ITER ORGANIZATION

ANNUAL REPORT 2020

iter

china eu india japan korea russia usa


7
Members
35
Nations
42
Years
989
Staff
2025
First Plasma

What is ITER?

In a rural area of southern France, some of the world's most industrialized nations are collaborating on an experiment that aims to advance hydrogen fusion from the realm of "potential" energy source to that of "promising" energy source.

Project Members China, the European Union, India, Japan, Korea, Russia and the United States are building the world's largest fusion device, a tokamak.

ITER will be the first fusion device to produce net energy.

ITER will be the first fusion device to test the integrated technologies and materials for the commercial production of fusion-based electricity.

And ITER will be the first fusion device to create a burning plasma.

A "burning plasma" – a state of ongoing, self-sustained fusion reactions in which the need for external heating is sharply reduced or eliminated – is an essential condition for one day generating electricity from fusion power. Its achievement will usher in a new era of fusion research.

The buildings and infrastructure of the ITER scientific installation are on schedule and the assembly of the 23,000-tonne tokamak has begun.

At the ITER Organization and the Domestic Agencies, in laboratories and industries around the world, thousands of people are working toward the success of ITER and – ultimately – the success of fusion.

ITER
An "international project that aims to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes, an essential feature of which would be achieving sustained fusion power generation." (From Article 2 of the ITER Agreement)

PROJECT MEMBERS
The People's Republic of China, the European Atomic Energy Community (Euratom), the Republic of India, Japan, the Republic of Korea, the Russian Federation, and the United States of America are the seven signatories to the ITER Agreement.

THE ITER AGREEMENT
Signed by all Members in November 2006, the ITER Agreement establishes the ITER Organization and defines the joint implementation of the ITER Project.

ITER ORGANIZATION
Established to construct, operate, exploit and de-activate the ITER facilities in accordance with project objectives; encourage the exploitation of the ITER facilities by the laboratories, other institutions and personnel participating in fusion energy research and development programs of the Members; and promote public understanding and acceptance of fusion energy. (Article 3)

ITER COUNCIL
The governing body of the ITER Organization. The Council is responsible for the promotion and overall direction of the ITER Organization and has the authority to appoint the Director-General, to approve the Overall Project Cost (OPC) and Overall Project Schedule (OPS), to approve the annual budget, and to decide on the participation of additional states or organizations in the project. (Article 6)

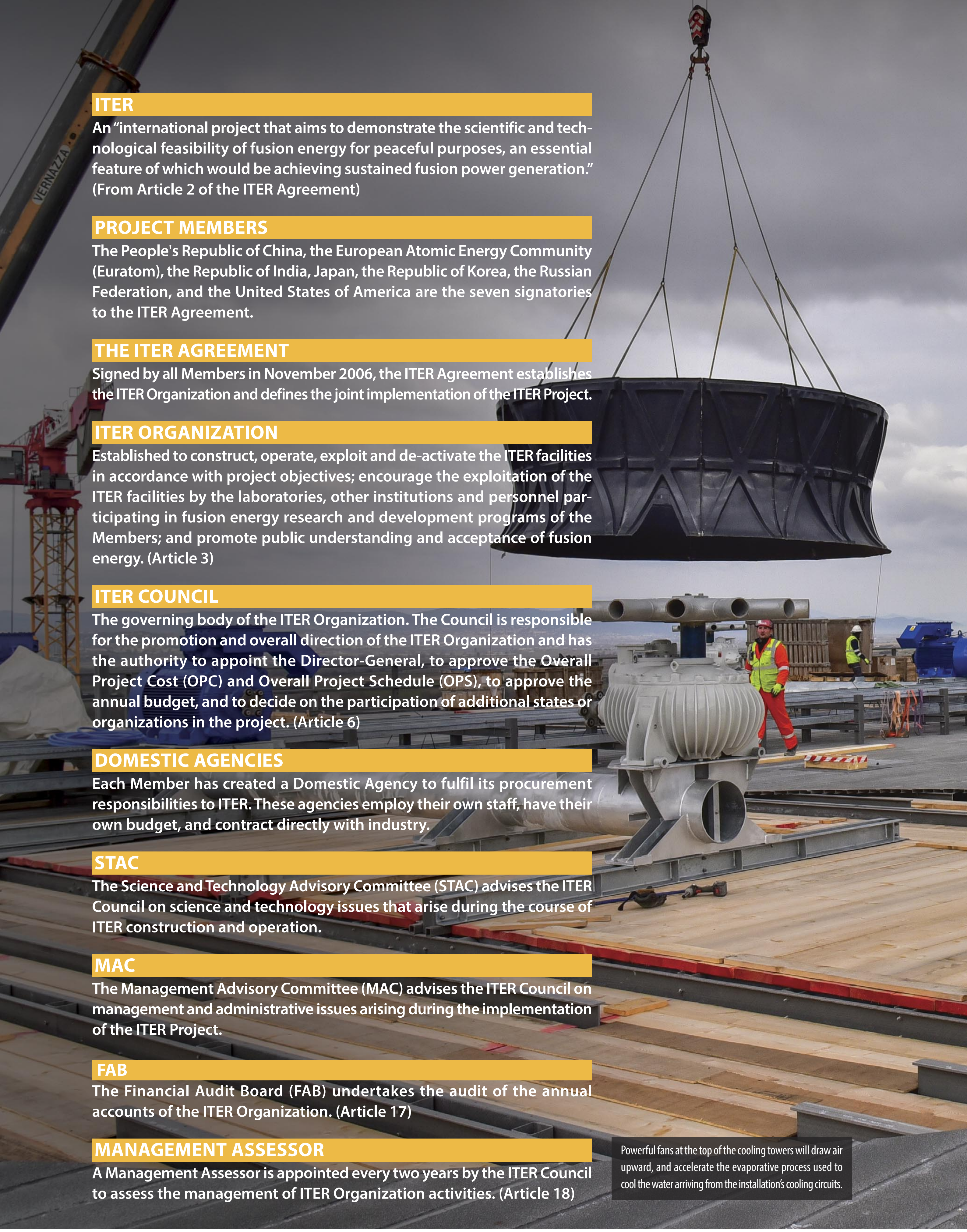
DOMESTIC AGENCIES
Each Member has created a Domestic Agency to fulfil its procurement responsibilities to ITER. These agencies employ their own staff, have their own budget, and contract directly with industry.

STAC
The Science and Technology Advisory Committee (STAC) advises the ITER Council on science and technology issues that arise during the course of ITER construction and operation.

MAC
The Management Advisory Committee (MAC) advises the ITER Council on management and administrative issues arising during the implementation of the ITER Project.

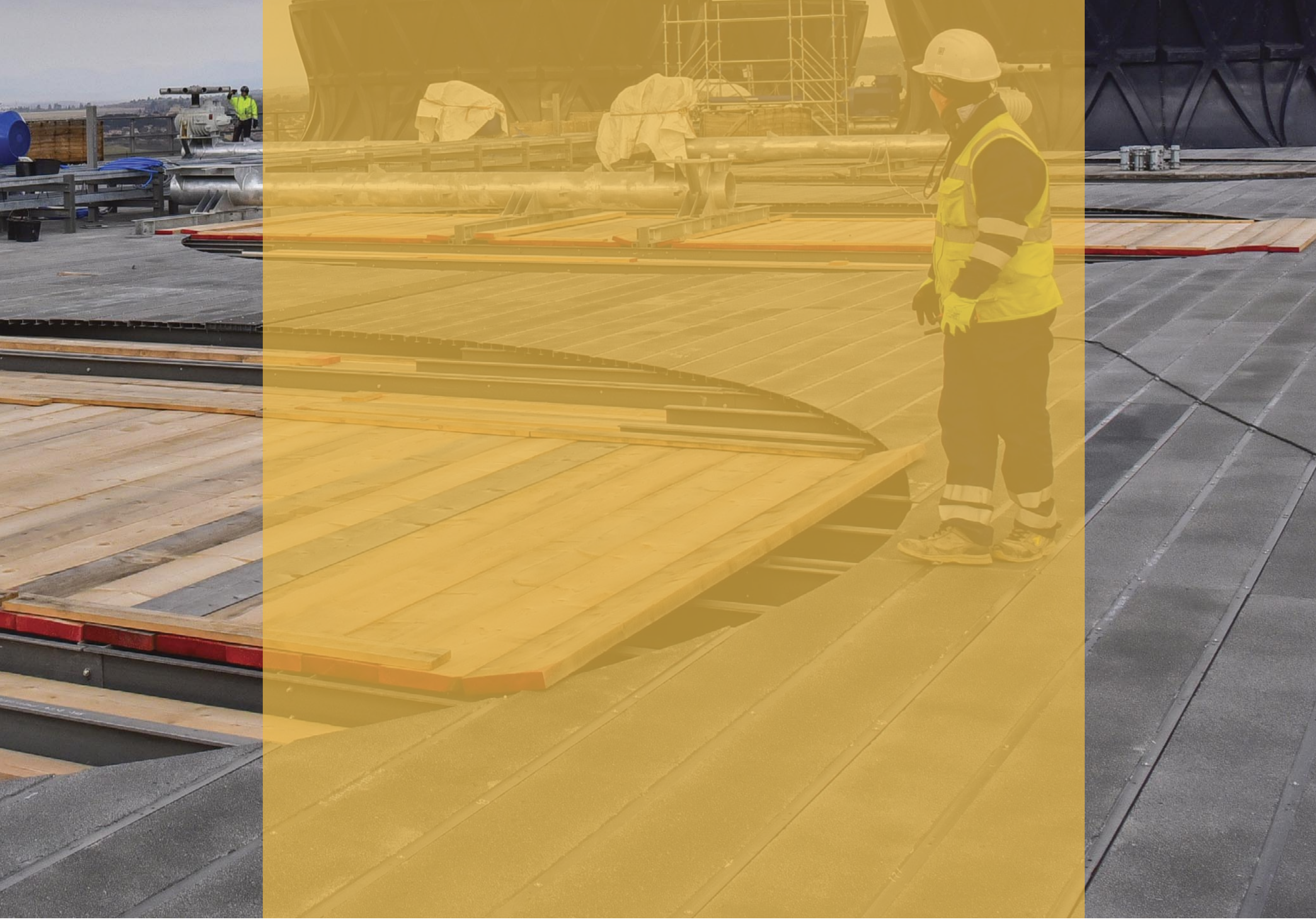
FAB
The Financial Audit Board (FAB) undertakes the audit of the annual accounts of the ITER Organization. (Article 17)

MANAGEMENT ASSESSOR
A Management Assessor is appointed every two years by the ITER Council to assess the management of ITER Organization activities. (Article 18)



Powerful fans at the top of the cooling towers will draw air upward, and accelerate the evaporative process used to cool the water arriving from the installation's cooling circuits.

Contents



A busbar is to an ITER magnet what an extension cord is to a bedside lamp – a way to connect an electrical device to a power source (although many times more powerful). Once bolted to their supports in the Diagnostics Building, busbars must be connected to one another and to cooling water.

Foreword from the Chair of the ITER Council

The year 2020 was one of change and adjustment, as the ITER community adapted to the global Covid-19 pandemic and the transformation it imposed on our way of working. For the ITER Council, this meant a year during which Member representatives could not meet face to face, instead gathering twice by video conference for statutory Meetings in June and November to supervise the work and overall direction of the ITER Organization.

This challenging year coincided with a critical period in the ITER schedule – the completion, transport, and arrival on site at ITER of major First-of-a-Kind components. Some of these components, such as the first vacuum vessel sector or the first toroidal and poloidal field magnets, had been in preparation for five or even ten years. All were needed on time to maintain ITER's closely integrated project schedule.

The ITER Council watched with pride as the ITER community came together to develop a continuity plan that prioritized critical activities while ensuring the wellbeing of staff and collaborators through rigorous adherence to health and safety measures. Despite the pandemic, a series of remarkable manufacturing, construction, and assembly milestones were successfully achieved during the year. The deliveries of First-of-a-Kind components as mentioned above, the handover by the European Domestic Agency of the full assembly theatre to the ITER Organization, the first heavy lifts of machine assembly, the qualification of Assembly Hall handling tools, and progress in the installation of major Tokamak plant systems all across the site are all examples.

On behalf of the ITER Council, I congratulate Dr. Bigot for his unwavering leadership during this difficult period, and I salute the entire ITER community – every Member, every Domestic Agency, every supplier company and contractor, and every staff member – for their dedication, perseverance, commitment, and hard work.

The most recent review of progress reports and performance metrics shows that, despite mitigation efforts, the ITER Organization and its collaboration partners are facing unprecedented pressure due to the Covid-19 pandemic and difficulties encountered in manufacturing some of ITER's First-of-a-Kind components. Accordingly, the ITER Council has requested the ITER Organization, in

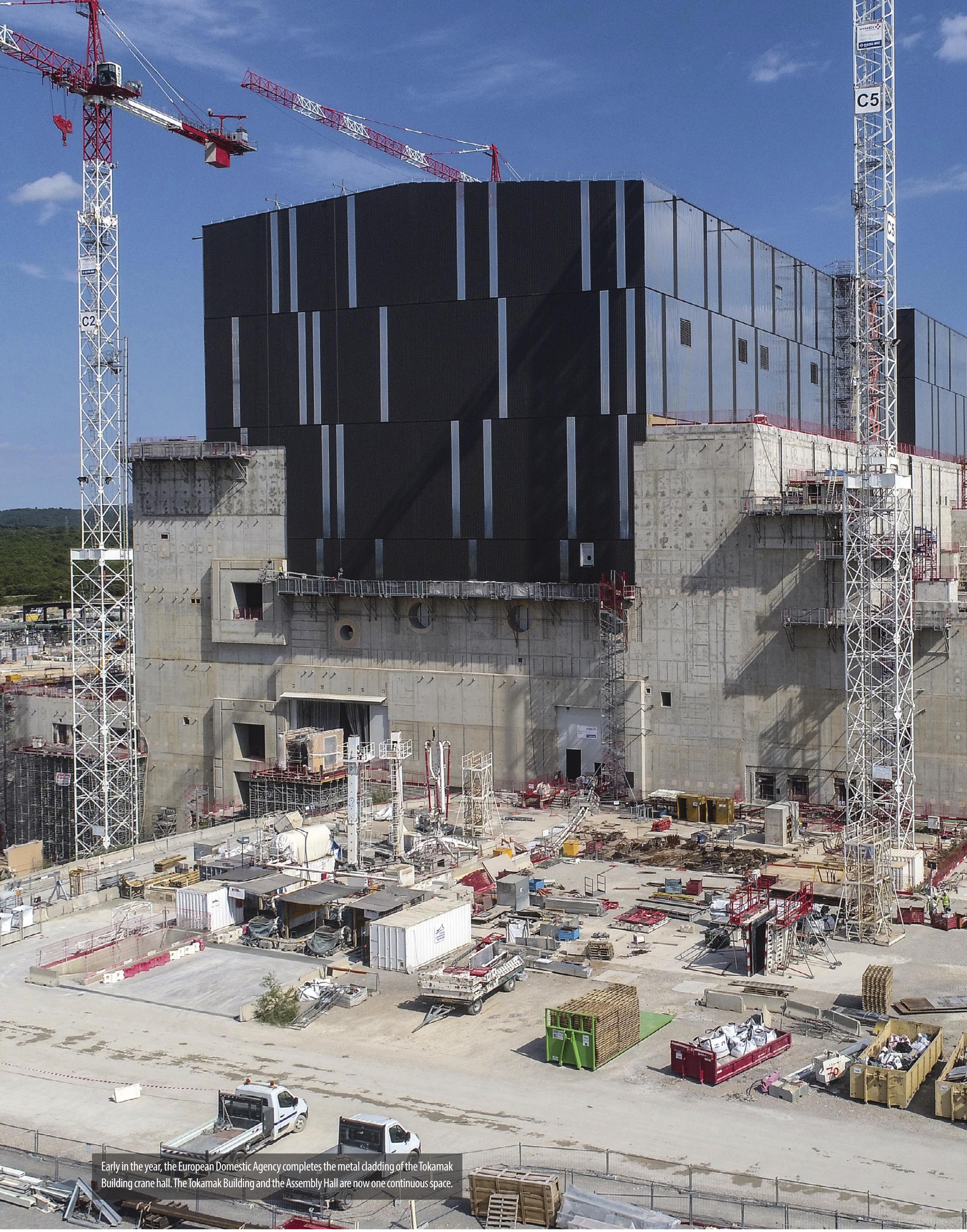
cooperation with the Domestic Agencies, to continue to take all possible measures to minimize and recover schedule delays to ensure Fusion Power Operation in 2035 as currently planned.

If the ITER community is able to face the challenges of the machine assembly phase ahead in the same way it has faced challenges in the past – together, as a "One ITER" team – I have great confidence that we will succeed.

During the start-of-assembly celebration on 28 July 2020, French President Emmanuel Macron celebrated the confidence in the future that is at the core of the ITER Project. "Breakthroughs in human history have always proceeded from daring bets, from journeys fraught with difficulty: at the start, it always seems that the obstacles will be greater than the will to create and progress. ITER belongs to the spirit of discovery, of ambition. At its core is the conviction that science can truly make tomorrow better than today."

All ITER Council members have reaffirmed their strong belief in the value of the ITER Project mission and vision to develop fusion science and technology, and resolved to work together to find timely solutions to facilitate ITER's success.

LUO Delong
Beijing, China
June 2020



Early in the year, the European Domestic Agency completes the metal cladding of the Tokamak Building crane hall. The Tokamak Building and the Assembly Hall are now one continuous space.

Foreword from the Director-General

The period covered in this ITER Organization Annual Report was remarkable in many ways.

- After 10 years of intensive construction, the Tokamak Building and its central machine well were handed over to the ITER Organization in March, opening the way for the start of machine assembly.
- Purpose-built assembly tools passed all qualification activities.
- The first pieces of the ITER jigsaw puzzle – the cryostat base and lower cylinder – were installed in the Tokamak pit as planned, successfully and to within tolerances of just a few millimetres.
- The first major machine components – a vacuum vessel sector from Korea, five toroidal field coils from Europe and Japan, and the first-completed poloidal field coil – arrived at ITER and passed all site acceptance tests.
- Major construction/installation contracts are in place.
- Equipment installation progressed for every major ITER plant system across the site.
- Project execution to First Plasma passed the 70% mark.
- A virtual start-of-assembly event in July drew major worldwide attention to the ITER Project.

That these milestones could be achieved in the context of a worldwide pandemic is testimony to the extreme dedication of all ITER actors and to the collaboration and co-support of the ITER Organization and Domestic Agency teams, who stood shoulder to shoulder as every difficulty was addressed and mitigated. Although the continuity plan implemented by the ITER Organization was highly effective in avoiding critical-path installation and assembly impacts on the ITER site in 2020, some critical component deliveries from the Domestic Agencies are clearly being delayed by the pandemic's impact on the global industry and transportation sectors, as well as by technical challenges related to First-of-a-Kind components.

For a project that spans decades, it is inevitable that there will be events along the way that are out of our control. What we *can* control is the efficiency and determination with which we react to unexpected circumstances and the way in which adversity strengthens our collaboration instead of weakening it. Every aspect of project management – project controls, systems engineering, risk management, financial management, reporting, schedule

management, and logistics – must perform with the highest standards and the precision of a Swiss watch. We have a complicated script to follow over the next few years.

And the pandemic is not yet over. As agreed by the ITER Council during its November 2020 meeting, the ITER Organization and Domestic Agencies will continue implementing, and measuring performance against, the schedule approved by the ITER Council in June 2018 (the Revised Construction Strategy) until such time as it is possible to complete a full assessment of the pandemic's impact across the project. In the interim, all efforts are being made to focus on optimization efforts within the Overall Project Cost to minimize the impact on the date of First Plasma, in particular by focusing on opportunities in the ITER assembly and installation schedule, and to elaborate a path to maintaining the date of Deuterium Tritium Operation in 2035.

We feel a deep sense of gratitude for the enduring support of ITER Members. We are grateful to the governments that provide us with funding and direction. We are grateful to the 10,000 workers at every level, in every ITER Member country, who are committed to making ITER succeed. The stakes of bringing a new form of safe, environment friendly, high-density energy to the grid with no impact on climate are growing with each passing year, and ITER has an irreplaceable role to play in validating the technologies and the science of reactor-scale fusion energy.

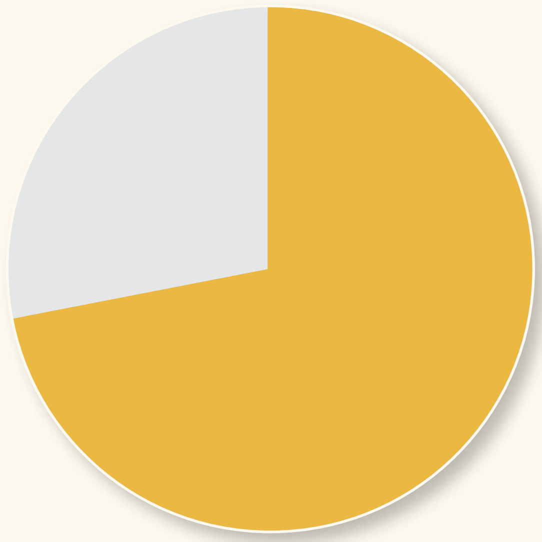
Bernard Bigot
St. Paul-lez-Durance
June 2021

Year in review

Physical work achieved to First Plasma

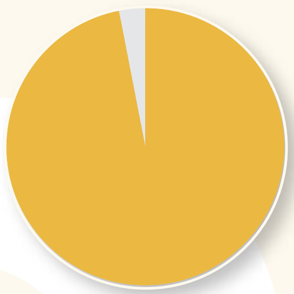
(design, component manufacturing, building construction, shipment and delivery, assembly and installation)

72.1%

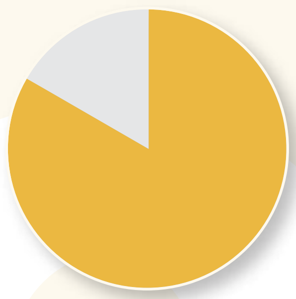


Progress toward the realization of First Plasma systems and components

97.0%
of design completed

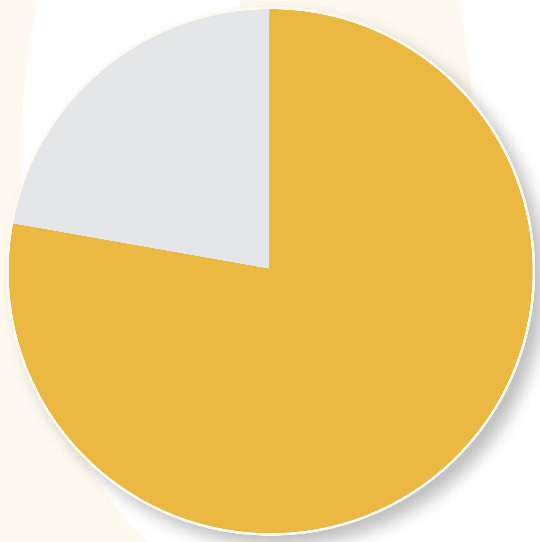


83.4%
of manufacturing completed



Building construction completed on site

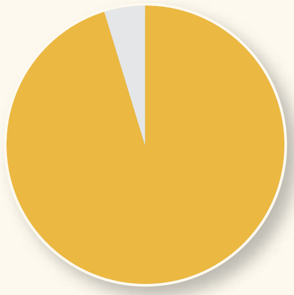
78.0%
First Plasma scope



2020

Procurement Arrangement* signatures

88.0%
in number



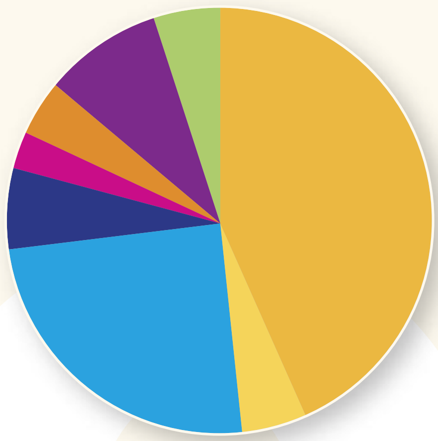
95.5%
in value

*A Procurement Arrangement is an agreement that is signed between the ITER Organization and the Domestic Agencies, authorizing work for the development and manufacturing of the ITER installation.

Intellectual property declarations*

Declaration of "Generated Intellectual Property," cumulative

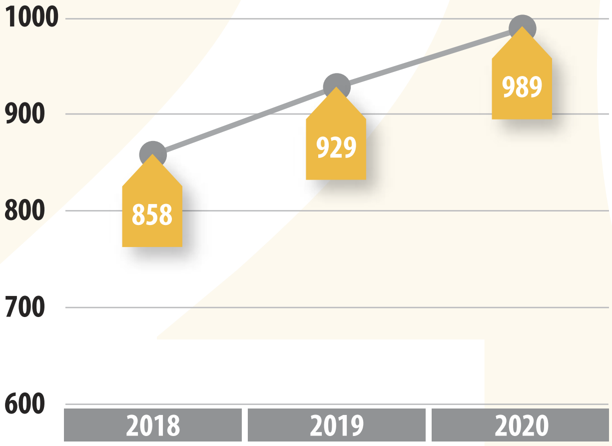
- ITER 44%
- CHINA 5%
- EUROPE 25%
- INDIA 6%
- JAPAN 3%
- KOREA 4%
- RUSSIA 9%
- USA 5%



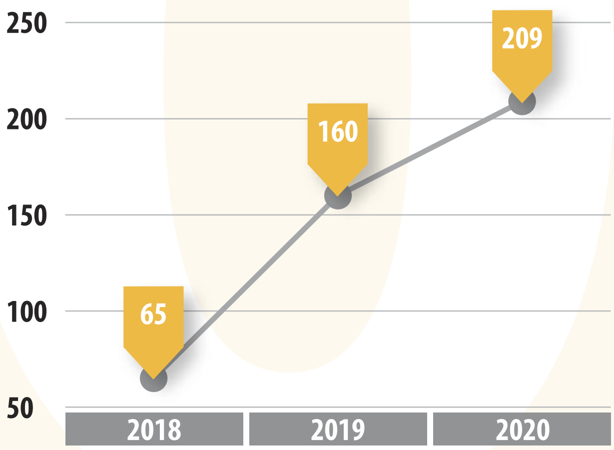
* The ITER Organization and the seven Members support the widest appropriate dissemination of intellectual property generated in the course of activities for ITER.

Staff

(see page 46)



ITER Project Associates*



* Experts from the Members' scientific, technological and industrial communities who work at ITER while remaining employed by their home institute.

Crane access over the Tokamak pit becomes possible on 28 March 2020, as the ITER Organization, the European Domestic Agency Fusion for Energy, and contractors validate the full crane path – from the Assembly Hall through the entire length of the Tokamak Building – under load. Machine assembly can begin.

2020 CONSTRUCTION UPDATE

42-hectare
construction platform

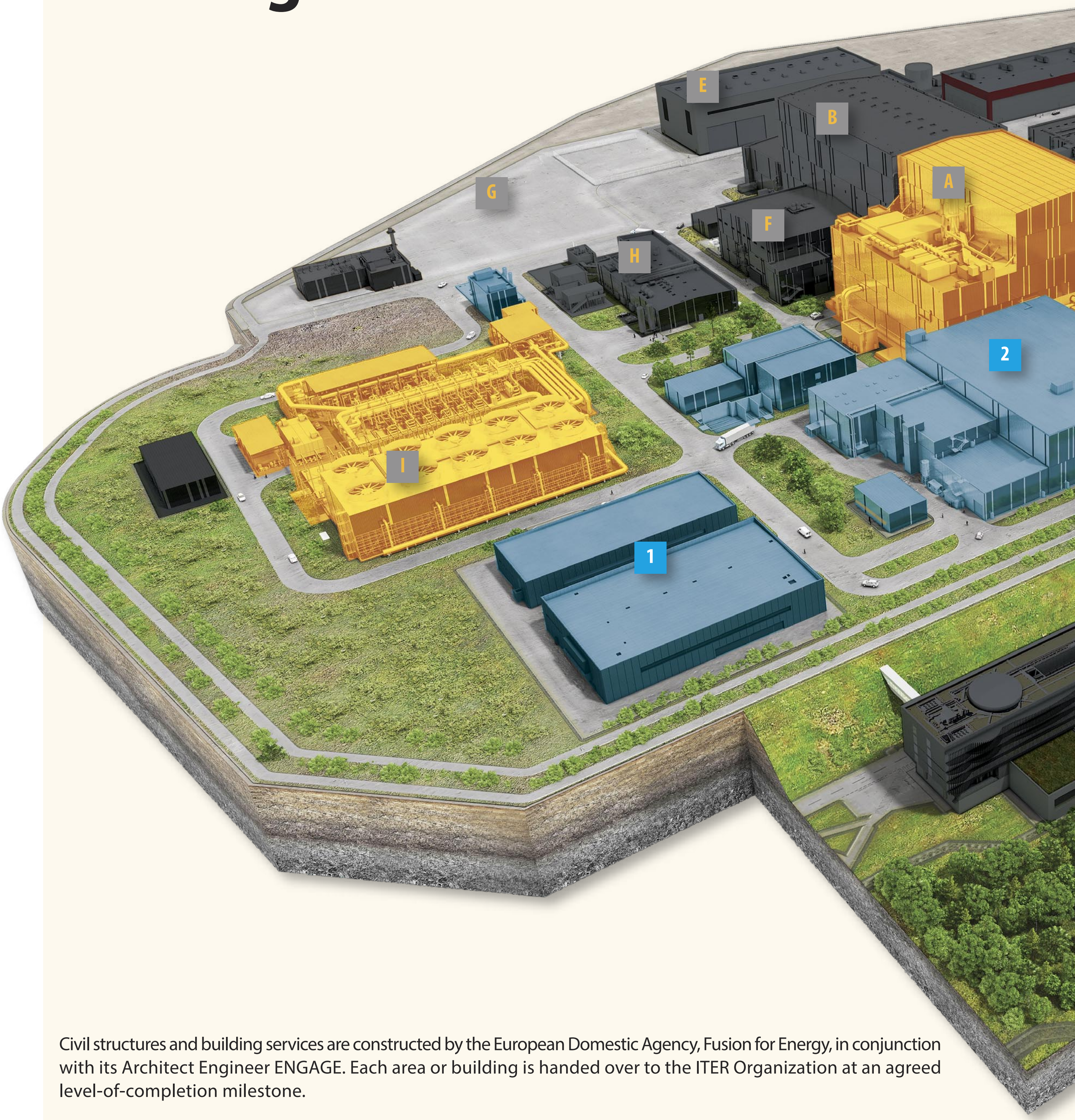
39 buildings
and technical areas

78%
construction completed (First Plasma scope)

3,600
construction and assembly workers daily

160,000
site visitors since 2007

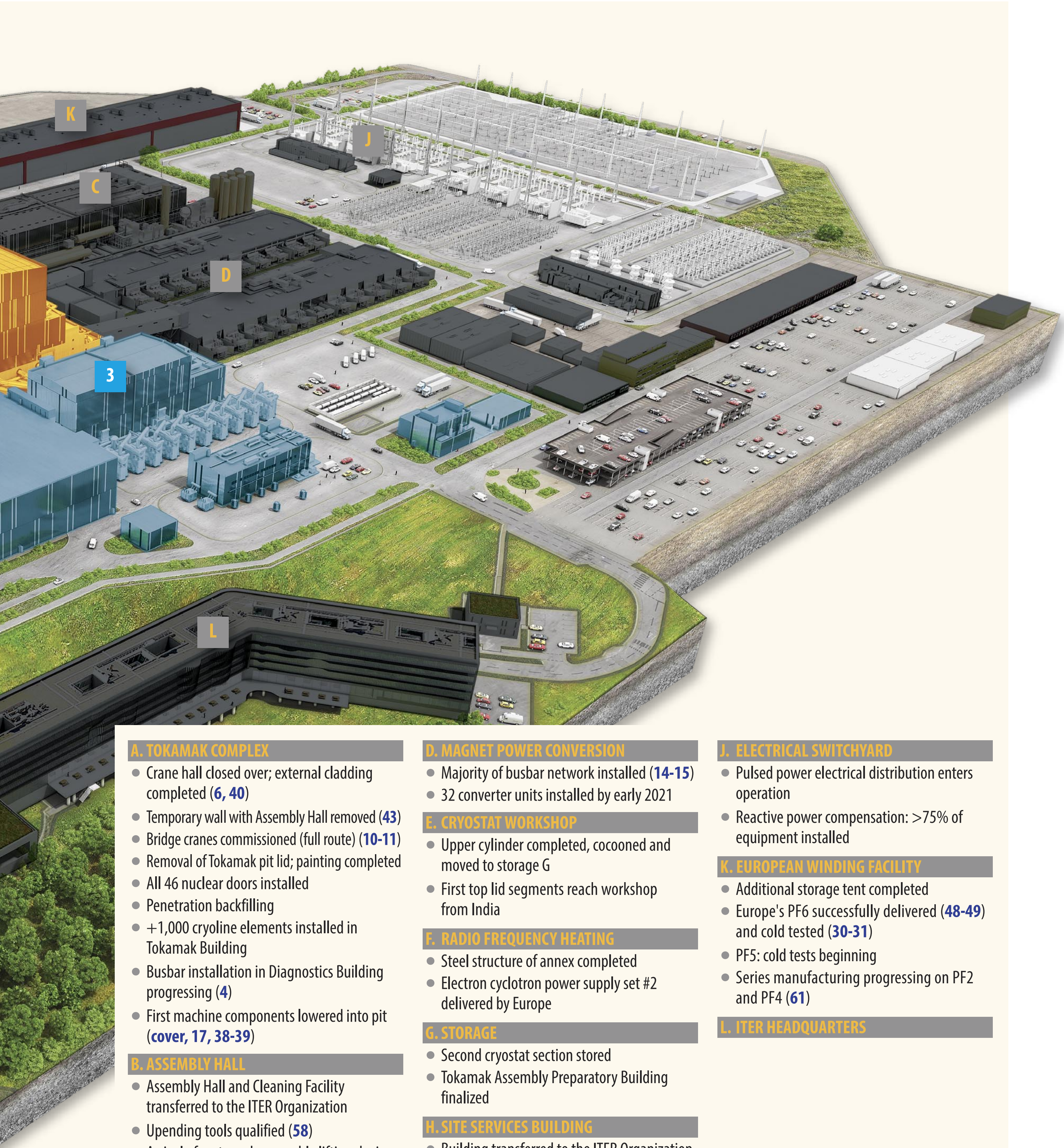
Buildings



Civil structures and building services are constructed by the European Domestic Agency, Fusion for Energy, in conjunction with its Architect Engineer ENGAGE. Each area or building is handed over to the ITER Organization at an agreed level-of-completion milestone.

Buildings in place **Buildings in progress** **Buildings to come**

Site image courtesy of Fusion for Energy



A. TOKAMAK COMPLEX
- Crane hall closed over; external cladding completed (**6, 40**)
- Temporary wall with Assembly Hall removed (**43**)
- Bridge cranes commissioned (full route) (**10-11**)
- Removal of Tokamak pit lid; painting completed
- All 46 nuclear doors installed
- Penetration backfilling
- +1,000 cryoline elements installed in Tokamak Building
- Busbar installation in Diagnostics Building progressing (**4**)
- First machine components lowered into pit (**cover, 17, 38-39**)

B. ASSEMBLY HALL
- Assembly Hall and Cleaning Facility transferred to the ITER Organization
- Upending tools qualified (**58**)
- Arrival of sector sub-assembly lifting devices from Korea
- Start-of-assembly celebration 28 July 2020 (**18**)
- Thermal shield trials on sector sub-assembly tools

C. CRYOPLANT
- 90% of equipment installed
- Some pre-commissioning tasks launched

D. MAGNET POWER CONVERSION
- Majority of busbar network installed (**14-15**)
- 32 converter units installed by early 2021

E. CRYOSTAT WORKSHOP
- Upper cylinder completed, cocooned and moved to storage G
- First top lid segments reach workshop from India

F. RADIO FREQUENCY HEATING
- Steel structure of annex completed
- Electron cyclotron power supply set #2 delivered by Europe

G. STORAGE
- Second cryostat section stored
- Tokamak Assembly Preparatory Building finalized

H. SITE SERVICES BUILDING
- Building transferred to the ITER Organization
- First mechanical system ready for operation (liquid/gas, water, air networks)

I. COOLING TOWER ZONE
- 99% of piping and equipment delivered by India; installation progressing (**2-3**)
- Commissioning begins with basin fill tests

J. ELECTRICAL SWITCHYARD
- Pulsed power electrical distribution enters operation
- Reactive power compensation: >75% of equipment installed

K. EUROPEAN WINDING FACILITY
- Additional storage tent completed
- Europe's PF6 successfully delivered (**48-49**) and cold tested (**30-31**)
- PF5: cold tests beginning
- Series manufacturing progressing on PF2 and PF4 (**61**)

L. ITER HEADQUARTERS

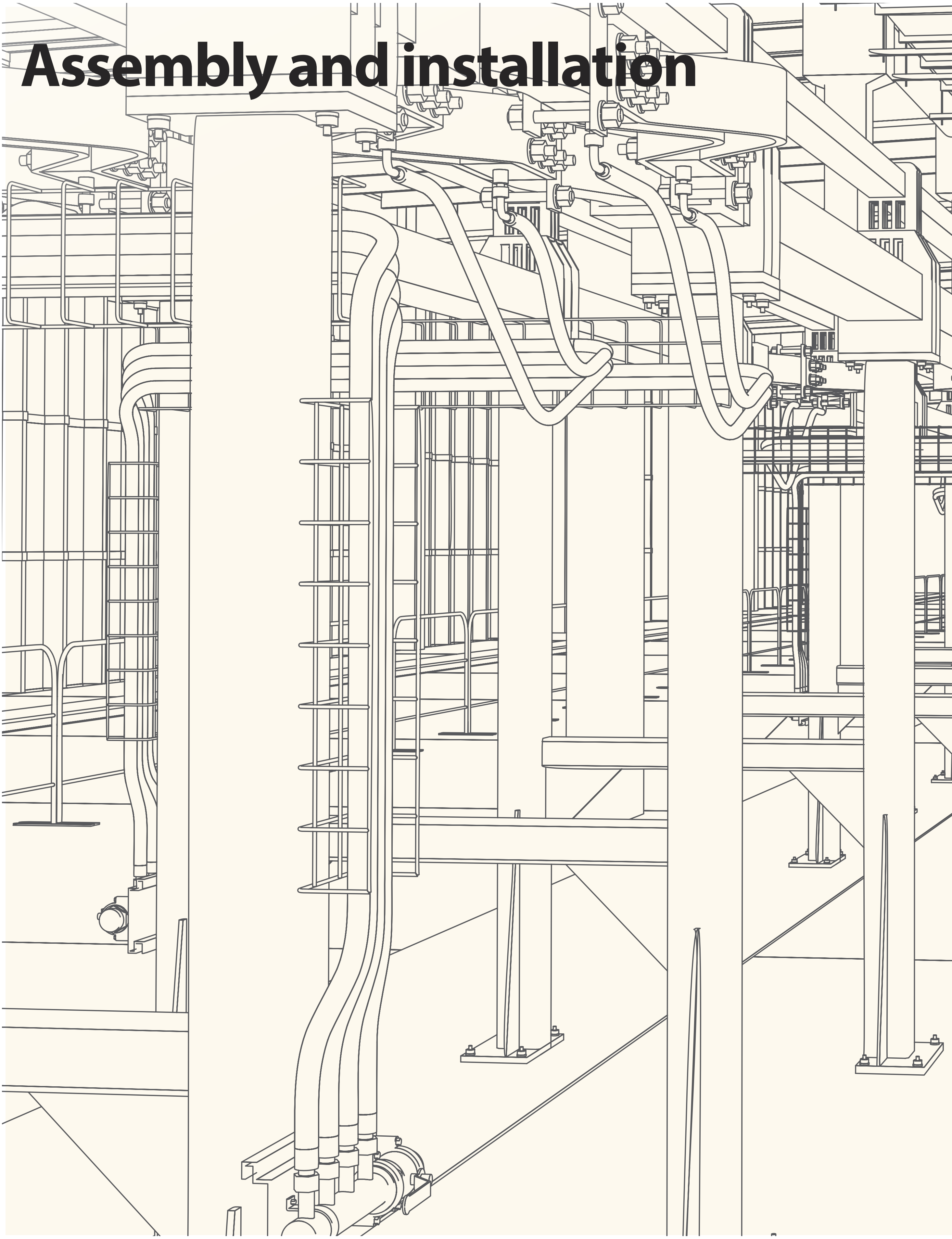
Buildings to come

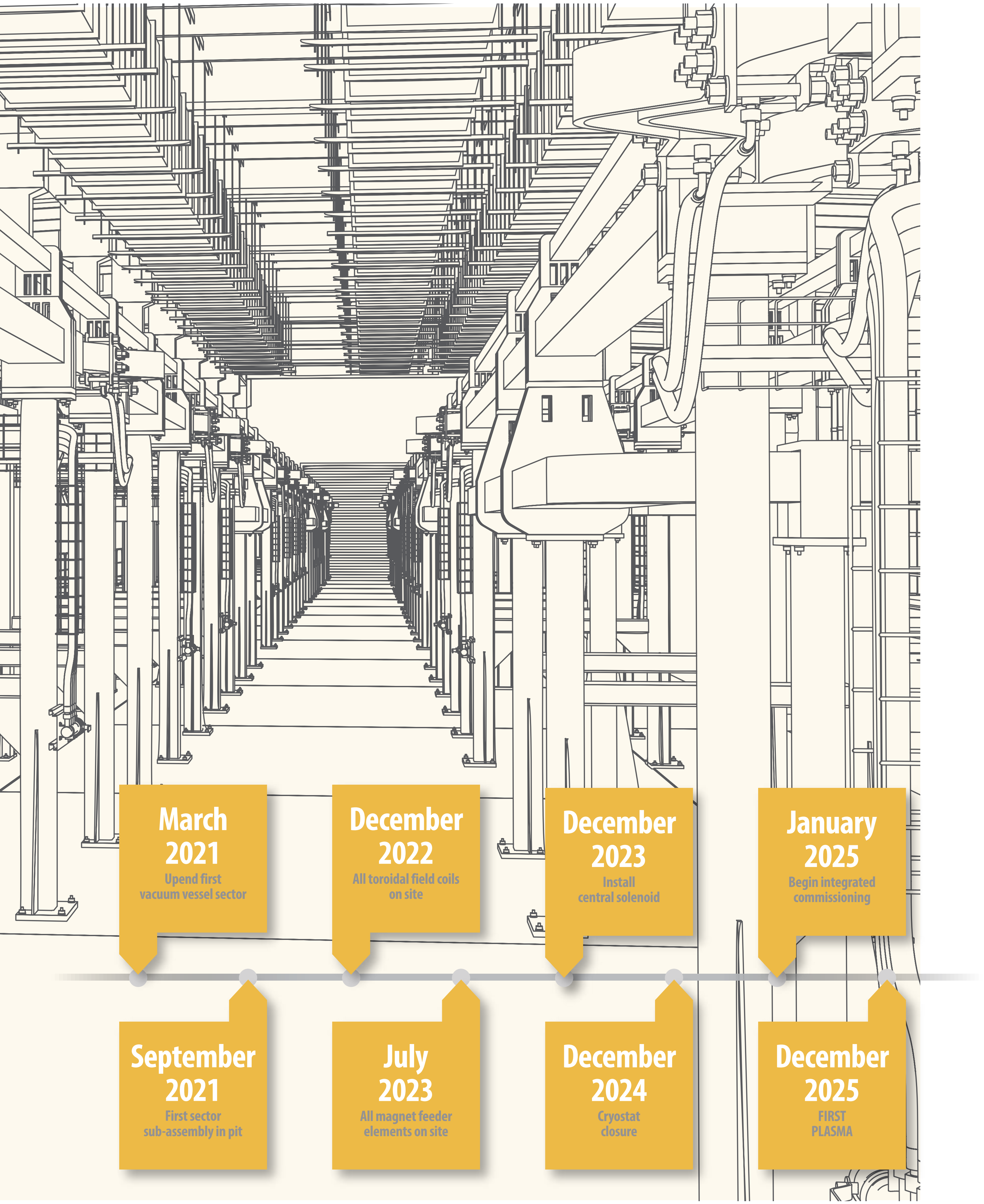
1. Control Building (excavation started)

2. Hot Cell Complex

3. Neutral Beam Power Supply (excavation started)

Assembly and installation



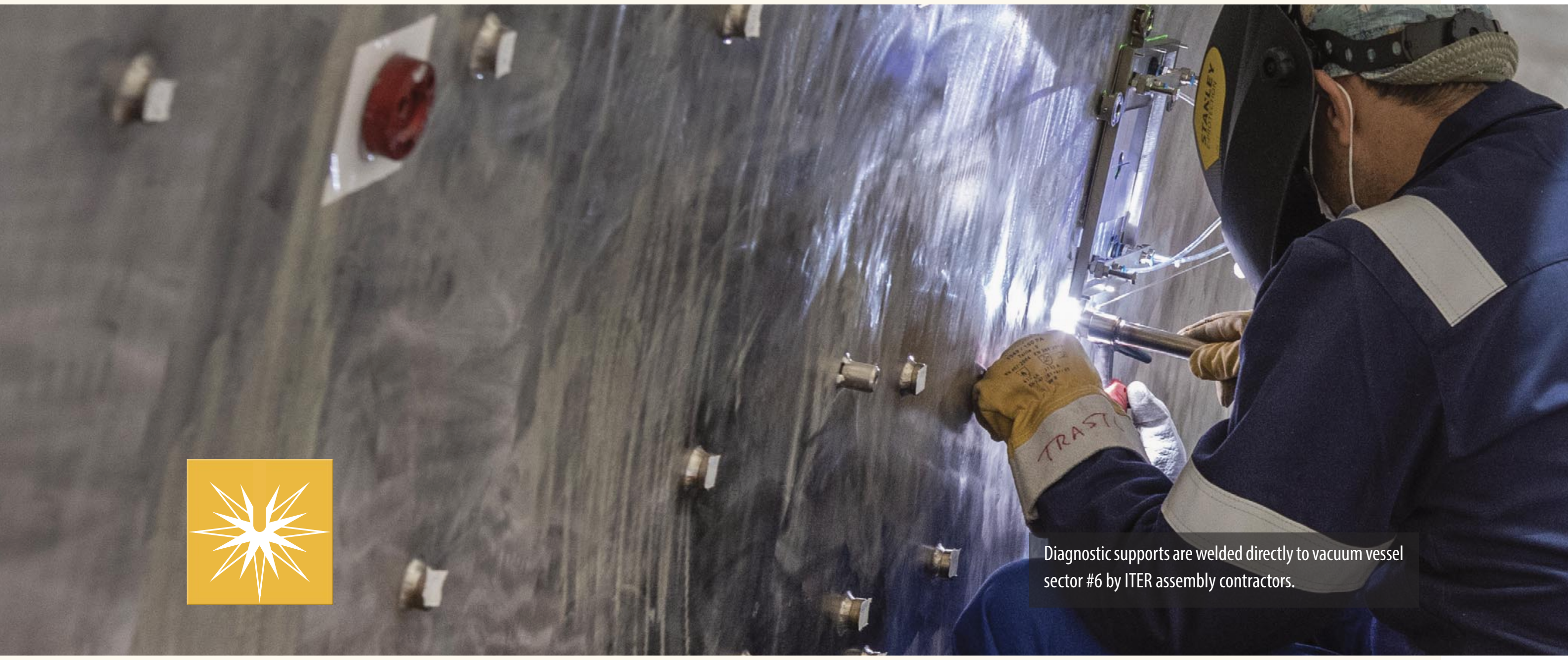

March 2021
Upend first vacuum vessel sector
September 2021
First sector sub-assembly in pit
December 2022
All toroidal field coils on site
July 2023
All magnet feeder elements on site
December 2023
Install central solenoid
December 2024
Cryostat closure
January 2025
Begin integrated commissioning
December 2025
FIRST PLASMA

Assembling the machine and plant

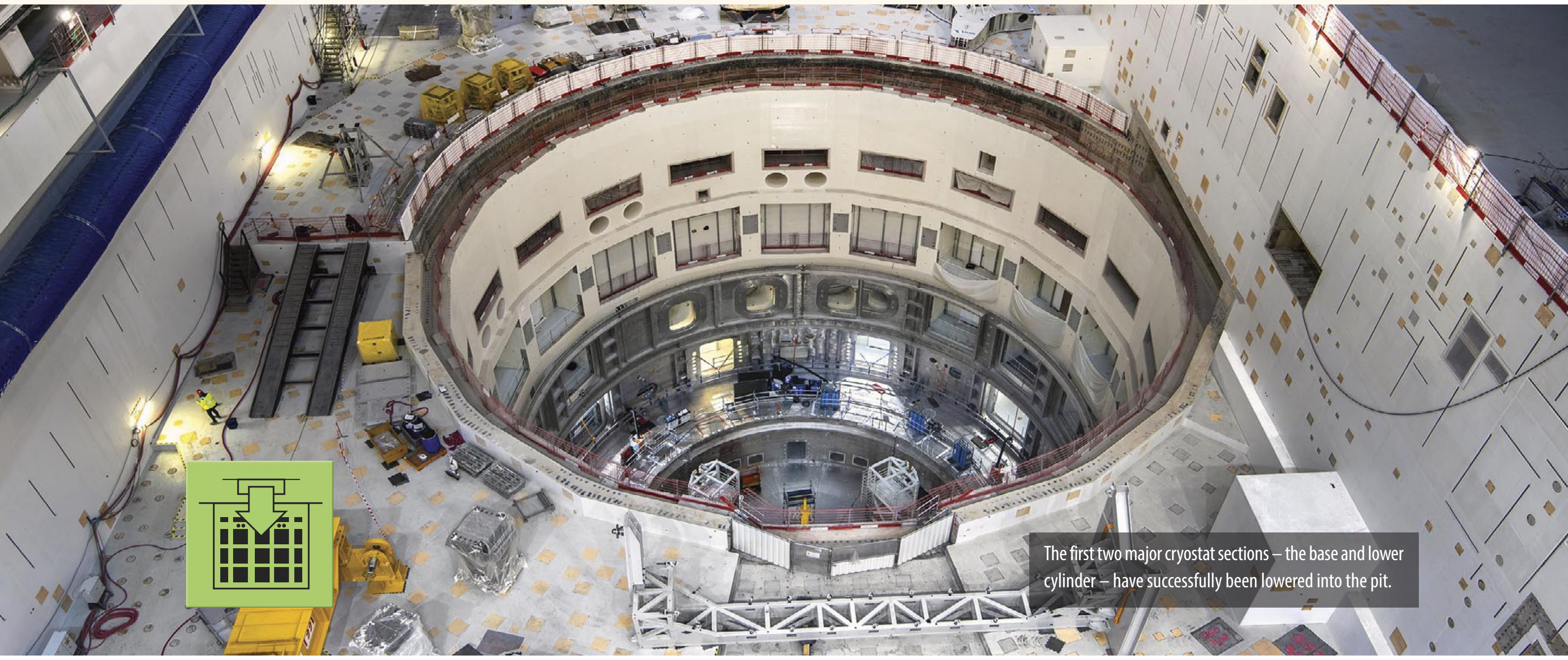
Month	ASSEMBLY IN PIT	ASSEMBLY PREP/PRE-ASSEMBLY	ARRIVALS
JANUARY			
FEBRUARY			Thermal shield segments (Korea), multiple deliveries in 2020
		Upending tool: horizontal load tests	
		Assembly Hall/Tokamak Building temporary wall removed	
MARCH			In-pit assembly tool (Korea)
		Overhead cranes: dynamic load tests, full route	
		Crane access to Tokamak Building validated	
APRIL		Removal of Tokamak pit temporary lid	
			Toroidal field coil #9 (Europe)
			Toroidal field coil #12 (Japan)
MAY	CRYOSTAT BASE INSTALLED		
JUNE			Poloidal field coil #6 (Europe)
JULY			Toroidal field coil #13 (Japan)
		Thermal shield lift frame: commissioning tests	
		Celebration for the official start of machine assembly	
			Feeder segments (China), multiple deliveries in 2020
AUGUST			Vacuum vessel sector #6 (Korea)
	CRYOSTAT LOWER CYLINDER INSTALLED		Sector lift tool (Korea)
			Seven cryostat top lid segments (India)
SEPTEMBER		Assembly Hall: clean zone established	
		Successful leak test on vacuum vessel sector #6	
			Toroidal field coil #11 (Europe)
		Start vacuum vessel sector sub-assembly activities	
		Thermal shield panels for sector #6 unwrapped	
OCTOBER		Start welding diagnostic components to vacuum vessel sector #6	
	START WELDING CRYOSTAT LOWER CYLINDER TO BASE	Start assembly of lower cryostat thermal shield	
NOVEMBER		First toroidal field gravity supports in staging	
		Sector lift tool: functional tests achieved	
		Vacuum vessel, toroidal field coil, and thermal shield upending tools qualified	
		Thermal shield lift trials	
DECEMBER			Bottom correction coils #1 and #5 (China)
			Toroidal field coil #5 (Europe)
		Extensive work to ready toroidal field coils #12 and #13 for sub-assembly	

2020

A 360-tonne toroidal field coil produced by Europe is on its way to ITER.



Diagnostic supports are welded directly to vacuum vessel sector #6 by ITER assembly contractors.



The first two major cryostat sections – the base and lower cylinder – have successfully been lowered into the pit.

Assembling the machine and plant

Machine assembly began in 2020 with the lowering of ITER's heaviest component – the 1,250-tonne cryostat base – into the Tokamak assembly pit. With this spectacular first step, a five-year period of intense coordination and precision opens as the Tokamak basic machine is assembled piece by piece, layer by layer. ITER Organization staff from the Construction and Engineering Domains are piloting the works on site, and hundreds of contractors have joined the assembly effort.

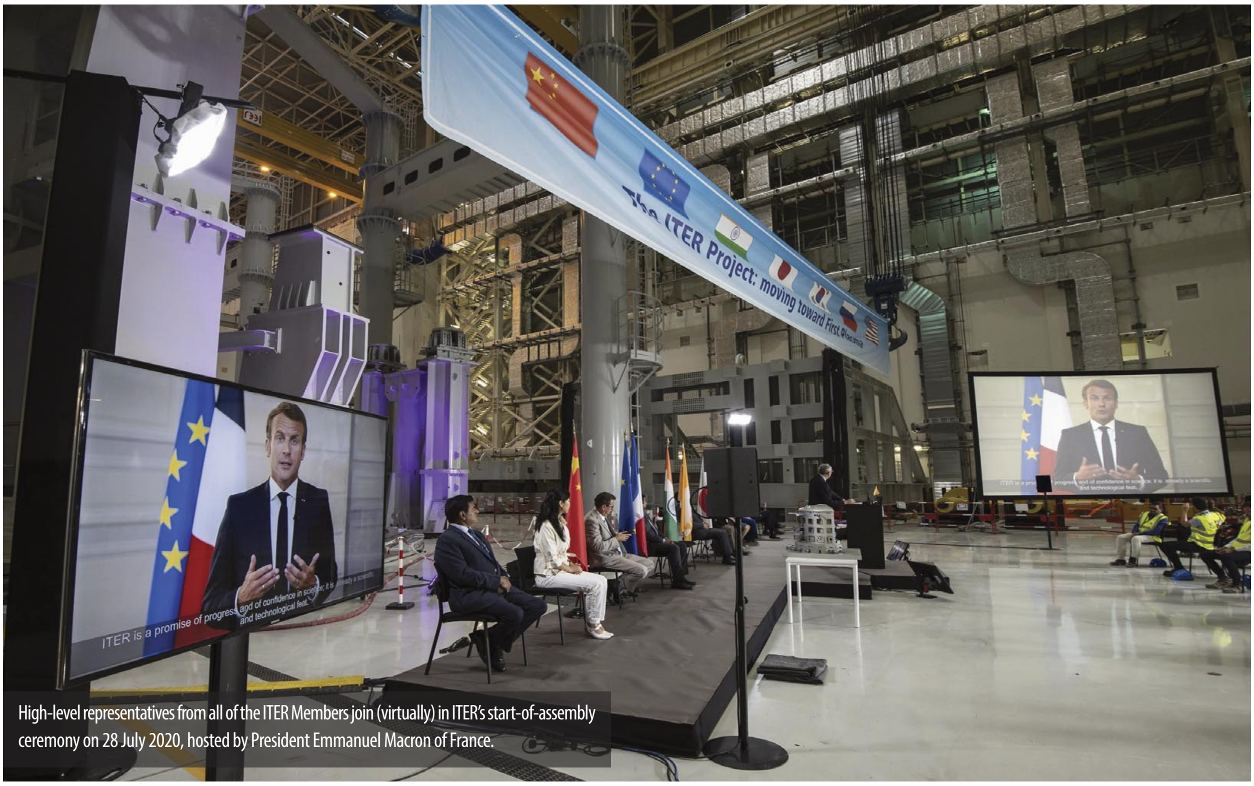
A new phase begins – The ITER community celebrated the start of machine assembly on 28 July 2020, as the first vacuum vessel sector shipped by Korea was travelling between the French port of Fos-sur-Mer and the ITER site. The virtual ceremony was hosted by President Macron of France, with dignitaries from the seven ITER Members. ''ITER is clearly an act of confidence in the future," said President Macron. ''At its core is the conviction that science can truly make tomorrow better than today."

ITER Council milestone #50 – In March 2020, the European Domestic Agency successfully demonstrated the full path of the overhead crane – from the Assembly Hall through the entire length of the Tokamak Building – under load. The on-time achievement of this ITER Council milestone paved the way to the first lift and installation operations.

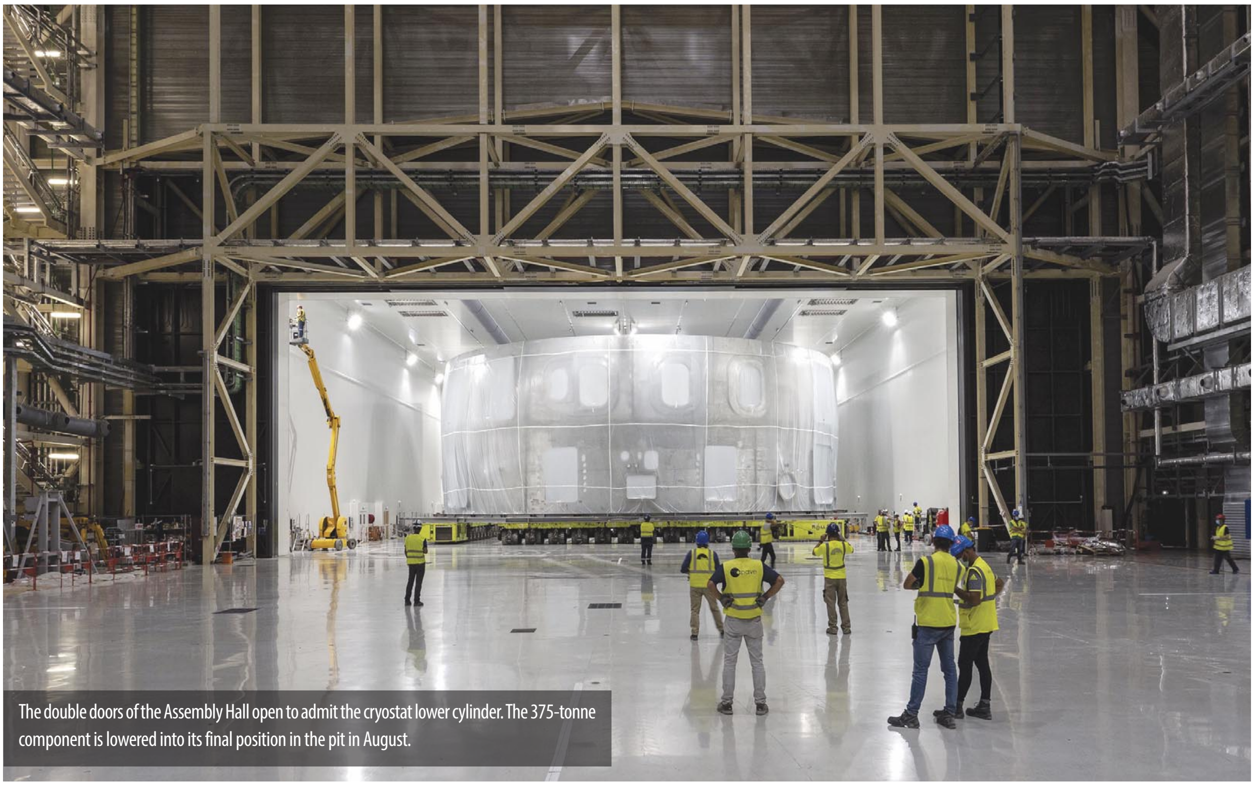
Major component arrivals – The first major machine components have been delivered to ITER. Five toroidal field coils (360 tonnes each), one poloidal field coil (400 tonnes), and one vacuum vessel sector (440 tonnes) are among the 29 "highly exceptional loads" to travel along the ITER Itinerary during the year. Their number will increase in 2021.

Sector sub-assembly – With all of the necessary components now on site, the first "vacuum vessel sub-assembly" activity has begun. On one of the giant sub-assembly tools in the Assembly Hall, vacuum vessel #6 will be paired with toroidal field coils #12 and #13 and inboard and outboard thermal shield segments. This first "sector sub-assembly," weighing 1,200 tonnes, will be the first of nine introduced into the Tokamak pit.

Assembly tooling – The frames designed to "upend" the sector sub-assembly components have all been qualified through trial and testing. The sector lift tool, which will be used under the overhead cranes during the transfer of vacuum vessel sectors to help lift and balance the loads, has passed functional tests. The central column and radial beams of the in-pit assembly tool, built to support, align and stabilize the vacuum vessel sub-assemblies as they are joined and welded, have arrived on site.



High-level representatives from all of the ITER Members join (virtually) in ITER's start-of-assembly ceremony on 28 July 2020, hosted by President Emmanuel Macron of France.



The double doors of the Assembly Hall open to admit the cryostat lower cylinder. The 375-tonne component is lowered into its final position in the pit in August.

Metrology, and more metrology – The metrology teams are on hand during every assembly operation – from measuring components before handling to ensure they have been manufactured as designed, to verifying component positions within lift tooling, during transfer, and at final destination. Despite the size of the first components installed in the pit (30 metres in diameter), extreme accuracy (3 mm) has been achieved.

Major contracts concluded – All major assembly and installation contracts have now been awarded by the ITER Organization for Assembly Phase I. Two major contracts for core machine assembly, two others for systems installation in the Tokamak Complex, and five contracts for plant installation on site are now running; a contract has also been concluded for vacuum vessel sector-to-sector welding. ITER Construction is supported by a Construction Management-as-Agent (CMA) contractor, MOMENTUM, to perform efficient project management, preparation, coordination, supervision and completion of these contractor works. The collaboration between the ITER Organization construction teams and MOMENTUM has now been further reinforced through the creation of an ITER-CMA integrated team.

Organizing assembly spaces – In the 170-metre-long assembly theatre, the arrival, staging, and movement of major machine components must be carefully planned. ITER construction coordinators are using 4D visualization techniques to display complex work packages to validate the use of space and assembly sequences. 4D planning merges 3D models of the relevant components and workspaces with scheduling data.

Cleanliness – Homogenous temperatures are required in the ITER assembly spaces because a change of a few degrees could introduce minute alterations in component dimensions. A powerful HVAC system in the Assembly Hall is complemented by temporary systems in the Tokamak pit and the Tokamak Complex to maintain temperature, humidity and cleanliness to support machine construction. Extensive effort is employed to remove remaining dust from the vicinity of the components and to keep the assembly space tidy.

Tokamak Complex systems – 100 workers are involved in the installation of cryolines, cooling water lines, busbars, cable trays and supports, and HVAC equipment in the lowest level of the Tokamak and Diagnostics buildings. Contractors are progressing room by room and in a counter clockwise direction around the Tokamak pit before moving to the next level. Approximately 10% of First Plasma systems have been installed in the Tokamak Complex.

Balance of Plant – Systems installation in the cryoplant, the heat rejection zone, and the magnet power conversion buildings has passed 90%; the next step is commissioning. ITER contractors have installed approximately half of the 53 kilometres of 66 kV cables that connect the converters in the electrical switchyard to equipment inside the conversion buildings. In the reactive power compensation area, the installation of reactors, capacitors, resistors and thyristors is over 75% complete.

The European consortium AMW (Ansaldo Nucleare, Mangiarotti, Walter Tosto), supported by an extended network of sub-suppliers located in France, Germany and Spain, is manufacturing five ITER vacuum vessel sectors. Pictured, one part of sector #5 at Walter Tosto.

2020 ENGINEERING AND MANUFACTURING UPDATE

15
major plant systems

> 1,000,000
components

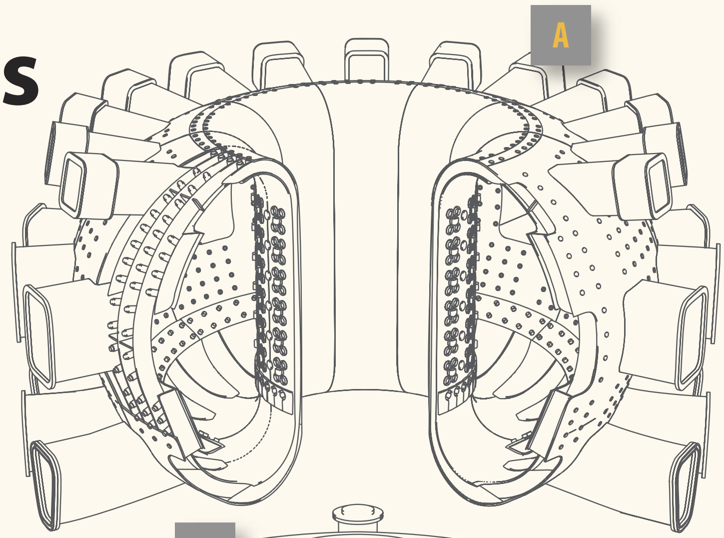
> 10,000,000
parts

7
procuring Domestic Agencies

3,000+
contracts (design, R&D, fabrication)

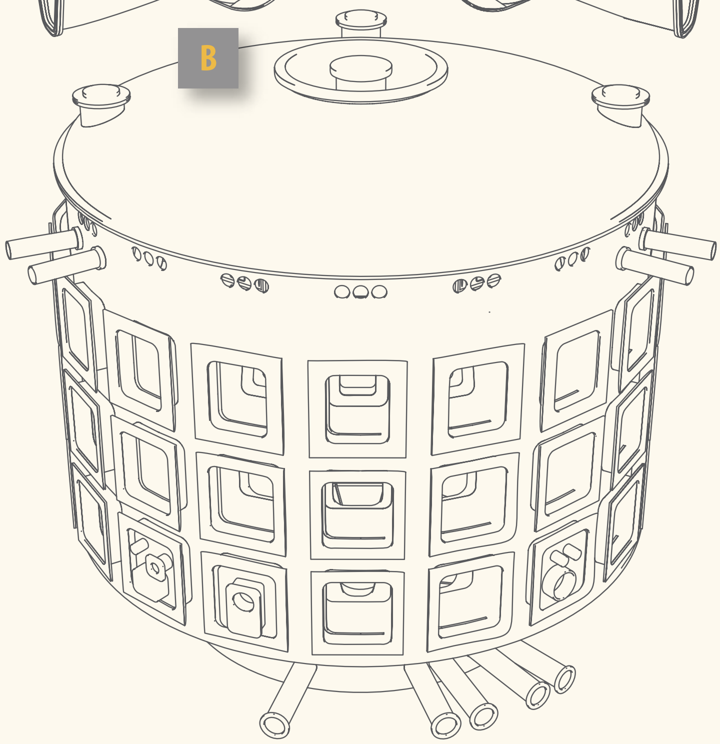
Key components

First-of-series elements from the vacuum vessel and magnet programs came off production lines in 2020, more than 10 years after the industrial effort for these challenging and cutting-edge machine components began. This success opens the way to the expeditious production of the next-in-line items and significantly reduces the first-of-a-kind risk to the ITER Project. Today, 97% of the design and 83% of the manufacturing has been completed for First Plasma components and systems.



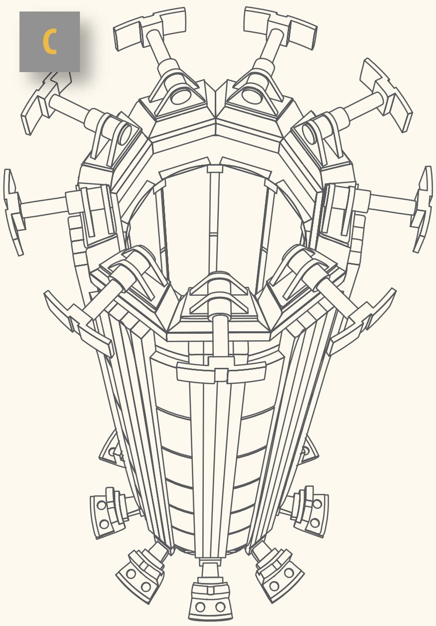
A. VACUUM VESSEL 90%

Nine D-shaped sectors form the toroidal chamber at the centre of the ITER machine – a 5,000-tonne steel vessel that will house the world's first reactor-scale fusion plasma. Four Domestic Agencies are participating in its procurement: Korea (four main sectors, all equatorial and lower ports, gravity supports); Europe (five main sectors); Russia (all upper ports); and India (in-wall shielding). **In a major industrial milestone, the first-completed 40-degree sector (#6) arrived on site from Korea (28)** in August. Two other sectors are near completion in Korea, and the first European sector (#5) is 87% finalized. All other vacuum vessel components are advancing on schedule (upper ports 73%; equatorial and lower ports 65%; in-wall shielding 99.8%).



B. CRYOSTAT 82%

The 30 x 30 metre cryostat insulates the superconducting magnets from the outside environment and contributes to the structural reinforcement of the ITER machine by supporting its mass. Since fabrication began in India in 2013, 54 segments (3,800 tonnes of material) have been finalized and all but the last segments of the top lid have reached ITER. **Machine assembly was launched in 2020 with the installation of the cryostat base (May, cover) and lower cylinder (August, 19)**; the upper cylinder, cocooned in protective wrap on the construction platform, is also ready for installation. The 665-tonne top lid will be assembled and welded on site in 2021.

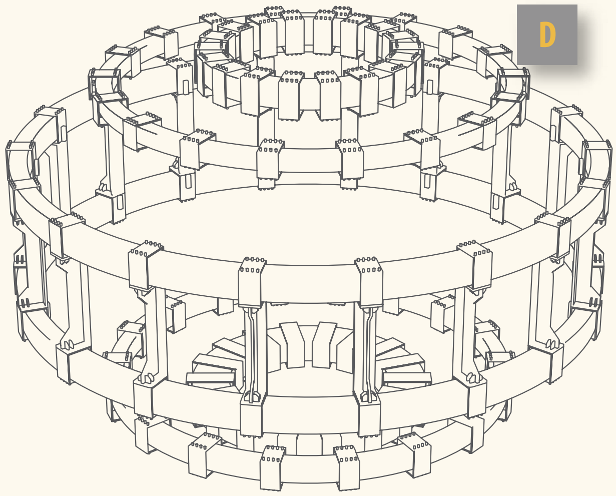


C. CENTRAL SOLENOID 96%

The United States is procuring seven central solenoid modules (including one spare) – each made from 5.6 km of niobium-tin superconductor supplied by Japan. Once stacked at ITER and supported by a cage-like structure, the 1,000-tonne central electromagnet of the ITER machine will allow a powerful current to be induced in the ITER plasma and maintained during long plasma pulses. Lessons learned during the testing of the first module, completed in 2020, have led to a change of approach for the design of the coaxial joints and the insulation of quench-detection wires – important feedback for the fabrication of the companion modules. **The first two modules are expected on the ITER site in 2021**, along with central solenoid tooling and support structures.

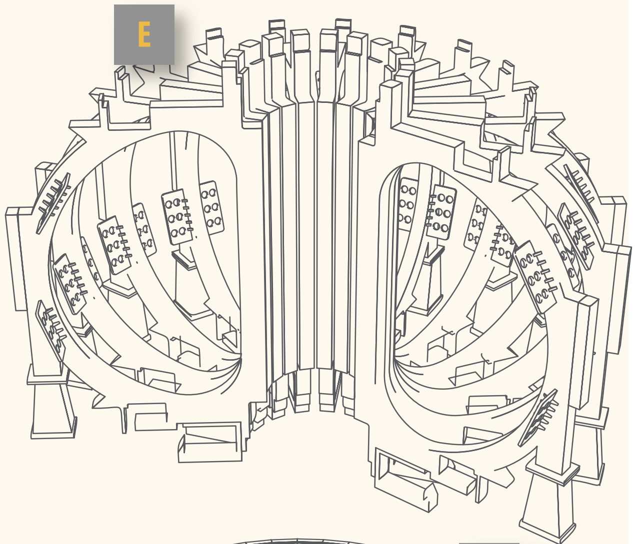
D. POLOIDAL FIELD MAGNETS 94%

Procurement of ITER's six poloidal field coils is the responsibility of Europe (PF2-6) and Russia (PF1), from raw material produced by China, Europe and Russia. **In 2020, the first ITER magnet coil expected in the machine assembly schedule, PF6, was completed by European contractors in China and shipped to the ITER site (48-49)** where it successfully passed all tests (30-31). Four other poloidal field coils are in production: PF5 (in cold testing), PF2 (impregnation completed) and PF4 (winding completed, 61) in Europe's winding facility on site; and PF1 in Russia, expected on site late 2021. Installed around the ITER vacuum vessel and toroidal field magnet system, the poloidal field coils contribute to the plasma's shape and stability.



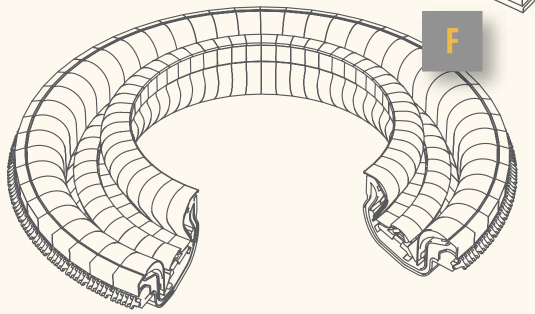
E. TOROIDAL FIELD MAGNETS 98%

Using giant tools in the ITER Assembly Hall, two toroidal field coils will be associated structurally with each vacuum vessel sector before the new unit, called a vacuum vessel sub-assembly, is lowered into the Tokamak pit and welded to its neighbours. **The toroidal field coil procurement programs performed strongly in 2020, delivering the first completed coils** (three from Europe (17) and two from Japan (24)) to the ITER site. Because the precision of coil geometry is critical to creating the magnetic field required for plasma confinement, any non-conformity or misalignment can result in errors in magnetic configuration. As a result, particular attention is paid to dimensional control throughout the fabrication process – from the manufacturing of the core winding pack and case structures, to the insertion of the winding pack inside the case, and finally closure welding and machining.



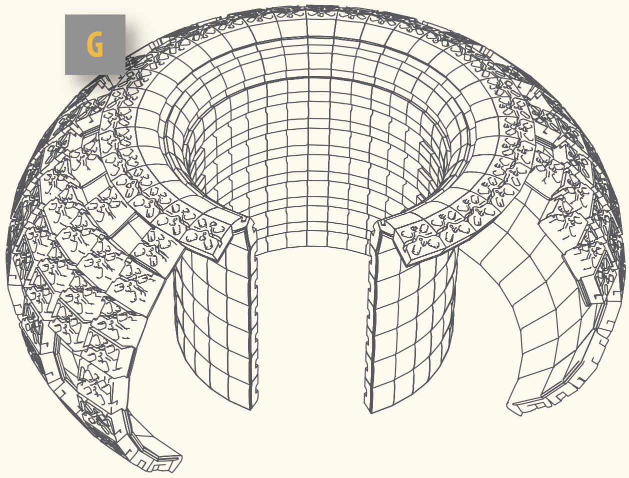
F. DIVERTOR 44%

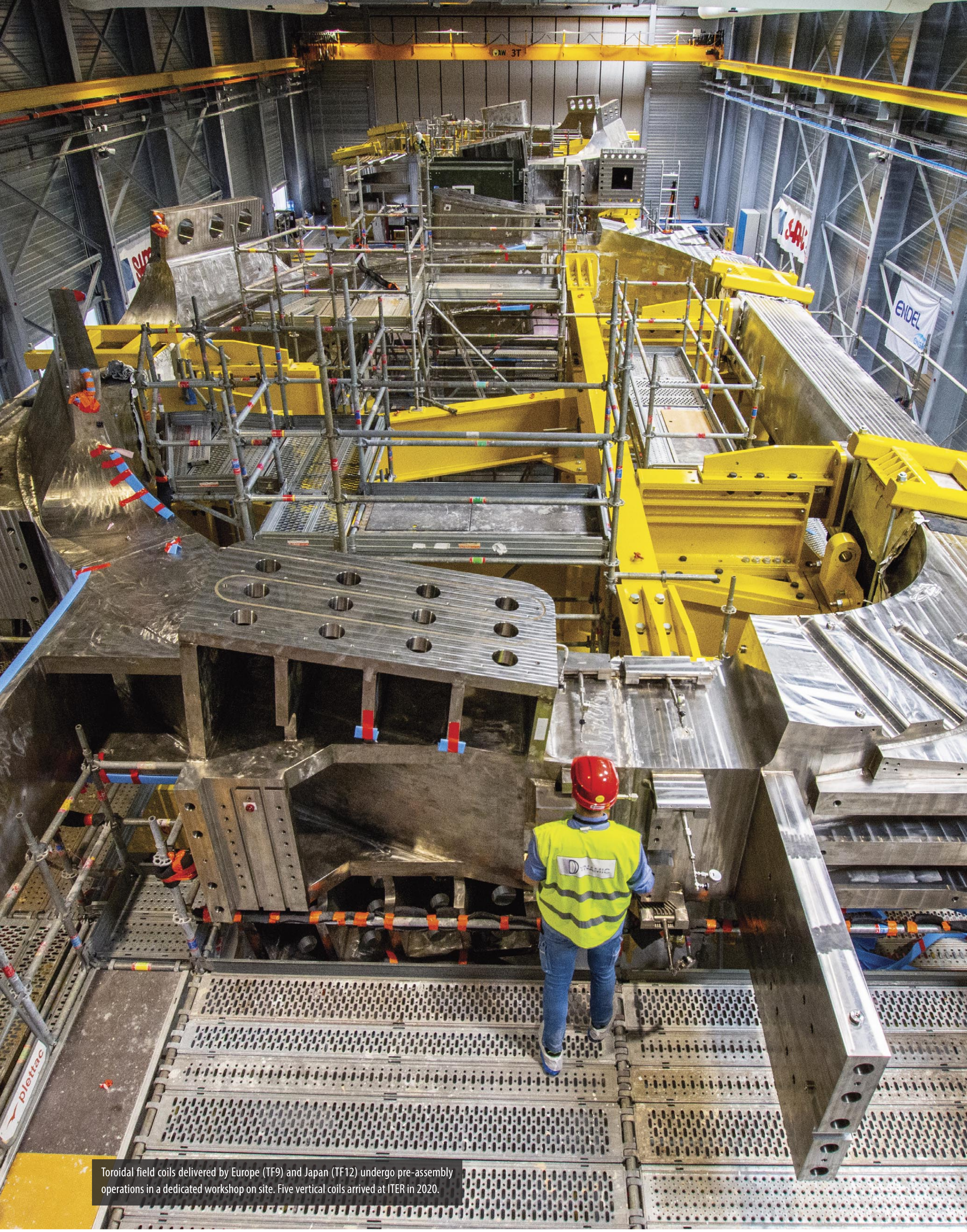
From its position at the bottom of the vacuum vessel, the divertor controls the exhaust of waste gas and impurities from the reactor. After a long qualification phase for the cassette bodies – the component's structural backbone – the manufacturing of 19 units has been launched in Europe through two suppliers. For the actively cooled plasma-facing elements (the "targets" and the "dome") qualification continues. **A full-scale prototype of the dome was finalized in Russia** and 34 prototype tungsten-coated units were successfully tested, the first full-scale prototype of the inner vertical target passed all factory acceptance testing in Europe, and a contract was awarded in Japan for the manufacturing of eight plasma-facing units.



G. BLANKET 54%

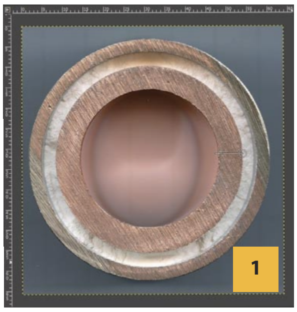
Spread over a surface of 600 m² on the inside of the vacuum vessel, the blanket protects the rest of the reactor by absorbing most of the radiative and particle heat fluxes from the hot plasma. The plasma-facing first wall, made of beryllium tiles bonded with a copper alloy, is the subject of stringent qualification programs in Europe (normal heat flux panels), and China and Russia (enhanced heat-flux panels); **in 2020, full-scale first wall prototypes were completed in Europe**. For the massive shield blocks that are situated behind the first wall panels, series production is underway in China and Korea. **Korea successfully qualified its first shield block production module this year.**





Toroidal field coils delivered by Europe (TF9) and Japan (TF12) undergo pre-assembly operations in a dedicated workshop on site. Five vertical coils arrived at ITER in 2020.

Engineering and manufacturing highlights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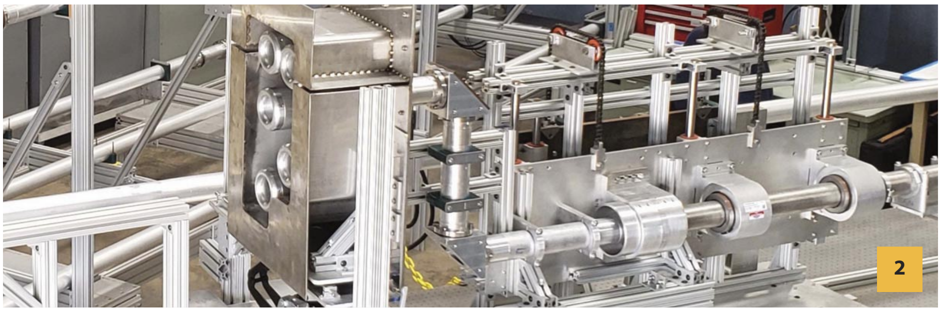
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- The non-superconducting coil systems inside the ITER vacuum vessel require a special type of mineral-insulated conductor, capable of withstanding transient electromagnetic fields, high radiation flux, and high temperature. The first batches – conductor lengths for the vertical stability coils – have been delivered, and bending and winding trials begin next year. **[1]**
- Korea has completed the manufacturing of 32 AC/DC converters. Installation activities are underway on 12, another 11 have been delivered, and factory acceptance testing has been concluded on the final 9.
- Critical to the control, evaluation and optimization of plasma performance on ITER are the 60 diagnostic instruments that will measure 101 parameters. All seven Domestic Agencies are supplying diagnostics; today, 34% of the global procurement program has been achieved. Pictured: a test stand in the United States for the low field side reflectometer (©General Atomics). **[2]**
- The first captive hardware for the neutron flux monitor has been installed in the Tokamak pit.
- India has finalized the manufacturing of all in-wall shielding components. The last batches will ship in early 2021.
- The ownership of 12 assembly tools procured by Korea has been transferred to the ITER Organization. The sector sub-assembly tools, the upending tools, the sector lifting tool, and the first radial beams will all enter into operation next year.
- Poloidal field coil #2 (PF2) has been ground insulated, and is now ready for resin impregnation. After PF5, this is the second ring magnet to take shape on the European winding line at ITER. **[3]**
- Hardware fabricated in the United States for ITER's disruption mitigation system has been tested on shattered pellet injector experiments at the JET (UK) and KSTAR (Korea) tokamaks.
- The outer rim of each toroidal field coil case will be braced from below by a strong pillar called a gravity support, capable of transferring the full gravity load of the ITER magnets to the cryostat. Ten units (out of 18) have been delivered by China for installation on the cryostat base. **[4]**
- The first vacuum vessel sector to arrive at ITER, #6 from Korea, has passed a helium leak test with flying colours, confirmed to be leak tight to two orders of magnitude better than acceptance criteria. **[5]**

Engineering and manufacturing highlights


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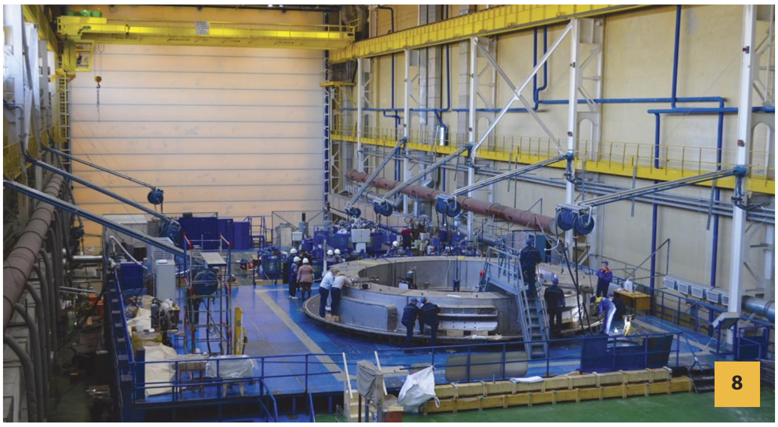
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- Twenty-four energy-generating gyrotrons are needed for the electron cyclotron heating system of the ITER device (eight by First Plasma). The procurement program is progressing on schedule in Japan, Russia, India and Europe.
- Composite pre-compression rings will have an important role to play in protecting ITER's toroidal field coils. Installed at the top and bottom of the coil structures, they will exert a strong radial force, pulling the coils into contact and reducing toroidal tension in the outercoil structures. Europe has now delivered all nine rings (six plus three spare). **[6]**
- The Chinese Domestic Agency is procuring 100% of the gas injection system, including the fuelling manifold system that delivers different gas species from the Tritium Plant to the vacuum vessel. Fifty-eight manifold spools have arrived at ITER for installation. **[7]**
- The first central solenoid module has completed all testing in the United States and is ready for shipment. Fabrication and delivery of central solenoid structures and tooling is ongoing.
- The final consignments of pipes, pipe fittings and spares for the heat rejection system, the component cooling water system, and the chilled water system have been delivered to the ITER site by India.
- Europe has delivered electron cyclotron power supply set #2.
- The first set of cubicles for ITER's central interlock system – the control system designed for machine protection – has arrived on site.
- At the Sredne-Nevsky Shipyard near Saint Petersburg, Russia, ITER's smallest ring coil – PF1 – has passed all winding tests; the next stage, impregnation, is imminent. The transport frame designed for this 200-tonne component is ready to enter service in late 2021. **[8]**
- Four more batches of coil power supply equipment have arrived from Russia, including switching equipment (photo), busbars, energy-absorbing resistors, and control racks for the power supply and protection of the superconducting magnets. **[9]**
- Manufacturing is about to start in the United States on the high-power microwave transmission lines for the electron cyclotron heating system, after several years of design analysis, prototyping and strict attention to complex structural demands. The microwave heating system includes over 4 km of transmission lines plus components such as switches, bends, couplings and bellows.
- After the cryostat base and lower cylinder last year, India has finalized the cryostat upper cylinder. The 430-tonne cryostat component has been cocooned

in a protective film and moved to storage on the platform (photo). The last section, the top lid, will be assembled and welded next year. **[10]**

- Mechanical installation in the ITER cryoplant has now passed 90% and the first pre-commissioning activities are underway. One major component procured by India and installed this year, the termination cold box (photo), collects the cooling fluids from the cryoplant and redirects them to the Tokamak Building. **[11]**
- The ITER Hot Cell Complex is the primary resource for the maintenance of the ITER Tokamak, providing a secure environment for the processing, maintenance, repair or disposal of components that have become activated by neutron exposure. The delivery of this important project is the co-responsibility of the ITER Organization (responsible for requirements engineering, conceptual design, and the design, procurement, installation and commissioning of process equipment) and the European Domestic Agency (construction and commissioning of civil works and building services). Design activities are accelerating and, since October, the Hot Cell Complex project has been executed under the oversight of the integrated Hot Cell Complex Project Team Steering Board to ensure its technical, reglementary, and financial success.
- Magnet feeder elements are arriving on site with increasing regularity from China. Seventy-seven components were delivered in 2020, including four in-cryostat feeder rings. **[12]**
- Korea has completed a six-year program to manufacture all vacuum vessel and cryostat thermal shield sectors. The panels are shipped in batches and assembled at ITER; once installed, they will represent a surface area of approximately 10,000 m^2. **[13]**
- Deliveries and fabrication continue on track for the tokamak cooling water system under Arrangements signed between the US Domestic Agency and the ITER Organization.
- The first blanket shield block has been completed in Korea (photo); series manufacturing can now accelerate. Korea and China are each producing 220 blanket shield blocks for ITER. **[14]**


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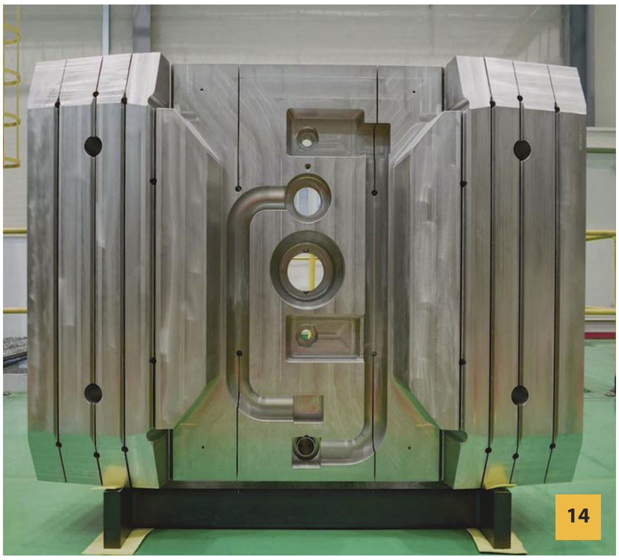
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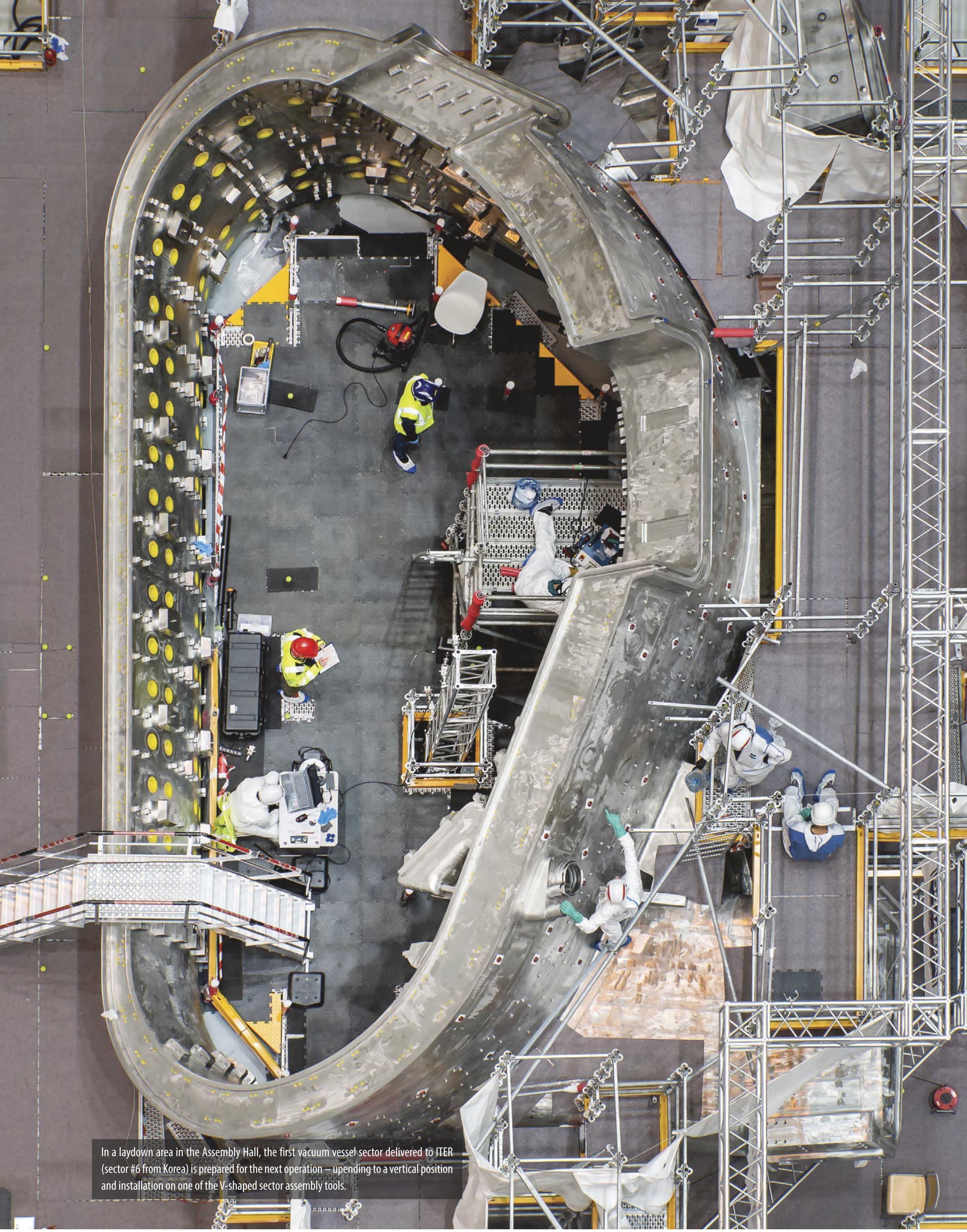

In a laydown area in the Assembly Hall, the first vacuum vessel sector delivered to ITER (sector #6 from Korea) is prepared for the next operation – upending to a vertical position and installation on one of the V-shaped sector assembly tools.

Engineering and manufacturing highlights

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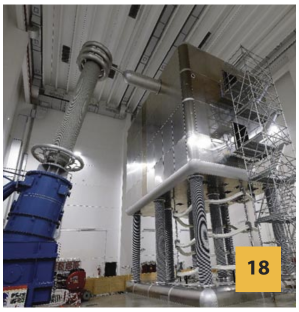
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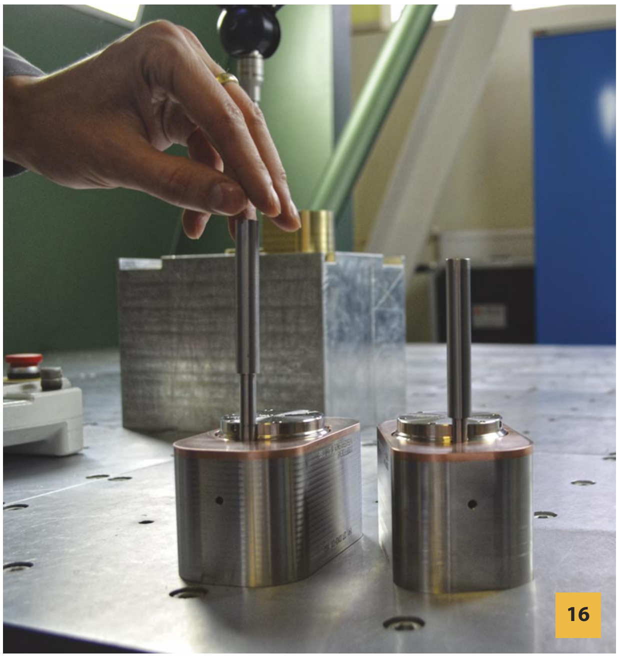
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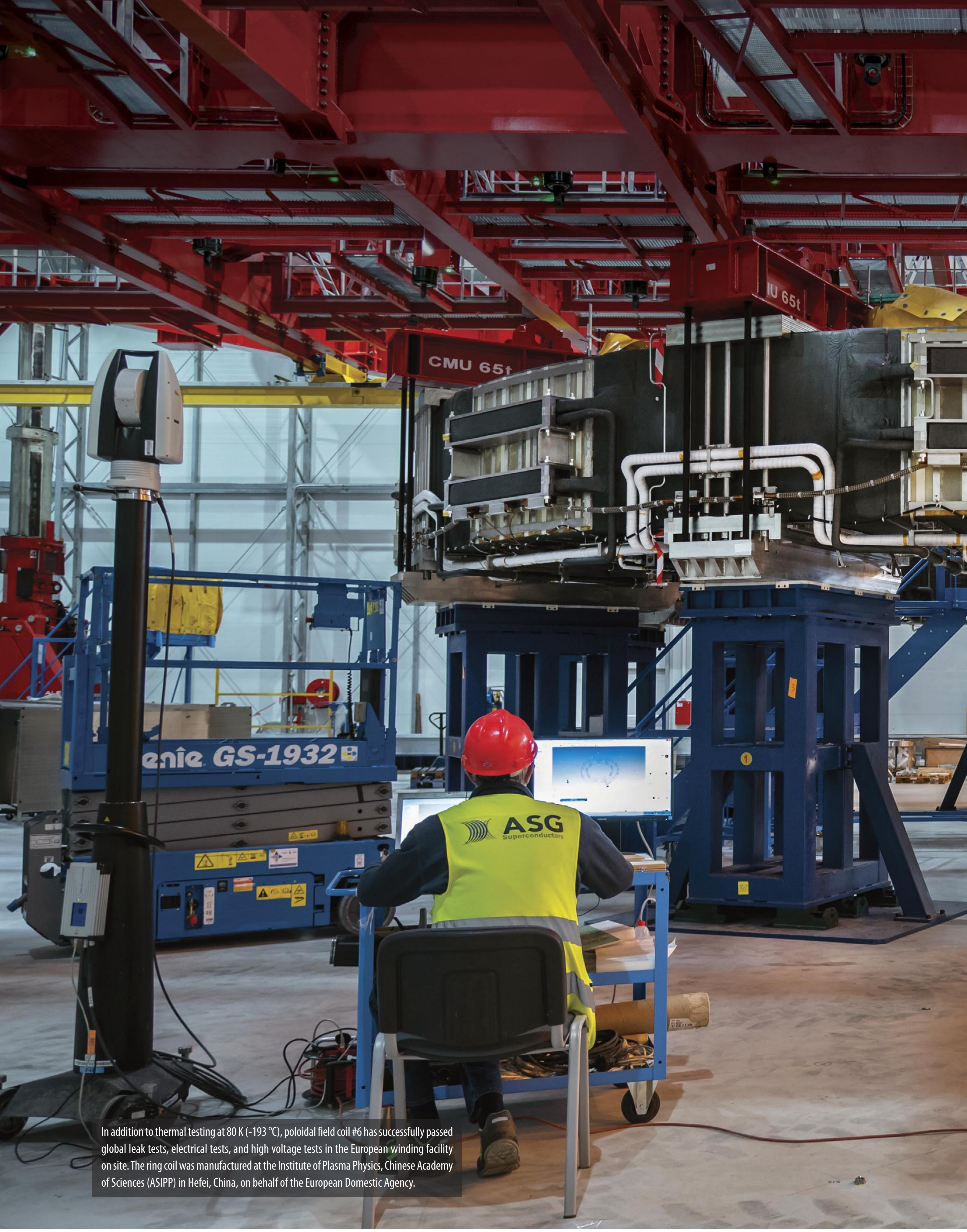
- Two suppliers have been chosen by Europe to manufacture the first 19 divertor cassette bodies (out of 58). Following successful manufacturing readiness reviews this year, both suppliers are proceeding to fabrication. **[15]**
- The qualification of beryllium first wall components for the ITER blanket is progressing strongly: Russia is manufacturing and testing prototype elements and preparing for the fabrication of a full-scale prototype; China has completed the manufacturing readiness review for its full-scale prototype; and Europe has signed the first two contracts for series production.
- The first bimetal pedestals have arrived from Russia. Attached to the inner wall of the vacuum vessel, they will support blanket electrical connectors and act as low-impedance electrical bridges between blanket modules and the vacuum vessel. **[16]**
- China has delivered all reactive power compensation components and installation is underway. Pictured are 39 current transformers (sensors that monitor current variation), aligned in the one-hectare reactive power compensation area on the ITER site. **[17]**
- Challenging remote handling operations on ITER components are being tested for ITER at the UK Atomic Energy Authority's RACE facility. The trials allow ITER's remote handling team and system owners to verify that component designs are well matched with the maintenance capabilities of the project.
- Power supply components procured by Japan and Europe for ITER's neutral beam injector prototype, MITICA, have been tested together for the first time at 50 kV. The next step is testing at nominal power, 1MV. **[18]**
- Both Japan (photo) and Europe complete the first magnets of their toroidal field coil programs in 2020. Five coils reached ITER – two from Japan (TF12 and TF13) and three from Europe (TF9, TF11 and TF5). **[19]**
- A second European supplier has produced a full-scale prototype of the divertor inner vertical target. The prototype will now undergo high heat flux testing at the ITER Divertor Test Facility in Russia.
- Five out of six bottom correction coils have been manufactured in China. The first coils (#1 and #5) reached ITER in December.



In addition to thermal testing at 80 K (-193 °C), poloidal field coil #6 has successfully passed global leak tests, electrical tests, and high voltage tests in the European winding facility on site. The ring coil was manufactured at the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP) in Hefei, China, on behalf of the European Domestic Agency.

SCIENCE AND PRE-OPERATION

- **December 2025** — First Plasma
- **June 2026** — Assembly II (blanket, divertor, in-vessel coils, electron cyclotron heating)
- **June 2028** — Assembly II ends
- **December 2028** — Pre-Fusion Operation I (hydrogen/helium)
- **June 2030** — Assembly III (neutral beams, test blanket modules, ion cyclotron heating)
- **September 2031** — Assembly III ends
- **June 2032** — Pre-Fusion Operation II (hydrogen/helium, full heating)
- **March 2034** — Assembly IV (full tritium plant, radwaste treatment)
- **March 2035** — Assembly IV ends
- **June 2035** — FUSION POWER OPERATION

Science and pre-operation

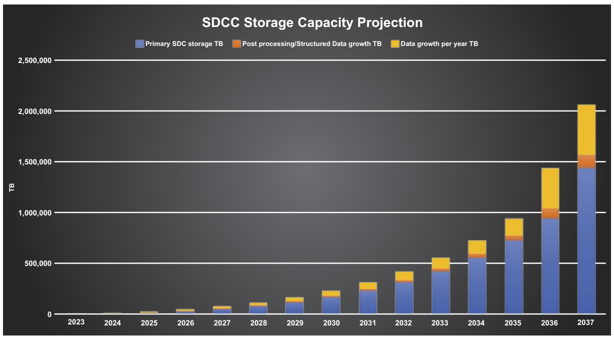
Planning for a tsunami of data

By the time the ITER Project reaches fusion power operation in 2035, it will be producing 2 petabytes of data every day – the equivalent of 1 trillion pages of standard printed text. By far the biggest producers of data will be the diagnostic systems taking at least two different kinds of measurements for every key operating parameter.

ITER will require exabyte-scale storage as well as strong computation capacity for on-site neutronics, physics modelling, simulation, and analysis tasks. (The most computationally intense tasks will be performed on supercomputers in the ITER Members.) Plans are already underway for a Scientific Data Computing Centre (SDCC) to be built and equipped at ITER Headquarters in time for First Plasma, ready to expand in size and capacity as needs increase (*see Figure*).

One important driver for the centre's design is the ability to provide remote access to data for scientists participating from off-site locations. Data norms have already been established in the shape of the ITER Integrated Modelling and Analysis Suite (IMAS) so that, while first-stage processing and analysis will immediately follow an experiment, a much more detailed analysis can be performed by affiliated scientists in the ITER Members. The ITER Science Division is also looking to train artificial neural networks to spot patterns of input data that produce a given output – essentially accelerating the treatment of ITER data.

Extracting as much information as possible from operation will allow ITER to make the most efficient use of the machine. Some of the data will be immediately needed as input into models that help determine the state of the plasma, while virtually all of the data will be needed for rigorous analysis that will help researchers to better model nuclear fusion, ultimately providing essential tools and expertise to the designers of future demonstration or commercial fusion reactors.



Controlling divertor power fluxes in 3D

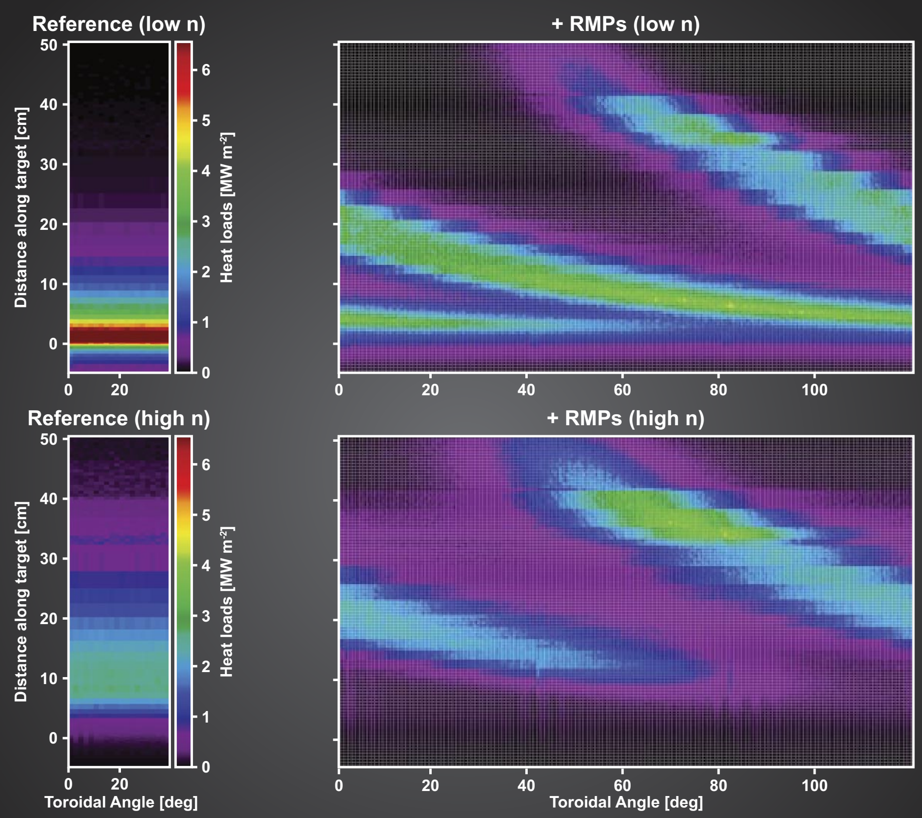
Tokamak plasmas are basically symmetrical toroidally – and so are the power loads to the divertor. Power fluxes change with distance along the divertor targets when looking at the cross section of the torus but not in the toroidal direction (*see Figure p.33*).

In ITER, these power fluxes are deposited in a very small fraction of the divertor area, so their magnitude can be very large for high-performance plasmas and can exceed the design guidelines for the ITER divertor plasma-facing components (10 MWm^{-2}) for high Q plasmas. *(For an explanation of "Q" see pages 36-37.)*

To reduce these power fluxes, impurities are purposely injected in the divertor plasma to enhance losses by electromagnetic radiation (i.e., the emission of light). This so-called semi-detached radiating divertor regime, on which ITER high Q operation is based, is routinely demonstrated in operating fusion experiments. In addition to the stationary power fluxes described above, ITER also needs to control transient power fluxes associated with high confinement plasmas (so-called H-modes) that are required for the achievement of high Q. The specific transients associated with H-mode plasmas are called ELMs (edge localized modes). ELMs cause small losses of plasma energy, but on very short timescales (tenths of milliseconds). In ITER, because of the large plasma energy required to produce fusion power, the associated power fluxes can heavily erode the divertor target, reducing its operational lifetime to unacceptable values.

ELMs need to be mitigated or, even better, eliminated. To achieve this transient power load control, ITER is equipped with a set of 27 in-vessel ELM control coils. By applying electrical currents in these coils it is possible to modify the edge magnetic field and mitigate or eliminate the ELMs altogether, but in doing so the edge plasma is no longer toroidally symmetric and thus has a full 3D structure. This can affect the radiative divertor solution, which relies on a 2D plasma assumption. It is therefore necessary to confirm that the 2D stationary and 3D transient power flux control methods, impurity injection, and ELM control coils, can be compatible for the operation of high-performance ITER plasmas.

Initial experiments on the EAST tokamak (China) showed that, indeed, 3D edge magnetic fields deeply affect the access to radiative divertor conditions as the plasma



Power fluxes to the outer divertor plasma at low and high plasma density (radiative divertor conditions): 2D toroidally symmetric plasma (left), and 3D edge plasma with a magnetic field modified by ELM control coils (right).

density is increased. Near the intersection of the plasma with the divertor target, the power flux decreased with increasing density – similar to the 2D situation. However, far from this intersection, where the plasma power fluxes are non-toroidally symmetric, the power fluxes increased with increasing density. Further research has been carried out at ITER Member tokamak experiments equipped with ITER-like ELM control coils to study this issue in detail.

Some tokamak experiments are equipped with ITER-like ELM control coils to study this issue in further detail (ASDEX Upgrade, DIII-D, EAST, KSTAR, NSTX), but it has not been possible to reproduce the divertor and main plasma conditions that are expected in ITER simultaneously. This has prevented the direct extrapolation of present experimental results to ITER and has made another approach to solving the conundrum necessary.

This issue was put to the ITER Scientist Fellows – a group of leading plasma modelling experts from the ITER Members supported by their national fusion programs (the US Department of Energy and EUROfusion in this case) and the ITER Organization – and they rose to the challenge. Through the effort of Scientist Fellow specialists in 3D edge plasmas, 3D magnetic fields, and their collaborators – and coordinated by staff from the ITER Organization – a first understanding of power flux control in ITER's 3D plasmas has emerged.

The results, published in *Physical Review Letters*, show that the qualitative behaviour initially observed in EAST will be reproduced in ITER plasmas, and that this is due to the specific 3D structure of the edge magnetic field that the ELM control coils will create in ITER plasmas. This understanding provides a way to optimize the control of stationary and transient power fluxes by tuning the 3D edge magnetic fields applied for ELM control in ITER.

H. Frerichs, O. Schmitz, X. Bonnin, A. Loarte, Y. Feng, L. Li, Y. Q. Liu, and D. Reiter. "Detachment in Fusion Plasmas with Symmetry Breaking Magnetic Perturbation Fields." Physical Review Letters 125, 155001 (9 October 2020). ***https://doi.org/10.1103/PhysRevLett.125.155001.***

Ground investigation and excavation has begun on the site of the ITER Control Building. To maximize the use of the unique ITER experimental device and its research potential, planners expect to run the machine for two to three shifts a day. © *Enia Architectes, France*

Science and pre-operation

Science and pre-operation

Learning from the JT-60SA start-up phase

The ITER Organization is gaining knowledge and experience through active involvement in the commissioning activities underway on the JT-60SA tokamak in Japan. This valuable collaboration is made possible through a trilateral agreement with the partners of the Broader Approach*.

Under the terms of a trilateral collaboration agreement signed in November 2019 by the ITER Organization, Japan's QST, and the European Domestic Agency for ITER (Fusion for Energy), the ITER Organization will directly benefit from the experience gained from the assembly, installation, integrated commissioning and operation of the tokamak JT-60SA.

Between 2013 and 2020, the joint European-Japanese implementing team conducted a major modification of the existing JT-60U tokamak, redesigning and rebuilding all core machine components. As ITER begins the assembly of its machine and plant, the lessons learned shared by JT-60SA colleagues are particularly valuable for risk mitigation. The ITER team is also actively participating in integrated commissioning, which is a series of functional tests (vacuum pumping, magnet cool down) that will culminate with the device's first plasma in 2021.

While it was originally foreseen that several ITER staff members would be involved in-person at the QST Naka site, due to the COVID-19 restrictions most of the participation had to take place remotely and only one ITER staff member could be present at Naka this year. This notwithstanding, remote collaboration has been effective with ITER staff participating in JT-60SA weekly progress and planning meetings on integrated commissioning activities by teleconference, as well as in specially arranged meetings to share knowledge and experience gained by the JT-60SA team with a wide range of ITER specialists.

The Broader Approach is an agreement between Europe and Japan on advanced fusion activities. See* ***https://www.ba-fusion.org/ba/*

R. Maekawa (ITER, left) participating in integrated commissioning activities with K. Natsume (QST, centre) and S. Davis (Fusion for Energy, right) at the JT-60SA Torus Hall.

Supporting the ITER Research Plan

In November 2020, the ITER Organization released a prioritized list of ITER Research Plan R&D support needs as a publically available ITER Technical Report (ITR-20-008). Issues listed as high impact, warranting priority focus in ongoing R&D at the ITER Member fusion research institutes, include: issues related to completion of systems designs; specific choices and options to be explored in the early stages of ITER operation; and strategic assumptions on the development of the experimental program toward high Q operation (*see next item*).

Support from ITER Member fusion research institutes provides an essential contribution to the further refinement of the Research Plan, which was updated in 2018. The publication of ITER's consolidated R&D priorities aims to promote a more effective collaboration between the ITER Organization and the fusion community.

"Required R&D in Existing Fusion Facilities to Support the ITER Research Plan" can be downloaded from the ITER website: ***https://www.iter.org/technical-reports.***

Plasma scenarios for ITER'S three power production goals

To understand the fusion gain parameter "Q" is to understand the most essential operating parameter as well as the *raison d'être* of the ITER Project.

Q is the ratio between the thermal power produced by the fusion reactions and the external power required to sustain the reactions via plasma heating. Energy breakeven, or Q = 1, means that the power released by the hot plasma is equal to the required heating power. Beyond Q= 5, the fusion plasma begins to significantly self-heat, which scientists refer to as a burning plasma. At infinite Q, a plasma is self-sustaining (*ignition*).

In fusion history, no fusion device has achieved Q = 1, the breakeven point. The closest to date has been Q = 0.67

and only sustained for ~ 1 second, which was reached at the European Union tokamak JET (UK). The programmatic goal of ITER, Q ≥ 10, signifies delivering ten times more power than that which is used to heat up the plasma. ITER is designed to produce a fusion power output of at least 500 megawatts from input power of 50 megawatts to heat the deuterium-tritium plasma.

More precisely, ITER will strive to achieve three fusion power production goals during its Fusion Power Operation (FPO) phase:

- **Q ≥ 10 for 300 to 500 seconds**
- **Q = 5 in steady-state scenarios**
- **Q ≥ 5 for 1000 seconds**

ITER should demonstrate flexibility by operating in a range of plasma scenarios to achieve these three fusion goals. The Q ≥ 10 goal will be achieved in the conventional H-mode plasma scenario where most of the current circulating in the plasma is driven inductively by the central solenoid. The Q = 5 steady state will be achieved by plasma scenarios in which the plasma current is not driven by the central solenoid but by the heating and current drive systems and by plasma processes; these are effective when a high level of plasma pressure compared to the poloidal magnetic field is achieved in tokamaks. This requires better energy confinement than the conventional H-mode scenario, and involves improved plasma transport and edge plasma stability that have been demonstrated in present tokamak experiments under some conditions. The Q ≥ 5 for 1000 seconds goal will be achieved by plasma scenarios which have intermediate properties between those required for the Q = 5 steady-state and the Q ≥ 10 inductive scenario.

A new study has been completed to determine the plasma characteristics and requirements to achieve the Q = 5 steady-state goal by applying the baseline heating and current drive systems in ITER and their foreseen upgrades. This assessment has been published in the journal *Nuclear Fusion* and has shown that stable plasma conditions can be obtained in ITER by using the flexibility of the upgraded heating and current drive systems, namely neutral beam injection (NBI) and electron cyclotron heating and current drive (ECH/ECCD), provided improved plasma transport can be achieved. While the latter remains an open R&D issue, improved plasma transport to the level required in ITER has already been obtained in DIII-D tokamak plasmas with the same heating schemes foreseen for these scenarios in ITER (NBI + ECH/ECCD).

A.R. Polevoi, A.A. Ivanov, S.Yu. Medvedev, G.T.A. Huijsmans, S.H. Kim, A. Loarte, E. Fable and A.Y. Kuyanov, Reassessment of steady-state operation in ITER with NBI and EC heating and current drive, Nucl. Fusion 60 096024 (12 August 2020). ***https://doi.org/10.1088/1741-4326/aba335***


DIII-D tokamak (United States)

Plasma control system: design validated for First Plasma

A holistic and robust plasma control system is essential to sustained nuclear fusion, and ITER is applying the most advanced computer and communications technologies to design a system capable of evolving with the different phases of ITER operation. In 2020, the first major step towards the achievement of this goal was successfully taken.

The ITER Organization has completed the design of the plasma control system for First Plasma, following a multi-year effort supported by an external team of specialists. The final design was thoroughly reviewed in summer 2020 by a panel that included leading plasma control experts from the ITER Members. The panel concluded that the system design encompassed the technical scope and satisfied the performance requirements necessary for the successful execution of First Plasma operation.

Following the achievement of this key milestone, the implementation of the plasma control system for First Plasma will be undertaken by the Controls Division starting in 2021. The Science Division will proceed, from 2021 onwards, to design the plasma control system for the first Pre-Fusion Power Operation experimental campaign.

At a glance 2020

JANUARY

- New construction-focused management and organizational structure in place
- Four Heads of Domain named (Corporate, Engineering, Science & Operation, Construction)

MARCH

- Full crane path validated under load; assembly theatre officially ready
- The ITER Organization implements Covid-19 safety measures
- "Sans titre," by American sculptor Christine Corday, is integrated into the Tokamak Building

MAY

- First machine component – the cryostat base – installed in the Tokamak pit
- Prince Albert II of Monaco meets the Monaco-ITER Postdoctoral Fellows (remotely)
- Covid solidarity: masks delivered by ITER Members China and Korea

JUNE

- 26th ITER Council Meeting (remote)

JULY

- Virtual start-of-assembly ceremony hosted by French President Emmanuel Macron

SEPTEMBER

- EUROfusion joins efforts at the ITER Neutral Beam Test Facility

OCTOBER

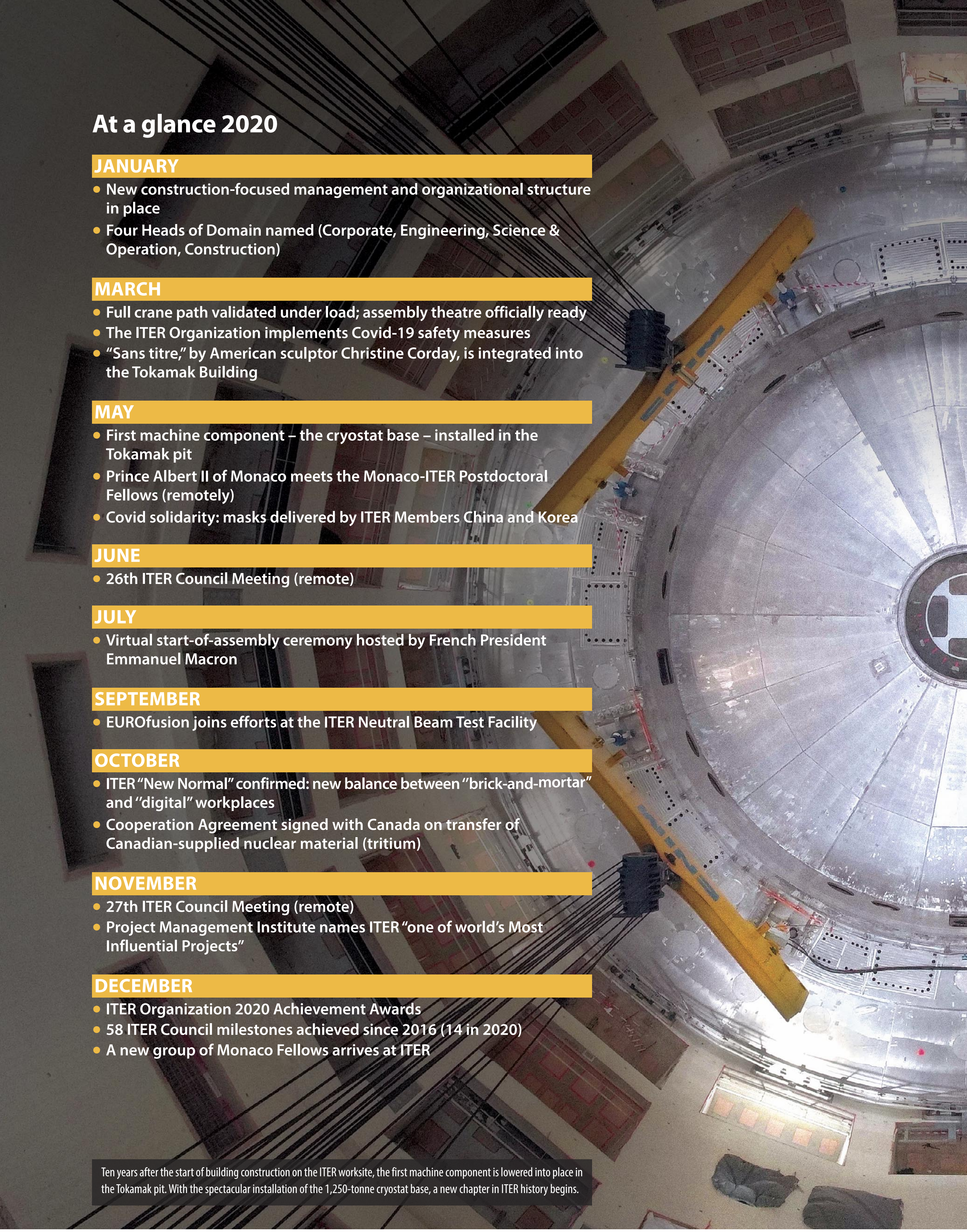
- ITER "New Normal" confirmed: new balance between "brick-and-mortar" and "digital" workplaces
- Cooperation Agreement signed with Canada on transfer of Canadian-supplied nuclear material (tritium)

NOVEMBER

- 27th ITER Council Meeting (remote)
- Project Management Institute names ITER "one of world's Most Influential Projects"

DECEMBER

- ITER Organization 2020 Achievement Awards
- 58 ITER Council milestones achieved since 2016 (14 in 2020)
- A new group of Monaco Fellows arrives at ITER



Ten years after the start of building construction on the ITER worksite, the first machine component is lowered into place in the Tokamak pit. With the spectacular installation of the 1,250-tonne cryostat base, a new chapter in ITER history begins.

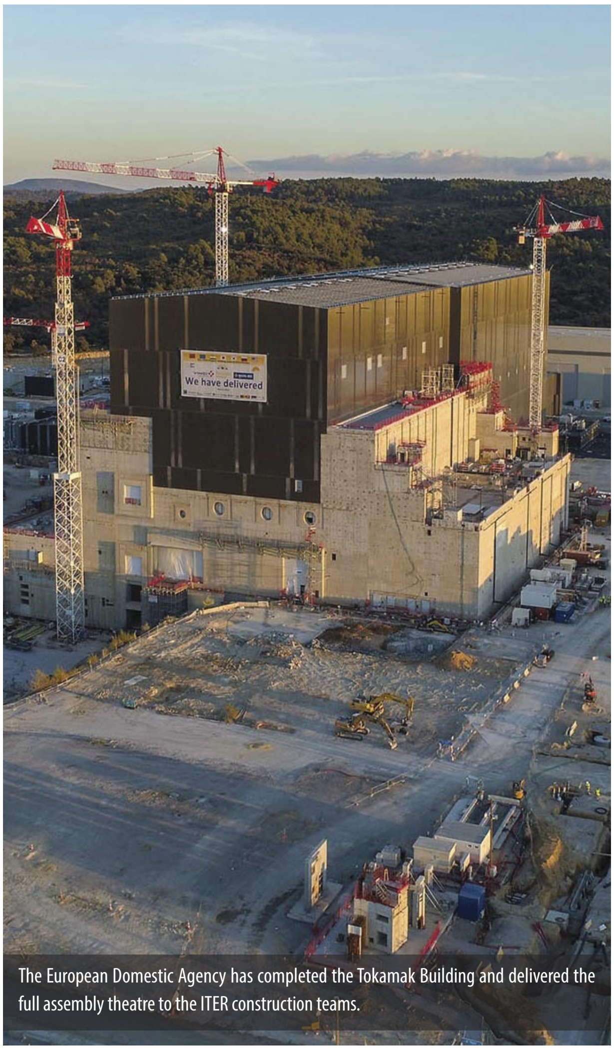

CORPORATE
HIGHLIGHTS

Corporate highlights 2020

The ITER Organization and the seven Domestic Agencies worked hand-in-hand in 2020 to limit the consequences of the Covid-19 pandemic on manufacturing and installation activities, implementing mitigation actions for schedule recovery and preserving critical activities on the worksite. The possibility of maintaining First Plasma in 2025 will depend on the success of these corrective actions, and on the duration of Covid-related disruptions to the ITER supply chain. Today project execution on the road to First Plasma stands at 72.1 percent (31 December 2020).

Covid-19 – The ITER Organization took strong and immediate measures at the start of the Covid-19 pandemic to preserve the continuity of the project while maximizing the protection of staff and implementing the recommendations of the French national authorities. Presence on site was initially limited to staff and contractors performing critical activities that could not be carried out remotely; all other staff (95% of office staff) successfully worked remotely from March to May. Following this initial period, management continued to implement precautions and instituted procedures that generalized remote working three days per week where applicable *(see "Staffing" on page 43)*. The continuity plan permitted critical activities to be maintained on the worksite; however, the supply chain for many critical components has been affected by factory closures, disruptions in international shipping, and an unavoidable drop in overall work rates. The full impact of the Covid-19 pandemic will be further assessed and reported in 2021.

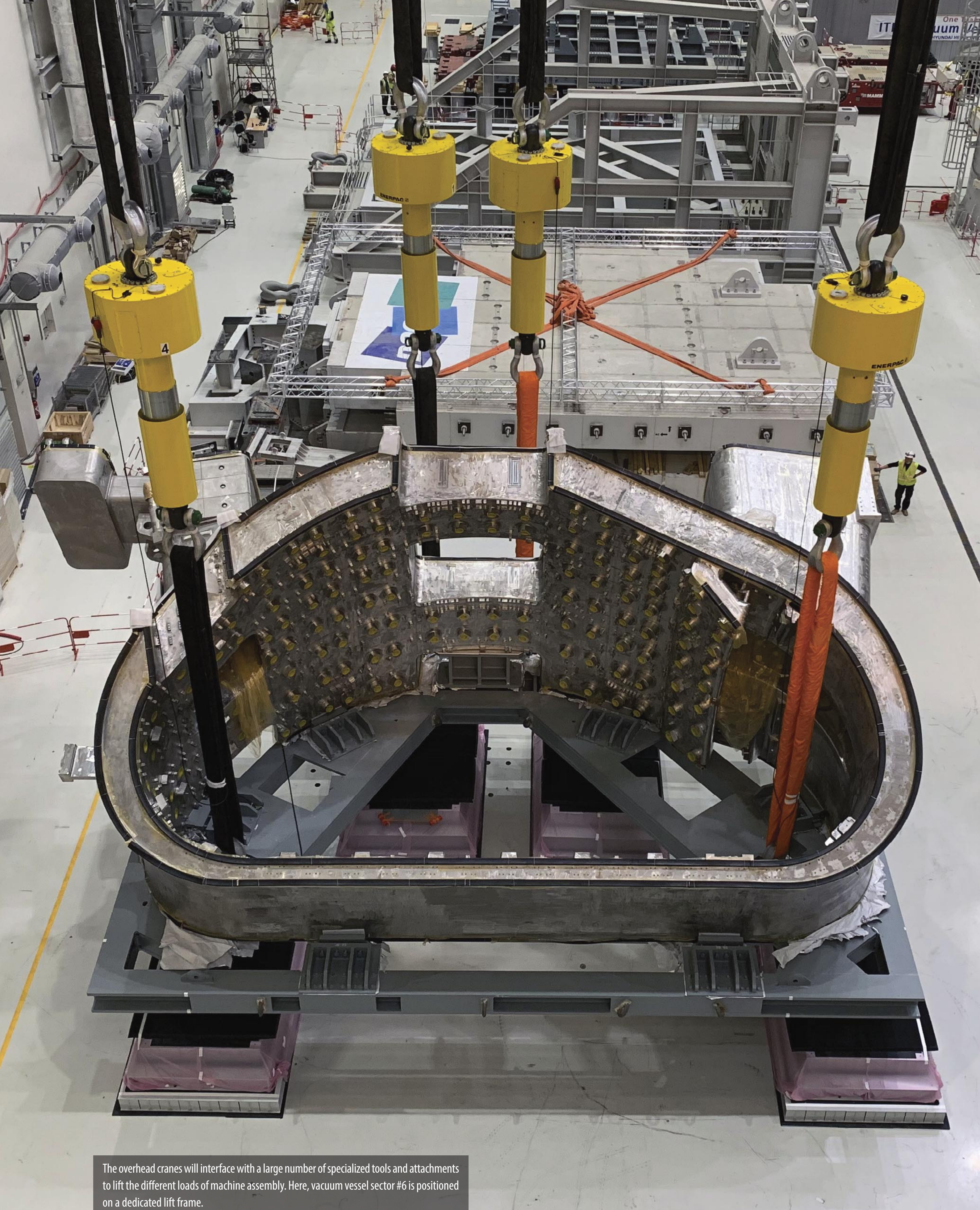
Maintaining productivity while adapting to a new reality.



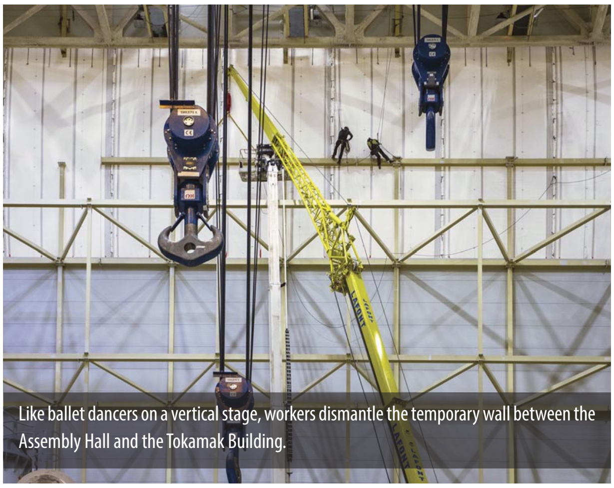
The European Domestic Agency has completed the Tokamak Building and delivered the full assembly theatre to the ITER construction teams.

Revised construction strategy – The ITER Organization and the Domestic Agencies continue to work according to the Project Baseline established in 2016 until such time that the global Covid-19 pandemic stabilizes and the impact on the ITER Project schedule can be fully assessed. A general slowdown in schedule performance has been observed due to delays in major component deliveries. To counter this, the project management team is pursuing the optimization of assembly sequences and identifying other opportunities for the acceleration of critical activities to minimize the impact on the First Plasma date and the intermediate plasma operation phases (Pre-Fusion Operation I and II), while maintaining the date of Fusion Power Operation in 2035. The project's critical path continues to pass through major machine component manufacturing and machine assembly – including the major vacuum vessel sub-assembly activities on the tooling in the Assembly Hall – while the installation of system components in the Tokamak Complex is near the critical path. Project performance is reported every two months to the ITER Council against a configuration-controlled set of ITER Council milestones; 58 of these milestones have been achieved since 1 January 2016, including 14 in 2020.

Close to one week of preparation, tests, measurements and rehearsals precedes the first lift of ITER assembly. Everything goes as planned, as the base of the machine is lifted to a cruising altitude of 24 metres, and then transported 110 metres to the other side of the assembly theatre.



The overhead cranes will interface with a large number of specialized tools and attachments to lift the different loads of machine assembly. Here, vacuum vessel sector #6 is positioned on a dedicated lift frame.



Like ballet dancers on a vertical stage, workers dismantle the temporary wall between the Assembly Hall and the Tokamak Building.

First-of-a-kind components – Technical risks inherent to first-of-a-kind components were substantially reduced in 2020 through the successful finalization of the first vacuum vessel sector and the first poloidal and toroidal field magnets. While their arrival on site was a major success, particularly in the context of the pandemic, delivery was later than planned due to the technological challenges associated with first-of-series components and the impact of Covid-19. The resulting follow-on effects include later-than-forecasted deliveries for other components from the same facilities, transport and storage bottlenecks, and slippage in the machine assembly schedule. As mitigation, the ITER Opportunity Task Force continues to identify and exploit schedule reduction opportunities in assembly and installation activites.

External review – The ITER Organization is actively implementing the recommendations of the Management Assessment 2019, as well as the action plans stemming from Council-commissioned In-Depth Independent Reviews (IIRs) on the assembly and installation strategy, design interface freezing, and configuration management. Regular external review ensures that the ITER Project maintains world-class project management practices.

Cost-Saving Program – A new cost-saving program created in 2020 introduces a mechanism for the continuous examination of cost-saving opportunities in the project. A list of 23 initial cost-saving ideas will be the first to be addressed; others will be added to the list in the future. The program aims to generate cost savings, avoid unnecessary costs and – more generally – create a cost-conscious project culture at the ITER Organization.

Regulatory environment – As an *Installation nucléaire de base (INB)* – a nuclear installation under French nuclear safety regulations– the construction of key buildings, the fabrication of safety-important components, assembly, and the start of each operational phase are all subject to a set of controls and authorizations. Five inspections took place in 2020, including inspections on the installation of the cryostat base and preparations for vacuum vessel assembly. A complete report on the conformity of the Tokamak Complex with nuclear and radiation safety requirements has been sent to the French Nuclear Regulator for review. This report is part of the ongoing process to meet a regulatory hold point on Tokamak assembly in time for the start of welding of the first two vacuum vessel sectors in the Tokamak pit.

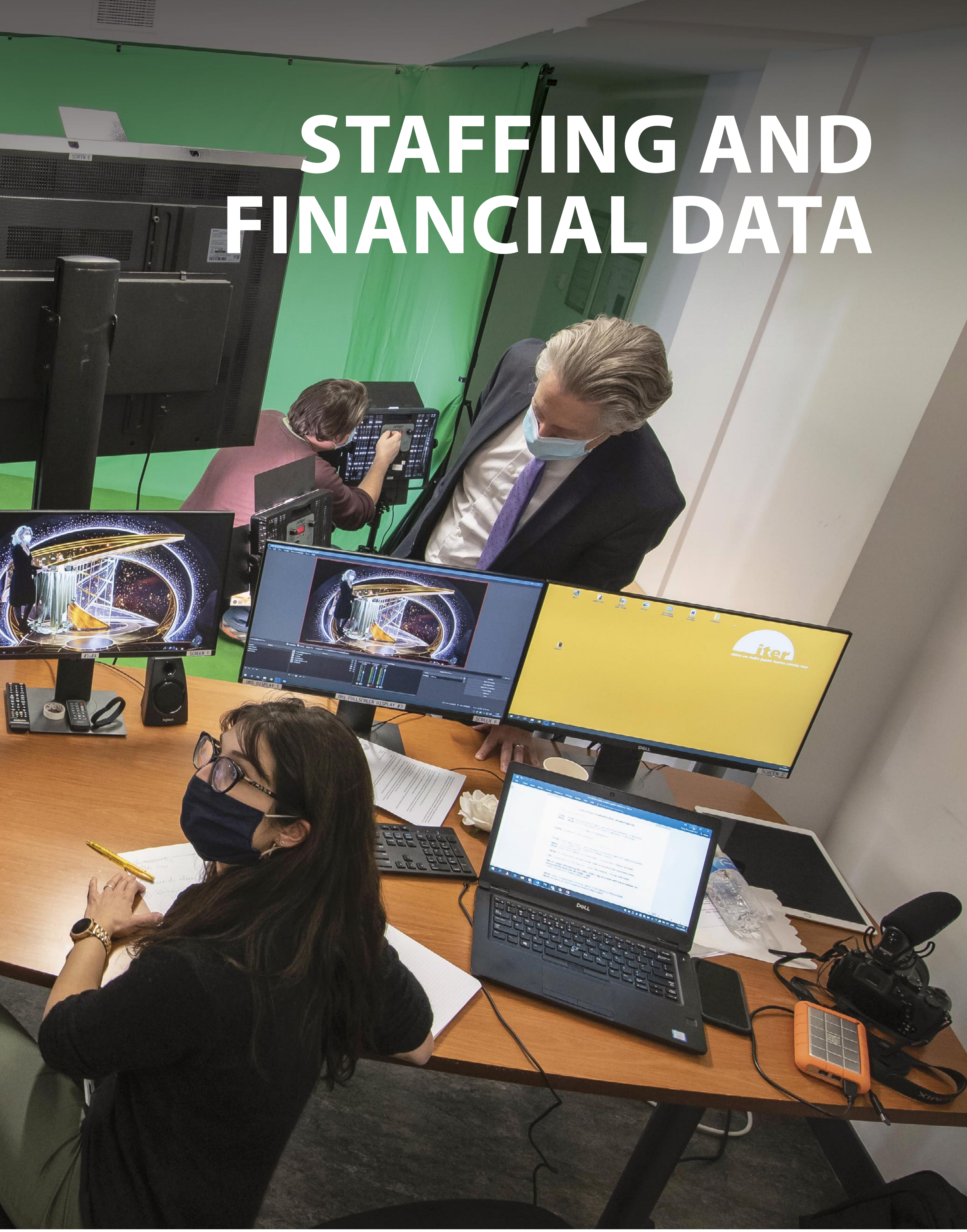
Staffing – ITER Organization staffing is progressing in step with project resource estimates and projections. As of 31 December 2020, 989 people were directly employed by the Organization. Sixteen experts, 4 visiting researchers, 16 interns, and 209 ITER Project Associates (experts from the Members' scientific, technological and industrial communities who work at ITER, while remaining in the employment of their home institutes) were also present. A new construction-focused management and organizational structure was introduced in January 2020 for the optimized execution of the assembly and installation phase. Finally, taking into account the lessons learned from the continuity plan implemented during the early months of the Covid-19 pandemic, the ITER Organization implemented a "New Normal" way of working (minimum of two days per week on site, complemented by telework) in October.

International cooperation – Under Article 19 of the ITER Agreement, " [...] upon a unanimous decision of the ITER Council, the ITER Organization may, in furtherance of its purpose, cooperate with other international organizations and institutions, non-Parties and with organizations and institutions of non-Parties, and conclude agreements or arrangements with them to this effect." The ITER Organization currently has international cooperation agreements with the laboratories and educational establishments of the ITER Members (*see list on page 59*), international organizations, and non-Member states. Of note in 2020, a Cooperation Agreement was signed with Canada that sets out the terms for cooperation in the transfer of Canadian-supplied nuclear material (tritium) and tritium-related equipment and technology.

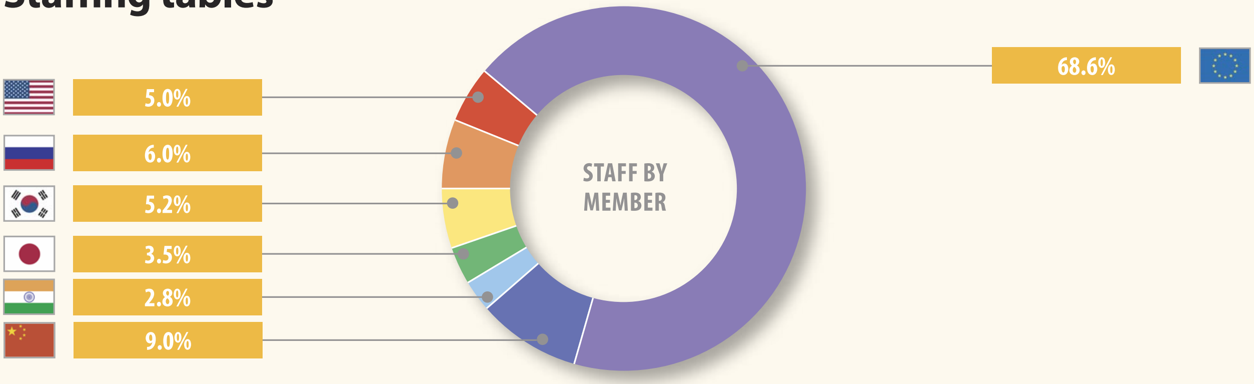
Five months will be necessary to weld the cryostat lower cylinder to the base and complete all testing.

A virtual studio at ITER Headquarters has been an important asset in this unprecedented year, allowing ITER staff to give presentations, participate in conferences, and even organize a virtual end-of-year ceremony for employees and families remotely.

STAFFING AND FINANCIAL DATA



Staffing tables



Staff by Member

	31/12/2016	31/12/2017	31/12/2018	31/12/2019	31/12/2020
China	67	77	79	87	89
European Union	512	571	599	634	678
India	30	36	36	28	28
Japan	25	25	27	32	35
Republic of Korea	32	32	32	49	51
Russian Federation	36	36	37	47	59
United States of America	38	48	48	52	49
TOTAL	740 [1]	825 [2]	858 [3]	929 [4]	989 [5]

[1] *Includes 4 Monaco Postdoctoral Fellows and staff funded for work on the Tokamak Cooling Water System (TCWS, 23), vacuum system (VAS, 2) and the safety control system for nuclear (SCS-N, 1)*
[2] *Includes 5 Monaco Postdoctoral Fellows, staff funded for work on the TCWS (27), VAS (2) and SCS-N (1)*
[3] *Includes 5 Monaco Postdoctoral Fellows, staff funded for work on the TCWS (25), VAS (2) and SCS-N (1)*
[4] *Includes 5 Monaco Postdoctoral Fellows, staff funded for work on the TCWS (29), VAS (3) and SCS-N (1)*
[5] *Includes 7 Monaco Postdoctoral Fellows, staff funded for work on the TCWS (27), VAS (2) and SCS-N (2)*

Staff by Organizational Unit* as of 31/12/2020

	Professional & Higher	Support	TOTAL
DG	3		3
ODG	19	13	32
SQD	47	22	69
Total DG	69	35	104
CORP	18	14	32
FPD	26	24	50
HRD	8	13	21
PCO	17	7	24
Total CORP	69	58	127
ENGN	13	67	80
CIO	63	14	77
EDD	146	16	162
Total ENGN	222	97	319
CNST	1		1
CMO	30	9	39
MCD	166	39	205
PLD	79	19	98
Total CNST	276	67	343
Total SCOP	75	21	96
TOTAL	711	278	989

* For the full names of units, see the Organization chart on page 60.

Main Financial Data

Commitments Execution

Amounts in thousands of Euro

Budget Headings	Total Commitment Appropriations 2020	Total Actual Commitments 2020	Unused Commitment Appropriations carried forward to 2021
	a	b	c = a - b
Title I: Direct Investment (Fund)	531,159	398,787	132,372
Title II: R&D Expenditure	1,641	(26)	1,666
Title III: Direct Expenditure	289,507	240,244	49,263
TOTAL COMMITMENTS	**822,307**	**639,006**	**183,301**

Payments Execution

Amounts in thousands of Euro

Budget Headings	Total Payment Appropriations 2020	Total Actual Payments 2020	Unused Payment Appropriations carried forward to 2021
	a	b	c = a - b
Title I: Direct Investment (Fund)	582,248	209,902	372,346
Title II: R&D Expenditure	2,055	60	1,995
Title III: Direct Expenditure	330,304	230,759	99,545
TOTAL PAYMENTS	**914,607**	**440,721**	**473,886**

Contributions Received From Members In Cash

Amounts in thousands of Euro

Members	2020	Cumulative
Euratom	177,696	1,576,537
People's Republic of China	40,857	299,434
Republic of India	5,850	164,996
Japan	42,121	293,957
Republic of Korea	36,093	293,328
Russian Federation	38,475	308,697
United States of America	47,954	226,237
TOTAL CONTRIBUTIONS	**389,046**	**3,163,185**

Contributions Received From Members In Kind

	Amounts in ITER Unit of Account (IUA)		Amounts in Thousands of Euro	
Members	2020	Cumulative	2020	Cumulative
Euratom	75,324	498,533	133,235	845,972
People's Republic of China	5,103	143,623	8,807	244,456
Republic of India	43,959	142,840	77,722	246,654
Japan	29,110	307,046	51,514	518,757
Republic of Korea	44,134	132,899	77,976	227,558
Russian Federation	9,474	109,051	16,754	185,108
United States of America	7,840	88,815	13,988	150,683
TOTAL CONTRIBUTIONS	**214,944**	**1,422,808**	**379,996**	**2,419,188**

Procurement highlights key

- R&D, manufacturing, installation milestones
- Major contracts
- ITER Organization-Domestic Agency milestones
- Completed package

The figures on the following pages are adjusted annually for changes in credit value due to Procurement Arrangement Refinements (PAR) and Additional Direct Investments (ADI) related to Project Change Requests. Please note that 2020 figures supersede all previously published figures.

Poloidal field coil #6 travels along the byways of the ITER Itinerary, taking four days to reach ITER. Adding to the weight of the coil (400 tonnes), the transport frame and trailer bring the total load to 800 tonnes.

DOMESTIC AGENCY PROCUREMENT HIGHLIGHTS

ITER CHINA (CN-DA)

www.iterchina.cn

PROCUREMENT ARRANGEMENTS*

Fourteen PAs signed since 2007 representing…

100% in number

100% of the total value of CN-DA in-kind contributions

Over 85 design or fabrication contracts related to ITER procurement have been signed with laboratories and industry.

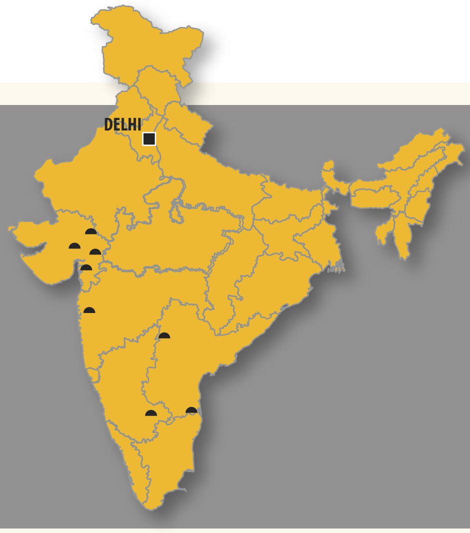
Chinese procurement highlights in 2020	% of ITER system procured by China
MAGNET SYSTEMS	
Toroidal Field Conductor	7.5%
All conductor unit lengths delivered	
Poloidal Field Conductor	65%
All conductor unit lengths delivered	
Magnet Supports	100%
10 of 18 gravity supports delivered to IO	
Correction coils: batch 2 and 3 supports delivered to IO; thermal shield for batch 1 and 2 also delivered	
Poloidal field (PF) coil supports: clamps and pipes for PF1 delivered to RF-DA	
Feeders	80%
Three batches (77 components) delivered, including four correction coil in-cryostat feeder rings	
Another 10 cryostat feedthroughs and coil terminal boxes in fabrication	
Correction Coils	100%
All 6 bottom correction coils (BCCs) manufactured	
BCC1 and BCC5 delivered to IO	
Top correction coils: series production underway	
Side correction coil (SCC) qualification ongoing; start of SCC case enclosure welding imminent	
Correction Coil and Feeder Conductors	100%
All correction coil and feeder conductors delivered	
POWER SYSTEMS	
Pulsed Power Electrical Network (PPEN)	100%
All components of PPEN sub-package delivered	
AC/DC Converters	55%
All main components of AC/DC converters delivered	
Most DC busbar supports and spares also delivered	
Reactive Power Compensation	100%
Cable and cable trays plus all reactive power compensation components delivered	
BLANKET	
Blanket First Wall	12.6%
Insulation coating for first wall components successfully developed and accepted by IO	
MRR completed for first wall full-scale prototype fabrication	
Blanket Shield Block	50.2%
316(L)N forgings completed for shield block #18 (SB18)	
Second hot helium leak test facility developed and commissioned	
Low friction coating demonstrated for SB components	
FUEL CYCLE	
Gas Injection System	100%
58 gas injection system manifold spools manufactured and delivered	
PDR for gas valve boxes closed; FDR preparation ongoing	
Glow Discharge Cleaning	100%
Sandwich design feasibility review completed	
DIAGNOSTICS	
Diagnostics	3.2%
Neutron flux monitor #07 support frame plus tools and spare delivered to IO; installation completed	
Divertor Langmuir probe preliminary design ongoing	
Preliminary design of remaining neutron flux monitors ongoing	
FDR closures ongoing for EQ#12 port integration and radial X-ray camera	

Abbreviations • **CDR** Conceptual Design Review • **DA** Domestic Agency • **FDR** Final Design Review • **I&C** Instrumentation & Control • **IO** ITER Organization • **IC** ITER Council • **FAT** Factory Acceptance Tests • **MIP** Manufacturing & Inspection Plans • **MRR** Manufacturing Readiness Review • **PA** Procurement Arrangement • **PDR** Preliminary Design Review • **SAT** Site Acceptance Tests

* Does not include Complementary Diagnostic Arrangements

ITER INDIA (IN-DA)

www.iter-india.org



PROCUREMENT ARRANGEMENTS*

Fourteen PAs signed since 2007 representing…

100% in number

100% of the total value of IN-DA in-kind contributions

50 design or fabrication contracts related to ITER procurement have been signed with industry and R&D organizations since 2007.

Indian procurement highlights in 2020	% of ITER system procured by India
CRYOSTAT	
Cryostat	100%
■ Completion and acceptance of cryostat upper cylinder **(IC milestone)**	
■ Base section and lower cylinder installed in Tokamak pit; welding for joining base to lower cylinder in final stage	
■ Manufacturing of top lid and all loose items (except top lid fasteners) completed in India. All major sectors shipped to IO	
CRYOGENIC SYSTEMS	
Cryolines & Cryodistribution	100%
■ Lower pipe chase cryolines completed	
■ More than 90% of cryoline header elements installed at B2 level of the Tokamak Building	
■ Incoming inspection and installation carried out for the cryoplant termination cold box (CTCB)	
■ Cold circulators manufactured; shipment to IO in progress	
■ Manufacturing and shipment of other cryolines in progress; installation continues at ITER site	
HEATING & CURRENT DRIVE SYSTEMS	
Diagnostic Neutral Beam (DNB) Power Supply and Beam Line	100%
■ Manufacturing of beam source and beam line components in advanced stage. FAT completed for the Indian Test Facility calorimeter	
■ Dummy assembly performed for the extractor and accelerator system grid mounting flanges to check for adherence to alignment requirements	
■ Hot helium leak tests performed for the first time on angled plasma grid segments, bias plate segments, and extractor grid segments (25 bar @ 150 °C) and on neutralizer panels (25 bar @ 80 °C)	
■ FDR for the DNB vacuum vessel held; chit resolution underway	
NBTF components (beam dump & 100 kV power supply)	2%
■ All NBTF components completed	
Ion Cyclotron Radio Frequency (RF) Power Sources	100%
■ In-house development of 3dB hybrid combiner and other transmission line components in progress	
■ Review of tender for driver and final stage amplifier for IO deliverables ongoing	
Ion Cyclotron Heating & Current Drive RF Power Supply (8 out of 18)	44%
■ Upgrade of controller hardware for high voltage power supply R&D unit in progress	
Electron Cyclotron High Voltage Power Supply	30%
■ Installation of 55kV, 110A main high voltage cathode power supply at ITER India lab in progress	
Electron Cyclotron RF Gyrotron Power Sources (2 gyrotrons out of 24)	8%
■ Contract signed for test gyrotron; design and manufacturing activities launched	
■ Factory testing of test gyrotron tube in progress, along with the matching optic unit	
COOLING WATER SYSTEMS	
Heat Rejection System, Component Cooling Water System, Chilled Water System	100%
■ Final consignments of pipes, pipe fittings and spares delivered to IO	
■ CCWS-2A water polishing units (first part) delivered after successful FAT	
■ FAT completed successfully for CCWS-2A water polishing units (last part)	
■ Stage-II of the contract completed	
■ Experimental pool scrubber tank (PST-X): design, manufacturing and FAT completed successfully as part of the Task Agreement	
VACUUM VESSEL	
In-Wall Shielding (IWS) Block Assemblies	100%
■ In-wall shielding blocks for all nine vacuum vessel sectors plus field joints manufactured	
■ All deliveries to KO-DA and EU-DA completed successfully	
■ SAT completed for all block assemblies delivered to EU-DA (5 vessel sectors); IWS SAT completed for three KO-DA vessel sectors out of four	
DIAGNOSTICS	
Diagnostics	3.1%
■ PDR-related activities continued for upper port #09	
■ Activities initiated toward final design of X-ray crystal spectroscopy (XRCS) survey system	
■ Experimental activities in lab carried out	
■ Design activities of several other systems/components progressing	

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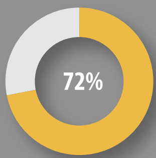
* Does not include Complementary Diagnostic Arrangements

ITER JAPAN (JA-DA)

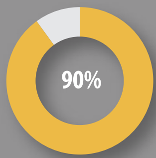
www.fusion.qst.go.jp/ITER/english/iter.html

PROCUREMENT ARRANGEMENTS*

Thirteen PAs signed since 2007 representing…



in number



of the total value of JA-DA in-kind contributions*

More than 800 design or fabrication contracts related to ITER procurement have been signed with industry since 2007.

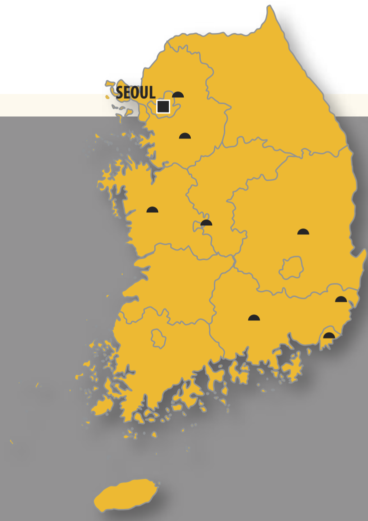
Japanese procurement highlights in 2020	% of ITER system procured by Japan
MAGNET SYSTEMS	
Toroidal Field Conductor	25%
■ All conductor unit lengths delivered	
Toroidal Field Magnet Windings (9 out of 19)	47%
■ Two toroidal field coils (#12, #13) delivered to IO	
■ Another JA-DA coil is ready for shipment; three others are in the coil insertion phase	
Toroidal Field Magnet Structures	100%
■ Seventh toroidal field coil structure (TFCS) set delivered to EU-DA	
■ Three other TFCS sets are under assembly with JA-DA winding packs	
Central Solenoid Conductor	100%
■ All conductor unit lengths delivered	
HEATING & CURRENT DRIVE SYSTEMS	
ITER & Neutral Beam Test Facility (NBTF) High Voltage Bushing	100%
and Accelerator	33%
■ Procurement of high voltage bushing completed	
Neutral Beam Power Supply System for ITER and NBTF	59%
■ Installation work 100% completed for power supply components	
■ High-voltage test underway	
Electron Cyclotron Radio Frequency Power Sources (8 gyrotrons out of 24)	33%
■ FAT gyrotron #3 completed	
■ Gyrotrons #6 and #7 manufactured	
■ Finalized fabrication and tests of #5-#8 anode/body power supply and control cubicles	
■ Two sets of magnets and matching optics units delivered to IO	
Electron Cyclotron Equatorial Launcher	71%
■ Cooling water feedthrough prototype test completed; prototype of millimetre wave propagation under preparation	
■ Final design of equatorial launcher in progress	
REMOTE HANDLING	
Blanket Remote Handling System	100%
■ Feasibility study for new requirements such as humid in-vessel atmosphere completed	
DIVERTOR	
Outer Target	100%
■ Plasma-facing unit prototypes (for high heat flux testing) and full-scale prototypes: contracts placed	
■ Contract placed for hot helium leak test facility design	
■ Contracts for series production materials placed (tungsten monoblocks, 316L tubes and forgings, XM-19 forgings)	
TRITIUM PLANT	
Atmosphere Detritiation System	50%
■ Progress on qualification activities: manufacture of integration system test rig ongoing	
■ Detritiation system joint procurement (phase II) signed with IO; joint procurement activities proceeding	
DIAGNOSTICS	
Diagnostics	14.2%
■ Contract awarded for microfission chamber end-processing of mineral insulated cable	
■ Structural design of edge Thomson scattering beam dump progressing	
■ FDR held for poloidal polarimeter retroreflector	
■ IR thermography: neutron and gamma ray irradiation tests for grasses advancing	
■ Thermal cycle tests completed for metal mirrors of divertor impurity monitor	

Abbreviations • **CDR** Conceptual Design Review • **DA** Domestic Agency • **FDR** Final Design Review • **I&C** Instrumentation & Control • **IO** ITER Organization • **IC** ITER Council • **FAT** Factory Acceptance Tests • **MIP** Manufacturing & Inspection Plans • **MRR** Manufacturing Readiness Review • **PA** Procurement Arrangement • **PDR** Preliminary Design Review • **SAT** Site Acceptance Tests

* Includes Complementary Diagnostic Arrangements

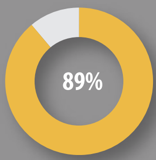
ITER KOREA (KO-DA)

www.iterkorea.org



PROCUREMENT ARRANGEMENTS*

Eight PAs signed since 2007 representing…



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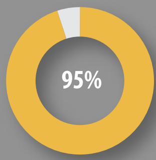

of the total value of KO-DA in-kind contributions

177 design or fabrication contracts related to ITER procurement have been signed with universities, laboratories and industry since 2007.

Korean procurement highlights in 2020 — **% of ITER system procured by Korea**

VACUUM VESSEL

Main Vessel (2 of 9 segments) — 21.20%

- First vacuum vessel sector (S#6) delivered to the ITER site **(IC milestone)**
- Activities progressing well on Sector #7 (98% complete), Sector #8 (92.4%), and Sector #1 (85%)

Equatorial Ports and Lower Ports — 100%

All lower port stub extensions delivered to sector workshops

- Neutral beam port in-wall shielding and field joint ex-wall shielding delivered to the port workshop and IO
- Vacuum vessel gravity support superbolt and insert manufacturing contract concluded in February

Blanket Shield Block — 49.82%

- Successful testing and certification of first production unit
- Series production underway; all row 6 shield blocks in manufacturing

POWER SYSTEMS

AC/DC Converters — 40.62%

- FAT completed for AC/DC converters CCU/L-2,3,4,5,6 and CS-2,3,4,5
- Delivery of AC/DC converters VS1-2, CCS-2,3 CCU/L-2,3,4,5,6 and CS-2,3,4
- Installation activities progressing on AC/DC converters VS1-1,2 CCS-1,2,3 CCU/L-1,2,3,4 and CS-1,2,3

MAGNET SYSTEMS

Toroidal Field Conductor — 20.18%

- All conductor unit lengths delivered

THERMAL SHIELD

Vacuum Vessel Thermal Shield and Cryostat Thermal Shield — 100%

- Delivery of thermal shield for vacuum vessel sector #6 accomplished **(IC milestone)**
- Thermal shield completed for all nine vacuum vessel sectors; shipments to ITER proceeding
- Cryostat thermal shield completed; shipments to ITER proceeding

ASSEMBLY TOOLING

Machine Assembly Tooling — 99.90%

- Frame and radial beams delivered to IO; sector lifting tool and upending tool passed all functional tests
- Central column, bottom cylinder, and in-pit working floor delivered to IO
- Ownership of 12 tools transferred to the ITER Organization

TRITIUM PLANT

Tritium Storage & Delivery — 94.24%

- PDR held in July; panel report approved in September
- Full-scale experimental getter bed performance test under practical operating conditions ongoing

DIAGNOSTICS

Diagnostics — 1.99%

- Manufacturing contract established for neutron activation system package #1
- Thermal cycling and steam ingress test conducted for vacuum ultraviolet spectrometer first mirror

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* Does not include Complementary Diagnostic Arrangements

ITER RUSSIA (RF-DA)

www.iterrf.ru

PROCUREMENT ARRANGEMENTS*

Twelve PAs signed since 2007 representing…

100% in number

100% of the total value of RF-DA in-kind contributions

800 design or fabrication contracts related to ITER procurement have been signed with industry since 2007.

Russian procurement highlights in 2020 — **% of ITER system procured by Russia**

POWER SYSTEMS

Switching Network, Fast Discharge Units, DC Busbar and Instrumentation — 100%

- Four batches of coil power supply systems delivered to ITER; others in manufacturing
- FDR held for DC busbars (toroidal) and fast discharge unit resistors

MAGNET SYSTEMS

Toroidal Field Conductor — 19.3%

- All conductor unit lengths delivered

Poloidal Field Conductor — 20%

- All conductor unit lengths delivered

Poloidal Field Magnet No.1 — 100%

- Preparation for impregnation completed, clamp assembly prepared; winding coil acceptance tests carried out
- Transport frame tested; delivery documentation in preparation

BLANKET

Blanket First Wall — 40%

- Coordination with IO on manufacturing and control documentation for full-scale prototype
- Trial manufacturing/testing of full-scale prototype elements (fastening system and electrical connection elements, finger cases, beam, central bolts)
- Hot isostatic pressing (HIP) of steel/bronze bimetallic covers done
- Longevity plasma testing of the thermal armour mockups (stage 2020) carried out; intermediate products manufactured

Blanket Module Connectors — 100%

- 530 bimetallic pedestals and corresponding inserts manufactured; 142 pedestals delivered
- Intermediate products manufactured for test blanket module connectors

DIVERTOR

Dome — 100%

- Full-scale prototype manufactured and prepared for delivery to IO; pre-shipment tests realized
- Pilot manufacture of semi-finished dome elements; longevity plasma testing of thermal armour mockups (stage 2020)

Plasma-Facing Component Tests — 100%

- High-heat flux testing of dome plasma-facing units in preparation
- Quality assurance documentation approved by IO

VACUUM VESSEL

Upper Ports — 100%

- Lateral upper ports/port stub extensions #01, #07, #13, #15, #17 manufactured
- Central upper ports/port stub extensions #16, #14 delivered to KO-DA
- Lateral upper ports/port stub extensions #03, #11, #09, #05, #01, #13 delivered to IO

Port Plug Test Facility (PPTF) — 100%

- Manufacturing started for dummy plug and handling system, non-nuclear stand #3 components
- Handling system MRR passed

DIAGNOSTICS

Diagnostics — 17%

Port Plug Integration Engineering

- 3D models of upper port #02, #07, and #08 structures updated to final design level
- Mockup manufactured for #02 gas/water inlet pipe (version 3); manufacture of #07 structure underway
- Equatorial port plug #11 structure (stage 1) manufactured; preparations made to manufacture structures for diagnostics systems integration
- Integration site subsystems created for testing of mockups for diagnostics system integration (stage 4)
- Front and back rack designs, rack locking systems developed for lower port #08 integration

Diagnostics

- Neutron flux monitor: data acquisition system prototype tested jointly with ITER-like fission chambers under intensive neutron flux at IBR-2 (JINR, Dubna); prototype detector unit developed and tested
- Mockups, components created for CXRS (Charge eXchange Recombination Spectroscopy) and vertical neutron camera; testing carried out
- Architecture developed for high field side reflectometer data collection and management system
- Functional mockup unit prototype manufactured for H-alpha and spectroscopy; mockups created for neutral particle analyzer and divertor Thomson scattering

HEATING & CURRENT DRIVE SYSTEMS

Electron Cyclotron Radio Frequency Power Sources (8 gyrotrons out of 24) — 33%

- Final FAT for set #5 carried out; manufacturing completed on set #6
- Materials for set #7 purchased

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* Does not include Complementary Diagnostic Arrangements

US ITER (US-DA)

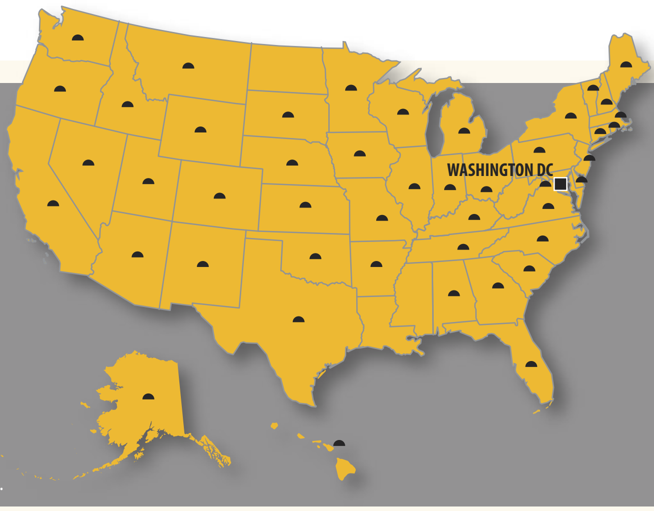
www.usiter.org

PROCUREMENT ARRANGEMENTS*

Seventeen PAs signed since 2007 representing…

100% in number

100% of the total value of US-DA in-kind contributions



The US has awarded more than 600 design or fabrication contracts to US industry, universities, and national laboratories in 46 states plus the District of Columbia since 2007.

US procurement highlights in 2020	% of ITER system procured by US
COOLING WATER SYSTEM	
Tokamak Cooling Water System	100%
■ Continued piping and fittings fabrication (via Arrangement with IO)	
■ Awarded remaining non-ESPN hardware required for First Plasma (FP)	
■ Continued progress in procuring ESPN hardware required for FP (via Arrangement with IO)	
MAGNET SYSTEMS	
Central Solenoid (CS) Modules, Structure and Assembly Tooling	100%
■ First central solenoid module successfully completed testing	
■ Twelve deliveries of structural components and assembly tools to ITER site	
Toroidal Field Conductor	8%
■ All conductor unit lengths delivered	
DIAGNOSTICS	
Port-Based Diagnostic Systems	14%
■ Low field side reflectometer completed final design review	
HEATING & CURRENT DRIVE SYSTEMS	
Ion Cyclotron Transmission Lines	88%
■ Transmission lines and matching system in development, using simulation tools and high-power tests in a dedicated lab	
Electron Cyclotron Transmission Lines	88%
■ FDR completed (Part 1)	
■ Awarded fabrication contract for the H3 chiller system	
■ Awarded waveguide manufacturing development contracts	
FUEL CYCLE	
Vacuum Auxiliary and Roughing Pump Stations	100%
■ PDR for roughing pump stations Part I of the cryostat and non-active service vacuum system roughing pumps and related I&C	
■ Awarded contract for the manufacture of cryogenic guard vacuum system	
Pellet Injection System	100%
Disruption Mitigation System up to a capped value	
■ Fabricated test hardware for shattered pellet injector experiments at JET and KSTAR	
TRITIUM PLANT	
Tokamak Exhaust Processing System	88%
POWER SYSTEMS	
Steady State Electrical Network	75%
■ All components delivered	

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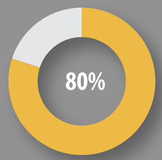
FUSION FOR ENERGY (EU-DA)

www.fusionforenergy.europa.eu

PROCUREMENT ARRANGEMENTS*

Thirty-nine PAs signed since 2007 representing…



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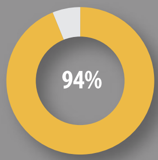

of the total value of EU-DA in-kind contributions

The EU has awarded 725 design or fabrication contracts related to ITER procurement to universities, laboratories and industry since 2007.

EU procurement highlights in 2020 — **% of ITER system procured by the EU**

BUILDINGS

Building Construction, Tokamak Pit Excavation and Drainage, Ground Support Structure, Seismic Isolation Pads — 100%
- Anti-seismic bearings completed
- Excavation and ground support completed
- Assembly Building completed **(IC milestone)**
- Limited crane access between Assembly Hall and Tokamak Building (RFE 1B stage 2) achieved **(IC milestone)**
- Tokamak Building access granted in L3 West area (T4-T5) to allow for feeder installation to begin **(IC milestone)**
- Site Services Building handed over to IO
- Contract signed for the completion of the Tritium Building (TB18)
- Contract signed for electrical equipment (TB13)

Architect Engineer Services — 100%

ITER Headquarters — 53.5%
- Headquarters building completed

MAGNET SYSTEMS

Toroidal Field Conductor — 20%
- All conductor unit lengths completed

Toroidal Field Magnet Windings and TF Coils (10 out of 19) — 53%
- Complete FAT for PA work scope for first EU toroidal field coil **(IC milestone)**
- 3 coils delivered to IO, 5 others in different stages of production
- 10 out of 10 winding packs completed; 8 delivered to insertion facility

Pre-Compression Rings — 100%
- All pre-compression rings completed in 2020

Poloidal Field Conductor — 18%
- All conductor unit lengths completed

Poloidal Field Magnets No. 2-6 — 100%
- PF5 ready for cold test **(IC milestone)**
- PF6 manufactured and delivered to IO **(IC milestone)**
- Impregnation completed on PF2; double pancake winding has begun for PF4

HEATING & CURRENT DRIVE SYSTEMS

Power Supply Heating Neutral Beam — 35%
- All NBTF power supplies completed, installed and transferred to IO

Neutral Beam Test Facility (NBTF) Components — 64.7%
- MITICA vacuum vessel completed, installed and transferred to IO
- Rotating platform for MITICA beam source installed
- SPIDER cesium ovens completed

Neutral Beam Assembly, Testing, Active Compensation & Correction Coils — 100%

Neutral Beam Source and High Voltage Bushing — 41%

Neutral Beam Pressure Vessel, Magnetic Shielding — 100%

Ion Cyclotron Antenna — 60%

Electron Cyclotron Control System — 40%
- First batch of cubicles delivered to IO site

Electron Cyclotron High Voltage Power Supply — 62%
- Second power supply set completed and delivered to IO
- MV AC cells (switchgears) for electron and ion cyclotron systems completed and delivered to IO

Electron Cyclotron Upper Launchers — 76%

Electron Cyclotron Radio Frequency Power Sources (6 gyrotrons out of 24) — 25%
- Procurement Arrangement for the Electron Cyclotron Radio Frequency Gyrotrons signed in September

VACUUM VESSEL

Main Vessel (5 of 9 segments) — 56%
- Final assembly phase started for Sector #5
- Outer shell welding started for Sectors # 4, #9, #3 and #2
- Risk and schedule optimization plans launched

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EU procurement highlights in 2020	% of ITER system procured by the EU
DIVERTOR	
Inner Vertical Targets	100%
First full-scale prototype (FSP) successfully completed; test assembly of a second FSP completed and ready for high heat flux testing	
Cassette Body	100%
Design, engineering and qualification phases for Stage I cassette body series production completed	
Divertor Rail	100%
BLANKET	
Blanket First Wall	47.4%
Framework contracts signed for series production	
Framework contracts signed for beryllium material procurement	
Call for tender launched for copper-chromium-zirconium alloy material procurement	
Procurement Arrangement for Blanket Manifolds signed in May	
REMOTE HANDLING	
In-vessel Divertor Remote Handling System	100%
Deep into the cassette toroidal mover final design; launched cassette multifunctional mover final design	
Cask and Plug Remote Handling System	100%
Completed preliminary design of MA-1 units, started the others	
Neutral Beam Remote Handling System	100%
Manufacturing the crane prototype in support of final design	
In-Vessel Viewing System	100%
Started prototyping in support of final design	
Common Technologies	100%
Camera demonstrator built and operated	
Multiplexer electronics generation 1 completed	
GENROBOT framework software integration into DTP2 (Divertor Test Platform 2) started	
POWER SYSTEMS	
Steady State Electrical Network (SSEN) and Pulsed Power Electrical Network (PPEN): Detailed System Engineering Design	100%
Installation and Commissioning	100%
LV and MV load centres for all First Plasma non-nuclear buildings are operational **(IC milestone)**	
Emergency Power Supply	100%
SSEN Components	25%
FUEL CYCLE	
Front End Cryo-Distribution: Warm Regeneration Lines	100%
Warm generation line package completed in 2020	
Front End Cryo-Distribution: Front End Cryopump Distribution	100%
FDR of cold valve boxes	
Cryopumps, Torus (6) and Cryostat (2)	100%
Qualification of special technologies	
Cryopumps, Neutral Beam	100%
Supply of all cryopanels and thermal radiation shields	
Qualification of charcoal coating process	
Leak Detection	100%
Award of leak detection system contract	
TRITIUM PLANT	
Water Detritiation System	100%
Water holding tanks and emergency tanks completed	
Hydrogen Isotope Separation System	100%
CRYOPLANT	
Cryoplant: LN2 Plant and Auxiliary Systems	50%
Completion of mechanical installation	
DIAGNOSTICS	
Diagnostics	25%
Four Complementary Diagnostics Arrangements (CDA) signed, completing all CDA arrangements envisaged	
All remaining outer vessel coils delivered to IO, completing the CDA	
First batch of inner vessel coil platforms delivered to IO site	
PDRs held for low field side collective Thomson scattering, radial neutron camera in-port plug systems, diagnostic pressure gauges, and magnetics software	
FDR held for vacuum vessel electrical feedthroughs	
RADIOACTIVE MATERIALS	
Waste Treatment and Storage	100%
Radiological Protection	100%
Call for tender for the supply of environmental and beryllium radiological and environmental monitoring systems	

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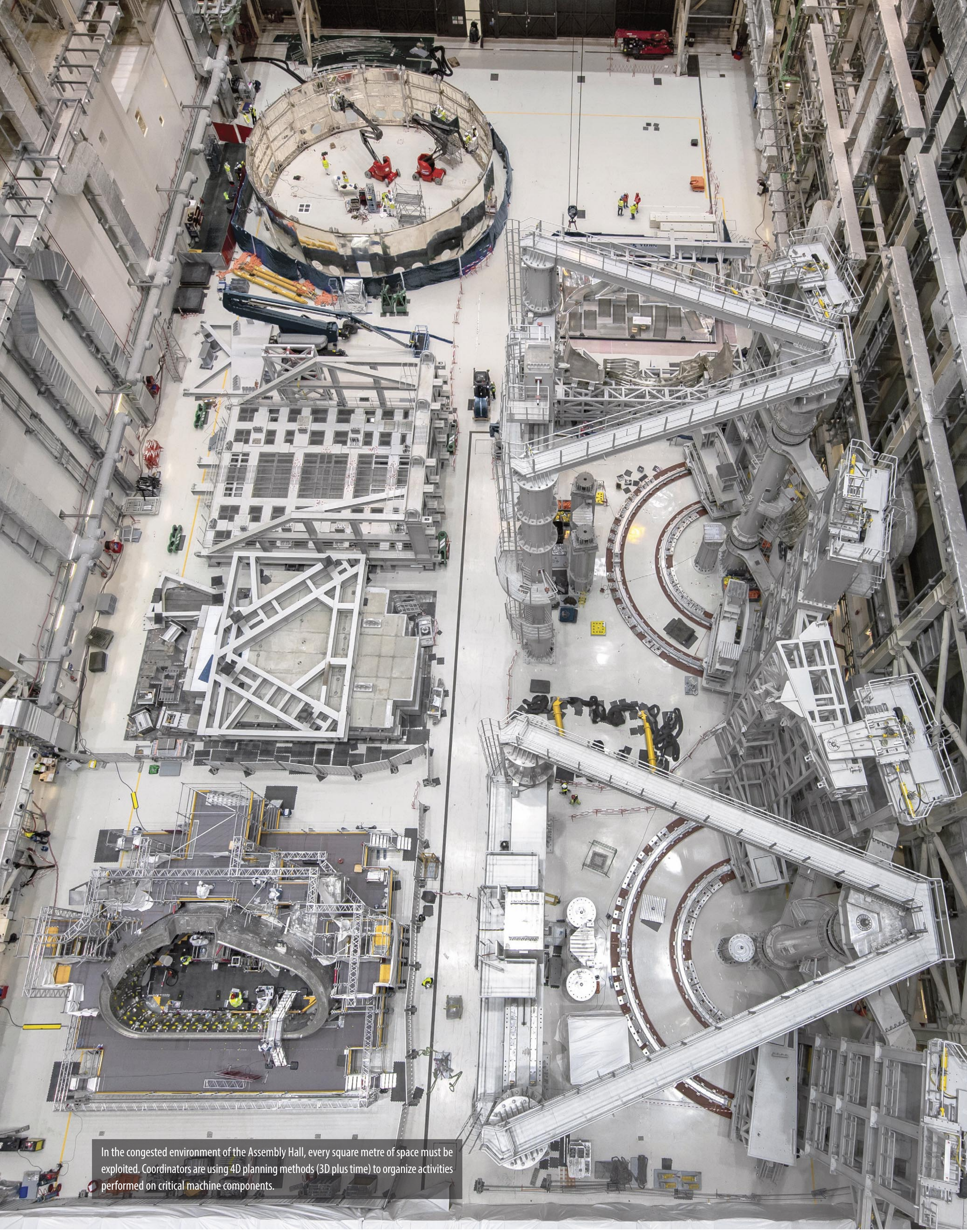

In the congested environment of the Assembly Hall, every square metre of space must be exploited. Coordinators are using 4D planning methods (3D plus time) to organize activities performed on critical machine components.

International Cooperation

The following entities have signed Cooperation Agreements with the ITER Organization (excludes agreements signed within the framework of the ITER Project Associates, Scientist Fellows, and ITER Operation Network programs.)

	Country
INTERNATIONAL ORGANIZATIONS	
International Atomic Energy Agency	**Austria**
CERN (European Organization for Nuclear Research)	**Switzerland**
NATIONAL LABORATORIES	
Belgian Nuclear Research Centre (SCK-CEN)	**Belgium**
Institute of Plasma Physics Chinese Academy of Sciences (ASIPP)	**China**
Southwestern Institute of Physics (SWIP)	**China**
Wuhan Institute of Technology	**China**
State Nuclear Power Engineering Company (SNPEC)	**China**
Institute of Plasma Physics of the Academy of Science of the Czech Republic (IPP-Prague)	**Czech Republic**
Commissariat à l'Energie Atomique et aux Energies alternatives (CEA)	**France**
Protisvalor Méditerranée	**France**
Karlsruhe Institute of Technology (KIT)	**Germany**
Max-Planck-Institut für Plasmaphysik (IPP)	**Germany**
Forschungszentrum Jülich Gmbh	**Germany**
Wigner Research Centre for Physics	**Hungary**
Società Gestione Impianti Nucleari (SOGIN-S.p.A)	**Italy**
National Institute for Fusion Science (NIFS)	**Japan**
Korea Institute of Fusion Energy (KFE) (former National Fusion Research Institute)	**Korea**
Nuclear Physics, Polish Academy of Sciences (IFJ Pan)	**Poland**
Instituto Superior Técnico (IST)	**Portugal**
The Ioffe Institute	**Russian Federation**
The Budker Institute of Nuclear Physics of Siberian Branch Russian Academy of Sciences (BINP SB RAS)	**Russian Federation**
Barcelona Supercomputing Center	**Spain**
Centro de Investigaciones Energeticas Medioambientales y Technologías (CIEMAT)	**Spain**
Catalonia Institute for Energy Research	**Spain**
United Kingdom Atomic Energy Authority (UKAEA-CCFE)	**United Kingdom**
UNIVERSITIES	
University of Leuven	**Belgium**
The Southwest Jiaotong University	**China**
University of Beihang (BUAA)	**China**
Huazhong University of Science and Technology	**China**
Dalian University of Technology (DLUT)	**China**
Anhui University of Science and Technology	**China**
Shanghai Jiao Tong University (SJTU)	**China**
Åland University of Applied Sciences	**Finland**
Université Aix-Marseille	**France**
Université Sorbonne Paris Nord	**France**
Centre for Energy Research	**Hungary**
University of Nirma	**India**
University of Pisa – Department of Civil and Industrial Engineering	**Italy**
University of Rome – Sapienza	**Italy**
University of Milano-Bicocca	**Italy**
University of Bologna – Department of Electronic and Information Engineering (DEI)	**Italy**
University of Rome Tor Vergata (URTV)	**Italy**
Universita degli studi di Brescia	**Italy**
University of Genoa – Department of Electrical, Electronic, Telecommunications Engineering and Naval Architecture (DITEN)	**Italy**
The Italian National Agency for New Technology, Energy and Sustainable Economic Development (ENEA)	**Italy**
Kyushu University	**Japan**
Kyoto University	**Japan**
Seoul National University	**Korea**
Eindhoven University of Technology	**Netherlands**
University of Ljubljana	**Slovenia**
Universidad Nacional de Educación a distancia (UNED)	**Spain**
Universidad de Sevilla	**Spain**
Universidad Politecnica de Madrid	**Spain**
University of Basel	**Switzerland**
University of Peter the Great St. Petersburg Polytechnic	**Russian Federation**
National Research TOMSK Polytechnic University (TPU)	**Russian Federation**
The National Research Nuclear University (Moscow Engineering Physics Institute- MEPhI)	**Russian Federation**
University of Strathclyde	**United Kingdom**
University of Columbia	**United States**
University of Wisconsin-Madison	**United States**
University of Texas-Austin	**United States**
University of Illinois	**United States**
Lehigh University	**United States**
University of California, Los Angeles (UCLA)	**United States**
NATIONAL SCHOOLS	
The Royal Institute of Technology (KTH)	**Sweden**
OTHER	
Broader Approach Activities (EU/Fusion for Energy + JA/National Institutes for Quantum and Radiological Science and Technology, QST)	**Europe/Japan**
Google Ireland Ltd	**Ireland**
Consortium RFX (ENEA, the University of Padova, Acciaierie Venete S.p.A., and the Italian National Institute for Nuclear Physics)	**Italy**
Nippon Telegraph and Telephone (NTT)	**Japan**

Organization chart

ITER COUNCIL

DIRECTOR-GENERAL BERNARD BIGOT

- DEPUTY OF THE DIRECTOR-GENERAL
- INTERNAL AUDIT SERVICE IAS
- OFFICE OF THE DIRECTOR-GENERAL ODG
  - LEGAL AFFAIRS LGA
  - COMMUNICATION COM
  - SENIOR ADVISERS SA
- ITER COUNCIL SECRETARIAT ICS

SAFETY AND QUALITY DEPARTMENT SQD

Security, Health & Safety
Occupational Health & Safety
Security

Environmental Protection & Nuclear Safety

Quality Management

CORPORATE DOMAIN CORP

FINANCE & PROCUREMENT DEPARTMENT FPD

Finance & Budget
Accounting, Treasury & Systems
Budget Management
Financial Control

Procurement & Contracts
Construction, Assembly & Logistics
Engineering, Science, Operation & Corporate

HUMAN RESOURCES DEPARTMENT HRD

Talent Management
Human Resources Services

PROJECT CONTROL OFFICE PCO

Engineering & Commissioning Project Control

Building & Construction Project Control

INFORMATION TECHNOLOGY

IT Applications & Development
IT Systems & Operation

SCIENCE AND OPERATION DOMAIN SCOP

SCIENCE, CONTROLS & OPERATION SCOD

Science
Experiments & Plasma Operation
Plasma Modelling & Analysis

Controls
Data, Connectivity & Software
Facility Control System
Central Control Integration

Operations
Electrical Power Distribution

ENGINEERING DOMAIN ENGN

CENTRAL INTEGRATION OFFICE CIO

Configuration Management
Design & Configuration Control
Document Control
Integrated Engineering Analyses

Physical & Functional Integration
Design Integration
System Integration

ENGINEERING DESIGN DEPARTMENT EDD

Port Plugs & Diagnostics
In-Vessel Diagnostics
Ex-Vessel Diagnostics
Diagnostic Engineering

Internal Components
Blanket
Divertor
Tritium Breeding Blanket Systems

Heating & Current Drive
Electron Cyclotron
Ion Cyclotron
Neutral Beam

Fuel Cycle
Fuel & Wall Conditioning
Tritium Plant

Remote Handling & Radwaste Management
Hot Cell & Radwaste
Remote Handling

DESIGN OFFICE

CAD Infrastructure
CAD Activities

CONSTRUCTION DOMAIN CNST

MACHINE CONSTRUCTION DEPARTMENT MCD

Machine Assembly Planning & Contract Management
Machine Assembly Integration

Sector Modules Delivery & Assembly
Vacuum Vessel
Toroidal Field Coils

Ex-Vessel Delivery & Assembly
Magnet
In-Cryostat, CTS, Auxiliaries

Tokamak Complex
Process Installation
Vacuum Delivery & Installation
Tokamak Cooling Water System

PLANT CONSTRUCTION DEPARTMENT PLD

Supply & Service Installation

Field Engineering Installation
Electrical Systems Installation Surveillance
Mechanical & Piping Installation Surveillance

Electrical Implementation
Coil Power Supply
I&C Infrastructure

Mechanical Implementation
Cooling, Mechanical & Welding
Cryogenics

CONSTRUCTION MANAGEMENT OFFICE CMO

Site Planning & Coordination
Site Management
Building & Civil Works

Caption cover image: With only 50 centimetres to spare on either side, the insertion of the cryostat base into the pit must be carefully planned and executed. In its final position at the bottom of the pit, metrology confirms that extreme accuracy (3 mm) has been achieved.

Looking ahead: 2021

Two poloidal field coils have been completed and a third is in fabrication in the European winding facility on site.

- Achieve first 1,200-tonne vacuum vessel sub-assembly
- Finalize cryostat top lid
- First central solenoid modules on site; begin structural assembly
- Install poloidal field coils #6 and #5 in pit
- Receive next-in-line vacuum vessel sectors
- Receive next-in-line toroidal field coils
- Launch cryoplant commissioning
- Lower first vacuum vessel sub-assembly in pit
- Start construction of ITER Control Building

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