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PROGRESS IN PICTURES

NOVEMBER 2015

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A STAR WILL BE BORN

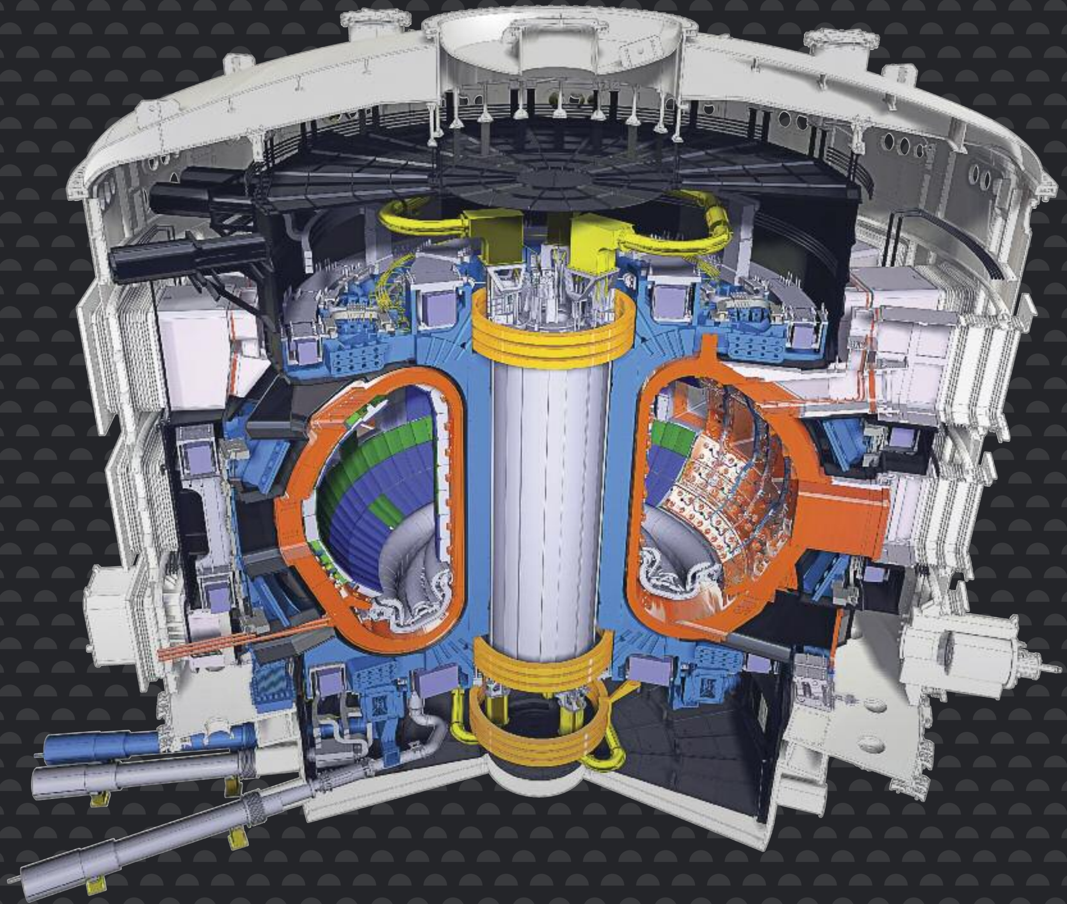
A new star will soon be born, a star unlike any other… a man-made star. ITER – the Latin word for "The Way" – will light up in the next decade. From a scientific and technological point of view, it will be one of humankind's historic achievements. The creation of an artificial star, and the mastery of 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. What was the aspiration of three generations of physicists is now the reality of the hundreds of scientists and engineers working in southern France, where the ITER installation is under construction, and in the labs, offices and factories of the ITER Members.

The seven ITER Members, representing half the world's population, share the responsibility for building the ITER machine and facilities. Every Member, essentially, has a part in every system.

As buildings rise on the ITER platform (part of the European contribution, pages 4 to 15), component manufacturing advances in ITER Member factories (pages 24 to 47).

This booklet takes 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 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	**840m^3**
Temperature at plasma core	**150,000,000°C**
Fusion power	**500 MW**

SITE MAP

On 28 June 2005, the ITER Members unanimously agree on the site proposed by Europe: a 180-hectare stretch of land located in the Durance River Valley some 75 kilometres north of Marseille, France. Preparation work on the ITER site begins in January 2007. Over two years a 42-hectare platform is cleared, levelled and readied for building construction, which begins in the summer of 2010.

THE ITER SITE, LOOKING EAST

A little over half of the "ITER parcel" has been cleared – the rest remains wooded. Behind the platform, a 9,000 m^2 warehouse is now in place for the storage of delivered components.
September 2015

A TOWERING STRUCTURE

Since the completion of its metal structure the Assembly Building is the tallest building on the ITER platform, rising 60 metres above ground level. Here pre-assembly activities will be carried out on the principal tokamak components prior to machine installation. *September 2015*

LAST POUR FOR THE TOKAMAK COMPLEX BASEMAT

Four years of work in the Tokamak Pit to create the ground support structure and foundations of the Tokamak Complex are brought to a successful conclusion as the last segment of the B2 slab – the basemat that will support the machine and systems – is poured. *August 2014*

The end of a work day on the ITER site.
November 2014

TOKAMAK COMPLEX: CONSTRUCTION LAUNCHED

Work is underway on the lowest basement level (B2) of the seven-storey Tokamak Complex. To the east, the first pillars of the Assembly Hall are visible.
February 2015

RADIAL SUPPORT SYSTEM FOR THE MACHINE

Eighteen radial structures will link the cryostat support "crown" to the surrounding concrete bioshield, helping to distribute the considerable force that will be exerted by the combined mass of the machine and the cryostat (25,000 tonnes) as well as structural movement. *March 2015*

FIRST BASEMENT LEVEL ADVANCES

Work progresses in 2015 on the columns and walls of the first basement level (B2) of the Tokamak Complex. At the same time, the metal structure of the giant Assembly Hall takes shape.
July 2015

A 730-TONNE LIFT

In a carefully programmed operation that lasts 14 hours, the 730-tonne roof structure of the Assembly Building is successfully lifted into place. Now, the building can be fitted out with exterior cladding and rails for the heavy-lift cranes.

September 2015

60 METRES TALL

When completed, the Tokamak Building (under construction, in the centre of the basemat) will be as tall as the just-topped Assembly Building.
September 2015

PREPARING FOR WINDING OPERATIONS

In ITER's largest on-site manufacturing facility, two clean areas are framed out to prepare for the delivery of the first winding tooling. In this 257-metre-long building, Europe will wind and assemble the four largest poloidal field coils.

September 2015

The 3.2-metre-thick ITER bioshield will completely enclose the ITER Tokamak and its cryostat. In the dense reinforcement set into place in advance of concrete pouring, openings are visible for the arrival of electrical and cryogenic supplies.

October 2015

THE FIRST HIGHLY EXCEPTIONAL LOAD

A US-procured electrical transformer is the first ITER component to be transported along the 104-km ITER Itinerary. At least 250 exceptional convoys are expected during the construction and assembly phases of ITER.

January 2015

NEW STORAGE WAREHOUSE

This 9,000 m^2 storage facility was erected in 2015 by the ITER Organization to house machine and plant components sent by the ITER Domestic Agencies.
It is the largest of four warehouses on site.

COMPONENT DELIVERIES INTENSIFY

Five on-site warehouses are now in place for the storage of in-kind contributions to ITER. (Pictured: a water detritiation tank procured by Europe.)
April 2015

GOVERNING ITER

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

A NEW DIRECTOR-GENERAL

The third Director-General in ITER Organization history takes up his post on 5 March 2015. Bernard Bigot, from France, is appointed by the ITER Council at a critical time, as the project transitions from design completion to full construction.

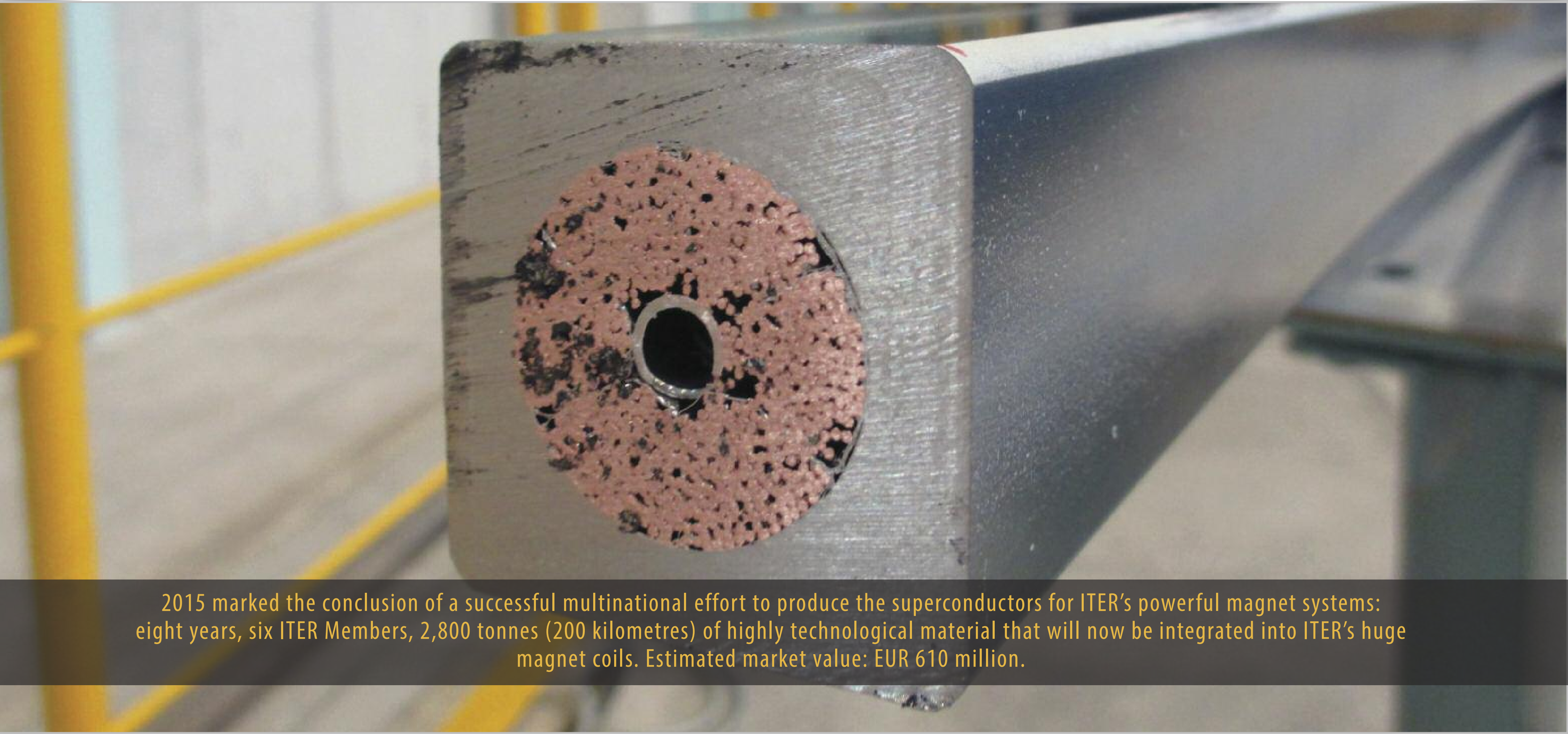
INTERNATIONAL COLLABORATION AT WORK

A new Executive Project Board brings together decision makers at the ITER Organization Central Team with those at the seven Domestic Agencies. Tight collaboration during the years to come is absolutely critical to adhering to the ITER construction and assembly schedule.

In May 2015 the ITER Director-General fields questions from international media representatives and describes his action plan for the ITER Project.

COME ONE, COME ALL

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. The machine mockup pleases young visitors with its blinking lights and a figurine that shows just how big the machine is.



2015 marked the conclusion of a successful multinational effort to produce the superconductors for ITER's powerful magnet systems: eight years, six ITER Members, 2,800 tonnes (200 kilometres) of highly technological material that will now be integrated into ITER's huge magnet coils. Estimated market value: EUR 610 million.

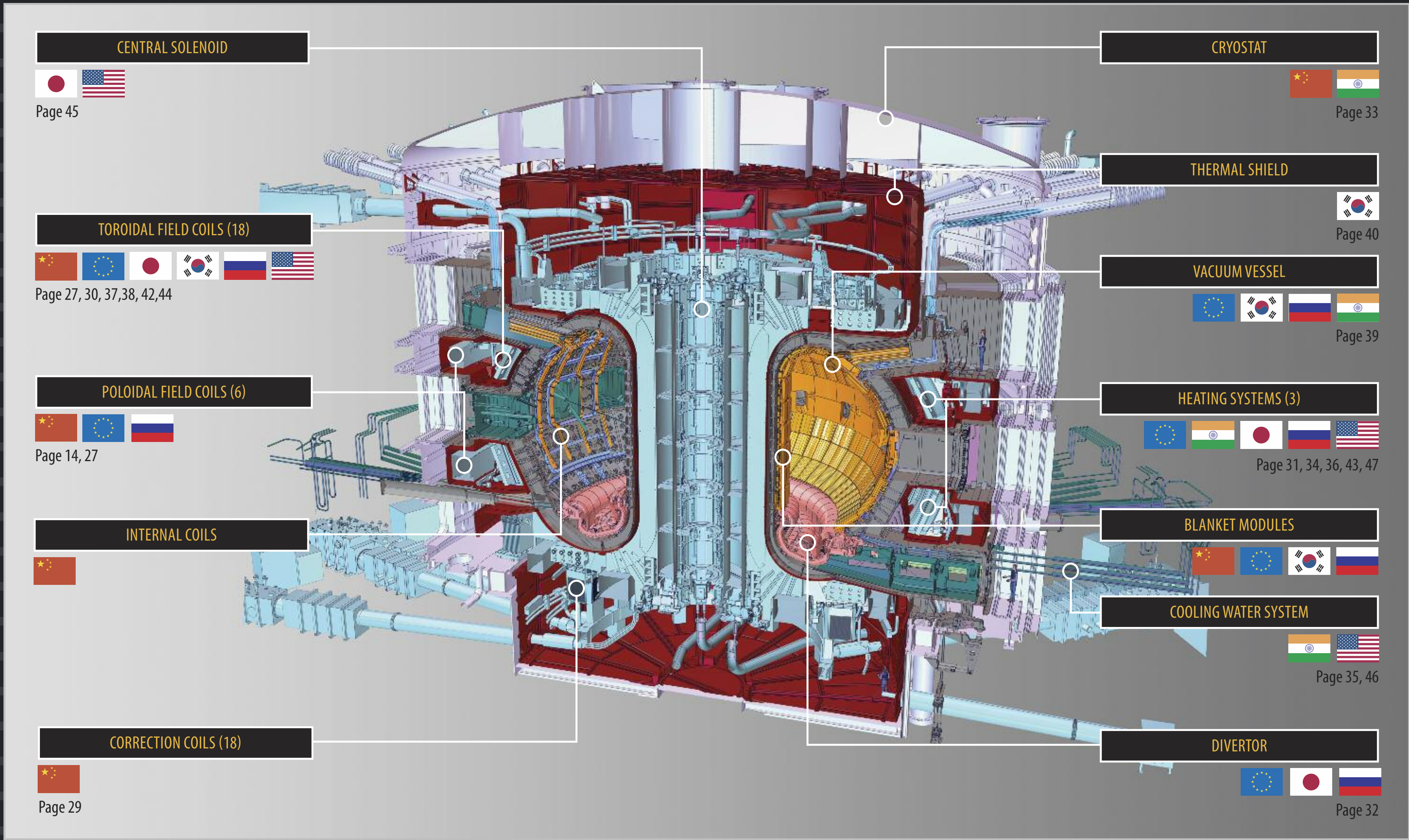
MANUFACTURING

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%.

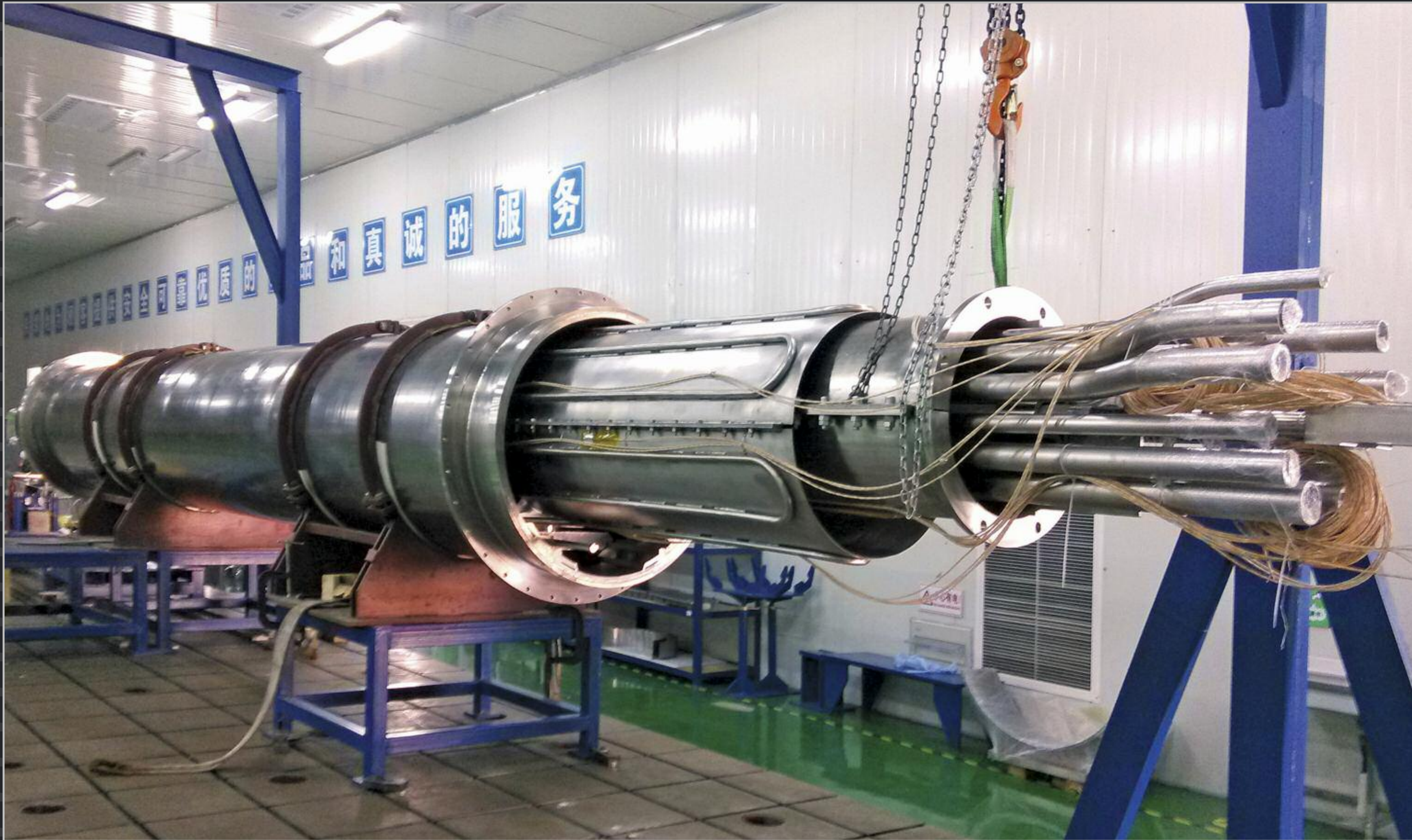
In-kind procurement is at the core of ITER's founding philosophy, offering the ITER Members invaluable experience in the manufacturing of components for a fusion installation. By contributing to the construction of the experimental machine, the ITER Members are creating the technological and industrial basis for the commercial fusion reactors of the future.

WHO MANUFACTURES WHAT?



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

CRYOSTAT FEEDTHROUGH PROTOTYPE



Cryostat feedthroughs cross through the cryostat and bioshield to provide a passageway to the ITER magnets for cooling pipes, power cables and instrumentation cables. This 10-metre prototype was manufactured, integrated and commissioned in November 2014 at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP).

POWERING THE PULSED SYSTEMS

The pulsed power electrical network (PPEN) provides power to the "pulsed" systems of ITER, including the magnet power supplies and plasma heating systems. A first batch of PPEN equipment (surge arresters, current transformers, potential transformers, disconnecting switches and earthing switches) has been manufactured and tested in China, and is now ready for shipment.

CORRECTION COIL QUALIFICATION ACTIVITIES

Momentum is building on the fabrication of the ITER correction coils in China. At ASIPP, a five-metre qualification length of niobium-titanium conductor has been fabricated and one prototype winding pack has been successfully manufactured and tested. (The face of the conductor sample pictured is 11 x 9 cm.)

SERIES PRODUCTION OF RADIAL PLATES AND COVERS

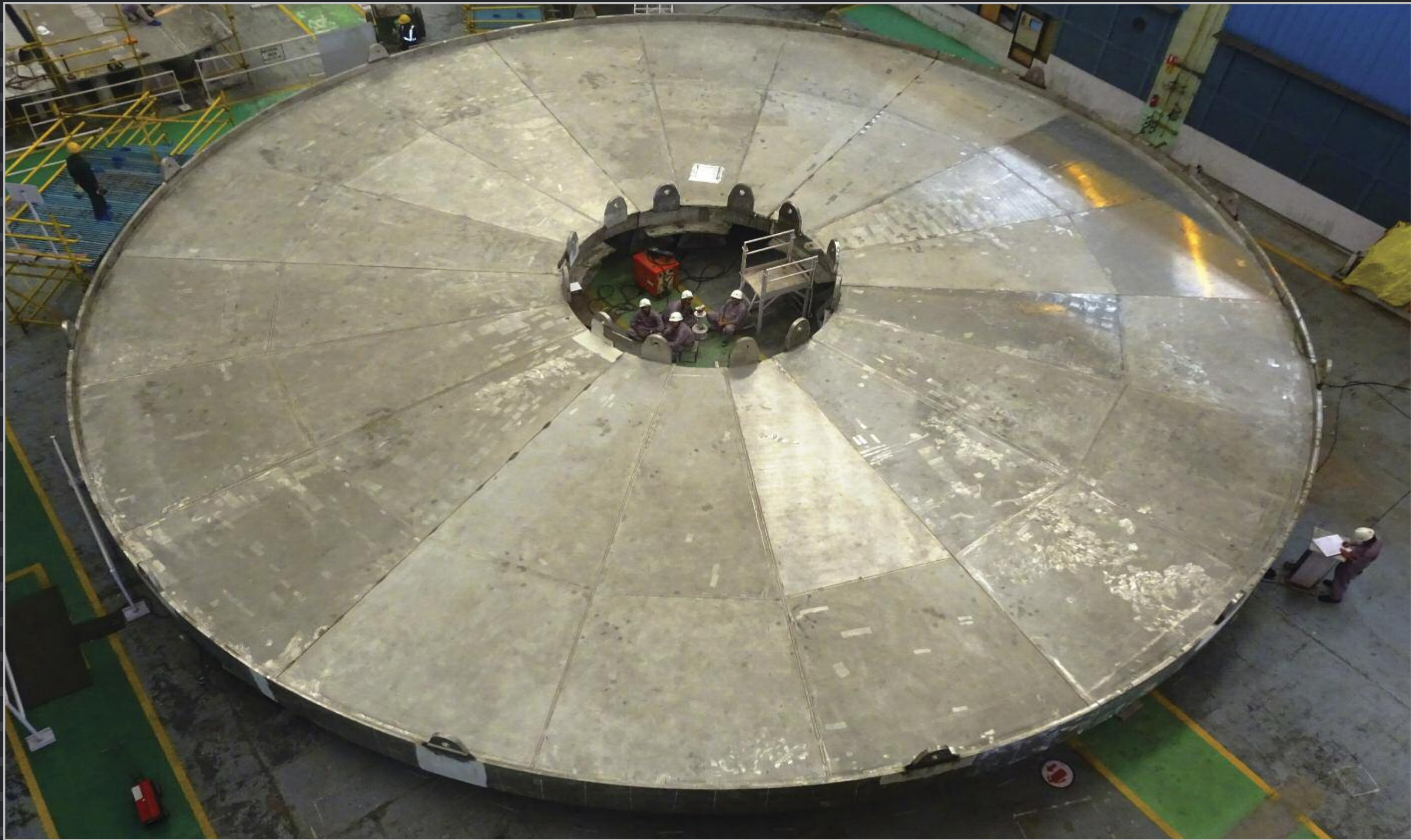
Inside of the large D-shaped toroidal field winding packs, specially grooved stainless steel radial plates, plus covers, will hold the conductor in place.
In Europe, manufacturing is underway on seventy 13 x 9 m radial plates.

At the PRIMA facility in Padua, Italy, ITER neutral beam technology will be tested in advance of operation on SPIDER (an ITER-scale radio-frequency negative ion source) and MITICA (a full-scale ITER neutral beam injector at full acceleration voltage and power). Europe, Japan and India are all contributing components. In 2015, Europe delivered the SPIDER vacuum vessel pictured above.

DIVERTOR REMOTE HANDLING

Europe is responsible for procuring the remote handling systems for the ITER divertor, the neutral beam, the cask transfer system, and the in-vessel viewing and metrology system. Pictured: the final demonstration of divertor cassette remote handling is successfully performed in 2015 at the DTP2 Divertor Test Platform facility in Tampere, Finland.

CRYOSTAT BASE COMPLETED



At the Larsen & Toubro factory in Hazira, India, Tier 1 of the cryostat base is assembled on the shop floor to verify tolerances before being shipped in six 60° segments to the ITER site. The entire cryostat base (Tier 1 plus Tier 2) will weigh in as the heaviest load of ITER assembly (1,250 tonnes).

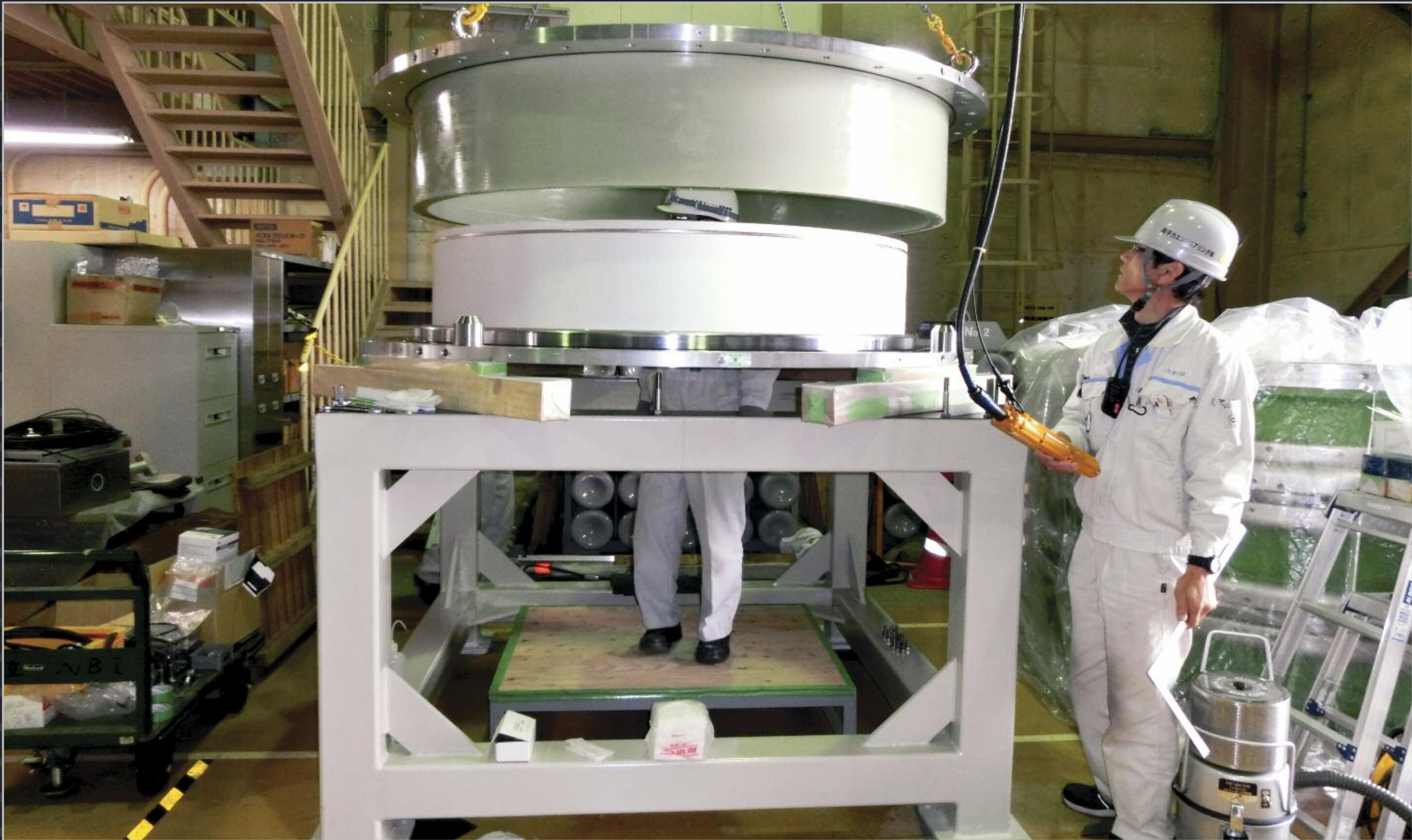
FIRST IN-KIND DELIVERY FOR INDIA

In December 2014, India celebrates its first in-kind delivery to the ITER Project – a beam dump for the full-scale ion source test bed at the PRIMA neutral beam test facility in Padua, Italy.

COOLING WATER PIPING REACHES SITE

The first cooling water piping under Indian scope reaches ITER in September 2015. In all, India will ship 100 containers of piping for ITER's chilled water and heat rejection systems.

THE LARGEST CERAMIC BUSHING RING IN THE WORLD

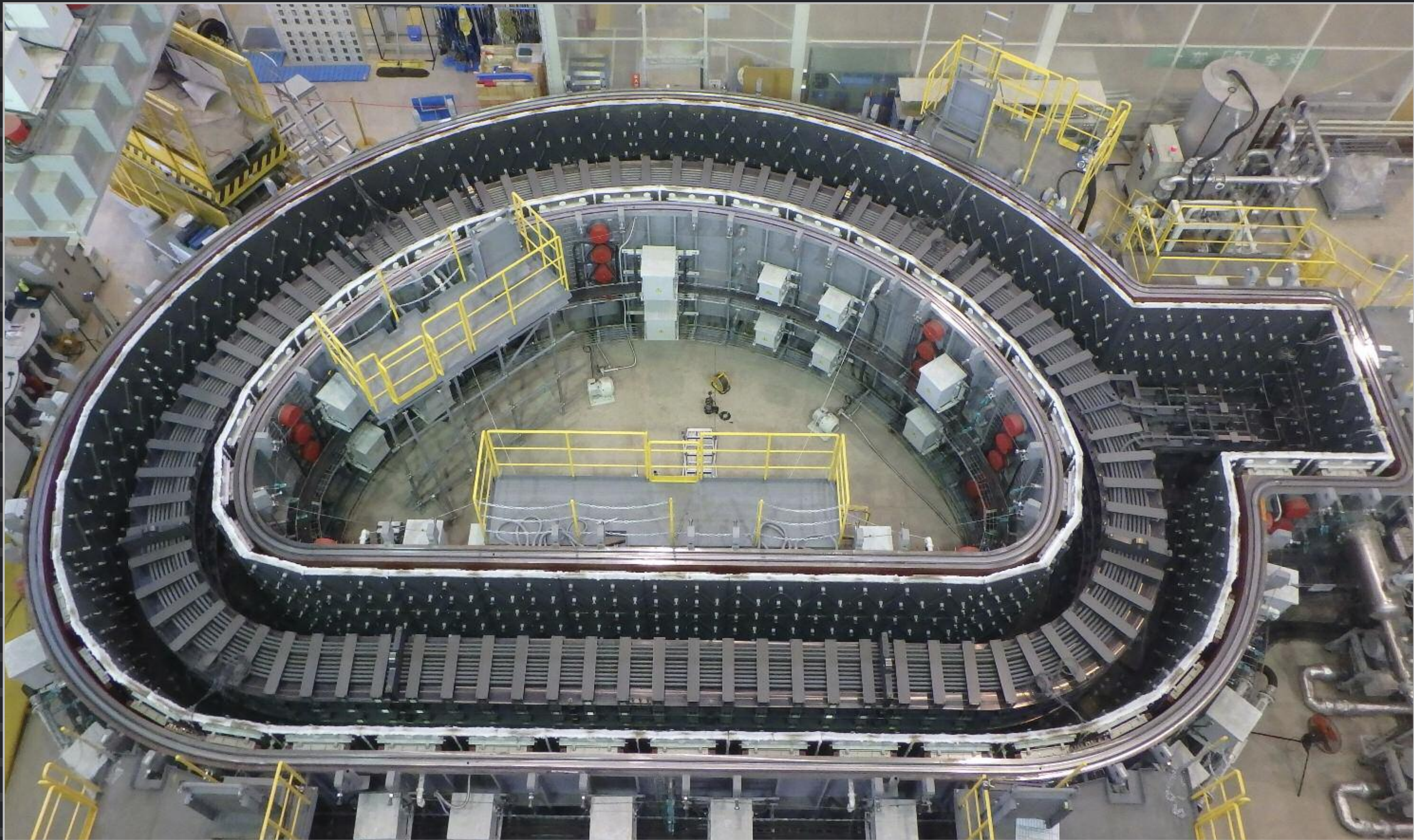


Ceramic bushing rings serve as insulators on ITER's neutral beam heating system, connecting the high pressure transmission lines for the 1 MV power supply with the vacuum chamber inside the system. This one, assembled at the Japan Atomic Energy Agency with an outer tube in fibre-reinforced plastic, has a diameter of 1.56 metres, making it the largest in the world.

CONDUCTOR TRANSFER TOOLING COMMISSIONED

Unit lengths of conductor are wound into a D-shaped double spiral called a "double pancake" before being heat treated, electrically insulated, and finally inserted into the grooves of a radial plate. At Mitsubishi Heavy Industry's Futami factory, transfer tooling has been successfully commissioned.

100 HOURS AT 650° C

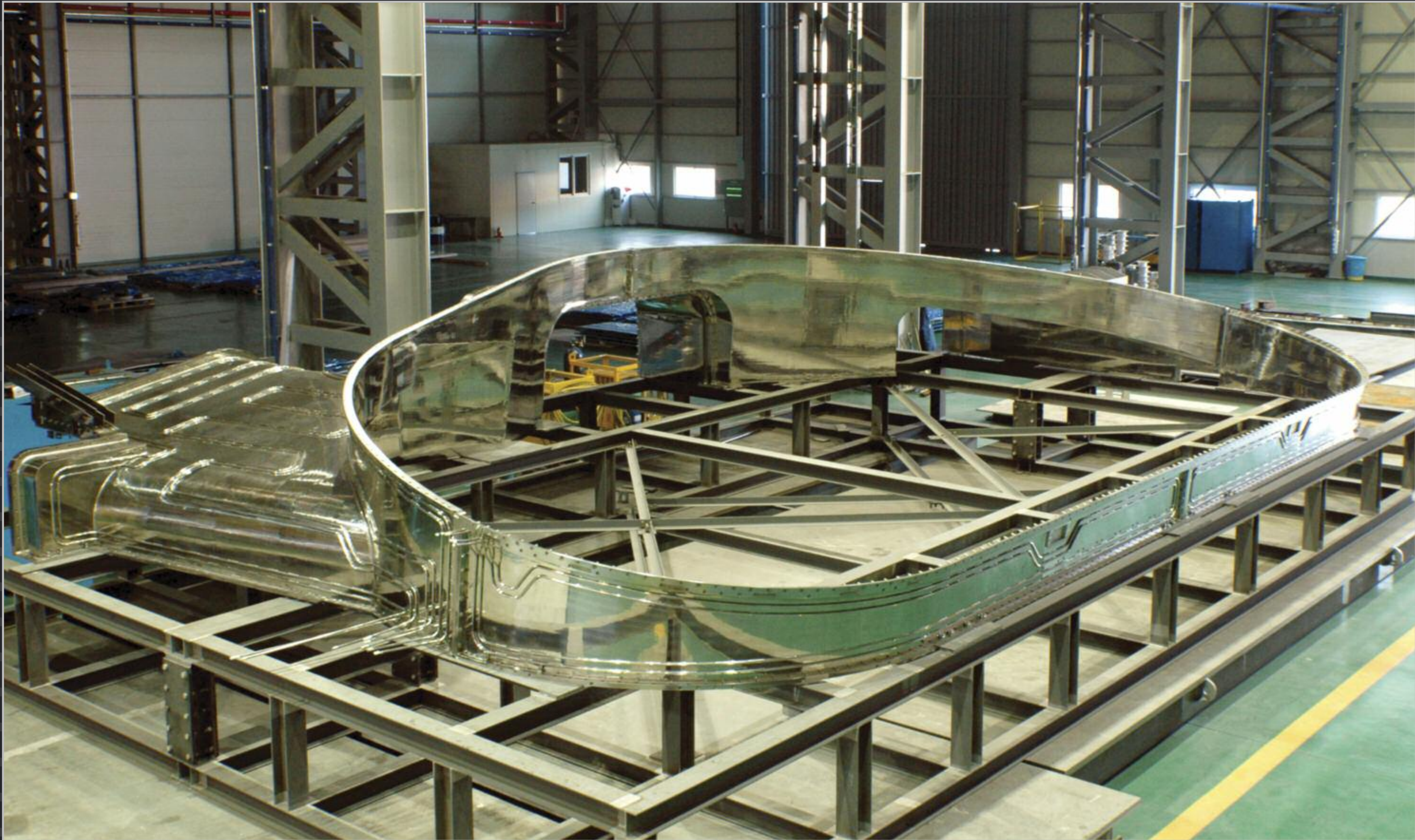


Toroidal field coil windings must be heat treated at 650 °C for 100 hours to react tin and niobium to form the superconducting compound Nb3Sn. In this furnace at Mitsubishi Heavy Industry's Futami factory, seven toroidal coil windings have been successfully heat treated.

VACUUM VESSEL MANUFACTURING UNDERWAY

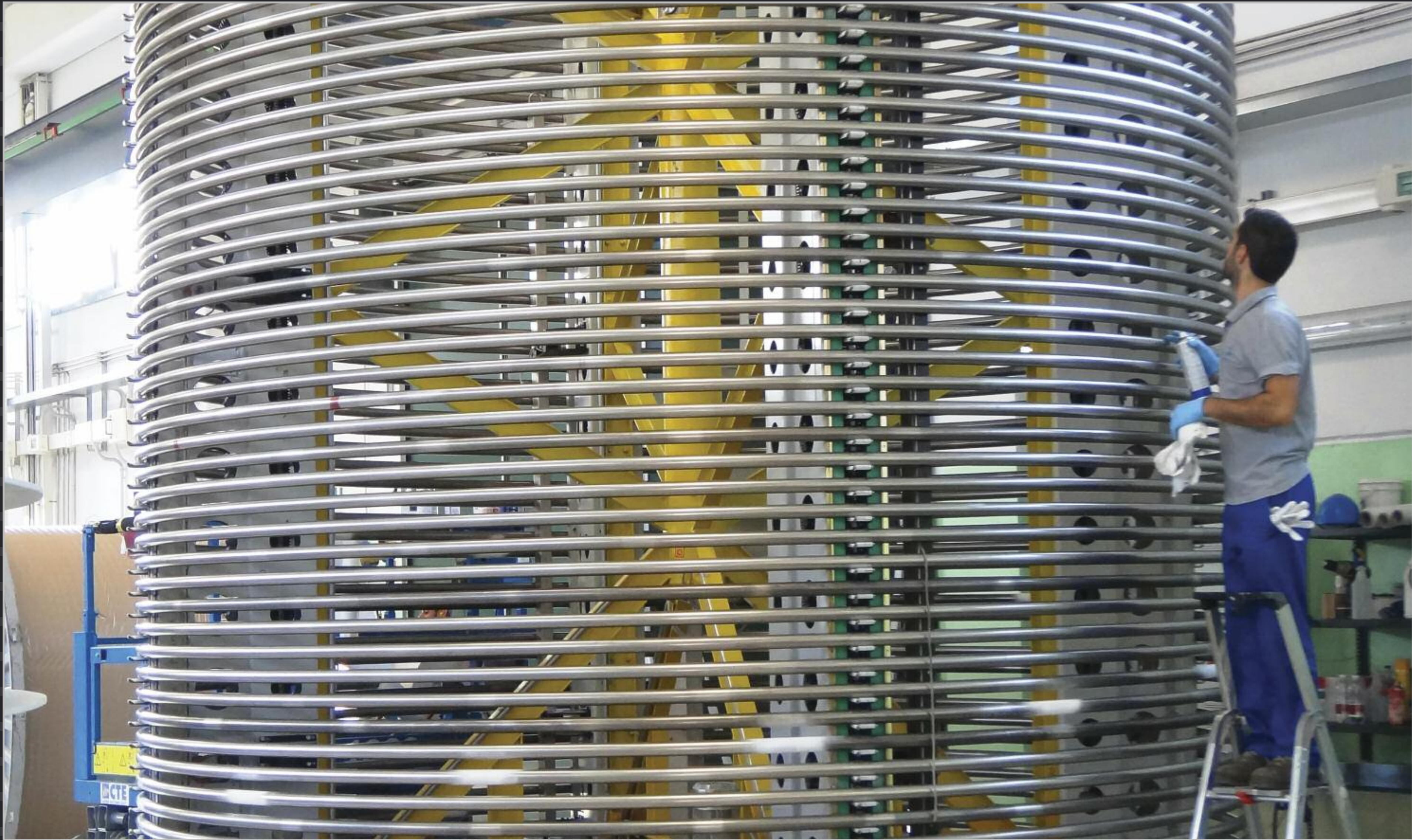
Manufacturing of the ITER vacuum vessel is underway in Korea, which is responsible for procuring two sectors out of nine. Pictured: welding operations at Hyundai Heavy Industries in Ulsan on an inner shell upper section – only a small part of one sector.

FULL-SIZE PROTOTYPE FOR VACUUM VESSEL THERMAL SHIELD



Inserted between the vacuum vessel and the toroidal field magnets, the vacuum vessel thermal shield will minimize the thermal radiation from the warm components to those operating at 4.5 K such as the magnets. A full-size prototype has been manufactured at SFA Engineering Corp in order to verify all design and manufacturing parameters.

TOROIDAL FIELD CONDUCTORS MANUFACTURED SUCCESSFULLY



In November 2014, Korea completes all manufacturing activities for its share of toroidal field conductor (29 unit lengths).

TOROIDAL FIELD CONDUCTOR MILESTONE

At the Institute of High Energy Physics in Protvino, Russia, the last production lengths of toroidal field conductor are jacketed and compacted in June 2015. This marks the end of a five-year campaign to manufacture 28 production lengths, or more than 120 tonnes of material, for ITER's toroidal field coils.

GYROTRON PROTOTYPE PASSES TEST

A gyrotron prototype successfully passes factory acceptance tests at Gycom Ltd in Nizhny Novgorod in May 2015. Russia is responsible for procuring 8 of the 24 energy-generating devices that will inject powerful microwave beams into the ITER vacuum vessel to heat the plasma and drive plasma current.

FINAL SHIPMENT FOR TOROIDAL FIELD CONDUCTOR

In September 2015, the last lengths of Russian-procured conductor for ITER's toroidal field magnets are loaded onto trailers at the Kurchatov Institute in Moscow for shipment to the European winding facility in La Spezia, Italy. This completes Russia's longest-lead procurement campaign for ITER.

CENTRAL SOLENOID WINDING BEGINS

The central solenoid winding line is inaugurated in April 2015 at the General Atomics Magnet Technologies Center in Poway, California. Winding activities have begun on the magnet packs for the six central solenoid modules.

DRAIN TANK FABRICATION COMPLETED

Five drain tanks for ITER's tokamak cooling water system have been successfully fabricated at the Joseph Oat Corporation in Camden, New Jersey and shipped to the ITER site.
The tanks arrived in two convoys (May and September 2015).

ION CYCLOTRON TRANSMISSION LINES

The ion cyclotron system heats the ions in the plasma with a high-intensity beam of electromagnetic radiation.
In the US, an ion cyclotron transmission line prototype undergoes seismic testing.

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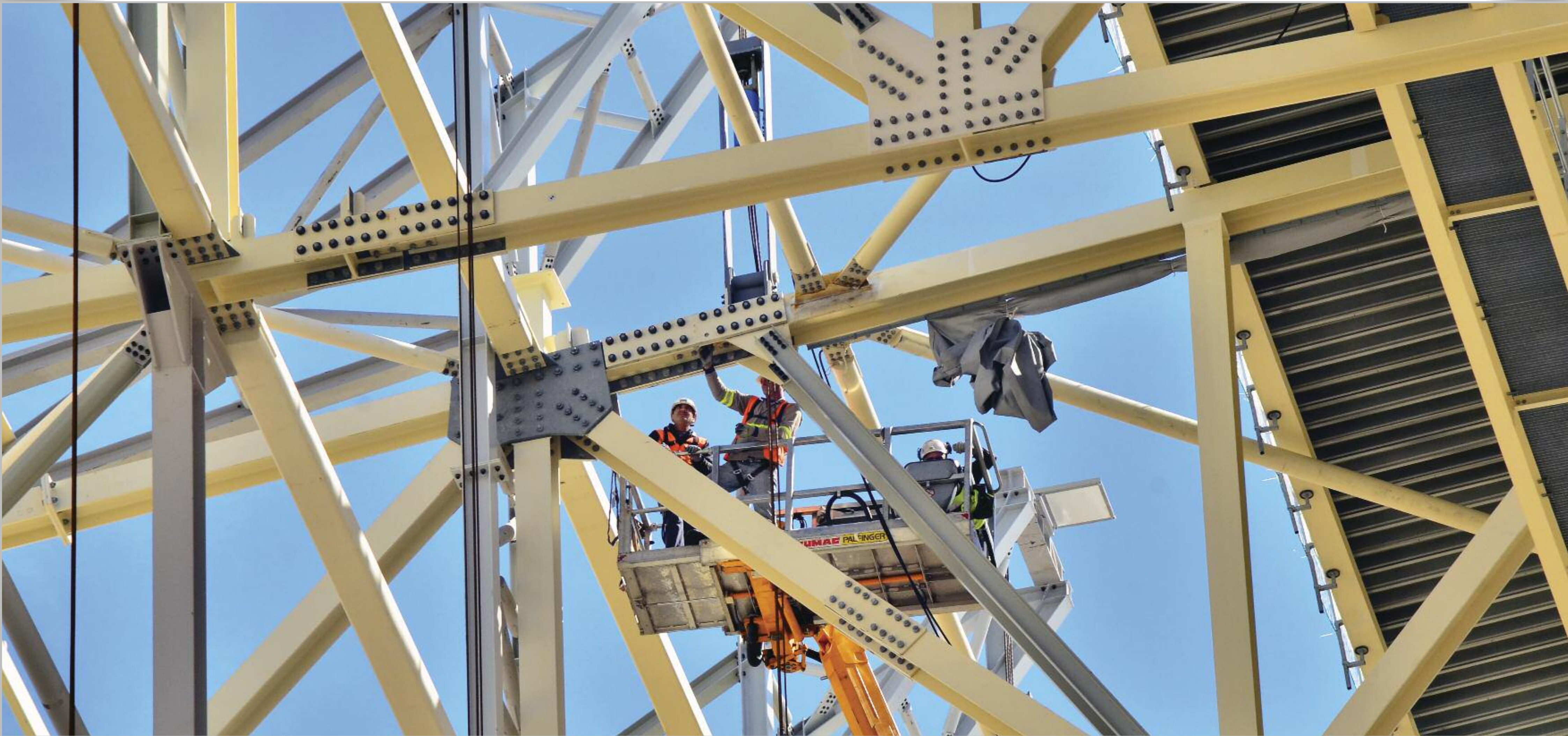

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