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ANNUAL REPORT 2022

ITER ORGANIZATION

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WHAT IS ITER?

Seven ITER Members—China, the European Union, India, Japan, Korea, Russia and the United States—are collaborating to build the world's largest tokamak, a donut-shaped device that has been designed to prove the feasibility of fusion as a large-scale and carbon-free source of energy.

Based on the same energy source that powers our Sun and stars, fusion in the laboratory has only been achieved up to now for very short, intense bursts. ITER will take a major step forward by generating 500 MW of fusion power in its plasma for much longer pulses and by reaching a "burning plasma"—an environment in which the energy of the helium nuclei produced by the fusion reactions is enough to maintain the temperature of the plasma, reducing the need for external heating.

Understanding the dynamics of a burning plasma, and learning to sustain and control it, is critical to harnessing fusion power as a source of safe and sustainable energy for the world.

7 MEMBERS | 1 GOAL

This lift fixture in the Assembly Hall displaces the modules of the central solenoid through radial pressure. Nine rectangular wedge pads (three visible in this image) exert 220 kN of force each.


W3

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). The ITER Organization is licensed as a nuclear operator under French law.

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 the ITER Organization activities. (Article 18)

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2022 CONTENTS

ANNUAL REPORT

Visible progress on the worksite in 2022: the Tritium Building (concrete, centre) and the Control Building (foreground).

FOREWORD FROM THE CHAIR OF THE ITER COUNCIL

With the passing of Director-General Bernard Bigot on 14 May 2022, the ITER community lost a devoted and talented leader who contributed greatly to project progress over the seven years of his tenure. We will honour him best through our continued efforts, as a global team, to build and operate ITER. I would like to thank Eisuke Tada for leading the ITER Organization during the interim period and the ITER team for their continued efforts.

The ITER Council unanimously appointed Pietro Barabaschi Director-General of ITER Organization in September 2022 at an extraordinary meeting in Paris. Mr Barabaschi brings years of successful experience in fusion engineering, construction, and project management to his new role, which are key assets to lead the project through the critical months and years ahead.

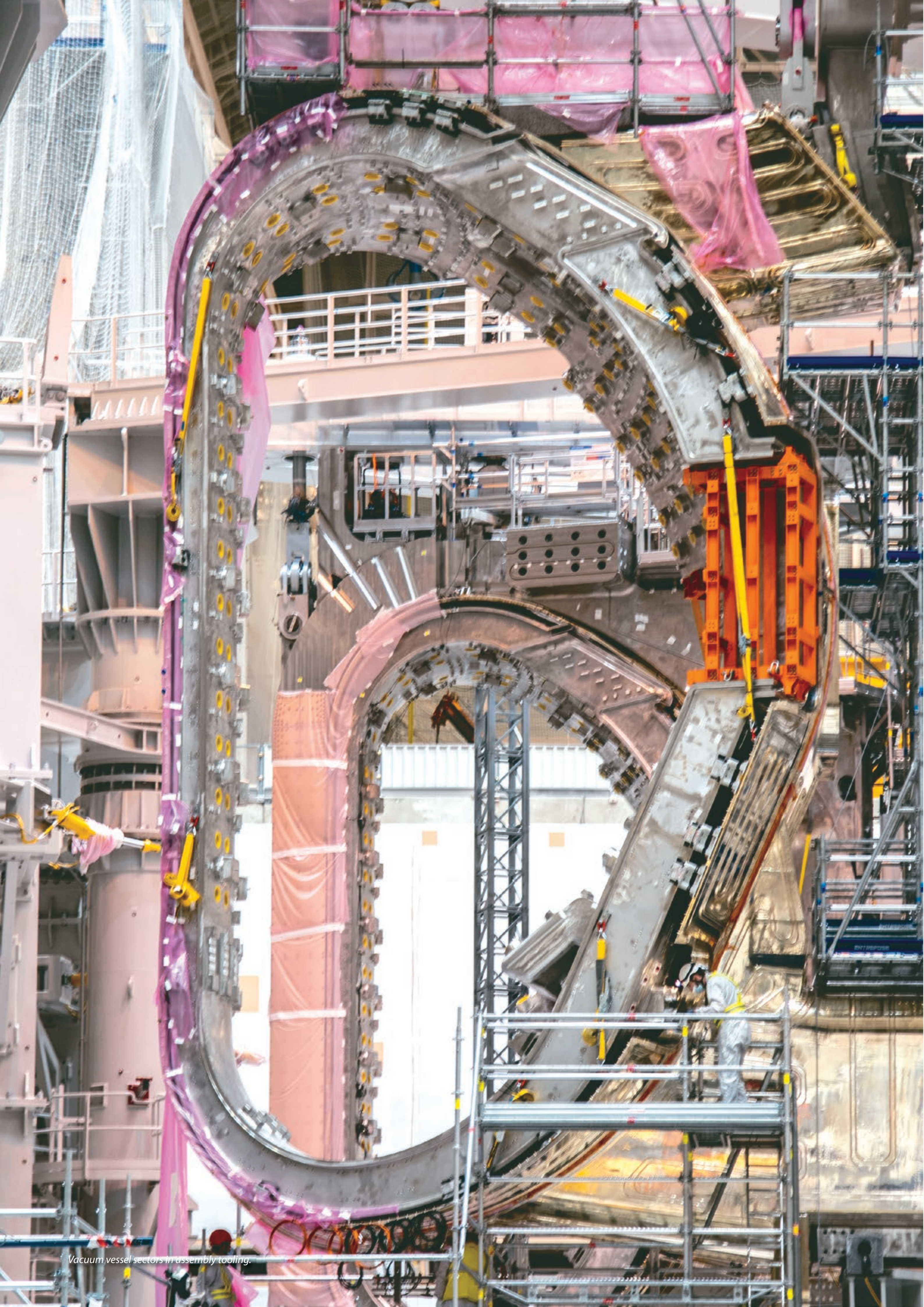
Since the ITER Council approved in November 2016 the new ITER Baseline, schedule slippages have accrued due to pandemic-related supply chain issues, to delays in the manufacturing of first-of-a-kind components, and to technical challenges with the assembly of these components. The discovery of quality issues affecting vacuum vessel sectors and thermal shield cooling pipes will further increase the delays with respect to the 2016 Baseline, making a comprehensive update of the project's technical scope, schedule and cost a top priority. The updating of the Baseline—a joint effort led by an ITER Organization/Domestic Agency task force—is underway now under the leadership of the new Director-General, with the expectation that a new Baseline proposal can be presented for Council consideration and approval in 2024.

As part of its work, the Baseline Development Task Force is revisiting the four-stage approach to ITER operation. Since important delays are unavoidable to achieve First Plasma, an "Augmented First Plasma" is under consideration as a way to enhance the scope and scientific value of ITER's first experimental campaign. Furthermore, merging of assembly and/or operation phases are considered to start the nuclear operation as soon as possible, close to the date planned in the 2016 Baseline. Two distinct nuclear phases are envisaged, designed around the achievement of specific project goals, which would enable a phased approach to ITER licensing. The ITER Council will have to approve this new Baseline based on these proposals from the ITER Organization. The ITER Council encourages the ITER Organization, as a nuclear operator, to develop a licensing approach that takes into account the learnings from the different stages of operation, the possible adjustments and their associated implications, in full transparency with the French Nuclear Safety Regulator (ASN) and under its authority.

The ITER Council also supports the Director-General's initiatives to encourage a project-wide culture of transparency, strengthen quality control measures at all stages of fabrication, improve technical quality culture as a way to mitigate project cost increases, and develop a highly performing construction structure with clear delegations of authority and responsibility. Such a structure is an absolute must for the project's success.

ITER has a historic role to play in determining the future of fusion as a source of energy and in fostering a global scientific and industrial ecosystem around it. The ITER Council will continue supervising the activities of the ITER Organization to ensure that it delivers on its objectives.

Massimo Garribba
Luxembourg
August 2023



Vacuum vessel sectors in assembly tooling.

FOREWORD FROM THE DIRECTOR-GENERAL

I was deeply honored by the decision of the ITER Council to appoint me as Director-General of the ITER Organization in September 2022. My first priority in taking up my duties was to carry out an exhaustive survey of project status. Although I have a familiarity with the ITER machine that dates back to my participation in its engineering phase, I had much to learn about the people, processes and systems in place and the interaction between different constituent parties to the project. As a first observation, I am pleased to say that there is a very high level of commitment at every level of the ITER Organization and the Domestic Agencies. This is the most important asset as we will seek as a team to deliver Project Phase 1, ending with plasma commissioning.

I consider the project to be at a critical juncture. Just as the challenges of the pandemic years were receding, defects were discovered in the ITER thermal shield and the vacuum vessel sectors. These are recoverable, but their repair/replacement will add delay and cost to the Project Baseline. Competitive tender processes have been launched for this recovery work, and contract signatures are expected soon; however, until the resources and time needed for the repairs have been specified and agreed upon, an update to the Baseline cannot be proposed. In the interim, project performance is tracked against the 2023 Annual Work Plan.

Technical setbacks of this nature are not unusual in first-of-a-kind engineering endeavours; indeed, in the course of assembling the complex ITER machine, we are likely to encounter further challenges. It is up to us to pay close attention to the root causes that have emerged in this instance and to use the lessons learned to grow a robust technical quality culture going forward—a culture in which technical issues can be flagged early, from anywhere in the project.

It is my assessment that a number of organizational changes would contribute positively to a change in culture. We have to establish an incentive structure that is aligned with the needs of the assembly phase of the project, and have clear lines of accountability within a matrix project structure. We need to better integrate the resources of the ITER Organization and those of the Domestic Agencies, and ensure that Domestic Agency specialists can be on site and engaged when their equipment is being installed and commissioned. We need a more agile structure at the ITER Organization, with fewer management layers, no silos, and increased top-down delegation. And we need to simplify our procedures and improve shared tools and processes. I have already taken some steps in these directions and will continue to implement this vision throughout 2023.

The context of reverse works and repair activities in the year ahead is also an opportunity to advance on other fronts. Previously known delays caused by Covid-related stoppages and other challenges related to the manufacturing of first-of-a-kind machine components will be addressed in parallel. The exercise underway to update our assembly hold point nuclear licensing files offers the occasion to revisit the planned four stages to full fusion power and consider adjustments that will enrichen our first operational campaign while limiting delay to the start of deuterium-deuterium and deuterium-tritium plasma operation. Potential future technical risks will be carefully weighed and mitigation strategies proposed.

Transition periods are never easy, and I am grateful for the trust placed in me by the ITER Members, and by my colleagues at the ITER Organization and the seven Domestic Agencies. It is obvious to me that the pride to work toward the ITER goal remains high, and this gives me even more energy to strive to make ITER a wonderful place to work, where all contributions are recognized, and where we work as a team to contribute to the fulfilment of the promise of fusion. I look forward to a productive year ahead.

Pietro Barabaschi
St. Paul-lez-Durance
June 2023

PROJECT
STATUS 2022

The ITER assembly theatre.

PROCUREMENT ARRANGEMENT* SIGNATURES

91.7% IN NUMBER

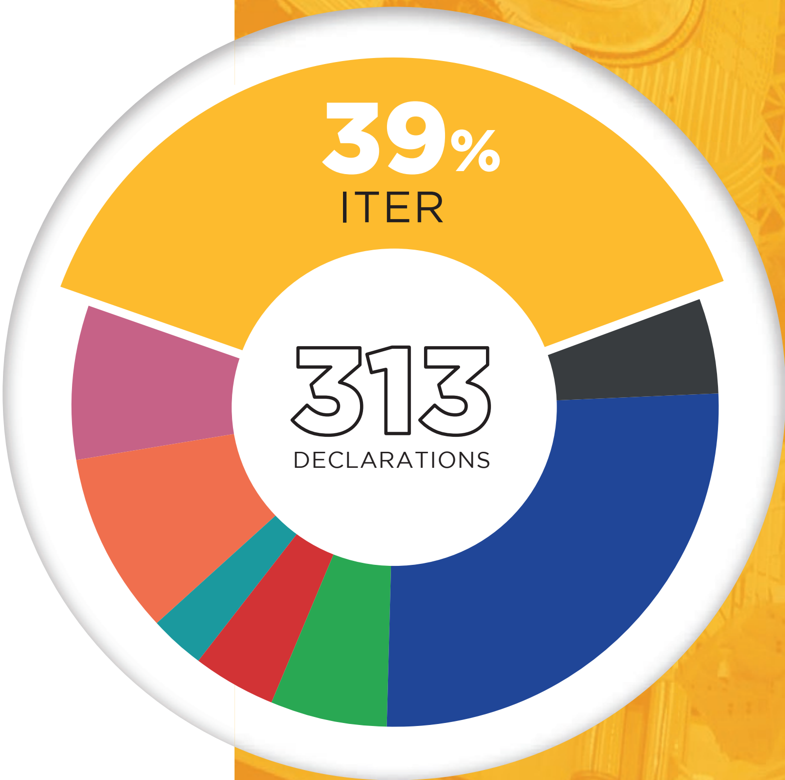
97.9% IN VALUE

* 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*

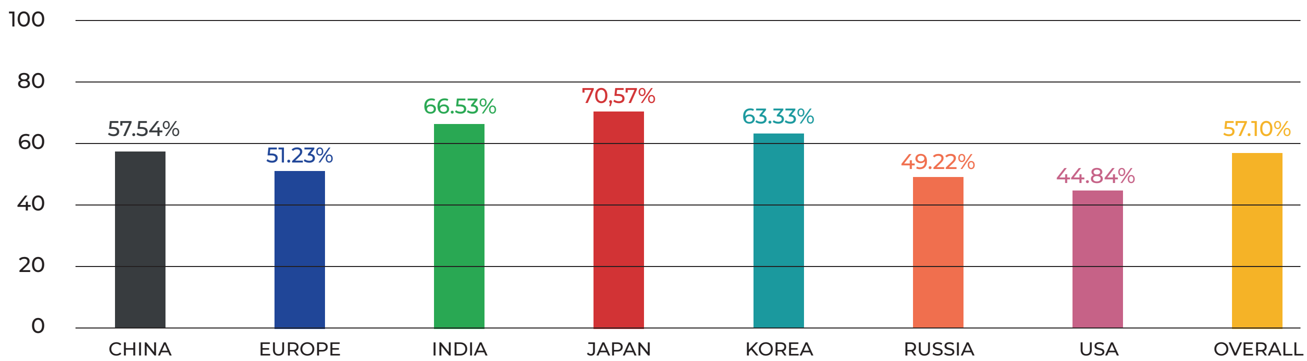
Declaration of
Generated Intellectual Property,
cumulative

- CHINA **5%**
- EUROPE **26%**
- INDIA **6%**
- JAPAN **4%**
- KOREA **3%**
- RUSSIA **9%**
- USA **8%**

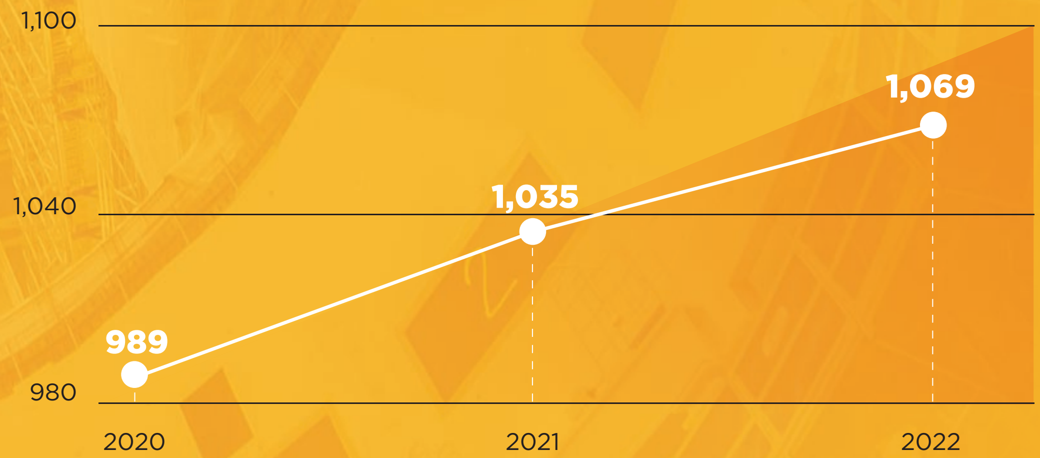


* The ITER Organization and the seven Members support the widest appropriate dissemination of intellectual property generated in the course of activities for ITER.

% CREDIT RELEASED (of signed Procurement Arrangements)

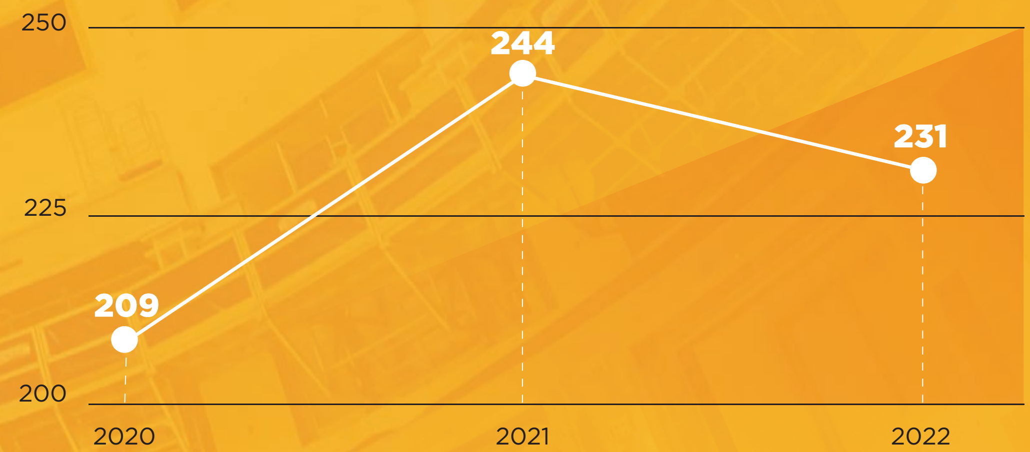


STAFF
(see page 44)



ITER PROJECT ASSOCIATES*

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



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CONSTRUCTION UPDATE 2022

ITER plant systems are distributed in buildings on both sides of the Tokamak Complex. Some 70% of plant system equipment has been installed.

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. Overall platform coordination is now managed by the ITER Organization.

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

Site image courtesy of Fusion for Energy.

A TOKAMAK COMPLEX
- Backfilling of penetrations
- Installation of captive components
- Ducts, supports, cable trays, cables, piping
- First pressure equipment (volume control tank) installed
- Vacuum vessel sector module #6 lowered into pit
- Tritium Building construction reaches level L5

B ASSEMBLY HALL
- First sector sub-assembly created on SSAT tooling
- Central solenoid lift fixture tested
- First central solenoid module on assembly platform

C CRYOPLANT
- Cryobridge to Tokamak Complex erected
- Completion of nitrogen storage area; tanks filled
- Liquid helium plant commissioning

D MAGNET POWER CONVERSION
- All First Plasma equipment installed
- Sub-system testing and commissioning underway

E CRYOSTAT WORKSHOP
- Last cryostat section (top lid) completed in March
- Building to be converted to the ITER Maintenance Test Facility

F RADIO FREQUENCY HEATING
- First electron cyclotron high voltage power supplies installed

G STORAGE
- Foundation built for cryostat lid

H SITE SERVICES BUILDING
- Now distributing cooling water and compressed air

I COOLING TOWER ZONE
- Final testing, inspection and walkdown completed
- Commissioning underway

J ELECTRICAL SWITCHYARD
- Reactive power compensation low-voltage commissioning

K EUROPEAN WINDING FACILITY
- End-stage manufacturing progressing on PF4 and PF3
- Winding table dismantled
- Cold test chamber mounted for PF4

L ITER HEADQUARTERS
- Work starts on the Scientific Data and Computing Center

M CONTROL BUILDING
- Civil works completed for non-nuclear building
- Ready-for-equipment milestone achieved
- First cubicles in server room

N NEUTRAL BEAM POWER SUPPLY
- Foundations completed
- High Voltage Building: structural frame erected
- Power Supply Building: civil works progressing

BUILDINGS TO COME

1 HOT CELL COMPLEX

2 EMERGENCY POWER SUPPLY

MACHINE

FEBRUARY

11 Two gyrotron sets (Japan)

25 SIXTH AND LAST BOTTOM CORRECTION COIL INSTALLED

MARCH

1 Radial beam wall supports finalized
7 Feeder segments: first joints
18 Toroidal field coil #16 (Japan)
24 Cryostat top lid (India)
25 In-pit sector assembly tooling finalized

APRIL

1 Vacuum vessel sector #8 (Korea)
11 Final metrology completed on sector module #6
15 Second sector sub-assembly (#1(7)) underway
20 Final batch of cryolines (India)
25 Toroidal field coil in-pit alignment tool (TIPI) ready for first module

MAY

6 Toroidal field coil #17 (Europe)

11 FIRST VACUUM VESSEL SECTOR MODULE (#6) INSTALLED

20 Central solenoid lift tool tests

JUNE

10 Temporary HVAC works completed in pit

JULY

8 Toroidal field coil #14 (Europe)
15 First feeder assembly joint connection completed
21 Central solenoid module #1 installed on assembly platform

SEPTEMBER

6 Central solenoid module #2 moved to assembly zone
9 Sector module #6: coil alignment achieved in pit
13 Third vacuum vessel sector (#8) docked in tooling

OCTOBER

12 Four gyrotron sets (Russia)
12 Set of handling tools for in-vessel installation finalized
19 Preservation activities on coils PF6 and PF5 in pit

NOVEMBER

21 Final reports received from expert groups; technical setbacks announced

DECEMBER

1 Studies ongoing for thermal shield cooling pipe and vacuum vessel sector bevel joint repair
10 Reverse activities underway on sector sub-assembly #1(7)
18 Planning for de-installation of sector #6 in Assembly Hall

Assembly in pit | **Arrivals** | **Assembly prep/ pre-assembly**

An operator monitors the first-completed sector module as it is lifted from tooling.


Cryoline installation in the Tokamak Complex.

A D-shaped toroidal field coil leaves Japan.

CONSTRUCTION UPDATE

–

ASSEMBLING THE MACHINE INSTALLING THE PLANT

PROGRESS PER AREA

WORKSITE 1
19%
MACHINE ASSEMBLY IN THE TOKAMAK BUILDING AND ASSEMBLY HALL

–

WORKSITE 2
16%
PLANT INSTALLATION IN THE TOKAMAK COMPLEX

–

WORKSITE 3
70%
PLANT INSTALLATION OUTSIDE OF ZONES 1 AND 2

In May 2022, the first of the nine modules required for the torus-shaped vacuum vessel was slowly extracted from sub-assembly tooling, transported over the wall separating the Assembly Hall from the Tokamak pit, and lowered with sub-millimetric precision onto its supports. The 1,380-tonne lift, which approached the very limits of the mechanical capacities of the overhead cranes and the building structure, required months of planning and a 50-person team to execute; metrology later confirmed that the final in-pit configuration, including coil alignment, was compliant with all operational and engineering requirements. Two and a half years into machine assembly the ITER Organization, its Construction Management-as-Agent contractor MOMENTUM, and the assembly contractors are working together and in concert with the Domestic Agencies who are providing the components to carry out the small and large tasks of the assembly program ... and to react to the unexpected.

TECHNICAL SETBACKS – In November, the project reported that vacuum vessel assembly would be halted as two key components—the thermal shield and the vacuum vessel sectors—required repair. The announcement came after many months of analysis by in-house and external experts in order to identify the source and the extent of the problems. For the thermal shield, analysis determined that the instances of stress corrosion cracking found in the cooling circuit were caused by a slow chemical reaction linked to the presence of chlorine residues near the pipe welds, compounded by the bending and welding of the pipes to the panels. Because this problem may affect other panels in time, repairs will involve replacing all cooling pipes. For the vacuum vessel, in-factory welding to form the D-shaped sectors from four smaller segments caused deviations from nominal dimensions in the three sectors that have been delivered. These dimensional non-conformities have modified the geometry of the outer shell field joints where the sectors are to be welded together, compromising the automated welding process. The geometry of these sectors must be restored to specification.

REPAIR PLANS – Experts from within the ITER Organization/Domestic Agency teams and Member industries are contributing to the development of remediation strategies. Planning is also underway to sequence the logistical operations that must precede repairs, including the removal of sector #8 from tooling, the

disassembly of sector module #1(7) in vertical tooling, and the transfer of sector module #6 from the Tokamak pit to tooling for disassembly. In addition to these reverse works, decisions must be made on where to store disassembled components, where to carry out the different repairs, and how to manage the impact on assembly contracts.

MACHINE ASSEMBLY THEATRE – The first 110-tonne central solenoid module has been transferred to the bespoke platform designed to support the construction of the magnet tower, formed from six stacked modules and a support structure. After completing superconducting electrical connections, the teams will carry out the final alignment of the first module before adding the second, which is already positioned in the central solenoid assembly zone. At the bottom of the Tokamak pit, contractors carried out preservation activities on poloidal field coils #6 and #5 to ensure that the components are maintained in good condition until commissioning for operation; they also completed the installation of the final bottom correction coil. The successful lowering of vacuum vessel sector module #6 was a major in-pit assembly achievement, validating the lifting equipment, the techniques and procedures, the coordination of the team, the safety protocols, and the metrology and alignment activities of an operation that will be repeated many times.

TOKAMAK COMPLEX – The Tokamak Complex is being equipped with a steady inflow of plant equipment, as cryolines, piping and piping supports, fuelling manifold spools, ducts, busbars, fast discharge units, and cable trays and supports are installed by the Tokamak Complex contractors according to planned sequences. A Design Integration Board is active in ensuring that these extensive system installation works are carried out in an integrated, clash-free manner. Another major focus is the installation of magnet feeder segments: 29 feeder segments have now been set in place in the galleries (out of 37 delivered) and contractors have successfully completed the first feeder joint assembly, joining the coil termination box for toroidal field coil #12 to its cryostat feedthrough. The first nuclear pressure equipment vessel, a volume control tank, was installed in 2022. Contractors also worked to place captive components, such as those serving laser and microwave diagnostic systems, in galleries and wall penetrations before access is cut off by other systems.

BALANCE OF PLANT – Just over 70 percent of installation tasks on Worksite 3—covering all areas outside of the Assembly Hall and Tokamak Complex—have been completed. The first activities under balance of plant contract BOP3 (electrical distribution) are underway, as field components and instrumentation and control cubicles are positioned around the site. Cubicle installation has begun in the main server room of the non-nuclear Control Building, and the first electron cyclotron high voltage power supplies delivered by Europe now equip the Radio Frequency Building. The Site Services Building has started distributing compressed air and demineralized water for commissioning activities.

MAJOR COMPONENT ARRIVALS – The on-time delivery of in-kind contributions from the Domestic Agencies continues to be a key driver for the progress of ITER assembly and installation. Since 2015, 132 "highly exceptional loads" have reached ITER; in 2022, these included three toroidal field coils (Europe, Japan), one vacuum vessel sector (Korea) and large feeder components (China). In addition, India completed the top lid of the cryostat, Russia initiated the first leg of transport for completed poloidal field coil #1, India delivered its last batch of cryolines, and both Japan and Russia delivered gyrotron sets to the ITER site.

Monthly management site visits.

iter

china eu india japan korea russia usa

ENGINEERING AND MANUFACTURING UPDATE 2022

Prior to final resin impregnation, poloidal field coil #4 (PF4) is manually wrapped with nine successive layers of glass-Kapton tape for electrical insulation.


W.L.L / C.M.U : 20 T
W.L.L / C.M.U : 20 T
W.L.L / C.M.U : 20 T
W.L.L / C.M.U : 20 T

KEY COMPONENTS

Hundreds of labs and companies around the world, through thousands of contracts, are helping to design, qualify, manufacture, and deliver state-of-the-art components for the ITER machine and plant. In contributing these in-kind contributions to ITER, the Members are also investing in the technological and industrial basis at home for the fusion industry of the future. In comparison with previous years, in 2022 manufacturing and delivery were much less affected by pandemic-related factory closures or shipping backlogs. That said, assembly activities related to the vacuum vessel had to be halted due to non-conformities identified in the bevel joint region of the sectors and the discovery of some instances of stress corrosion cracking in the thermal shield's cooling circuit. To repair these defects, the steps taken to assemble the vacuum vessel sector modules will have to be reversed.

A VACUUM VESSEL

Nine vacuum vessel sectors supplied by Europe and Korea are necessary to complete the torus-shaped plasma chamber, which houses the fusion reactions and acts as a first safety containment barrier. Five sectors are progressing in Europe, where completion rates range from 84% to 98%. **Korea delivered its third sector (#8) in April**, and has completed final assembly in factory on sector, #7(1). Vacuum vessel port fabrication continues in Korea (equatorial and lower) and Russia (upper), and all in-wall shielding has been delivered by India. At ITER, the first vacuum vessel module—created by assembling sector #6 with its thermal shield and two toroidal field coils—was successfully installed in the Tokamak pit in May 2022. This operation will have to be reversed in 2023, however, due to the necessary repair of non-conformities discovered on the three delivered sectors and defects in the cooling circuit of the thermal shield.

B CRYOSTAT

The ITER cryostat—the largest-volume stainless steel high-vacuum pressure chamber ever built—provides the high vacuum, ultra-cool environment for the ITER vacuum vessel and the superconducting magnets. Manufacturing took place in two stages: the fabrication of 54 segments in India, and their subsequent assembly at ITER into four large sections (base, lower cylinder, upper cylinder, top lid) in the Cryostat Workshop on site. **In 2022, the last section—the 665-tonne top lid—was completed**; now, the top lid will be wrapped protectively and stored outdoors until it is needed in the machine assembly sequence. Other elements of the cryostat scope, such as the torus cryopump housing (India) and the rectangular bellows (ITER), are in fabrication. India is also in charge of the welding activities inside the Tokamak pit that will create the final cryostat chamber.

C CENTRAL SOLENOID

The United States—responsible for delivering seven central solenoid modules (including one spare), all elements of the central solenoid support structure, and assembly tooling—is only a few percentage points from completing its scope. Two central solenoid modules have been delivered to ITER, and work to finalize five others is proceeding at a dedicated contractor facility. **All tooling components were completed in 2022** and are ready for shipment. **The first module has been placed on a dedicated platform** in the Assembly Hall and aligned; over the next years, the 18-metre-tall central solenoid tower will take shape under the responsibility of the ITER Organization team. The central solenoid is the "backbone" of ITER's magnet system, allowing a powerful current to be induced in the plasma and maintained during long plasma pulses. The niobium-tin superconductor for the central solenoid was supplied by Japan.

D TOROIDAL FIELD MAGNETS

Since 2020, 13 toroidal field coils have arrived at ITER; another two are currently travelling. **Only four coils, including one spare, remain to be finalized** at factories in Europe and Japan. Two coil pairs have already been mounted as part of vacuum vessel sub-assemblies on site, with coil alignment achieved in-pit for vacuum vessel module #6; these accomplishments will have to be reversed, however, to allow for repair work on the vacuum vessel sectors and thermal shield panels. The primary function of the toroidal field magnets is to produce a magnetic field that confines the plasma particles.

E POLOIDAL FIELD MAGNETS

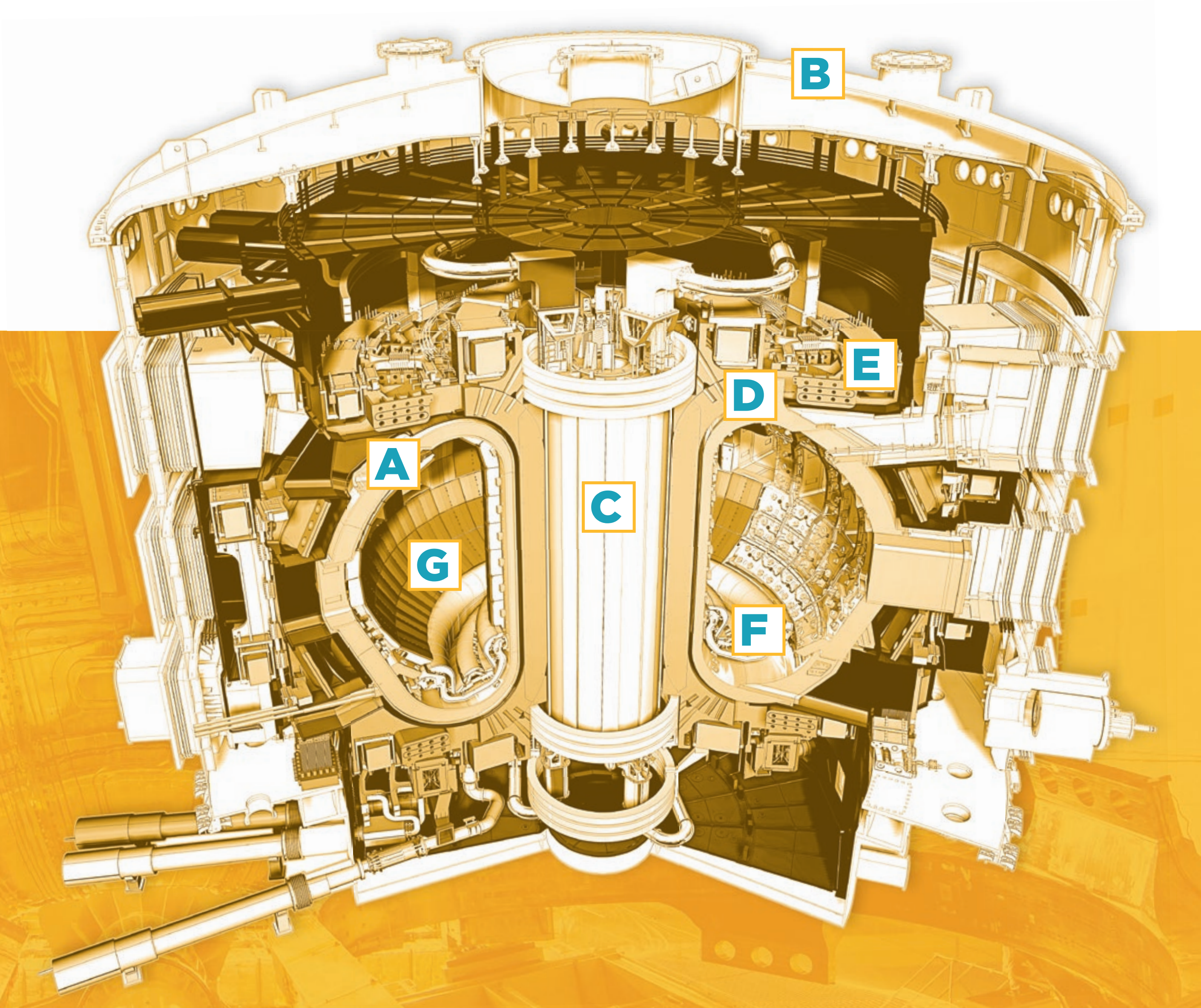
Like the toroidal field magnet system, the poloidal field magnets are nearing the end of the procurement program (and two have already been installed in the machine). In Russia, **all factory acceptance testing on PF1 was completed** in March and the first leg of component transport to ITER initiated; the coil will reach ITER early next year. Europe, after procuring PF6 from China in 2020 and completing PF5 and PF2 in its coil assembly facility on site in 2021, is now finalizing the last two coils. After progressing through all fabrication steps, **ring coil PF4 is ready for cold testing**. PF3, expected for delivery in early 2024, has passed the winding pack resin impregnation stage. Six poloidal field magnets will work together to help shape the plasma and contribute to its stability.

F DIVERTOR

Responsible for exhausting unspent fuel and helium ash from the ITER plasma, the divertor is built from 54 cassette assemblies attached to rails at the bottom of the vacuum vessel. These assemblies include a cassette body and three plasma-facing "targets" covered in tungsten tiles (the dome, inner vertical target and outer vertical target). Two suppliers in Europe are advancing the **series production of the intricately shaped cassette bodies**, with deliveries planned between 2025 and 2027. **Manufacturing is also starting for the plasma-facing elements**: in Russia, sub-parts of the dome have entered production; in Japan, manufacturing readiness reviews have been passed for the outer vertical target and steel support structure; and in Europe, the first production contract has been concluded for the inner vertical target.

G BLANKET

In a tokamak, the blanket shields the steel vacuum vessel and external machine components from high-energy neutrons produced during the fusion reaction. ITER has chosen a modular system, with 440 actively cooled blanket modules covering the inboard and outboard surfaces of the plasma chamber—each composed of a massive shield block and a plasma-facing first wall. In China and Korea, **shield block manufacturing is proceeding row by row, with 50% of scope completed**. The fabrication of ancillary systems such as module connectors (Russia) and cooling manifolds (Europe) is also progressing. Teams in China, Europe and Russia **are qualifying full-scale first wall prototypes**, including factory acceptance and high heat flux testing. These prototypes are critical to demonstrating that the challenging sub-millimetric tolerances specified for plasma-facing surfaces can be achieved.



ENGINEERING AND MANUFACTURING 2022

• Contributors to Europe's toroidal field coil procurement program gathered in May to celebrate the completion of TF14—the eighth toroidal field coil out of ten to be supplied to the ITER Project. This long-term procurement project in Europe, which will conclude in 2023, has mobilized 40 companies and 700 people. © SIMIC 1

• Correction coils installed between the major toroidal and poloidal field magnet systems will act to correct field errors caused by deviations in the shape or position of the main coils. All six bottom coils are in place in the machine; 12 others are in fabrication in China. Fully 85% of the manufacturing scope has been completed 2

• The technical specifications for ITER's full complement of in-kind diagnostic systems are contained in 54 Procurement Arrangements/Complementary Diagnostic Procurement Arrangements (CDPs) representing 66 projects. All Arrangements have now been concluded with the seven ITER Domestic Agencies, and just over 40% of the total work scope has been realized.

• India is making progress on elements of the diagnostic neutral beam, including the beam source and beamline components. The probe beam from this diagnostic will detect helium ash in the plasma.

• Eighty-five large rectangular bellows will be used between the ITER vacuum vessel, the cryostat and the walls of the Tokamak Building to isolate the ultra-high vacuum inside the cryostat from the building environment and to compensate relative movement that can occur. With the successful conclusion of the Manufacturing Readiness Review, series production is now underway in China under an ITER Organization contract.

• Tokamak exhaust processing is the tritium plant sub-system responsible for separating hydrogen isotopes from impurities. The system is currently in the final design stage under the responsibility of US ITER.

1

• The neutral beam cell, a two-story gallery inside the Tokamak Building that will house ITER's heating and diagnostic neutral beam injectors, will be equipped with a remote handling system for scheduled and non-scheduled maintenance tasks. An important part of the handling system is the monorail crane, which will move along ceiling rails to access different parts of the gallery. A prototype has been successfully tested, opening the way for the European Domestic Agency to award a contract for the final design phase of the system 3

• The smallest of ITER's six ring-shaped poloidal field coils, PF1, passed all factory tests in Russia in March. The 160-tonne coil has left Saint Petersburg and will be delivered to the ITER site in early 2023. 4

• The European Domestic Agency is supplying the mechanical components of the MITICA test bed—a full-scale prototype heating neutral beam injector that is in construction now at the ITER Neutral Beam Test Facility in Padua, Italy. Two major components, the beam source (photo) and the cryopump, are at an advanced stage of fabrication. 5

• Plasma disruptions—which create a sudden loss of stored thermal and magnetic energy—occur on all tokamaks, but ITER's size and high plasma current mean that the stored energies are at least an order of magnitude larger than on previous devices. The ITER Organization is planning a disruption mitigation system to protect machine components against excessive heat loads and electromagnetic forces resulting from these disruptions. Through collaborations with institutions and companies worldwide, strides are being made toward design validation and the development of novel concepts and components for the selected technology—shattered pellet injection—which delivers massive amounts of protium and neon in the form of small ice fragments into the plasma to convert the energy into radiation. 6

• Because the blanket and divertor will not have been installed when ITER begins operations, a temporary protective structure composed of first plasma protection components is planned. In China, a prototype limiter has been manufactured for test purposes; other prototype components are also underway.

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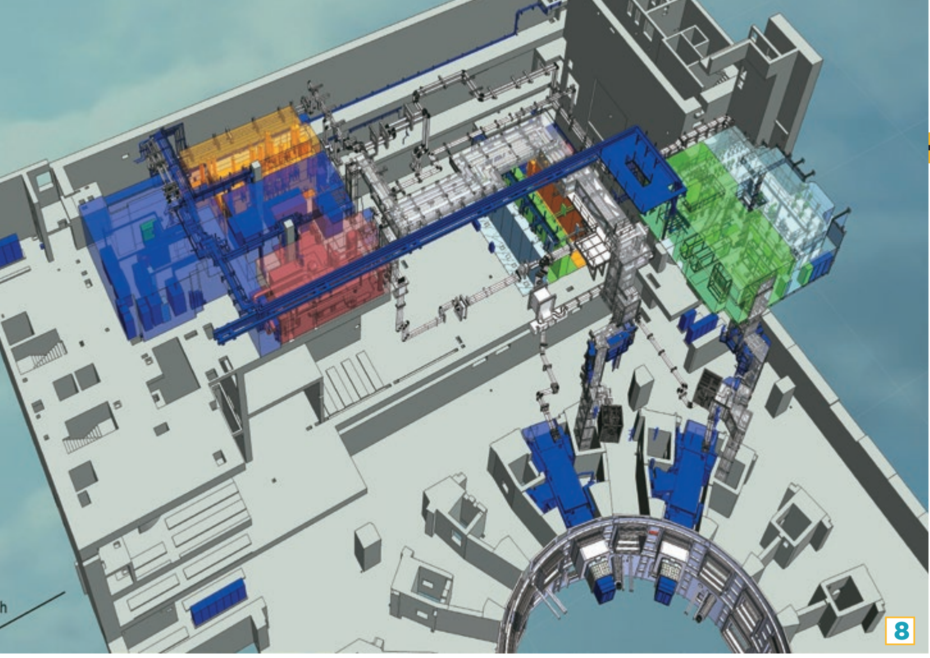

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- Every *port* in the ITER vacuum vessel has a corresponding *port cell* in the Tokamak Building; these corridor-like spaces allow heating and fuelling pipes, electricity cables, diagnostic lines and maintenance systems to pass through to the machine from outlying galleries. The ITER Organization is using a real-size mockup to perform safety-related tests and to practice maintenance actions for port-based diagnostic components. 7
- US ITER—responsible for 100% of the design, engineering, and procurement of the Tokamak Cooling Water System—is working closely with the ITER Organization under a work-sharing arrangement to expedite the design and fabrication of systems and components needed for First Plasma. Ultimately, over 100 major pieces of equipment, 3,000 valves, and 43.7 kilometres of piping will be required for this system, which provides heat removal during plasma operation from the vacuum vessel, in-vessel components, and the neutral beam injectors, as well as water chemistry control and draining/drying functions.

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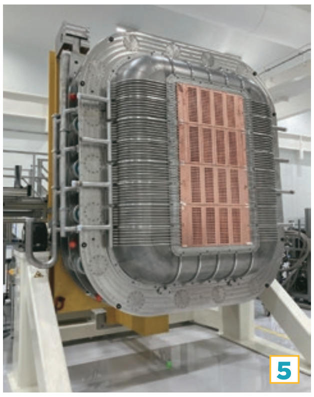

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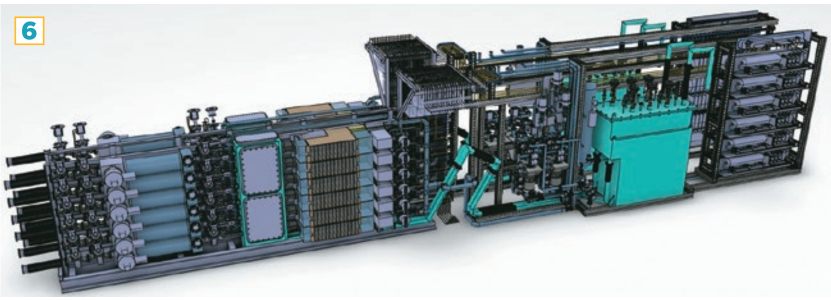
- To demonstrate the feasibility of producing tritium in a fusion reactor, the ITER Test Blanket Module program is planning for the initial installation and simultaneous operation of four test blanket systems on ITER, each formed from a unique test blanket module concept and ancillary systems (cooling, tritium extraction, control instrumentation, maintenance). R&D activities are underway in the ITER Members, with the aim to complete the systems' preliminary designs in two or three years. 8
- The magnet support package is close to completion in China, with 80% of supports delivered.
- The Korean Domestic Agency has delivered the first two vacuum vessel gravity supports to ITER. Nine, in total, will be installed between the cryostat toroidal pedestal and the lower port of each vacuum vessel sector.



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The winding table in Europe's poloidal field coil manufacturing facility (foreground) produces the 30th and final production double pancake in July. The space will progressively be turned over for other assembly and testing activities.

ENGINEERING AND MANUFACTURING 2022

- Elements of a micro fission chamber—a diagnostic that measures neutron emission from the fusion reactions—have arrived at ITER from Japan. This pencil-sized diagnostic will be installed between the blanket and the vacuum vessel wall in carefully selected locations. 9
- During machine operation, the irradiation environment inside the vessel will make human intervention for maintenance activities impossible. For the repair or replacement of the ITER blanket first wall and shield blocks, Japan is designing a dedicated remote handling system with, at its core, a robotic manipulator that travels along an articulated rail to reach any of the four-tonne modules. Prototype testing is underway. 10
- US ITER contractors are at the prototyping stage for a diagnostic that will measure the electron density profile, the electron density fluctuations, and the poloidal rotation of the plasma—the low field side reflectometer. Captive components for the system were delivered this year to the ITER site. 11
- The last consignment of group-X cryolines left the French warehouse of an ITER India supplier in March. With this final shipment, the Indian Domestic Agency has completed the procurement and supply of all cryolines and warmlines for the cryogenic distribution system. 12
- As part of final design activities for the ion cyclotron upper launcher, the ITER Organization is planning to demonstrate manufacturability and the achievability of tolerances via a quarter-size antenna prototype. A company will be selected in 2023.
- After 16 years of design, validation and manufacturing, contractors to the European Domestic Agency have delivered the first four "cold valve boxes." These technologically complex components will regulate the forced flow of supercritical helium to each of the eight cryopumps of the ITER vacuum system.

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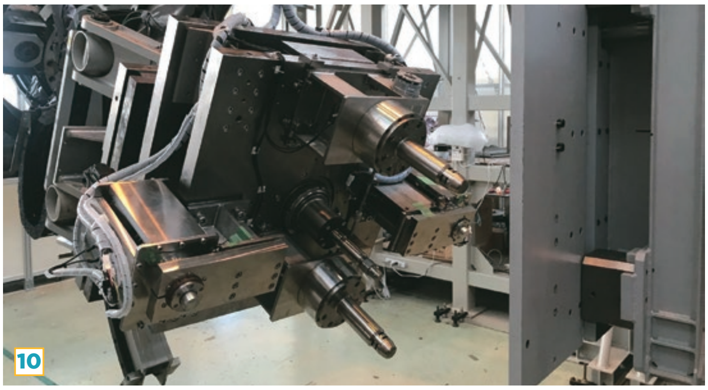
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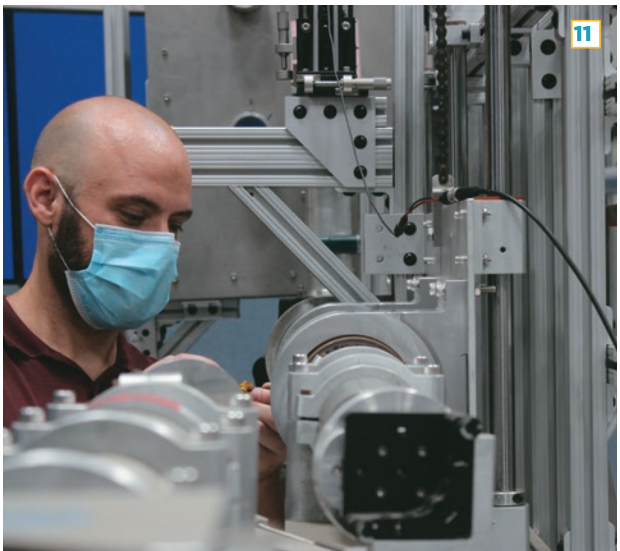
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- A new 740 m^2 building on site houses the ITER vacuum laboratory, where high-performance vacuum sealing, cryopumps, and other vacuum components can be tested before installation in the machine. There is also a space reservation in the building for the testing of prototype and first-production fuel cycle components.
- In Japan, where the qualification phase for the divertor outer vertical target is advancing, contractors have successfully completed prototypes of the steel support and the plasma-facing units.

ENGINEERING AND MANUFACTURING 2022

• A set of tools designed under ITER Organization contract for the installation of four types of in-vessel component systems—blanket shield blocks, blanket first wall panels, cooling manifolds (bundles of piping), and in-vessel ELM coils—has demonstrated better-than-required accuracy during factory acceptance testing. The test facility, which reproduces the volume and geometry of the ITER vacuum vessel environment (photo), will now be transferred to ITER to be reassembled as a technician training facility. 13

• All equipment required for First Plasma has been installed in the Magnet Power Conversion buildings, including transformers and converters from China (photo) and Korea, busbars and switching equipment from Russia, and cooling loop equipment from India. 14

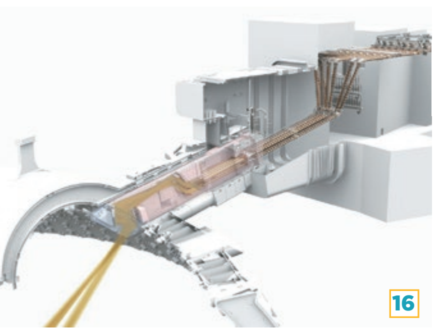
• The European Domestic Agency has been working with several European contractors to mitigate technical risks and ensure the best manufacturing technologies for the divertor inner vertical target. Following the successful qualification of full-scale prototypes, Europe has launched the manufacturing phase by signing a first production contract for 13 units. 15

• Europe is moving into the manufacturing phase for its part of the electron cyclotron resonance heating system. In 2022, contracts were signed for the production of six microwave-generating gyrotrons, and for the waveguides and upper launchers (photo) that will inject the microwaves into the plasma. 16

• Contractors to US ITER have started to fabricate the first elements of the electron cyclotron transmission line system, including waveguide prototypes.

• Of eight gyrotrons expected in total for First Plasma, four have been delivered from Russia (photo) and two from Japan. 17

• Planning for the ITER Hot Cell Facility 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). During the year, further optimization of tokamak maintenance strategies and related requirements as well as the implementation of a design-to-cost methodology for the Hot Cell Facility design and layout development have been implemented in the project.



The 665-tonne top lid—the thickest and most structurally complex of the four sections that make up the ITER cryostat—is finalized by the Indian Domestic Agency and contractors in March.

SCIENCE AND OPERATION 2022

The first sector module—representing one-ninth of the torus-shaped vacuum vessel—is lowered into the Tokamak pit in May. The successful accomplishment of this major lift operation has served to validate equipment, coordination and sequences for similar operations to come.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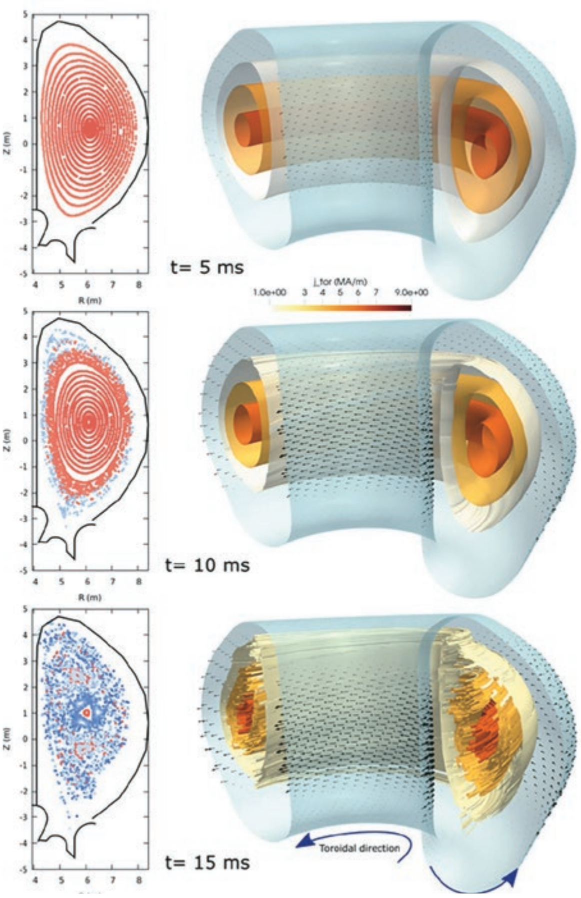
SCIENCE AND OPERATION

SCIENTISTS AND CLOUD COMPUTING PUSH THE BOUNDARIES OF ITER PLASMA DISRUPTION SIMULATIONS

To understand and predict the complex behaviour of hot, strongly magnetized plasmas in future reactor-scale tokamaks such as ITER and DEMO, scientists rely on numerical simulations to describe the dynamics of plasma transport. As supercomputers become more and more powerful and the fidelity of plasma simulations improves, scientists are able to make better predictions; nevertheless, there remain particularly challenging tokamak plasma phenomena such as disruptions in which the thermal and magnetic energy stored in the plasma is lost on very rapid timescales. Modelling these events to understand how to avoid them or mitigate their impact on tokamak operation pushes the limits of today's simulation capabilities.



A simulation showing how the "donut-shaped" magnetic surfaces, which confine the plasma, break due to the onset of a disruption. The left figures show the intersections of magnetic field lines with a poloidal cross-section after several toroidal turns (see the arrows in the bottom-right figure for the toroidal and poloidal directions). Field lines that quickly intersect the walls are shown in blue, while red shows confined lines that do not leave the plasma or that leave it after hundreds of toroidal turns. On the right, iso-surfaces of plasma current density are shown together with the vacuum vessel currents (black arrows).

In present tokamak experiments, a disruption may occur when operating near plasma stability limits or when systems malfunction. Although disruption events are rather short (expected to be less than 150 milliseconds in ITER), magneto-hydro-dynamic simulation codes need months of computations and millions of computer hours to simulate a few tens of milliseconds. For such tasks, supercomputers are really the only approach with which results can be obtained in a reasonable time. In 2022, thanks to a collaboration with Google, scientists from the ITER Organization and the Max Planck Institute for Plasma Physics in Germany simulated ITER mitigated disruptions to demonstrate a cloud computing proof of concept. Extensive Google Cloud services, together with those of the ITER Scientific Data and Computing Centre and the EUROfusion Marconi supercomputer, were leveraged to push towards more realistic plasma descriptions.

While there are still several modelling aspects to be further refined, these simulations confirm that the ITER disruption mitigation system will be able to reduce the global magnetic forces acting on the ITER vacuum vessel, blanket/first wall and divertor. Such forces arise during the loss of the plasma magnetic energy known as the "current quench" phase of the disruption, in which the plasma current decays very rapidly. During this collapse phase, electric currents induced in the vacuum vessel and in-vessel components drive the production of magnetic forces. A March 2022 paper* in *Nuclear Fusion* describes the benefits of a fast current quench (compared to the decay time of the vessel currents) in reducing these forces. The ITER disruption mitigation system will control the speed of the current quench by cooling down the plasma with cryogenic pellets—a technique demonstrated on research tokamaks such as ASDEX Upgrade, DIII-D, KSTAR and JET with the coordination of the ITER Disruption Mitigation Task Force.

** F.J. Artola et al 2022 Nucl. Fusion 62 056023*

FAVOURABLE IMPURITY DYNAMICS IN ITER CONFIRMED BY EXPERIMENT

Atoms eroded from the wall of fusion devices that enter the plasma risk diluting the fusion fuel and cooling the plasma due to the emission of radiation (visible, ultraviolet and X-ray light). Because both factors reduce fusion power production, the proportion of these "impurities" in the plasma needs to be kept at very low values. This is especially the case for tungsten—the material used for the ITER divertor. The amount of tungsten in an ITER high-fusion-gain plasma has to be kept under ~ 0.005 percent.

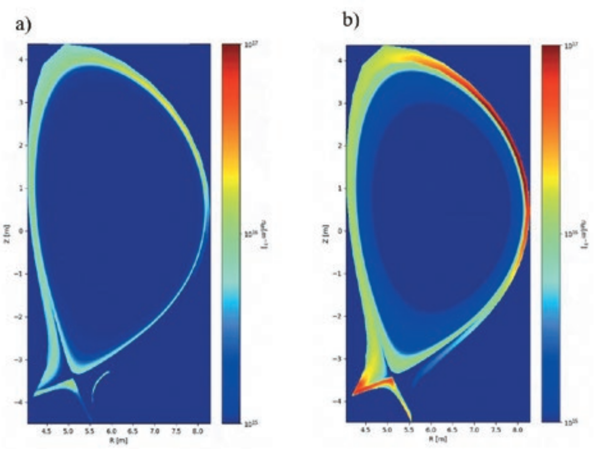
In detailed studies carried out a decade ago to simulate how tungsten atoms from ITER's walls penetrate the fusion plasma, some surprising results were obtained. They showed that ITER edge plasma characteristics are very effective in screening the fusion plasma from the tungsten atoms coming from the wall (Figure a), a behaviour never seen before.

This favourable tungsten behaviour was included in the planning of the ITER scientific program due to the solid physics basis of the predictions; however, an experimental demonstration remained outstanding. Further analysis of the physics involved in the original studies showed that this ITER-specific behaviour also had one less-desirable consequence—edge instabilities called ELMs would actually bring impurities into the plasma (Figure b). This is unlike in currently operating tokamaks, where such instabilities are employed to expel impurities from the plasma.

For ITER, this meant reformulating the ELM control strategy that had originally been considered. The new strategy relies on the suppression of these edge instabilities as soon as possible in the execution of the Research Plan, and in particular before high power (requiring radiative divertor operation) is applied. This strategy would allow ITER to benefit from the enhanced screening of tungsten predicted by physics, while avoiding the drawbacks of ELMs in such plasma conditions.

Despite the importance of this plasma physics behaviour for ITER scenario development and for the achievement of high-fusion performance with low tungsten concentration in the plasma, an experimental demonstration had never been achieved. That has now changed. As reported in a paper* published in December 2022 in *Nuclear Fusion*, scientists at the European tokamak JET were able to reproduce this ITER-like tungsten behaviour. The demonstration relied on the achievement of peripheral plasma parameters in JET that are comparable to those in ITER and on the development of complex analysis tools to determine tungsten behaviour from the acquired measurements in a quantitative way. These experimental findings provide key confirmation of the physics basis for tungsten transport at the edge of fusion-producing plasmas in ITER and of the strategy for tungsten impurity control adopted in the ITER Research Plan.

**A.R. Field et al 2023 Nucl. Fusion 63 016028*



Modelled tungsten (W) density between ELMs (a) and after an ELM (b) showing the good screening of W in the ITER plasma periphery between ELMs and the increase of the W density following an ELM. (Modelling carried out by UKAEA under a Fusion for Energy Task Agreement with the ITER Organization.)

NEW SOLPS-ITER CODE VERSION LAUNCHED

Like with so many other physical systems, what happens at the boundary of tokamak plasmas is critically determinant to their overall behaviour.

For fusion plasmas like those envisaged in ITER, two boundaries are of special interest. The first is the last closed flux surface, or separatrix, which encloses the magnetically confined plasma. The second is the vacuum vessel wall and its material surfaces. Plasma that leaks out of the separatrix is carried on the open magnetic field lines to meet these material surfaces. The divertor at the bottom of the machine is designed to be the place where most of these interactions take place, and the magnetic field lines direct the plasma to that region. The region between the separatrix and the divertor is called the scrape-off layer (SOL). Understanding and controlling the plasma behaviour in the SOL and the divertor regions has been a major focus of fusion research for many decades. In particular, various computational tools have been developed over the years to model these plasmas and improve our knowledge of them.

One such modelling tool is the SOLPS-ITER code suite. The SOLPS (Scrape-Off Layer Plasma Simulation) code grew, in the mid-1990s, from the union of the B2 (later B2.5) plasma fluid solver and the EIRENE Monte-Carlo kinetic code for neutral particle transport, which had both been developed in the 1980s. It became the main workhorse for ITER simulations during the divertor design phase. In the process, it also attracted a wide user base worldwide, and different research groups furthered the code development in different directions. In the mid-2010s, the ITER Organization took the initiative to regroup all the various code developments into a single common version, named SOLPS-ITER, which was launched in 2015. The ITER Organization manages and freely distributes the SOLPS-ITER code suite to fusion research institutional partners within the ITER Member States. With that support structure in place, the code is now one of the most common SOL plasma simulation tools in use across the ITER Members.

Of course, the code is not static, and the ITER Organization and many other research groups continue to advance its physics model and improve its numerical abilities. Indeed, one of the major limitations of SOLPS-ITER was that its plasma computational domain was limited in the SOL to magnetic field lines that start and end on a divertor structure, and thus could not properly take into account some important phenomena occurring at places where the plasma particles encounter other solid structures in the main vacuum vessel. Starting in 2017, a consortium led by Wouter Dekeyser (KU Leuven, Belgium) and Vladimir Rozhansky (Peter the Great St. Petersburg Polytechnical State University, Russia)—both current members of the ITER Scientist Fellow Network—was charged under an ITER contract with the challenging task of extending the code beyond that limit, to be able to model the full vacuum vessel cross-section. After two years of intensive work, and a near-complete rewrite of the code base, this goal was achieved in 2022.

As many in the plasma edge physics community have eagerly been awaiting this new code capability, a series of workshops for users has been organized.

UNDERSTANDING CURRENT FLOW DURING PLASMA DISRUPTIONS

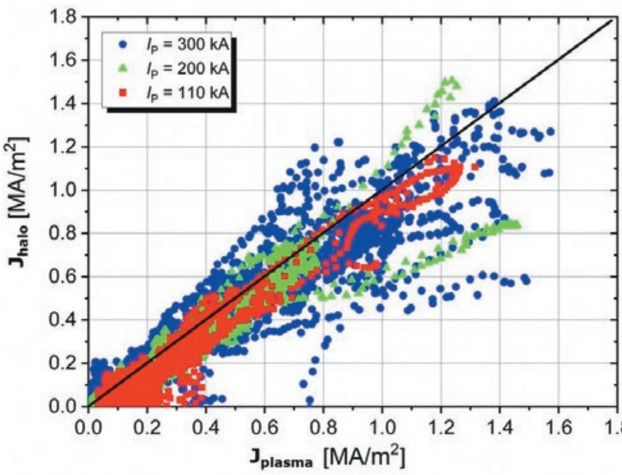
In tokamaks, disruptions are sudden losses of the thermal and magnetic energy stored within the plasma that occur when operating near plasma stability limits or when systems malfunction and plasma control is lost. Disruptions, particularly on large devices like ITER, can lead to high power fluxes and mechanical forces on in-vessel components, impacting their lifetime. A major contributor to these loads are the electric currents that circulate between the plasma and the components during the "current quench" phase of the disruption when the plasma current collapses. The amplitude and distribution of these electric currents (the so-called halo currents), together with the strong magnetic fields always present in tokamaks, determine the local mechanical stresses on the in-vessel components and thus need to be understood in detail to refine expectations for ITER.

Physicists from the COMPASS tokamak team at the Institute of Plasma Physics (Prague, Czech Republic) and from the ITER Organization collaborated to perform a series of experiments designed to measure the halo currents circulating between the plasma and surrounding components during disruption current quenches. The result is a unique database of high spatial resolution measurements of these currents.

The experiments, reported* in June 2022 in *Nuclear Fusion,* have demonstrated (Figure 1) that the local value of the halo current cannot exceed the local value of the plasma particle flux to the in-vessel components. This physics limit—already known for decades to apply under standard plasma conditions in the cool plasma edge where magnetic field lines intersect solid surfaces—has been found on COMPASS during these extremely transient disruptive phases using arrays of dozens of tiny, finely spaced electric sensors known as Langmuir probes embedded in the divertor target surfaces. This probe system captured the halo and the plasma flux simultaneously for the first time during purposely triggered disruptions. The experiments also confirmed previous findings elsewhere that the global value of the halo current is proportional to that of the current flowing in the plasma before the disruption. This, together with the new limit identified in these experiments, means that the area of in-vessel components over which the halo current flows grows with increasing current when the limit is at work. This spreads the halo current across the in-vessel components and lowers the local stresses compared to what would be predicted if such a limit were not applied.

The results show that inclusion of the newly identified halo current limitation in the simulation of disruptions is essential to reproduce plasma behaviour observed on COMPASS. To consolidate predictions for ITER disruptions, it is important to experimentally determine the role that the newly identified limit plays on the dynamics of disruptions across other operating tokamaks and to reproduce the observations using the simulation codes applied to model ITER. This will make it possible to both better understand and predict the loads expected during disruptions in ITER and to optimize their mitigation.

** J. Adamek et al 2022 Nucl. Fusion 62 086034*



Locally measured halo current during disruptions in COMPASS versus local plasma flux (both measured in Mega-Amperes per square m) over a range of plasma currents. A set of experiments performed by a joint Czech Academy of Sciences/ITER Organization team has provided the first experimental evidence of a physical limit to the flow of electric currents between the plasma and tokamak components during these events. This finding will help scientists to refine models and provide improved predictions of plasma dynamics and the associated forces on in-vessel components during ITER disruptions.

Electrical equipment needed for the neutral beam injection system will be located in a zone not far from the Tokamak Complex. The infrastructure is under construction.

SCIENCE AND OPERATION

TRANSLATING PHYSICS LIMITS TO MILLIMETRES

The millimetre-level alignment tolerance targets for ITER's magnetic and first-wall components are determined by physics requirements. Because the plasma must be as close to perfectly symmetric as possible, precise physics principles must guide their assembly to ensure that the machine can achieve its fusion goals. But translating physics limits into assembly millimetres is a delicate exercise: set them too large and the machine may not attain its goals; set them too small and the machine is impossible to assemble.

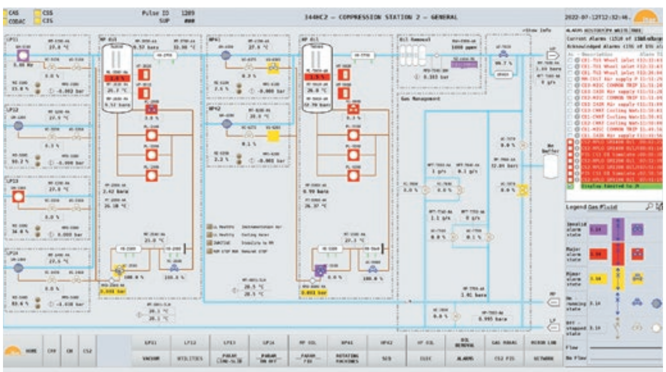
Close collaboration between the assembly, reverse engineering, blanket and science teams has enabled the development of a set of "just right" physics assembly guidelines. Together with parallel compliance assessments of the machine's mechanical interfaces, these guidelines form a grounded alignment strategy based on physics acceptability and engineering feasibility.

In 2022, the assembly of vacuum vessel sector module #6 and its positioning in the Tokamak pit was successfully implemented according to this integrated alignment strategy for the toroidal field coils. An extension of this approach is underway to include the remaining major coil systems in ITER so that it may be applied to the complete tokamak assembly process.

INTEGRATED CONTROL IS SUPPORTING COMMISSIONING

Integration and commissioning of plant system instrumentation and control progressed in 2022 as more systems—additional cooling water, electrical, liquid and gas, and buildings; reactive power compensation; cryoplant—were added. The scope of completion for First Plasma reached 18 percent as measured by the number of energized instrumentation and control (I&C) cubicles or the number of integrated process variables (data points).

The steady state electrical distribution system is complete on the southern side of the ITER platform. Supply and distribution of compressed air and demineralized water is operated routinely from the temporary main control room in ITER Headquarters (see below) as are three out of six secondary cooling water loops. Reactive power compensation completed low voltage commissioning and the cryoplant started the first liquid helium compressors. The integrated control system supported all these activities, operated either from the temporary main control room or from local temporary control rooms close to the equipment. The cumulative amount of archived data from these systems reached 3 TB. Applications were developed to access real-time data on the web or smart phone to further facilitate commissioning in the field.



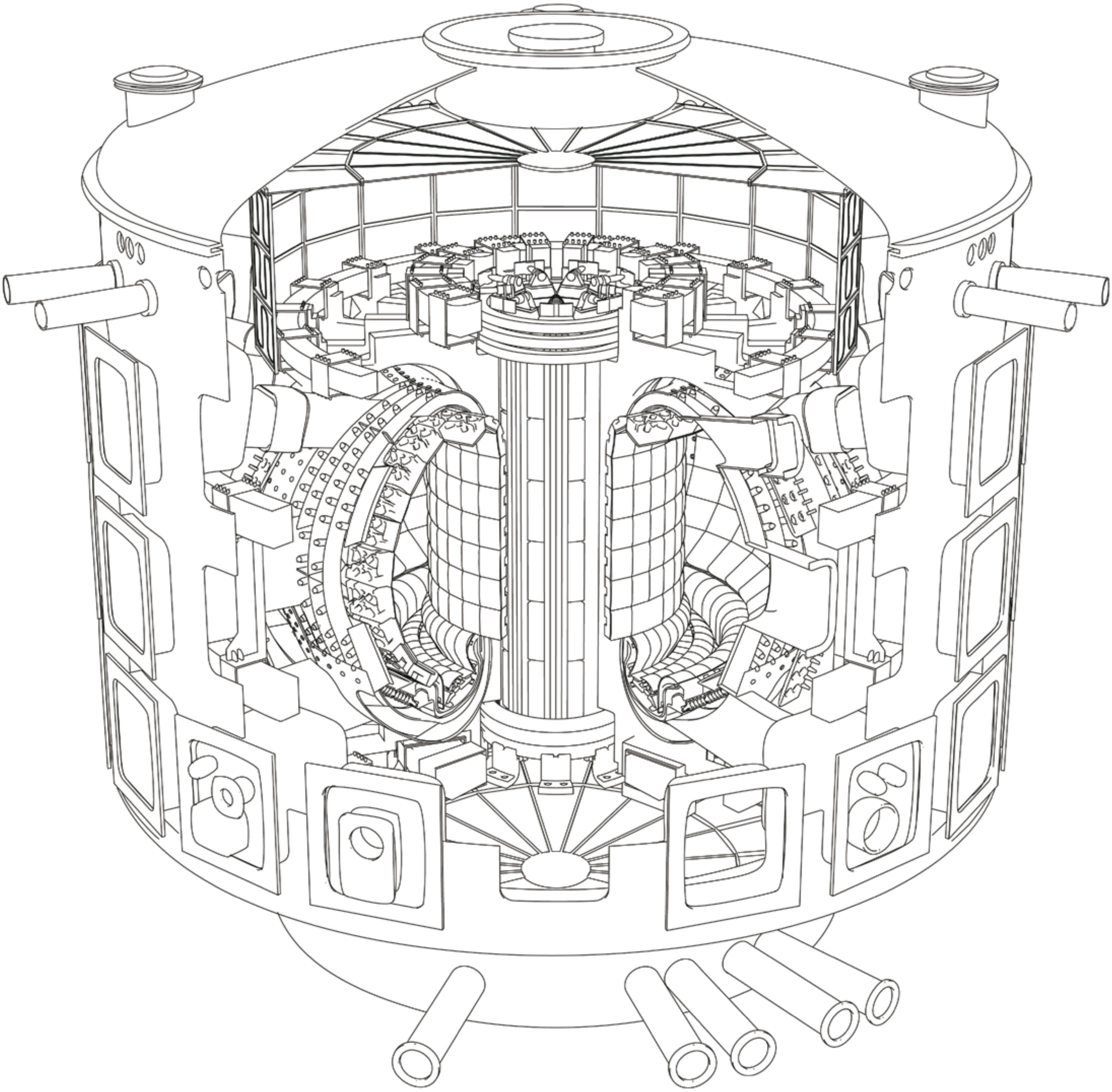
Screen shot of real-time human machine interface of electrical distribution.

MAIN CONTROL ROOM OPERATING TEMPORARILY OUT OF ITER HEADQUARTERS

Monitoring pressure and temperature levels, starting and stopping pumps, running sub-systems—from the temporary main control room in ITER Headquarters, operators are now helping to commission systems and supporting operators in the field.

Since November 2022, operators have been supporting commissioning activities from a temporary main control room (T-MCR) at ITER Headquarters. Staffed all week by a rotating team from the Operations Division, it deploys the same CODAC workstation, with the same human-machine interface, that will be used in the main control room when it opens in the Control Building. T-MCR operators are already helping to commission the secondary cooling loops, the heat rejection system, and liquid and gas systems; next year, the coil power supply and electron cyclotron heating systems will join the list. In close coordination with operators in the field, they start and stop pumps, monitor target flow rates, and track pressure and temperature levels. Systems already in operation—such as the distribution of compressed air to the cryoplant or the Assembly Hall, or demineralized water to the building for reactive power control—are also run and monitored from the T-MCR.

Through these activities, operators are fine tuning procedures, training on the interface, and practicing interaction with operators in the field—acquiring valuable experience before systems move from commissioning to operation.



The tokamak is an experimental machine designed to harness the energy of fusion. ITER will be the world's largest tokamak, with a plasma radius (R) of 6.2 m and a plasma volume of 840 m^3.

china eu india japan korea russia usa

CORPORATE HIGHLIGHTS

AT A GLANCE 2022

JANUARY
- Members of the European Parliament tour ITER

MARCH
- Ceremony at ITER for the completion of the cryostat
- Visit of US Senator Joe Manchin

APRIL
- Visit of Mohammad Sanusi Barkindo, Secretary General of OPEC
- Launch of new postdoctoral program for junior physicists and engineers

MAY
- First vacuum vessel sector sub-assembly lowered into the Tokamak pit
- ITER mourns the loss of Bernard Bigot (ITER Director-General, 2015-2022)
- Eisuke Tada becomes ITER Director-General interim
- ITER Robots competition, 11th edition
- Gabriela Hearst, creative director of Chloé, visits ITER

JUNE
- 30th Meeting of the ITER Council
- Public Open Doors Day

JULY
- The ITER Organization is a founding partner of Women in Fusion (www.womeninfusion.org)
- ITER International School #11 is held in San Diego, California
- High-level delegation from Korea (Vice Minister Oh Tae-Seog and former UN head Ban Ki-Moon)

SEPTEMBER
- Pietro Barabaschi is appointed ITER Organization Director-General (to start on 17 October)
- 10th ITER Games
- 2nd Safety Day: staff and construction personnel re-commit to "Safety First"
- First staff-focused Open Doors Day
- Chief scientist Tim Luce testifies to US Senate Committee

NOVEMBER
- 31st Meeting of the ITER Council
- Public Open Doors Day
- ITER Organization 2022 Achievement Awards

DECEMBER
- Highest-ever number of visitors to the ITER site in 2022: 19,559
- A new group of Monaco Fellows arrives at ITER

The facade of the Tokamak Complex glows at the end of an October day.


C2
delivered

CORPORATE HIGHLIGHTS 2022

Just as the challenges of the Covid-19 pandemic were receding—as factory shutdowns, disruptions to supply chains, and transport delays improved—the ITER Project was confronted with the first major technical setback of the machine assembly phase: defects discovered in key machine components will require extensive repair. The new Director-General of the ITER Organization has announced that his priorities as repairs advance will be to improve the technical quality culture across the project, to re-evaluate the mitigation strategies for other project risks related to first-of-a-kind components, and to re-align incentive structures by integrating the ITER Organization and the Domestic Agencies more closely.

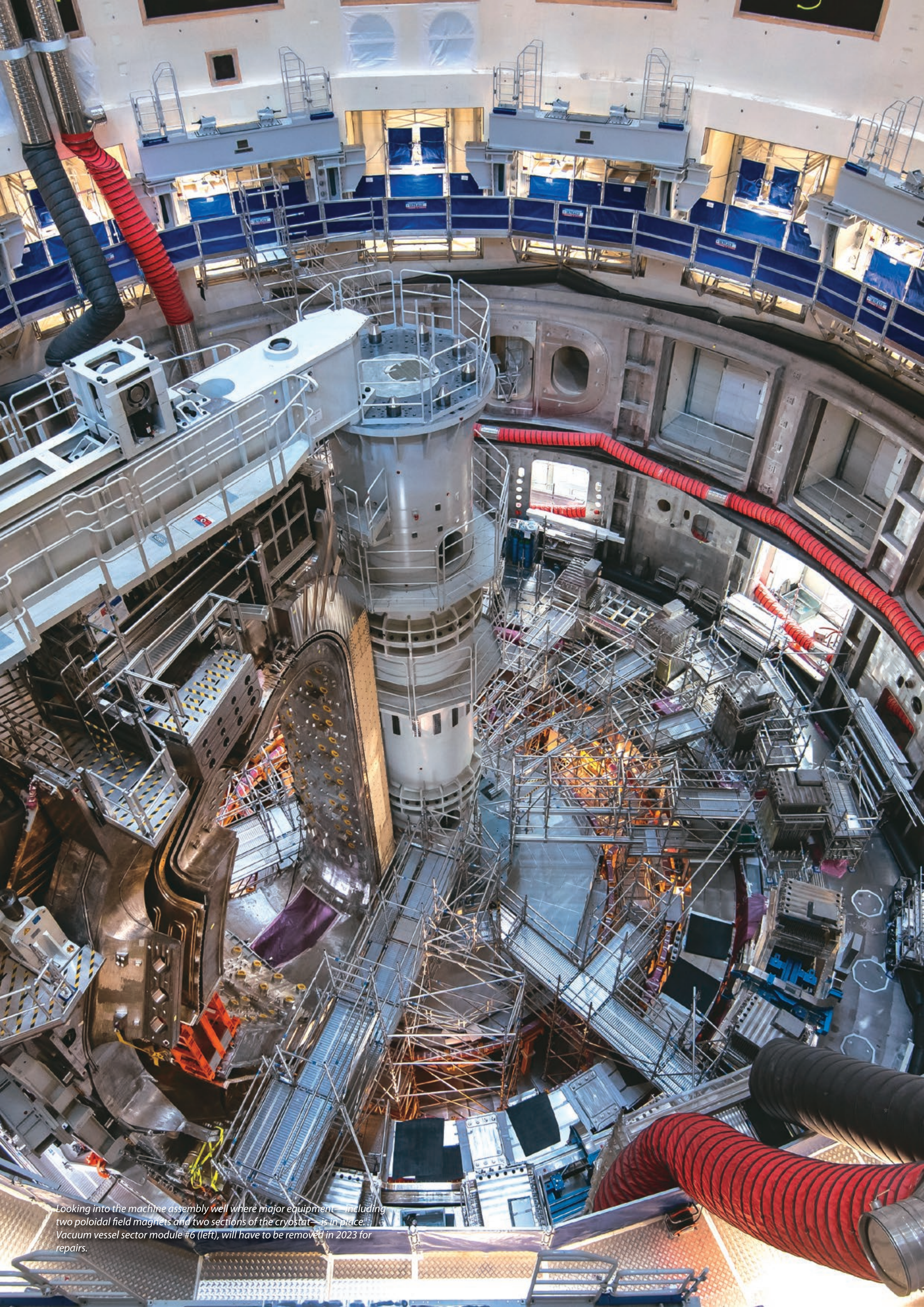
CHANGE AT THE HELM – Bernard Bigot, who had been Director-General of the ITER Organization since March 2015, passed away on 14 May 2022 due to illness. An inspirational leader for more than four decades across multiple fields of science and energy, his personal dedication and commitment to ITER over his seven-year tenure shaped every aspect of the project; he will be remembered for his profound sense of duty and for his unwavering belief in the promise of fusion. His deputy Eisuke Tada assumed the interim role of Director-General until the ITER Council, in an extraordinary meeting in Paris on 15 September 2022, unanimously appointed Pietro Barabaschi as the fourth Director-General in ITER Organization history. Director-General Barabaschi took up his appointment on 17 October 2022.

In memory of Bernard Bigot, ITER Director-General (2015-2022).


The 31st Meeting of the ITER Council in November.

REVISED CONSTRUCTION STRATEGY – The need for substantial repair works on major machine components has affected the effort underway to update the project's 2016 Baseline. Uncertainties related to the schedule of repairs and their effect on major assembly contracts, as well as the project's actions to minimize the overall impact of the technical setbacks, must be clarified through technical discussions between the ITER Organization, the Domestic Agencies, and external experts before an optimized approach to completing the Construction Baseline can be proposed. These discussions are taking place within the framework of the New Baseline Development Task Force. While Baseline updating is on hold, the ITER Organization has prepared a 2023 Work Plan reflecting the work that can realistically be expected to be accomplished based on the most recent information; a draft budget for 2023 will be submitted to the ITER Council early next year based on this Work Plan. Going forward, reverse works and repairs on the vacuum vessel sectors and thermal shield will be managed as a distinct sub-project, and progress will be reported quantitatively and qualitatively as works proceed. The procurement process for the work is well advanced, with the evaluation of tender offers underway. In 2023, an expert panel established by the Management Advisory Committee (MAC) will analyze and advise on the ITER Organization's contracting strategy, with a focus on the renegotiation of major assembly and installation contracts based on the ITER Organization's comprehensive review of these contracts. A feasibility study is also planned to examine the possibility of performing cold tests on some toroidal field coils as risk mitigation; the results of this study will be reported to the ITER Council.

Six independent magnet modules will be stacked to form the ITER central solenoid. The first 110-tonne module is lifted and positioned on a dedicated assembly platform in July.



Looking into the machine assembly well where major equipment—including two poloidal field magnets and two sections of the cryostat—is in place. Vacuum vessel sector module #6 (left), will have to be removed in 2023 for repairs.

CORPORATE HIGHLIGHTS 2022

Director-General Pietro Barabaschi, second from right, speaks to personnel from across the project in a hybrid-format meeting on 19 October 2023.

REGULATORY ENVIRONMENT – Exchanges between the ITER Organization and the French Nuclear Safety Authority (*Autorité de sûreté nucléaire*, ASN) on ITER's safety file for the authorization of machine assembly continued throughout the year, as ITER provided additional elements related to its self-supporting file. This process has now been paused due to the ongoing assessment of quality issues related to the vacuum vessel and thermal shield. The ITER Organization is planning to use this time to re-evaluate key topics related to nuclear safety, including the impact of the technical setbacks on the ITER Research Plan, possible evolutions in the ITER nuclear safety demonstration, and the update of the overall licensing roadmap in the context of the new ITER Baseline. The re-examination of the current four-stage approach to full fusion power—with the potential combination of assembly and/or operation phases—is also being considered. The new Director-General has emphasized his commitment to regular and transparent communication with the ASN on these matters.

STAFFING - As of 31 December 2022, 1,069 people were directly employed by the Organization (+4.7% over the previous year). Contributions to the project were also made by 13 experts, 2 visiting researchers, 17 interns, 231 ITER Project Associates, and 9 post-doctorates who were part of the Monaco-ITER Fellowship Program or recruited as part of the broader ITER Organization postdoctoral program launched in 2022 to attract highly trained early career professionals. Another priority for the ITER Organization overall is to improve the gender and geographical diversity of staff. Specific efforts have been made in this direction, including the creation of a new staff position focused on diversity, equity and inclusion (DEI). The ITER Council has also approved the Director-General's request for five new Deputy Director-General (DDG) level positions—two DDGs in a coordinating role for the whole organization, and another three to function as Chief Engineer, Chief Scientist and Construction Project Manager. Recruitment for the first two is already underway.

INTERNATIONAL COOPERATION - The ITER Organization maintains a large number of cooperation agreements with the labs and educational establishments of the ITER Members, international organizations and others. See pp 56-57 for the full list.

ITER's smallest ring-shaped magnet—poloidal field coil #1 (PF1)— is on its way to ITER from Russia.

iter
china eu india japan korea russia usa

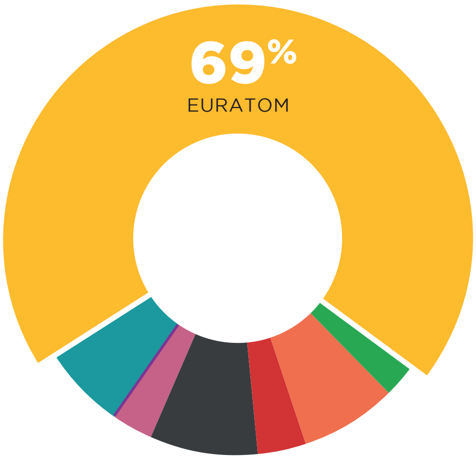
STAFFING AND FINANCIAL DATA 2022

This plasma-jet cutting tool is performing precise machining on the cryostat lid. The ultra-hot (30,000 °C) hydrogen-nitrogen-argon plasma slices through steel like butter.


KUKA

STAFFING TABLES

STAFF BY MEMBER

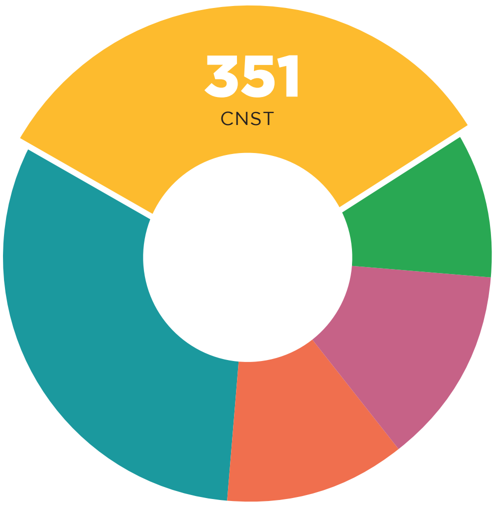


KOREA 6.1% · JAPAN 3.6% · OTHER 0.2% · RUSSIA 7.2% · USA 3.4% · INDIA 2.4% · CHINA 8.1%

	31/12 2018	31/12 2019	31/12 2020	31/12 2021	31/12 2022
CHINA	79	87	89	88	87
EURATOM	599	634	678	719	738
INDIA	36	28	28	22	26
JAPAN	27	32	35	37	38
KOREA	32	49	51	55	65
RUSSIA	37	47	59	68	77
USA	48	52	49	46	36
OTHER*					2
TOTAL	858 (1)	929 (2)	989 (3)	1,035 (4)	1,069 (5)

(1) Includes 5 Monaco Postdoctoral Fellows and staff funded for work on the Tokamak Cooling Water System (TCWS, 25), vacuum system (VAS, 2) and the safety control system for nuclear (SCS-N, 1)
(2) Includes 5 Monaco Postdoctoral Fellows and staff funded for work on the TCWS (29), VAS (3) and SCS-N (1)
(3) Includes 7 Monaco Postdoctoral Fellows and staff funded for work on the TCWS (27), VAS (2) and SCS-N (2)
(4) Includes 5 Monaco Postdoctoral Fellows and staff funded for work on the TCWS (25), VAS (2) and SCS-N (2)
(5) Includes 9 Postdoctoral Fellows (6 Monaco and 3 Korea) and staff funded for work on the TCWS (19), VAS (2) and SCS-N (2)
** "Other" refers to one Swiss and one Ukrainian staff member following ITER Council consultation and approval.*

STAFF BY ORGANIZATIONAL UNIT



ENGN 339 · SCOP 140 · CORP 129 · DG 110

	Professional & Higher	Support	Total
DG	3	0	3
ODG	23	13	36
SQD	50	21	71
TOTAL DG	76	34	110
CORP	25	11	36
FPD	30	20	50
HRD	8	12	20
PCO	17	6	23
TOTAL CORP	80	49	129
ENGN	14	64	78
CIO	60	12	72
EDD	176	13	189
TOTAL ENGN	250	89	339
CNST	1	0	1
CMO	33	11	44
MCD	122	28	150
PLD	134	22	156
TOTAL CNST	290	61	351
TOTAL SCOP	109	31	140
TOTAL	805	264	1,069

** For the full names of units, see the Organization Chart on page 58.*

MAIN FINANCIAL DATA

COMMITMENTS EXECUTION

Amounts in thousands of Euro

Budget Headings	Total Commitments Appropriations 2022 a	Total Actual Commitments 2022 b	Unused Commitments Appropriations carried forward to 2023 c = a - b
TITLE I: DIRECT INVESTMENT (FUND)	620,373	306,457	313,916
TITLE II: R&D EXPENDITURE	1,689	370	1,319
TITLE III: DIRECT EXPENDITURE	383,592	295,488	88,104
TOTAL COMMITMENTS	**1,005,655**	**602,315**	**403,339**

PAYMENTS EXECUTION

Amounts in thousands of Euro

Budget Headings	Total Payments Appropriations 2022 a	Total Actual Payments 2022 b	Unused Payments Appropriations carried forward to 2023 c = a - b
TITLE I: DIRECT INVESTMENT (FUND)	718,321	315,785	402,536
TITLE II: R&D EXPENDITURE	1,921	413	1,508
TITLE III: DIRECT EXPENDITURE	421,800	272,337	149,463
TOTAL PAYMENTS	**1,142,042**	**588,535**	**553,507**

CONTRIBUTIONS RECEIVED FROM MEMBERS IN CASH

Amounts in thousands of Euro

Members	2022	Cumulative
EURATOM	169,428	2,044,702
PEOPLE'S REPUBLIC OF CHINA	55,791	393,993
REPUBLIC OF INDIA	81,516	296,237
JAPAN	44,370	377,841
REPUBLIC OF KOREA	58,266	399,261
RUSSIAN FEDERATION	58,247	411,474
UNITED STATES OF AMERICA	143,969	442,980
TOTAL CONTRIBUTIONS	**611,587**	**4,366,489**

CONTRIBUTIONS RECEIVED FROM MEMBERS IN KIND

Amounts in ITER Unit of Account (IUA)

	Cumulative 31.12.2021	2022	Cumulative 31.12.2022
EURATOM	500,129	68,971	569,100
PEOPLE'S REPUBLIC OF CHINA	143,741	37,467	181,208
REPUBLIC OF INDIA	153,566	17,528	171,094
JAPAN	337,824	14,097	351,921
REPUBLIC OF KOREA	147,406	11,685	159,091
RUSSIAN FEDERATION	113,295	15,240	128,536
UNITED STATES OF AMERICA	88,725	10,139	98,864
TOTAL CONTRIBUTIONS	**1,484,686***	**175,128**	**1,659,814**

** Due to a change in presentation, this 2021 cumulative total excludes accrued revenues. This explains the difference with the 2021 figure published in the 2021 ITER Organization Annual Report.*

DOMESTIC AGENCY PROCUREMENT HIGHLIGHTS

PROCUREMENT HIGHLIGHTS KEY

—

- R&D, manufacturing 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 Investment (ADI) related to Project Change Requests. Please note that the 2022 figures supersede all previously published figures.

Packages allocated to the ITER Organization (some cryogenics, heating, tooling, tritium plant, and diagnostics) are not represented in these pages.

Vacuum vessel sector #8 is unloaded at Fos-sur-Mer harbour, France.

D11
C3
UHL FLASH
MADEIRA
IMO 9785407

ITER CHINA (CN-DA)

www.iterchina.cn

PROCUREMENT ARRANGEMENTS*
Fourteen PAs signed since 2007 representing:
100% in number and
100% of the total value of CN-DA in-kind contributions.

Over 87 design or fabrication contracts related to ITER procurement have been signed with laboratories and industry.

Chinese procurement highlights in 2022	% of ITER system procured by China	% Credit released out of allocation
MAGNET SYSTEMS		
TOROIDAL FIELD CONDUCTOR	7.5%	100%
All conductor unit lengths delivered		
POLOIDAL FIELD CONDUCTOR	65.2%	100%
All conductor unit lengths delivered		
MAGNET SUPPORTS	100%	45.93%
FEEDERS	100%	13.76%
Manufacture completed for all main busbar and correction coil high-temperature superconductor current leads		
7 feeder segments and 1 batch of auxiliary hardware delivered this year to IO		
Cumulative: 24 coil terminal boxes, 24 cryostat feedthroughs, 7 in-cryostat feeders (highly exceptional loads), 31 satellites, 3 batches of auxiliary hardware, and all bellows delivered		
CORRECTION COILS	100%	19.42%
CORRECTION COIL AND FEEDER CONDUCTORS	100%	100%
All correction coil and feeder conductors delivered		
POWER SYSTEMS		
PULSED POWER ELECTRICAL NETWORK (PPEN)	100%	100%
All components of PPEN sub-package delivered		
AC/DC CONVERTERS	53.2%	54.37%
All AC/DC convertors for First Plasma delivered		
REACTIVE POWER COMPENSATION	100%	96.61%
All reactive power compensation equipment installed on site; commissioning phase initiated		
BLANKET		
BLANKET FIRST WALL	12.6%	1.87%
Enhanced heat flux full-scale prototype assembled for process qualification		
BLANKET SHIELD BLOCK	50.2%	3.50%
40% of manufacturing and testing has been completed		
FUEL CYCLE		
GAS INJECTION SYSTEM	100%	34.98%
FDR held successfully for the fusion power shutdown system (via video)		
MRR held successfully for mass flow controlled valves (via video)		
GLOW DISCHARGE CLEANING	100%	7.92%
DIAGNOSTICS		
DIAGNOSTICS	3.8%	8.92%
FDR closure report approved for X-ray radial camera		
MRR (1A closure report) approved for EQ#12 port integration		
PDR closed for divertor Langmuir probe		
Maturity assessment for all neutron flux monitor I&C (PDR design) completed		

*Does not include Complementary Diagnostic Arrangements

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 Plan ; MRR Manufacturing Readiness Review ; PA Procurement Arrangement ; PDR Preliminary Design Review ; SAT Site Acceptance Tests

ITER INDIA (IN-DA)

www.iter-india.org

PROCUREMENT ARRANGEMENTS*

Fourteen PAs signed since 2007 representing:

100% in number and

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 2022

	% of ITER system procured by India	% Credit released out of allocation
CRYOSTAT		
CRYOSTAT	100%	87.11%

- Completion and acceptance of cryostat top lid (IC milestone)
- Cryostat I&C manufacturing ongoing; factory acceptance of I&C cubicles 90% completed
- Torus cryopump housing: material procurement completed; bellow prototype and qualification tests completed

	% of ITER system procured by India	% Credit released out of allocation
CRYOGENIC SYSTEMS		
CRYOLINES	100%	90.09%

- Lower pipe chase cryolines completed

CRYODISTRIBUTION	100%	17.88%

- Supply part of all cryolines and warmlines completed; only last minor components to be shipped
- Mechanical installation initiated in Tokamak Building/L3; provisional acceptance tests of Y lines and one W line installed in B2, B1 and shafts completed
- Completion of auxiliary cold box (ACB-3,ACB-4) FDR and MRR; thermal shield cold valve box (vacuum shell) FDR; ACB-5 (mechanical components) FAT; casing integration of 3 cold circulators in 3 ACBs; cryoplant termination cold box (CTCB) leak test and control cubicles energized

HEATING & CURRENT DRIVE SYSTEMS		
DIAGNOSTIC NEUTRAL BEAM (DNB) POWER SUPPLY	100%	31.01%
DNB BEAM LINE	100%	3.82%

- Ion source manufacturing at trial assembly testing stage; components ready for alignment and trial assembly testing
- Assembly and FAT completed for electrostatic residual ion dump (except HV test) and DNB neutralizer
- Final evaluation of bids for DNB and HNB3 vacuum vessels; tendering process completed
- Design approval for 200kW solid state RF generator; development of instrumentation and controller underway

NBTF COMPONENTS (BEAM DUMP & 100 KV POWER SUPPLY)	3.4%	100%

- All NBTF components completed
- Remote support provided for SPIDER operations

ION CYCLOTRON RADIO FREQUENCY (RF) POWER SOURCES	100%	0%

- Initiated umbrella tender strategy for components developed in house (excepting high-power amplifiers)
- Diacrode-based R&D chain tested at 60 MHz @ 1.5MW on dummy load (DL); 3dB hybrid combiner tested
- Tetrode-based system tested for 1MW at 45MHz on 1.5MW DL; installed and commissioned in SST1
- 10KW sold state power amplifiers manufactured; 3MW mis-match transmission line system delivered to ITER India
- Expression of Interest (EoI) published for driver and final-stage amplifier (IO deliverables) within the new strategy of procurement

ION CYCLOTRON RADIO FREQUENCY (RF) POWER SUPPLY	100%	4.46%

- FDR completed for HV power supplies
- HV power supply operated in Integrated mode with ICRF sources for 60 MHz at 1.5 MW; testing of hybrid combiner at 1.5MW

ELECTRON CYCLOTRON HIGH VOLTAGE POWER SUPPLY	25%	5.89%

- Main HV power supply: successfully used for SAT of 1 MW gyrotron supplied to ITER India by M/s. Gycom Russia

ELECTRON CYCLOTRON RF GYROTRON POWER SOURCES (2 GYROTRONS OUT OF 24)	7.7%	0%

- Megawatt-class ITER India Gyrotron Test Facility (IIGTF) developed; SAT successfully completed for 170 GHz test gyrotrons
- Integrated system design and performance validated as a template for ITER deliveries

COOLING WATER SYSTEMS		
HEAT REJECTION SYSTEM, COMPONENT COOLING WATER SYSTEM, CHILLED WATER SYSTEM	100%	94.91%

- Prepared EoI document for the procurement of safety-important (SIC) valves
- Delivered hydrogen mitigation system vessels (pool scrubber tank, quench tank, overflow tank) after successful FAT

VACUUM VESSEL		
IN-WALL SHIELDING (IWS) BLOCK ASSEMBLIES	100%	94.13%

- Technical clarification provided to EU-DA, KO-DA and IO as needed; all delivered IWS blocks successfully installed

DIAGNOSTICS		
DIAGNOSTICS	3.9%	0%

- X-ray crystal spectroscopy (XRCS)/Edge: design study completed for double-reflection-based spectrometer layout using ray tracing codes
- XRCS/Edge: Prototype hybrid photon counting detector (PILATUS3): tender processed and purchase order placed
- XRCS/Survey: configuration completed of front-end sight-tube; material (SS316-L(N)-IG) procured
- Electron cyclotron emission: design of stray radiation sensor completed, purchase order placed for prototype hot source
- Upper port #09: in-vessel integration revised
- Charge exchange recombination spectroscopy pedestal: prototype fibre bundle assembly developed with multiple terminations

*Does not include Complementary Diagnostic Arrangements

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 Plan ; MRR Manufacturing Readiness Review ; PA Procurement Arrangement ; PDR Preliminary Design Review ; SAT Site Acceptance Tests

ITER JAPAN (JA-DA)

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

PROCUREMENT ARRANGEMENTS*
Fifteen PAs signed since 2007 representing:
83% in number and
98% of the total value of JA-DA in-kind contributions.

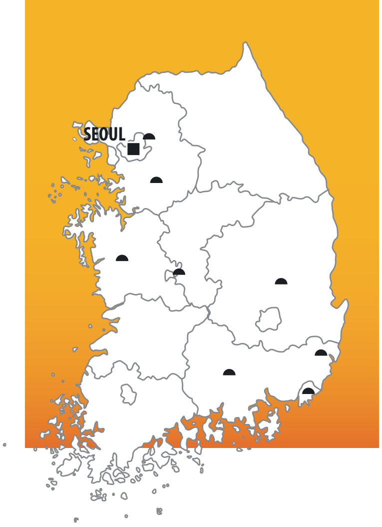
Over 100 design or 800 design or fabrication contracts related to ITER procurement have been signed with industry since 2007.

Japanese procurement highlights in 2022

Japanese procurement highlights in 2022	% of ITER system procured by Japan	% Credit released out of allocation
MAGNET SYSTEMS		
TOROIDAL FIELD CONDUCTOR	25%	100%
All conductor unit lengths delivered		
TOROIDAL FIELD MAGNET WINDINGS (9 OUT OF 19)	49.1%	96.94%
Toroidal field coil TF16 delivered to IO		
TF15 is in transit, expected at IO in January 2023		
Remaining two coils are under final machining		
TOROIDAL FIELD MAGNET STRUCTURES	100%	97.96%
Delivery of magnet structures completed in 2022		
CENTRAL SOLENOID CONDUCTOR	100%	100%
All conductor unit lengths delivered		
HEATING & CURRENT DRIVE SYSTEMS		
HIGH VOLTAGE BUSHING (MITICA)	100%	100%
Procurement of high voltage bushing completed		
NEUTRAL BEAM HIGH VOLTAGE BUSHINGS	100%	0%
NEUTRAL BEAM BEAMSOURCE (HNB2 ACCELERATOR)	100%	0%
NEUTRAL BEAM POWER SUPPLY	66%	36.76%
PA signed in July for Heating Neutral Beam (HNB) Power Supply		
ELECTRON CYCLOTRON RADIO FREQUENCY POWER SOURCES (8 GYROTRONS OUT OF 24)	36.2%	40.28%
First two gyrotrons (#1 and #2) delivered to IO with four superconducting magnets		
All anode/body power supply sets delivered to IO and installation has started		
All control cubicle sets delivered to IO and installation has started		
FAT completed for gyrotron #6		
ELECTRON CYCLOTRON EQUATORIAL LAUNCHER	100%	0%
Prototype of steering mirror assembly and waveguide successfully finished; final analysis underway to prepare for FDR		
REMOTE HANDLING		
BLANKET REMOTE HANDLING SYSTEM	100%	8.02%
Final design launched for main component		
DIVERTOR		
OUTER TARGET	100%	5.71%
Manufacturing of outer target prototypes in progress		
Commissioning of Hot Helium Leak Test Facility underway		
MRR for first six outer targets		
Series manufacturing launched for parts of first six outer targets		
TRITIUM PLANT		
ATMOSPHERE DETRITIATION SYSTEM	100%	5.40%
Qualification activities in Japan completed		
JA-DA/IO procurement activities proceeding		
DIAGNOSTICS		
DIAGNOSTICS	20.8%	4.02%
Microfission chamber: delivery of in-vessel components to IO		
Microfission chamber: final design underway for other components		
Edge Thomson scattering: FDR held for beam dump; final design of other components underway		
Poloidal polarimeter: retroreflector in manufacturing; FDR held for equatorial port #10; final design for other components		
Infrared thermography: final design in progress		
Divertor impurity monitor and lower port #2 integration: preliminary design in progress		

*Includes Complementary Diagnostic Arrangements

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 Plan ; **MRR** Manufacturing Readiness Review ; **PA** Procurement Arrangement ; **PDR** Preliminary Design Review ; **SAT** Site Acceptance Tests.



ITER KOREA (KO-DA)

https://www.iterkorea.org

PROCUREMENT ARRANGEMENTS*
Eight PAs signed since 2007 representing:
89% in number and
95.4% of the total value of KO-DA in-kind contributions.

Over 300 design or fabrication contracts related to ITER procurement have been signed with universities, laboratories and industry since 2007.

Korean procurement highlights in 2022	% of ITER system procured by Korea	% Credit released out of allocation
VACUUM VESSEL		
MAIN VESSEL (4 OF 9 SECTORS)	44%	100%
EQUATORIAL PORTS AND LOWER PORTS	100%	25.25%
BLANKET		
BLANKET SHIELD BLOCKS	49.8%	16.03%
POWER SYSTEMS		
AC/DC CONVERTERS	46.8%	77.36%
MAGNET SYSTEMS		
TOROIDAL FIELD CONDUCTOR	20.2%	100%
THERMAL SHIELD		
VACUUM VESSEL THERMAL SHIELD AND CRYOSTAT THERMAL SHIELD	100%	53.17%
ASSEMBLY TOOLING		
MACHINE ASSEMBLY TOOLING	100%	100%
TRITIUM PLANT		
TRITIUM STORAGE & DELIVERY	100%	0%
DIAGNOSTICS		
DIAGNOSTICS	4.3%	7.07%

VACUUM VESSEL

MAIN VESSEL (4 OF 9 SECTORS)
- Procurement Arrangement scope completed (S#6 and S#1(7) delivered)
- Responsible for another 2 sectors (S#8 and S#7(1)) under direct IO contract
- Third vacuum vessel sector (S#8) delivered to IO (**IC milestone**)
- Activities progressing on the last sector (S#7(1)) under IO contract (99.2% complete)

EQUATORIAL PORTS AND LOWER PORTS
- All neutral beam port stub extensions (#4, #5 and #6) delivered to IO and EU-DA
- Manufacturing now completed on nine vacuum vessel gravity supports; two sets delivered to IO
- Activities progressing on remaining ports, vacuum vessel gravity supports, superbolts and inserts

BLANKET

BLANKET SHIELD BLOCKS
- Raw materials fabrication: 137 blocks completed and 44 blocks in manufacturing
- Series production underway: 72/220 blocks completed and 17 blocks in manufacturing

POWER SYSTEMS

AC/DC CONVERTERS
- FAT completed for all master controllers
- Dummy load cubicle and LCC cubicles (17 sets) delivered to ITER site
- Installation activities progressing on AC/DC converters and transformers

MAGNET SYSTEMS

TOROIDAL FIELD CONDUCTOR
- All conductor unit lengths delivered

THERMAL SHIELD

VACUUM VESSEL THERMAL SHIELD AND CRYOSTAT THERMAL SHIELD
- All thermal shield main components delivered

ASSEMBLY TOOLING

MACHINE ASSEMBLY TOOLING
- All machine assembly tools delivered

TRITIUM PLANT

TRITIUM STORAGE & DELIVERY
- Storage and delivery system (SDS) preliminary design approved by IO

DIAGNOSTICS

DIAGNOSTICS
- FDRs held for neutron activation system (NAS) in-vessel and vacuum ultra violet spectrometer components
- Transfer line of NAS (vertical shaft 12/13) delivered to ITER site
- Contract signed for NAS manufacturing (in-vessel and L3 components)

*Does not include Complementary Diagnostic Arrangements

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 Plan ; **MRR** Manufacturing Readiness Review ; **PA** Procurement Arrangement ; **PDR** Preliminary Design Review ; **SAT** Site Acceptance Tests.

ITER RUSSIA (RF-DA)

www.iterrf.ru

PROCUREMENT ARRANGEMENTS*
Twelve PAs signed since 2007 representing:
100% in number and
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 2022	% of ITER system procured by Russia	% Credit released out of allocation
POWER SYSTEMS		
SWITCHING NETWORK, FAST DISCHARGE UNITS, DC BUSBAR AND INSTRUMENTATION	100%	63.02%
MAGNET SYSTEMS		
TOROIDAL FIELD CONDUCTOR	19.3%	100%
POLOIDAL FIELD CONDUCTOR	21%	100%
POLOIDAL FIELD MAGNET NO.1	100%	37.5%
BLANKET		
BLANKET FIRST WALL	39.6%	0.60%
BLANKET MODULE CONNECTORS	100%	0%
DIVERTOR		
DOME	100%	7.82%
PLASMA-FACING COMPONENT TESTS	100%	20.63%
VACUUM VESSEL		
UPPER PORTS	100%	70.09%
PORT PLUG TEST FACILITY (PPTF)	100%	5.96%
DIAGNOSTICS		
DIAGNOSTICS	19.5%	6.77%
HEATING & CURRENT DRIVE SYSTEMS		
ELECTRON CYCLOTRON RADIO FREQUENCY POWER SOURCES (8 GYROTRONS OUT OF 24)	31%	44.92%

POWER SYSTEMS

SWITCHING NETWORK, FAST DISCHARGE UNITS, DC BUSBAR AND INSTRUMENTATION

- Busbar elements for Tokamak Complex manufactured and tested
- Switching equipment for Diagnostics Building fast discharge units and switching network units manufactured and tested
- Scheduled batches of switching equipment delivered to IO (44 trailers)

MAGNET SYSTEMS

TOROIDAL FIELD CONDUCTOR

- All conductor unit lengths delivered

POLOIDAL FIELD CONDUCTOR

- All conductor unit lengths delivered

POLOIDAL FIELD MAGNET NO.1

- FAT (including leak tests and high-voltage tests) successfully carried out (**IC milestone**)
- Coil packaging and preparation completed; transport frame certified
- First stage of travel to IO initiated in November

BLANKET

BLANKET FIRST WALL

- Full-scale prototype: nondestructive testing performed for first wall regular pairs based on methodology agreed with IO
- First wall series production initiated (rough machining stage) after MRR approval

BLANKET MODULE CONNECTORS

- Full-scale prototypes tested (pads, flexible cartridge, components with low friction/anti-seize coating)
- Blanks series production started for connector components after MRR approval
- Last electric strap bimetallic pedestals shipped to IO (1,052 since 2020)

DIVERTOR

DOME

- Pilot manufacture performed for elements of first delivery lot (1-6) and semi-finished products

PLASMA-FACING COMPONENT TESTS

- High heat flux testing protocols approved for outer vertical target plasma-facing units
- Dome plasma-facing units (delivery lot 1-6) tested

VACUUM VESSEL

UPPER PORTS

- Nine upper port extensions manufactured
- Six upper port extensions delivered to IO

PORT PLUG TEST FACILITY (PPTF)

DIAGNOSTICS

DIAGNOSTICS

- PDR passed for upper ports #02, #08 and #07
- In-vessel FDR successfully performed for upper port #07
- 3D model work/structure integrity analysis advancing for several ports and port plugs
- Divertor neutron flux monitor (DNFM): in-vessel design reworked, engineering analysis ongoing
- DNFM FDR-1 (in-vessel) and FDR-2 (I&C) closure activities ongoing
- Full-scale mock-up of vertical neutral camera (VNC) data acquisition system tested
- First batch of VNC fission chambers for detection units manufactured and tested; diamond detectors passed thermocycling tests
- Neutral particle analyzer (NPA): detector line developed with new photoelectronic multiplier; collimator module neutron shield manufactured; first preliminary assembly of collimator modules and shield modules
- Charge exchange recombination spectroscopy: large-size 2D detector unit developed for high etendue spectrometers
- Divertor Thomson scattering: 3D models developed of components on divertor cassettes

HEATING & CURRENT DRIVE SYSTEMS

ELECTRON CYCLOTRON RADIO FREQUENCY POWER SOURCES (8 GYROTRONS OUT OF 24)

- FATs achieved on gyrotron set #6 and gyrotron control system
- Set #7 in fabrication
- Four gyrotron sets and tubes shipped to IO

*Does not include Complementary Diagnostic Arrangements

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 Plan ; **MRR** Manufacturing Readiness Review ; **PA** Procurement Arrangement ; **PDR** Preliminary Design Review ; **SAT** Site Acceptance Tests.

US ITER (US-DA)

www.usiter.org

PROCUREMENT ARRANGEMENTS*
Seventeen PAs signed since 2007 representing:
100% in number and
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 2022

	% of ITER system procured by the US	% Credit released out of allocation
COOLING WATER SYSTEM		
TOKAMAK COOLING WATER SYSTEM	100%	56.42%
MAGNET SYSTEMS		
CENTRAL SOLENOID (CS) MODULES, STRUCTURE AND ASSEMBLY TOOLING	100%	38.40%
TOROIDAL FIELD CONDUCTOR	7.8%	100%
DIAGNOSTICS		
DIAGNOSTICS	14.7%	1.87%
HEATING & CURRENT DRIVE SYSTEMS		
ION CYCLOTRON TRANSMISSION LINES	100%	3.44%
ELECTRON CYCLOTRON TRANSMISSION LINES	100%	15.02%
FUEL CYCLE		
VACUUM AUXILIARY SYSTEMS	100%	26.47%
VACUUM SYSTEM ROUGHING PUMPS	100%	0%
PELLET INJECTION SYSTEM	100%	2.63%
DISRUPTION MITIGATION SYSTEM UP TO A CAPPED VALUE		
TRITIUM PLANT		
TOKAMAK EXHAUST PROCESSING SYSTEM	100%	0%
POWER SYSTEMS		
STEADY STATE ELECTRICAL NETWORK	75%	100%

COOLING WATER SYSTEM

TOKAMAK COOLING WATER SYSTEM

- Drying system nitrogen tank fabricated and delivered to IO
- Fabrication continues for multiple components

MAGNET SYSTEMS

CENTRAL SOLENOID (CS) MODULES, STRUCTURE AND ASSEMBLY TOOLING

- Manufacturing complete for all CS tooling components, ready for shipment (**IC milestone**)
- Module 1 is in position on the CS stack in the IO Assembly Hall
- Structures: fabrication and deliveries to IO continue

TOROIDAL FIELD CONDUCTOR

- All conductor unit lengths delivered

DIAGNOSTICS

DIAGNOSTICS

- Water circuit welding study completed for low field side reflectometer
- Captive components for the low field side reflectometer delivered to IO

HEATING & CURRENT DRIVE SYSTEMS

ION CYCLOTRON TRANSMISSION LINES

- Contracts for prototype placed

ELECTRON CYCLOTRON TRANSMISSION LINES

- Waveguide: manufacturing approaches under development
- Prototype fabrication underway

FUEL CYCLE

VACUUM AUXILIARY SYSTEMS

VACUUM SYSTEM ROUGHING PUMPS

- Cryoguard vacuum system (CGVS) control cubicles: fabrication underway
- Valve cage fabrication complete for cryostat roughing and regeneration piping
- Service vacuum system first article contracts placed

PELLET INJECTION SYSTEM

- Design underway for preliminary design of containment cask

DISRUPTION MITIGATION SYSTEM UP TO A CAPPED VALUE

- Testing showed that 20 mm deuterium pellets could be reliably formed and fired at 7-8 Kelvin

TRITIUM PLANT

TOKAMAK EXHAUST PROCESSING SYSTEM

- Prototype fabrication underway

POWER SYSTEMS

STEADY STATE ELECTRICAL NETWORK

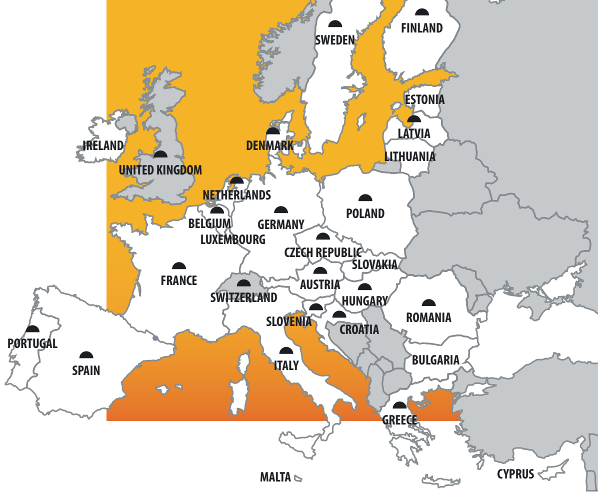
- All components delivered

*Includes Complementary Diagnostic Arrangements

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 Plan ; **MRR** Manufacturing Readiness Review ; **PA** Procurement Arrangement ; **PDR** Preliminary Design Review ; **SAT** Site Acceptance Tests.

FUSION FOR **ENERGY (EU-DA)**

https://fusionforenergy.europa.eu/



PROCUREMENT ARRANGEMENTS*
Forty-one PAs signed since 2007 representing
85% in number and
96.6% of the total value of EU-DA in-kind contributions.

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

EU procurement highlights in 2022 — % of ITER system procured by the EU — % Credit released out of allocation

BUILDINGS

TOKAMAK PIT EXCAVATION AND GROUND SUPPORT STRUCTURE, ANTI-SEISMIC BEARINGS (2 PAS) — 100% — 100%
- Excavation and ground support completed; Anti-seismic bearings completed
- Control Building (71N, non-PIC) ready for equipment (**IC milestone**)
- Ready for equipment: Fast Discharge & Switching Network Resistor Building (75), Cryoplant Compressor Buildings (51 and 52)
- Tokamak and Diagnostics buildings: civil works and painting handed over to IO; construction design of services completed (except I&C)
- Tritium Building civil and finishing works scope: levels B2/B1/L1 taken over by IO
- Tritium Building: doors procurement and installation contract signed

BUILDING CONSTRUCTION — 100% — 45.72%

ARCHITECT ENGINEER SERVICES — 100% — 66.07%
- Headquarters building completed

POLOIDAL FIELD (PF) COILS WINDING FACILITY — 100% — 95%
- PF Winding Facility completed

ITER HEADQUARTERS — 100% — 100%

MAGNET SYSTEMS

TOROIDAL FIELD CONDUCTOR — 20.2% — 100%
- All conductor unit lengths completed

TOROIDAL FIELD MAGNET WINDINGS (10 OUT OF 19) — 50.9% — 81.32%
- 2 coils delivered to IO; 1 other travelling

PRE-COMPRESSION RINGS — 100% — 100%
- All pre-compression rings completed

POLOIDAL FIELD CONDUCTOR — 13.9% — 100%
- All conductor unit lengths completed

POLOIDAL FIELD MAGNETS NO. 2-6 — 100% — 63.56%
- PF4: ready for cold testing
- PF3: winding pack impregnation underway
- Winding table dismantled after 30 production pancakes

HEATING & CURRENT DRIVE SYSTEMS

NEUTRAL BEAM (NB) POWER SUPPLY — 34% — 46.54%
- FDRs completed for the conversion system of the acceleration grid power supply (AGPS) and high voltage bushing assembly
- Manufacturing started for the residual ion dump power supply, the AGPS, and the high voltage bushing assembly

NB TEST FACILITY (NBTF) COMPONENTS — 96.6% — 61.01%
- MITICA beamline components: residual ion dump, neutralizer and calorimeter under manufacturing; assembly preparations underway
- MITICA beam source: ongoing manufacturing and testing of components

NB ASSEMBLY AND TESTING — 100% — 0%

NB SOURCE AND HIGH VOLTAGE BUSHING — 100% — 0%
- Pre-procurement activities ongoing

NB BEAMLINE COMPONENTS — 100% — 0%
- Pre-procurement activities ongoing

ITER NB CONFINEMENT AND SHIELD COMPONENTS — 100% — 0%
- Drift duct FDR held

NB ACTIVE COMPENSATION & CORRECTION COILS — 100% — 0%
- PA preparation for magnetic shielding ongoing (comprising passive magnetic shielding (PMS) and active compensation and corrective coils (ACCC))

ELECTRON CYCLOTRON HIGH VOLTAGE POWER SUPPLY — 75% — 68.79%
- All 8 sets of the electron cyclotron power supply (ECPS) system fabricated
- FAT successfully passed for the two units; delivery to ITER
- Installation of the first two units ongoing

ELECTRON CYCLOTRON UPPER LAUNCHERS AND EX-VESSEL WAVEGUIDES — 100% — 7.62%
- Signature of the first specific contract with the Technical Integrator

ELECTRON CYCLOTRON RADIO FREQUENCY POWER SOURCES (6 GYROTRONS OUT OF 24) — 25.1% — 0%
- Specific contract preparation activities ongoing

VACUUM VESSEL

MAIN VESSEL (5 OF 9 SECTORS) — 77.4% — 54.50%
- Sector #5: Final D-shape completed, sector outer shell welding ongoing
- Sector #4: Final D-shape completed, preparation for outer shell welding
- Sector #9 and #3: Segment outer shell welding completed
- Sector #2: Segment outer shell welding ongoing

	% of ITER system procured by the EU	% Credit released out of allocation

DIVERTOR

	% of ITER system procured by the EU	% Credit released out of allocation
INNER VERTICAL TARGETS	100%	15.75%
Signature of the first specific contract for series production		
CASSETTE BODY	100%	8.77%
Series manufacturing: both contractors progressing		
Signature of ancillary contract for pins, sleeves, and links		
DIVERTOR RAIL	100%	0%
Following the postponement of the PA signature, document preparation will start in 2023		

BLANKET

	% of ITER system procured by the EU	% Credit released out of allocation
BLANKET FIRST WALL	47.7%	0%
Production line preparation for series manufacturing of first wall panels		
Pre-series panel manufacturing started after the corresponding MRR		
BLANKET COOLING MANIFOLDS	100%	4.52%
Tender negotiation completed for the signature of multiple framework contracts for series production		
Parallel activities underway for additional testing of support designs and stress analysis supports		

REMOTE HANDLING

	% of ITER system procured by the EU	% Credit released out of allocation
Advances in GENOROBOT integration into Divertor Test Platform 2 (DTP2)		
Procurement and development of generation 2 rad-hard electronics for camera and multiplexer advancing		
IN-VESSEL DIVERTOR REMOTE HANDLING SYSTEM	100%	0%
Tender advancing for the final design contract of the cassette toroidal mover and development of the multifunctional mover, with R&D in support		
CASK AND PLUG REMOTE HANDLING SYSTEM	100%	4.63%
Final design of first assembly casks nearing completion; design review planned in March 2023		
EX-VESSEL NEUTRAL BEAM REMOTE HANDLING SYSTEM	100%	4.81%
Signature planned in April 2023 for the crane final design contract		
IN-VESSEL VIEWING SYSTEM (IVVS)	100%	26.65%
Final design of IVVS advancing along with prototyping and assembly		

POWER SYSTEMS

	% of ITER system procured by the EU	% Credit released out of allocation
STEADY STATE ELECTRICAL NETWORK (SSEN) AND PULSED POWER ELECTRICAL NETWORK (PPEN):		
DETAILED SYSTEM ENGINEERING DESIGN	100%	70.62%
SSEN AND PPEN INSTALLATION AND COMMISSIONING	100%	28.12%
EMERGENCY POWER SUPPLY	100%	0%
SSEN COMPONENTS	25%	33.36%

FUEL CYCLE

	% of ITER system procured by the EU	% Credit released out of allocation
FRONT END CRYO-DISTRIBUTION: WARM REGENERATION LINES	100%	100%
Warm generation line package completed		
FRONT END CRYO-DISTRIBUTION: FRONT END CRYOPUMP DISTRIBUTION	100%	30.03%
4 cold valve boxes delivered		
Contract signed for neutral beam cryolines and cryojumpers		
CRYOPUMPS, TORUS (6) AND CRYOSTAT (2)	100%	0%
Charcoal coating process qualified		
First pump plug assembly complete		
CRYOPUMPS, NEUTRAL BEAM	100%	4.91%
MITICA cryopump manufacturing completed		
LEAK DETECTION	100%	0%
Start of component qualification activities		

TRITIUM PLANT

	% of ITER system procured by the EU	% Credit released out of allocation
WATER DETRITIATION SYSTEM: WATER HOLDING TANKS AND EMERGENCY TANKS	100%	100%
Water holding tanks and emergency tanks completed		
WATER DETRITIATION SYSTEM: TANKS, MAIN SYSTEM, AND WATER DETRITIATION	100%	0%
HYDROGEN ISOTOPE SEPARATION SYSTEM	100%	0%

CRYOPLANT

	% of ITER system procured by the EU	% Credit released out of allocation
CRYOPLANT: LN2 PLANT AND AUXILIARY SYSTEMS	100%	88.46%
Liquid nitrogen tank and distribution system commissioned		

DIAGNOSTICS

	% of ITER system procured by the EU	% Credit released out of allocation
DIAGNOSTICS	33%	13.03%
Completion of planned deliveries to ITER of inner vessel (magnetics sensor) coils		
Closure of MRRs and manufacturing underway for: magnetics plant controller software and magnetics bespoke electronics, and divertor (magnetics sensor) coils		
MRR held for in-vessel supports		
Signature of major contracts for: manufacture of vacuum vessel electrical feedthroughs; design of vacuum vessel and divertor bolometer cameras		
Closure of 9 FDRs: port engineering of 4 upper ports (UP01, UP03, UP10 and UP17) and 2 equatorial ports (EP01 and EP10); EP12 collective Thomson scattering; vacuum vessel electrical feedthroughs; magnetics diagnostic data-analysis software		
Closure of 2 PDRs: port-mounted bolometer cameras and sensors; equatorial visible/IR wide-angle viewing system I&C		
PDR held for core plasma charge exchange recombination spectrometer UP03 systems		

RADIOACTIVE MATERIALS

	% of ITER system procured by the EU	% Credit released out of allocation
WASTE TREATMENT AND STORAGE	100%	0%
RADIOLOGICAL PROTECTION	100%	0%

*Does not include Complementary Diagnostic Arrangements

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INTERNATIONAL COOPERATION

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

INTERNATIONAL ORGANIZATIONS

International Atomic Energy Agency (IAEA)	**AUSTRIA**
CERN (European Organization for Nuclear Research)	**SWITZERLAND**
International Union of Pure and Applied Physics (IUPAP)	**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**
VTT Technical Research Centre	**FINLAND**
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**
Institut für Technische Optik (ITO)	**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)	**KOREA**
Dutch Institute for Fundamental Energy Research (DIFFER)	**NETHERLANDS**
Nuclear Physics, Polish Academy of Sciences (IFJ Pan)	**POLAND**
The Institute of Nuclear Physics	**POLAND**
Poznan Supercomputing and Networking Center (PSNC)	**POLAND**
Instituto Superior Técnico (IST)	**PORTUGAL**
The Ioffe Institute	**RUSSIAN FEDERATION**
The Budker Institute of Nuclear Physics, Siberian Branch, Russian Academy of Sciences (BINP SB RAS)	**RUSSIAN FEDERATION**
Barcelona Supercomputing Center	**SPAIN**
Centro de Investigaciones Energéticas 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**
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**
Research and Innovation Centre for Electrical Engineering (RICE) of the University of West Bohemia ... **CZECH REPUBLIC**
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 ... **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**
Università degli studi di Brescia ... **ITALY**
University of Genoa - Department of Electrical, Electronic, Telecommunications Engineering and Naval Architecture (DITEN) ... **ITALY**
University of Genoa ... **ITALY**
University of Padua ... **ITALY**
Università degli studi di Palermo ... **ITALY**
Politecnico di Milano ... **ITALY**
Politecnico di Torino ... **ITALY**
Kyushu University ... **JAPAN**
Kyoto University ... **JAPAN**
Tohoku University ... **JAPAN**
Seoul National University ... **KOREA**
Korean Advanced Institute of Science and Technology (KAIST) ... **KOREA**
Eindhoven University of Technology ... **NETHERLANDS**
Technical University of Lodz ... **POLAND**
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 Ljubljana ... **SLOVENIA**
Universidad de Sevilla ... **SPAIN**
Universidad Politécnica de Madrid ... **SPAIN**
Universidad Carlos III de Madrid ... **SPAIN**
Universitat Politècnica de Catalunya (UPC) ... **SPAIN**
University of Chalmers ... **SWEDEN**
Uppsala University ... **SWEDEN**
University of Basel ... **SWITZERLAND**
University of Strathclyde ... **UNITED KINGDOM**
University of Columbia ... **UNITED STATES OF AMERICA**
University of Wisconsin-Madison ... **UNITED STATES OF AMERICA**
University of Texas-Austin ... **UNITED STATES OF AMERICA**
Lehigh University ... **UNITED STATES OF AMERICA**
University of California, Los Angeles (UCLA) ... **UNITED STATES OF AMERICA**
William & Mary ... **UNITED STATES OF AMERICA**
University of California, Irvine (UCI) ... **UNITED STATES OF AMERICA**

NATIONAL SCHOOLS

The Royal Institute of Technology (KTH) ... **SWEDEN**

OTHERS

Broader Approach Activities (EU/Fusion for Energy + JA/ QST National Institutes for Quantum Science and Technology (JA/QST) ... **EUROPE/JAPAN**
École Nationale Supérieure d'Électrotechnique, d'Électronique, d'Informatique, d'Hydraulique et des Télécommunications TOULOUSE INP/ENSEEIHT "N7" ... **FRANCE**
Électricité de France ... **FRANCE**
Renaissance Fusion SAS ... **FRANCE**
Tunnel Euralpin Lyon Turin ... **FRANCE-ITALY**
Consortium RFX (Italian National Research Centre, ENEA, Università di Padova, Acciaierie Venete S.p.A., Italian National Institute for Nuclear Physics) ... **ITALY**
National Research Council ... **ITALY**
Google Ireland Ltd ... **IRELAND**
Italian National Agency for New Technologies, Energy and Nippon Telegraph and Telephone (NTT) ... **JAPAN**
Netherlands Organisation for Applied Scientific Research (TNO) ... **NETHERLANDS**
Rosatom Western Europe SARL ... **RUSSIAN FEDERATION**
Microsoft Corporation ... **UNITED STATES OF AMERICA**

ORGANIZATION CHART

ITER COUNCIL

DIRECTOR-GENERAL
PIETRO BARABASCHI

SAFETY AND QUALITY DEPARTMENT SQD

SECURITY, HEALTH & SAFETY
> Occupational Health & Safety
> Security

NUCLEAR SAFETY

QUALITY MANAGEMENT

DEPUTY OF THE DIRECTOR-GENERAL

INTERNAL AUDIT SERVICE IAS

OFFICE OF THE DIRECTOR-GENERAL ODG

- ITER COUNCIL SECRETARIAT ICS
- LEGAL AFFAIRS LGA
- COMMUNICATION COM
- SENIOR ADVISORS SA

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 & 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
> Commissioning & Operations Readiness

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
> Fuelling & Wall Conditioning
> Tritium Plant

HOT CELL FACILITY
> Hot Cell & Radwaste
> Remote Handling

DESIGN OFFICE (DO)
> 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, Cryostat Thermal Shield, Auxiliaries

TOKAMAK COMPLEX
> Process Installation
> Vacuum Delivery & Installation

PLANT CONSTRUCTION DEPARTMENT PLD

> Supply & Service Installation

FIELD ENGINEERING INSTALLATION
> Electrical Systems Installation Surveillance
> Mechanical & Piping Installation Surveillance
> In-Field Engineering Support

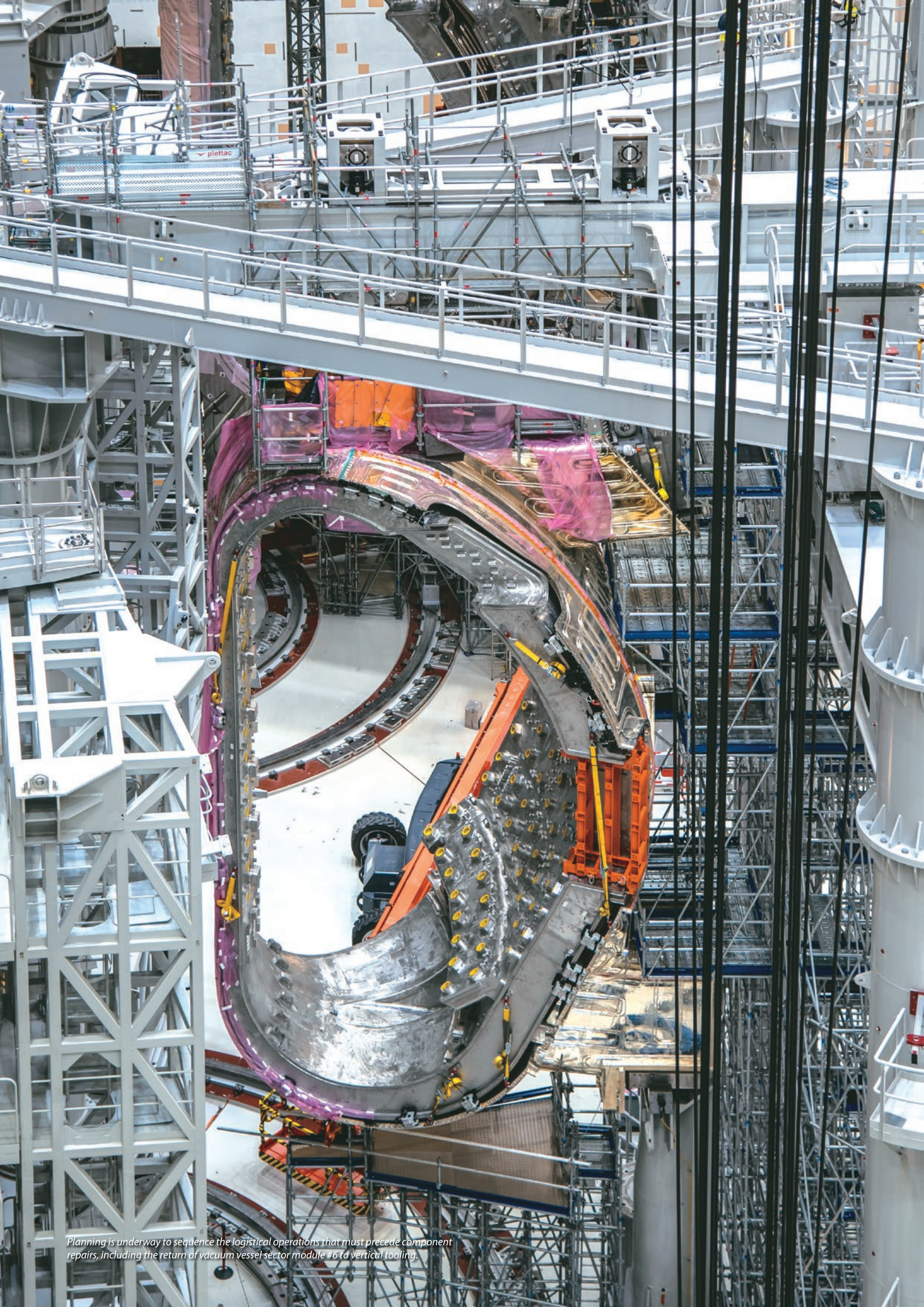
MECHANICAL IMPLEMENTATION
> Cooling, Mechanical & Welding
> Cryogenics
> Tokamak Cooling Water System

ELECTRICAL IMPLEMENTATION
> Coil Power Supply
> I&C Infrastructure

CONSTRUCTION MANAGEMENT OFFICE CMO

> Site Planning & Coordination
> Site Management
> Building & Civil Works

May: The 1,380-tonne load has just passed the wall separating the Assembly Hall from the machine assembly pit with a vertical clearance of 20 centimetres.



Planning is underway to sequence the logistical operations that must precede component repairs, including the return of vacuum vessel sector module #6 to vertical tooling.

LOOKING AHEAD:
2023

- CARRY OUT REVERSE WORKS ON THE THREE DELIVERED SECTORS TO PREPARE FOR REPAIRS
- SELECT CONTRACTORS FOR REPAIR CAMPAIGNS
- LAUNCH VACUUM VESSEL REPAIR AND THERMAL SHIELD REPAIR/ REPLACEMENT
- CONTINUE ASSEMBLING THE CENTRAL SOLENOID MAGNET TOWER
- CONSTRUCT THE ITER SCIENTIFIC DATA & COMPUTING CENTRE (HEADQUARTERS)
- FINALIZE NEUTRAL BEAM POWER SUPPLY BUILDINGS
- RECEIVE FINAL TOROIDAL FIELD COILS FROM EUROPE AND JAPAN
- RECEIVE POLOIDAL FIELD COIL #4 FROM EUROPE
- RECEIVE FIRST EUROPEAN VACUUM VESSEL SECTOR
- RECEIVE NEXT-IN-LINE CENTRAL SOLENOID MAGNETS
- RE-EXAMINE THE STAGED APPROACH TO FULL FUSION POWER

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