

ITER ORGANIZATION PROGRESS IN PICTURES 2020



















A STAR IS BORN

Astar will soon be born, a star unlike any other... a star Afashioned by human hands. ITER – the Latin word for "The Way" – will light up by the middle of this decade.

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

An unprecedented international collaboration that brings together China, the European Union (plus Switzerland through Euratom), India, Japan, Korea, Russia and the United States, the ITER Project marks the culmination of decades of research and years of diplomatic negotiation. What was the aspiration of three generations of physicists is now the reality of thousands of scientists, engineers, and labourers involved in ITER in France and throughout the world.

The seven ITER Members, representing half the world's population, share the responsibility for building the ITER machine and facilities. Every Member, essentially, is involved in every system and benefits from the intellectual property generated.

As buildings on the construction platform are nearing completion and First Plasma component manufacturing has passed 84%, ITER has now fully entered the machine assembly phase. In the exceptional context of the COVID-19 pandemic, the ITER Organization and the seven Domestic Agencies are adjusting and finding ways of maintaining critical activities while ensuring the safety and wellbeing of their staff and collaborators.

This seventh annual edition of the ITER photobook aims to take you into the heart of the project – from the rolling hills of Provence to factories on three continents where men and women from 35 nations are bent on realizing one of humankind's most enduring dreams: capturing the fire of the stars and making it available for generations to come.



THE ITER TOKAMAK



The ITER machine is a *tokamak*, the Russian acronym for Toroidal Chamber, Magnetic Coils. Tokamaks were developed in the 1960s at a time when nations were experimenting with all kinds of different systems to reproduce the nuclear reactions at work in the core of the Sun and stars.

A tokamak, like a star, is designed to fuse light atoms into heavier ones. A tokamak is a magnificent tribute to Albert Einstein's E=mc²: the tiny loss of mass that results from the fusion process translates into a huge quantity of energy. One gram of fusion fuel (the hydrogen isotopes deuterium and tritium) generates as much energy as eight tonnes of oil.

ITER will be by far the largest and most complex tokamak ever built. Designed from the experience accumulated in hundreds of fusion machines throughout the world, it will demonstrate that fusion energy is scientifically, technologically and industrially feasible.

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



The ITER Project transitions to a new way of working in 2020 in the context of the Covid-19 pandemic. Strong measures such as telework are implemented to protect staff, while critical activities such as machine assembly (photo) are maintained on the worksite. May 2020



CRANE HALL EMERGES







78% OF CIVIL WORKS COMPLETE



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Construction began on the 42-hectare scientific platform in 2010. Today, 78% of the buildings and infrastructure needed for First Plasma is in place. November 2020



SPACE FOR PRE-ASSEMBLY



In the ITER Assembly Hall, every square metre is accounted for. As machine components are brought in through the double doors at the far end, they are transferred by overhead crane to temporary laydown areas or zones reserved for sub-assembly activities. Then, in the order determined by assembly sequences, the cranes move them to the Tokamak pit. November 2020



filter small spikes in DC waveform before it is fed to the magnetic system. January 2020



LOST IN THE WILD? NOT REALLY



ITER's 180-hectare site fulfils all the technical requirements for hosting the world's largest tokamak, including geological, hydrological and seismic norms and access to water and electricity. In addition, as neighbour to France's Alternative Energies and Atomic Energy Commission's Cadarache site, it benefits from a rich scientific and industrial environment. *February 2020*



Most of the elements of the cryostat support system are in place on the concrete crown at the bottom of the assembly pit, including 18 ball-and-socket bearings (protected by dark grey material). Once machine assembly begins, these elements will disappear from view. *February 2020*





Sometimes a bolt is just a bolt; sometimes it is a work of art anonymously embedded in a work of science. Sans Titre, by American sculptor Christine Corday, is identical to the many thousands of bolts in the crane hall structure except for the inscription "ART." For Corday, who donated her work, it is a statement of Art's support for ITER. January 2020



Every gallery surrounding the ITER Tokamak on three levels has now been sealed off by a 60-tonne nuclear door. As thick as a stone wall and as heavy as a small steam locomotive, the doors are filled with specially formulated concrete that blocks the passage of neutrons and potential contamination. June 2020



TESTING THE LOAD PATH



Milestones achieved by the European Domestic Agency Fusion for Energy in March successfully open the way to machine assembly: the completion of the crane hall structure, the removal of the temporary wall separating the Assembly Hall from the Tokamak Building, and the demonstration of the overhead crane load path. In this image, overhead cranes are carrying mock loads of just over 1,000 tonnes. *March 2020*

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NETWORK OF SCIENTISTS



The project is benefitting from the assistance of world-renowned experts through the ITER Scientist Fellow Network program. Fellows remain employed at their home institutes, while accepting to focus their research on pending questions related to ITER operation. In 2020, coordination with ITER scientists took place through email or teleconference (photo). *February 2020*



FIRST D-SHAPED COIL ARRIVES



Europe's Fusion for Energy delivers the first D-shaped toroidal field coil of the ITER program (TF9) on 17 April 2020. Eighteen others are expected (including one spare) from Europe and Japan. April 2020



segments are dismantled and lifted. April 2020



Painting has been completed, captive components are in place, and the interfacing pieces for the cryostat base – 18 cryostat bearings and "female lugs" anchored in the bioshield wall – have been installed. The Tokamak pit is ready for its first machine component. *May 2020*

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SECOND D-SHAPED COIL DELIVERED



HOTEL PEYROLLES EN PROVENCE

Japan delivers TF12 on 25 April. Each toroidal field coil weighs 360 tonnes, but the load along the ITER Itinerary is closer to 600 tonnes when you count the transport frame and vehicle. *April 2020*



Welding the pipes inside the multi-process cryolines is a challenging operation, sometimes performed in an extremely cramped environment. Approximately 500 cryoline spools will be installed in the Tokamak Building to transport cooling fluids to clients in the ITER machine. *May 2020*





cryostat base goes off without a hitch. May 2020



Hydraulic jacks support the weight of the cryostat base until final metrology is performed and the load can be transferred to the cryostat support bearings. May 2020



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Two poloidal field coils, plus a cryogenic chamber for cold testing, are visible in this photo taken in the on-site European winding facility. A third coil (PF6, under the gantry crane far right) has arrived for cold testing. July 2020

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TOKAMAK BUILDING DELIVERED





new banner celebrates the completion of the Tokamak Building and eight years of collaborative work by the European Domestic Agency (Fusion for Energy, F4E), the joir ITER Organization/F4E Buildings Infrastructure and Power Supplies (BIPS) team, and the Vinci Ferrovial Razel-Bec (VFR) consortium. An estimated 1,000 men and women have taken part in construction. *June 2020*

COUNCIL MEETS UNDER COVID CONSTRAINTS



For the first time in ITER Council history, the Twenty-Sixth (IC-26) and Twenty-Seventh (IC-27) Meetings in June and November take place entirely by video conference. Working as an integrated team, the ITER Organization and seven Domestic Agencies are doing what they can to limit the consequences of the Covid-19 pandemic on manufacturing and installation activities. June 2020

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ALONG THE ITINERARY

china eu india japan korea rus



Poloidal field coil #6 is one of 29 "highly exceptional loads" to travel along the ITER Itinerary in 2020. It takes four nights for the largest convoys to travel the 104 kilometres that separate the port of Berre l'Etang from the ITER site. June 2020



The Tokamak Assembly Preparation Building – designed for the storage and handling of ITER's beryllium components – is completed to nuclear standards in just nine months. The building will be used for pre-assembly activities until the blanket first-wall panels begin arriving in late 2024. December 2020

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CAREFUL COORDINATION

Every convoy that travels the ITER Itinerary is unique and requires close coordination between the different actors involved, including ITER global logistics provider DAHER, Agence Iter France, the European Domestic Agency, the transport crew, and the French gendarmerie. Although all details have long been planned and rehearsed, a last briefing is always organized prior to a convoy's departure. June 2020



WE HAVE ARRIVAL



Procured by Europe and manufactured in China, ring-shaped poloidal field coil #6 will be the first to be integrated into the ITER machine. The massive component arrives in June after a 10,000-kilometre voyage from its manufacturing site in Hefei. June 2020



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Procured by Korea, the first sector of the ITER vacuum vessel is unloaded in France on 22 July after a one-month sea voyage. July 2020



After the cryostat base in May, the cryostat lower cylinder is successfully installed in August. The steel ring, although much taller than the base (12 vs 4 metres), is a considerably lighter load at 375 tonnes (vs 1,250). August 2020



The cryostat lower cylinder passes above the tallest tools of the Assembly Hall – the sector sub-assembly tools – to reach the Tokamak pit. August 2020



The success of each lift operation is dependent on a large number of actors – the ITER Organization assembly teams, the machine assembly contractors, ITER's construction management-as-agent, the crane operator, and safety and security managers. Each group plays an essential role and coordination is paramount. *August 2020*


ASSEMBLY PHASE KICKS OFF



French President Emmanuel Macron and leaders from China, the European Union, India, Japan, Korea, Russia, and the United States declare the start of a new energy era on 28 July 2020, as they officially launch the ITER machine assembly phase. July 2020



DELIVERING POWER



The installation of equipment has begun in the basement galleries of the Tokamak Complex. In this photo busbars, which deliver power to the ITER magnets, are bolted to supports in the Diagnostics Building and connected to one another and to cooling water. September 2020







FROM THE RAFTERS

In the 30-metre-deep Tokamak pit, the ITER machine will be constructed from bottom up. Already, two major cryostat components – the base and lower cylinder – have been installed. November 2020



The gap between the cryostat lower cylinder and the base is 40 millimetres deep. With 80 passes required to fill each predefined section, it will take Indian Domestic Agency contractors approximately five months to finish the in-pit welding and complete all testing. October 2020



Before it can be lifted, tilted to vertical, and installed on one of the sector sub-assembly tools, vacuum vessel sector #6 must be fully instrumented. Some 700 small attachments ("bosses") must be welded to the outer shell to host magnetic sensors and other instrumentation. October 2020



DRAIN TANKS ANCHORED



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A strong anchorage system replaces temporary bolts in the Tokamak Building drain tank room, where seven water tanks – part of the Tokamak cooling and vapour suppression systems – have a role to play during operation, maintenance, and off-normal events. December 2020



The lower cryostat thermal shield will fit inside the soup-dish-shaped depression of the cryostat base to form a heat barrier protecting the magnets at superconducting temperature. In the ITER Assembly Hall, all segments have been assembled. October 2020



bring cryogenic clients back to room temperature. November 2020



Inside the Reactive Power Control Building, and across a one-hectare area nearby, equipment procured by China for ITER's reactive power compensation and harmonic filtering is now in place. October 2020

SUBTERRANEAN WORLD







In the Poloidal Field Coils Winding Facility, data fed by approximately one hundred sensors allow European Domestic Agency contractors to closely watch over the process of resin impregnation for the tightly wound coil layers (double pancakes) that form the building blocks of every magnet. December 2020



4 DOMAIN HEADS, ONE CHALLENGE

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The ITER Organization implements a new construction-focused management and organizational structure early in the year, better aligned with the challenges of the assembly phase. The heads of the Science, Engineering, Corporate and Construction domains are picture here. *April 2020*



A new augmented reality tool developed by experts from France's Alternative Energies and Atomic Energy Commission (CEA) creates an "in-context" immersive reality in the galleries around the ITER Tokamak. By blending virtual elements (i.e., planned equipment) with real elements such as doors and walls, system designers and planners can explore the physical configuration of future environments. *October 2020*

china eu india japan korea russia usa

CANADA AND ITER SIGN COOPERATION AGREEMENT



A Cooperation Agreement signed in 2020 with the Canadian government sets out the terms for the transfer of Canadian-supplied nuclear material (tritium) and tritium-related equipment and technology. October 2020





From a new studio at ITER Headquarters, events, presentations, speeches and ceremonies can be broadcast to the world. In this photo, the Communication and IT teams prepare for a virtual end-of-year ceremony. December 2020

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ITER ORGANIZATION MANUFACTURING

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china eu india japan korea russia usa

A unique aspect of ITER implementation is the in-kind procurement system that was Aestablished at the onset of the project. Rather than contributing purely financial resources, China, the European Union, India, Japan, Korea, Russia and the United States provide 90% of their contributions in the form of machine components, systems and – in the case of Europe – also buildings.

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

The in-kind procurement arrangement is at the core of ITER's founding philosophy, offering the ITER Members invaluable experience in the manufacturing of components for a fusion installation

By contributing to the construction of the experimental machine, the ITER Members are creating and sharing the technological and industrial basis for the commercial fusion reactors of the future.

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



CRYOSTAT



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china eu india japan koren r



One by one, whether large or small, the elements of the feeder system that delivers electrical power, cryogenic fluids and instrumentation to the ITER magnets are arriving on site from China.



Eighteen gravity supports will be bolted to the cryostat base to support the toroidal field coil structure from below, shouldering the dead weight of the tightly integrated magnet system while withstanding the displacement of the coils during cooldown and operation. The cooling system of this unit is about to undergo helium leak testing.

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net system



first two bottom correction coils are shipped by the Institute of Plasma Physics of the Chinese Academy of Sciences (ASIPP) in 2020. Four other bottom coils, six side coils and six t coils will complete the procurement package.



ASIPP from China, and ASG Superconductors (European contractor in the winding facility) celebrate in front of the vacuum chamber where poloidal field coil #6 spent three months in thermal testing.

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LIQUID NITROGEN PLANT



Europe has nearly completed the welding work for liquid nitrogen equipment in the cryoplant. Here, a pipe is inspected prior to installation.



Pictured is the shop floor at Mangiarotti, where one segment of sector #5 (the first expected at ITER) is nearing completion.



Thousands of steel blocks fill just over half of the space between the double walls of the ITER vacuum vessel to shield components outside the vessel from neutrons. India's M/s Avasarala Technologies, Bengaluru, and subcontractors complete all fabrication – close to 9,000 individual blocks – in 2020.



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CRYOSTAT MANUFACTURING ENDS



IMD

With a flag-off ceremony in June for the top lid, the Indian Domestic Agency and Larsen & Toubro Heavy Engineering mark the end of an eight-year industrial adventure – the manufacturing of the ITER cryostat.



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







The first toroidal field coil delivered by Japan (TF12) undergoes pre-assembly operations in a dedicated workshop on site. One other Japanese coil (TF13) arrives at ITER in 2020.



A dummy load is assembled for the integrated tests of MITICA's 1 MV power supply. (Located at the Neutral Beam Test Facility in Padua, Italy, MITICA is a full-size prototype of ITER's heating neutral beam injectors.) Japan has supplied the megavolt bushing, the megavolt transmission line and the high voltage part of the megavolt power supply.



Ten years of planning and fabrication come to an end as Korean Domestic Agency contractor Hyundai Heavy Industries completes the first vacuum vessel sector in April.



On the inner surface of the ITER vacuum vessel, 440 blanket shield blocks will provide nuclear shielding for the vacuum vessel structure and coil systems, as well as support plasma-facing first wall panels. Korea, which is responsible for half of the shield blocks, has completed the first production unit after a lengthy qualification, manufacturing and testing phase. Production can now accelerate.



Six years after the start of fabrication, Korean contractor SFA completes the last 40° sector of the vacuum vessel thermal shield. The stainless steel panels, covered with a 5- to 10-micrometre-thick layer of silver, will be mounted on vacuum vessel sectors before they are lowered into the assembly pit.



At the Sredne-Nevsky Shipyard near Saint Petersburg, ITER's smallest ring coil – PF1 – has successfully passed all winding tests; the next stage, impregnation, is imminent. The transport frame designed for this 200-tonne component is ready to enter service in late 2021.


The Russian Federation has completed the first full-scale prototype of the divertor dome. One of three divertor targets designed to sustain the top heat flux of the ITER machine (10 to 20 MWm²), a dome component will be mounted on each of the 54 divertor cassettes.

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Attached to the inner wall of the vacuum vessel, bimetal pedestals will support blanket electrical connectors and act as low-impedance electrical bridges between blanket modules and the vacuum vessel. The first units have arrived at ITER.

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SIX MODULES OUT OF SEVEN





Six central solenoid modules are pictured in various stages of fabrication at General Atomics in Poway, California. At ITER, six modules will be stacked within a support structure to form the tower-like central solenoid; a seventh will be on hand as a spare.

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After enduring a battery of rigorous tests, the first superconducting magnet module has been given a clean bill of health. The module was subjected to the same extreme conditions it will face at ITER, including vacuum, high current and the cryogenic temperature required for niobium-tin to become superconducting.

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UNDERNEATH A MODULE





A view of the helium piping and manifolds inside a central solenoid module. The modules will be cooled to 4 K (-269 °C) during ITER operation.

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The assembly of the ITER machine begins with the installation of the cryostat base in May 2020. With this spectacular first step a five-year period opens as the Tokamak core machine is assembled piece by piece, layer by layer, and all of the supporting plant systems are installed on site.

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