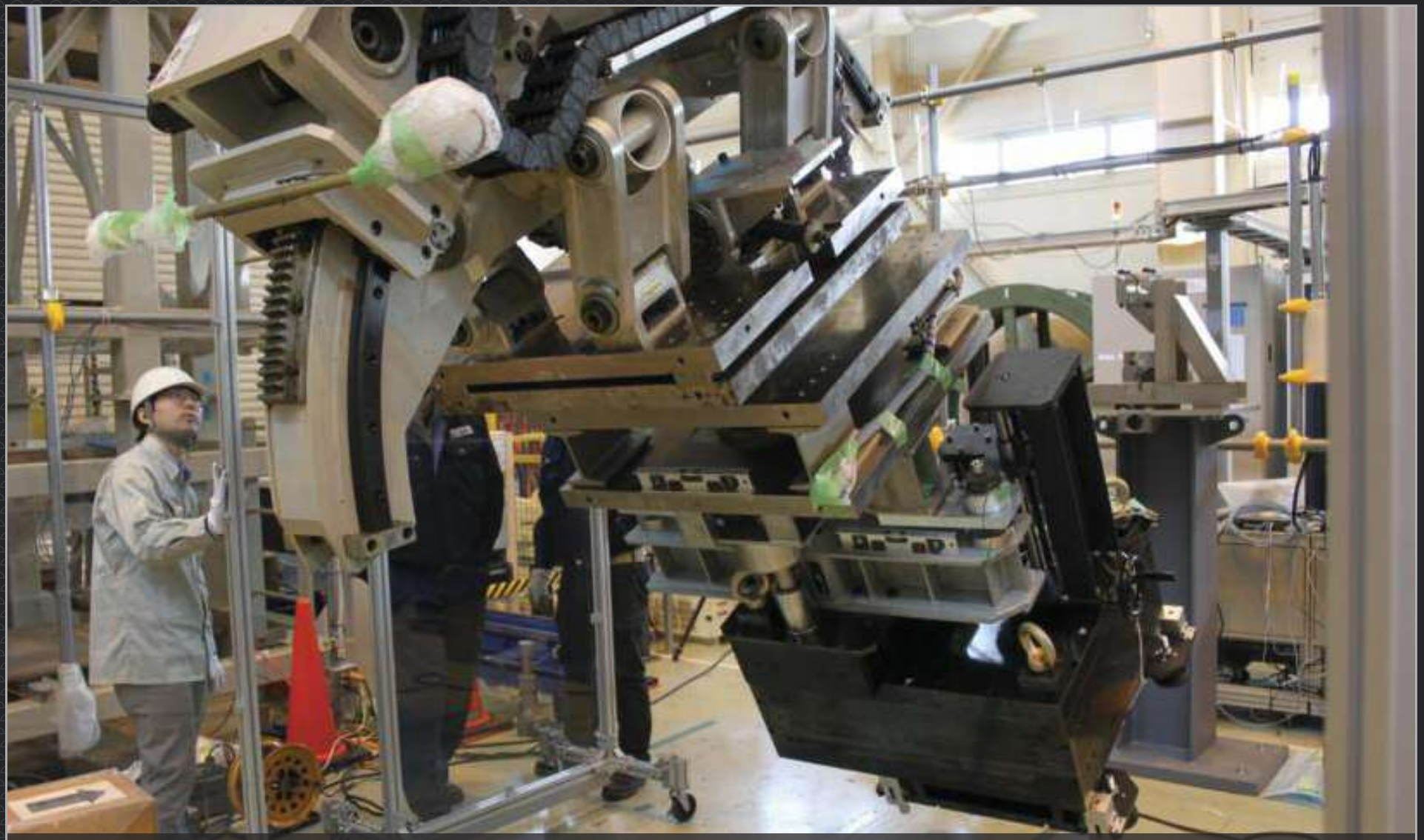
Arrivederci! Loading the Toroidal Field Coil Structure Onto a Boat Bound for Italy

A Toroidal Field Coil Structure being loaded onto a boat in Kobe port bound for Port Marghera, Italy.
The journey will take about 1.5 months.

Installing the HV Bushing

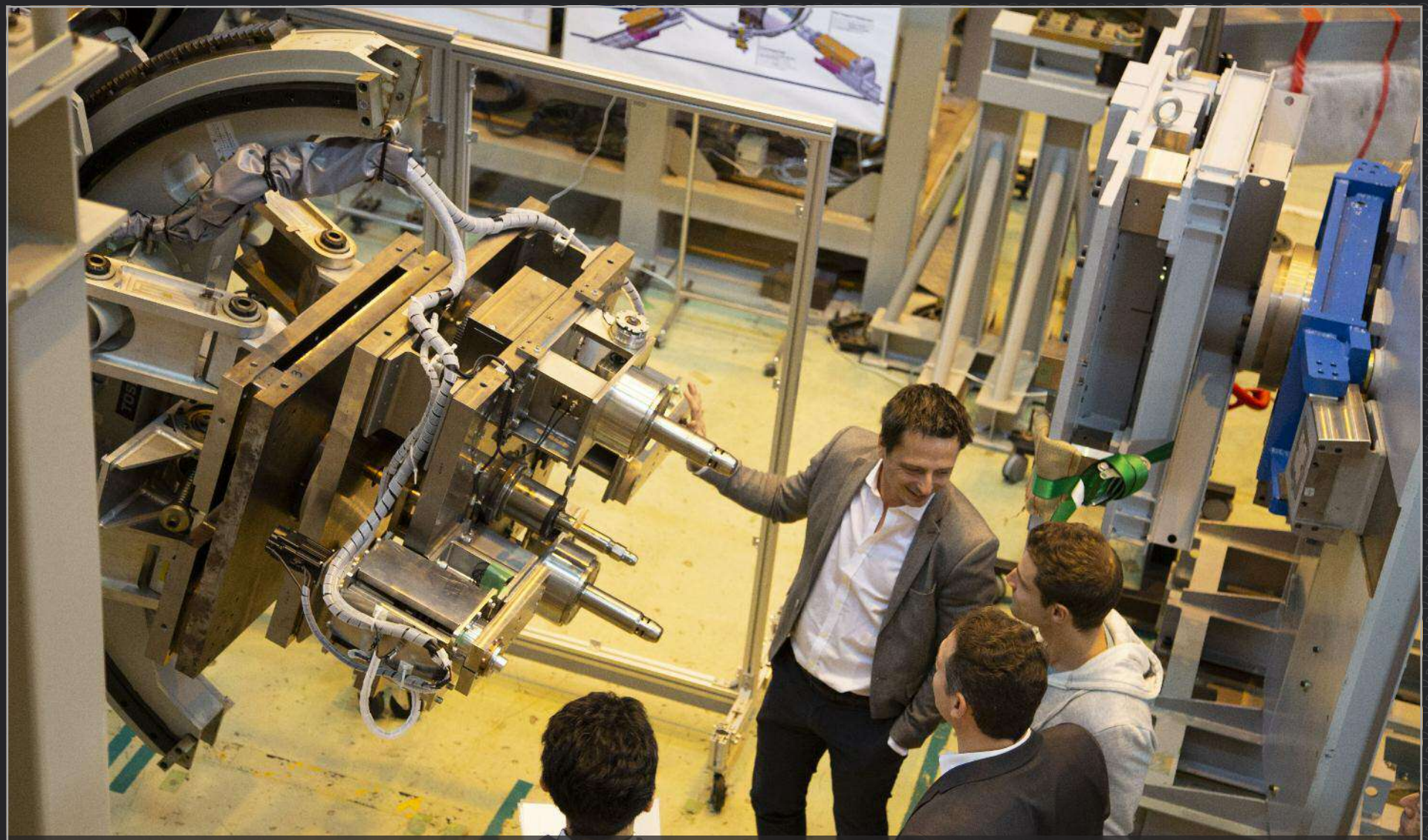
Delivered from Japan to the NBTF site, the HV bushing now sits atop its throne, the beam source vessel.

10 kNm of torque



Although not as powerful as the Infinity Gauntlet of comic book fame, the bolting tool (pictured) that will be used to install ITER's in-vessel blanket modules robotically is impressive. It will provide 10 kilonewton metres (kNm) of torque to tighten the massive bolts of the blanket first wall panels remotely.

Getting a Handle on the Blanket Modules!

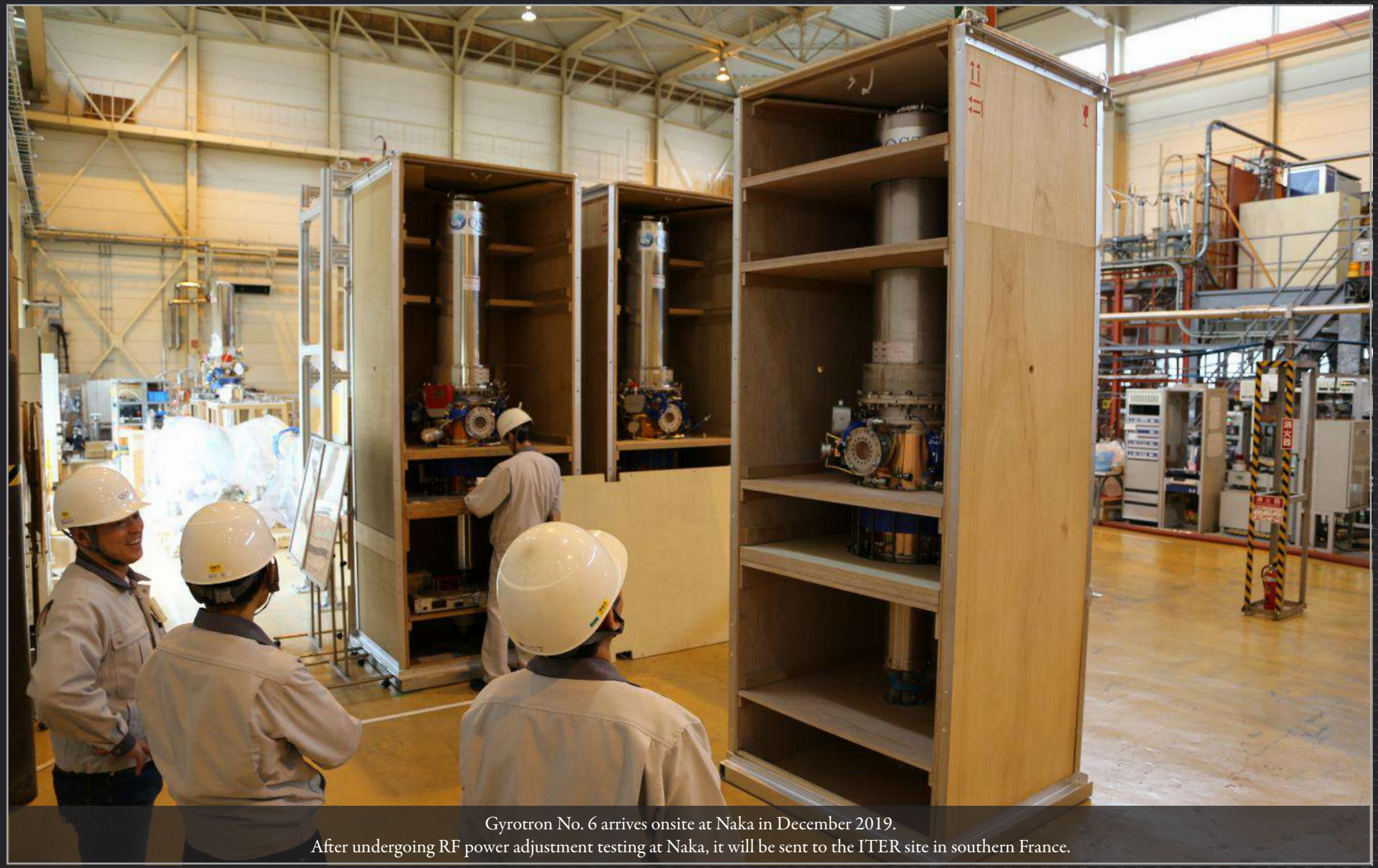


Fruitful meetings were held at QST with officers from the ITER Organization about the ITER Blanket and its Remote Handling System.
The gigantic manipulator in the picture is a part of the ITER Blanket Remote Handling System, which Japan is responsible for procuring.

Four of a kind

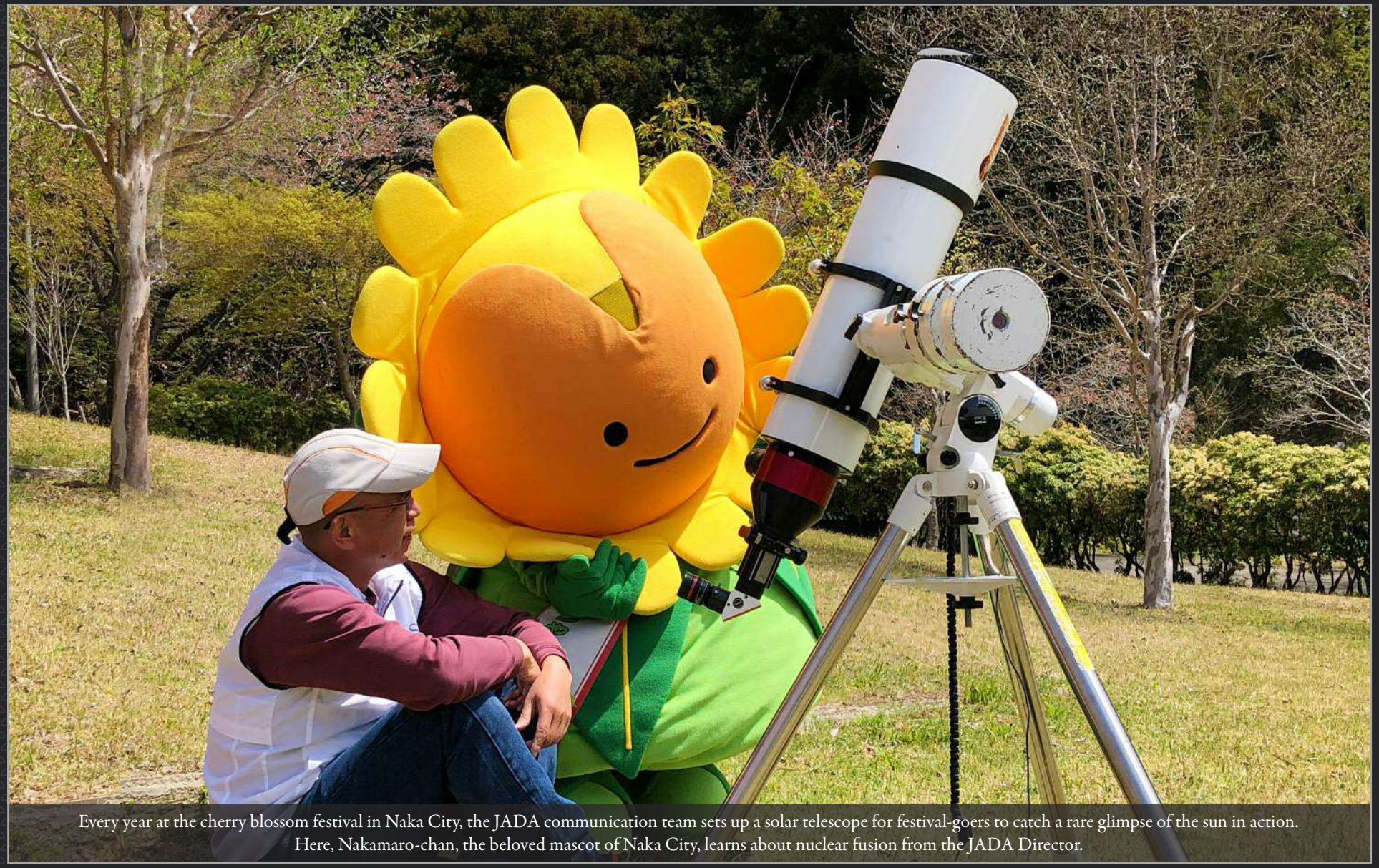
Japan is procuring 8 of the 24 energy-generating devices of the electron cyclotron resonance heating system, including 4 required by First Plasma. At the National Institutes for Quantum and Radiological Science and Technology (QST), all four have been manufactured and two have completed factory acceptance tests.

Hello Gyrotron No. 6!



Gyrotron No. 6 arrives onsite at Naka in December 2019.
After undergoing RF power adjustment testing at Naka, it will be sent to the ITER site in southern France.

Sun Meets Sun



Every year at the cherry blossom festival in Naka City, the JADA communication team sets up a solar telescope for festival-goers to catch a rare glimpse of the sun in action. Here, Nakamaro-chan, the beloved mascot of Naka City, learns about nuclear fusion from the JADA Director.

Last phase for Korean sector #6

The final activities on vacuum vessel Sector #6 are underway now at Hyundai Heavy Industries, as four completed segments (plus upper and lower port stub extensions) are assembled into the final D-shaped component. Korea is procuring four of ITER's nine vacuum vessel sectors.

Coated in silver

Korea has shipped the thermal shield panels required for vacuum vessel sector #6. Silver plating on every surface makes the components glimmer and shine.

Power to the magnets

The magnet power supply and distribution system will ensure that power received from the 400 kV transmission grid is converted into the controlled DC power needed by the different magnet systems. In 2019, factory acceptance tests are successfully completed in Korea on the first central solenoid converter unit.

Top ring

Specialists of the Sredne-Nevsky Shipyard and the Efremov Institute in Saint Petersburg have completed vacuum pressure impregnation on the eight double pancakes that will make up PF1 – ITER's smallest poloidal field coil (nine metres in diameter). The resin-hardened pancakes will now be stacked.

Small, but important

Many of ITER's diagnostics will be mounted in the port openings of the vacuum vessel, supported within "port plugs," and integrated into drawer-like structures called diagnostic shielding modules. Russian contractors are currently developing production technologies through mock-ups.

Electrical bridges

Between the blanket modules and the vacuum vessel, contractors will install low-impedance electrical bridges formed from bimetal "pedestals" (pictured, in testing) and electrical "straps."

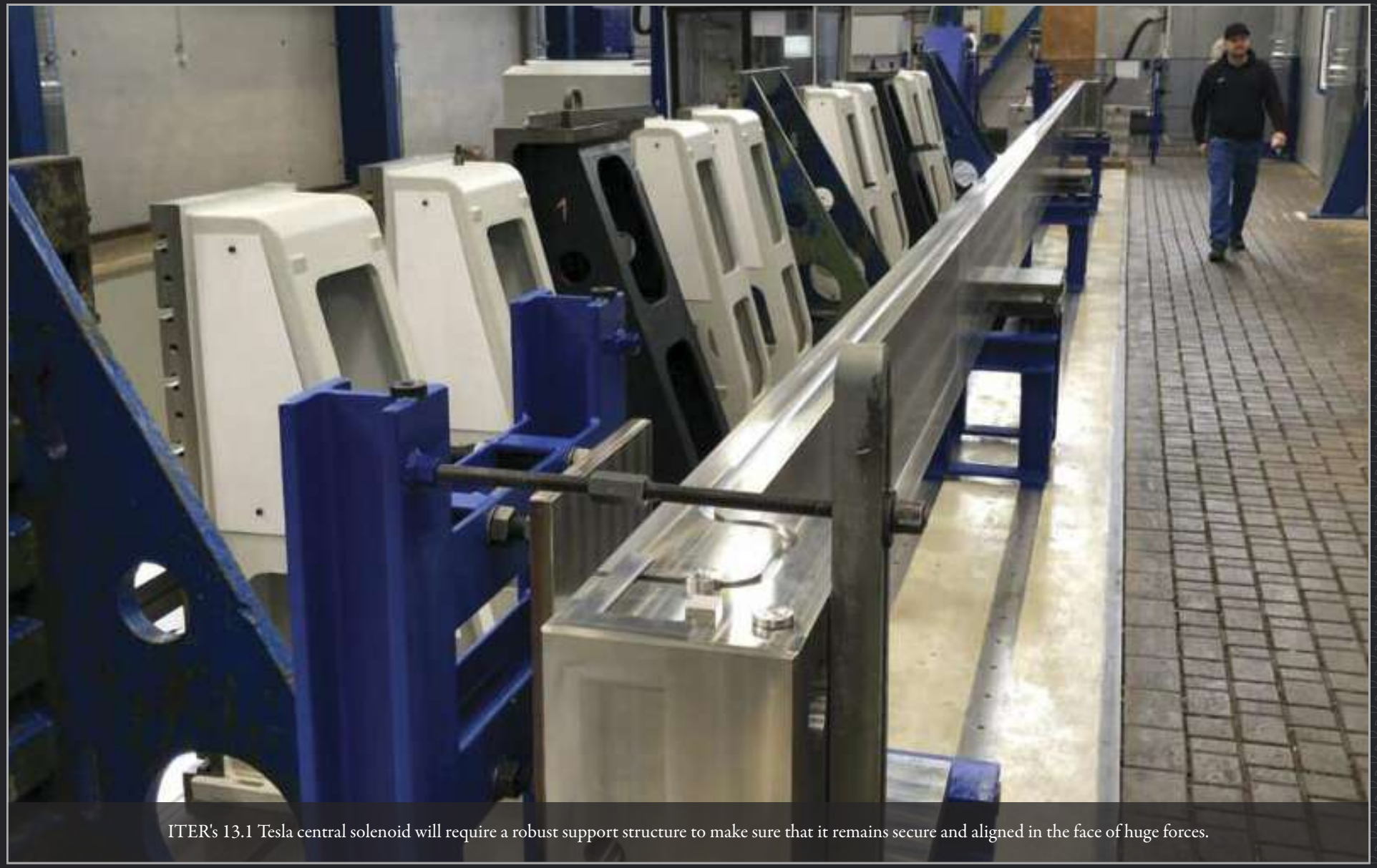
Turnover station

At different stages of fabrication, the top or bottom of a central solenoid module must be accessible. This turnover tool makes easy work offlipping the 110-tonne components.

Specialized tooling

Factory acceptance testing of the central solenoid module lifting fixture is underway in Bouc Bel Air, France. The 18-metre-tall electromagnet will be assembled in the ITER Assembly Hall using tooling supplied by US ITER.

Tying the modules together



ITER's 13.1 Tesla central solenoid will require a robust support structure to make sure that it remains secure and aligned in the face of huge forces.

2019

ITER ORGANIZATION

Highlights

The ITER Project has begun its countdown to First Plasma – only six years remain until the button is pushed to initiate the first operational event of the ITER scientific program.

Until then, many complex challenges lie ahead as construction is concluded on site, major one-of-a-kind components are finalized and delivered by the Domestic Agencies, and the ITER Organization team and contractors implement a carefully sequenced assembly, installation and commissioning program.

Based on the stringent metrics that measure overall project performance, 67 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) was completed at the end of 2019.

First Plasma will be a decisive step in the making of the human-made star that will demonstrate that fusion energy can produce power on an industrial scale.

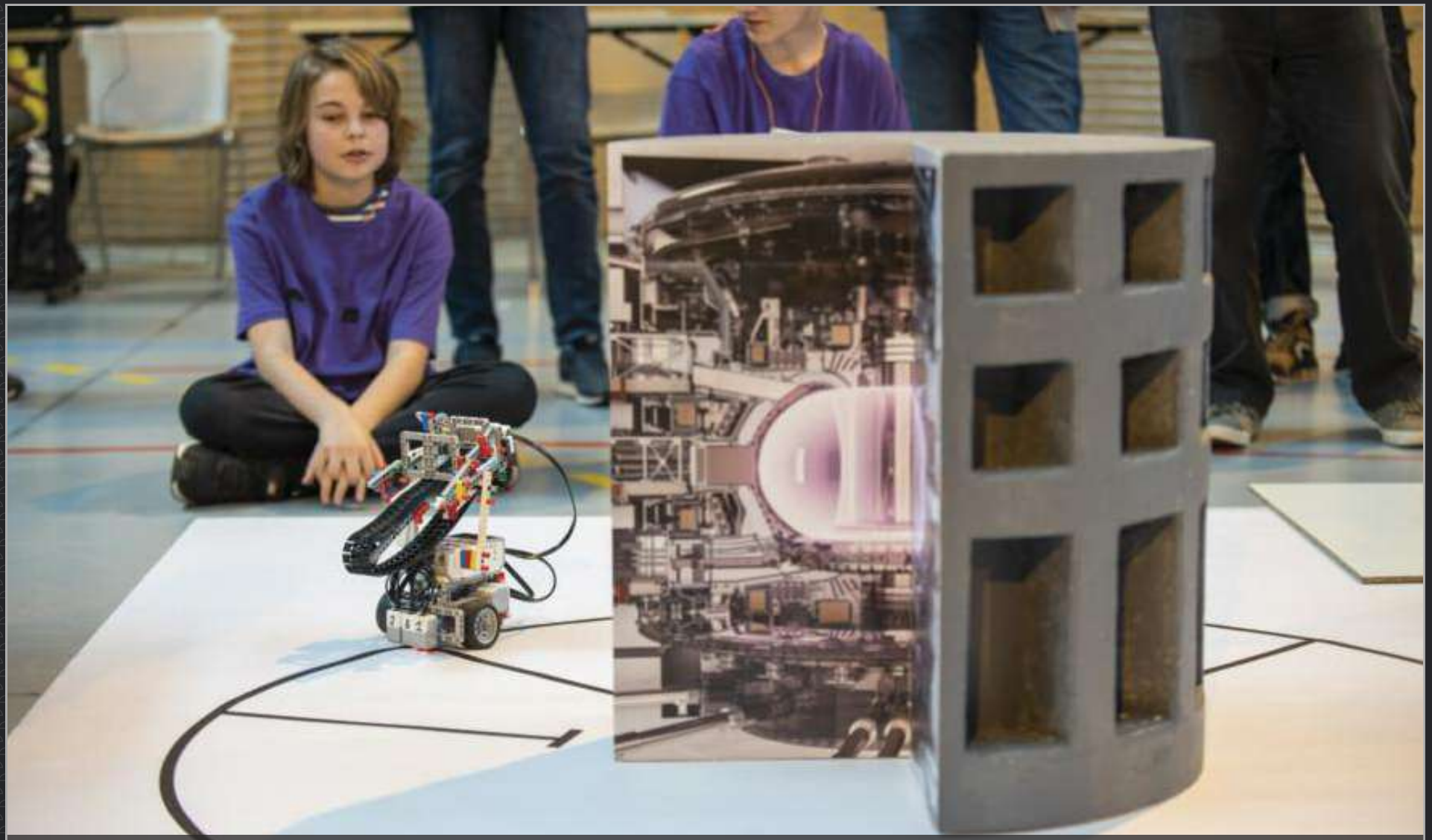
500 years, from Leonardo to ITER

Monday 15 April is Da Vinci Day at ITER, as the ITER Organization and the Consul General of Italy in Marseille co-host a celebration that traces patterns of innovation from the individual genius of Leonardo da Vinci to the collaborative inspiration of the ITER Project.

A Saturday well spent

Twice a year, ITER families and members of the public are invited to Open Doors Days for an "insider's tour" of the construction site and access to specialists in ITER science, engineering and construction.

ITER Robots, more popular than ever



The ITER Robots competition – now accredited by the French Ministry of Education – returns in May for the eighth time. Seven hundred students, organized into 49 teams, try their hand at building a small robot to simulate a maintenance situation inside the ITER Tokamak. In the process, they learn about engineering, programming, and ... ITER.

Bernard Bigot accepts a second term

Heads of Delegation from each ITER Member congratulate Bernard Bigot on his decision to accept a second five-year contract (2020-2025) as Director-General of the ITER Organization.

Cryostat 60% complete

The finalization of the cryostat base (pictured) and lower cylinder is celebrated on site in July. The 1,250-tonne base will be the first machine component lowered into the assembly pit next year.

Close to the 1,000 mark

Over 900 people now work directly for the ITER Organization in St-Paul-lez-Durance, France. A large portion of the staff gathers for a group photo in late November.

Fusion science on the weekend

Local science fairs – tailored particularly to school-age children – offer a fun and friendly way to discover projects like ITER. As part of outreach efforts, ITER sends volunteers to as many of these events as possible.

Following the fusion timeline

A new display in the lobby of the ITER Headquarters building retraces ITER and fusion history. In June, Director-General Bigot gives ITER Council members a guided tour.

iter
china eu india japan korea russia usa

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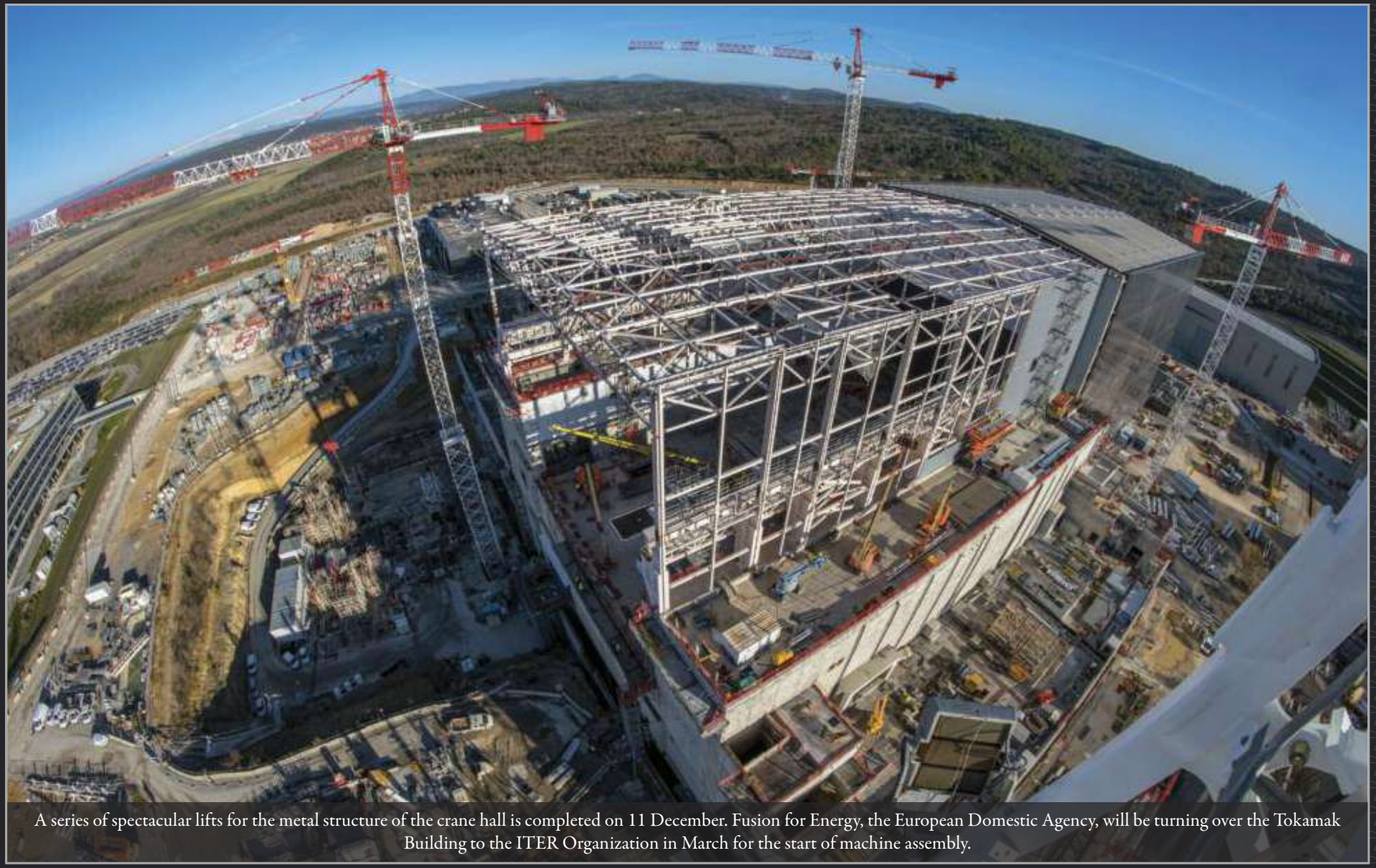

A series of spectacular lifts for the metal structure of the crane hall is completed on 11 December. Fusion for Energy, the European Domestic Agency, will be turning over the Tokamak Building to the ITER Organization in March for the start of machine assembly.

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