9th Dec. 2024
13th ITER International School

ITER Overview

Yutaka Kamada
Deputy Director-General
(Science & Technology)
ITER Organization

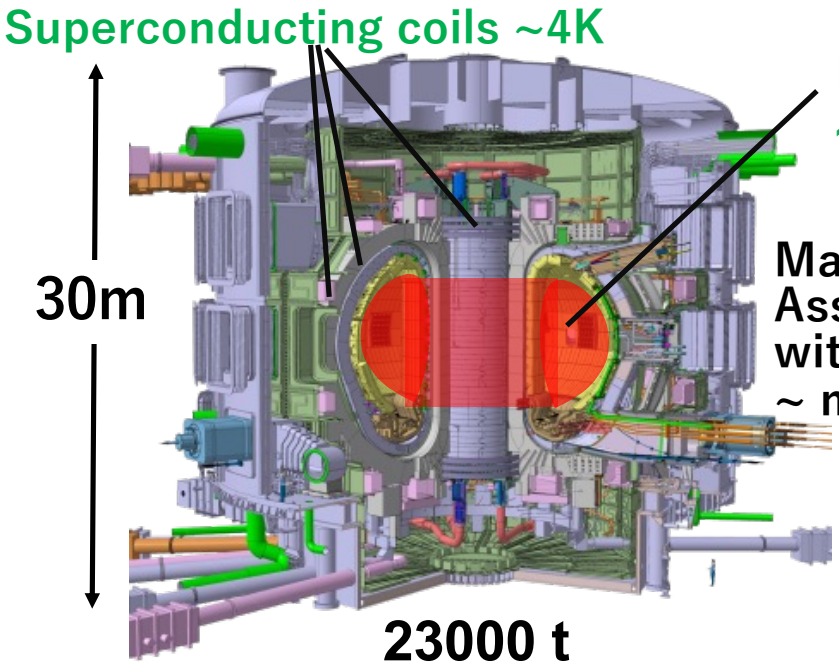
THE ITER MISSION:

Demonstrate the scientific and technological feasibility of fusion power for peaceful purposes at the reactor-scale

Controlled fusion plasma with DT Fusion gain : Q = 10, Fusion Power 500MW

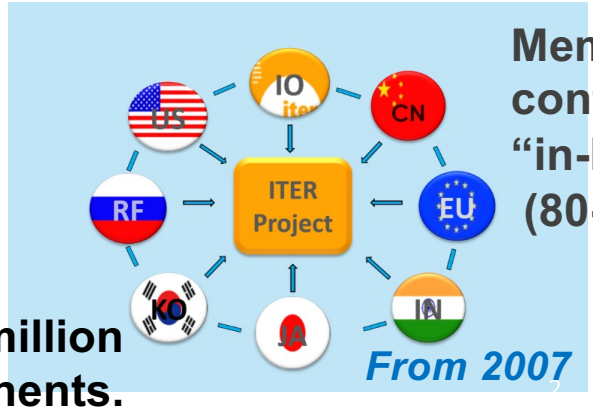
Availability and integration of technologies essential for a fusion reactor = Integrated Fusion Engineering System

First of a Kind fusion system: Many milestones for Fusion



Manufacture & Assembly with accuracy ~ mm

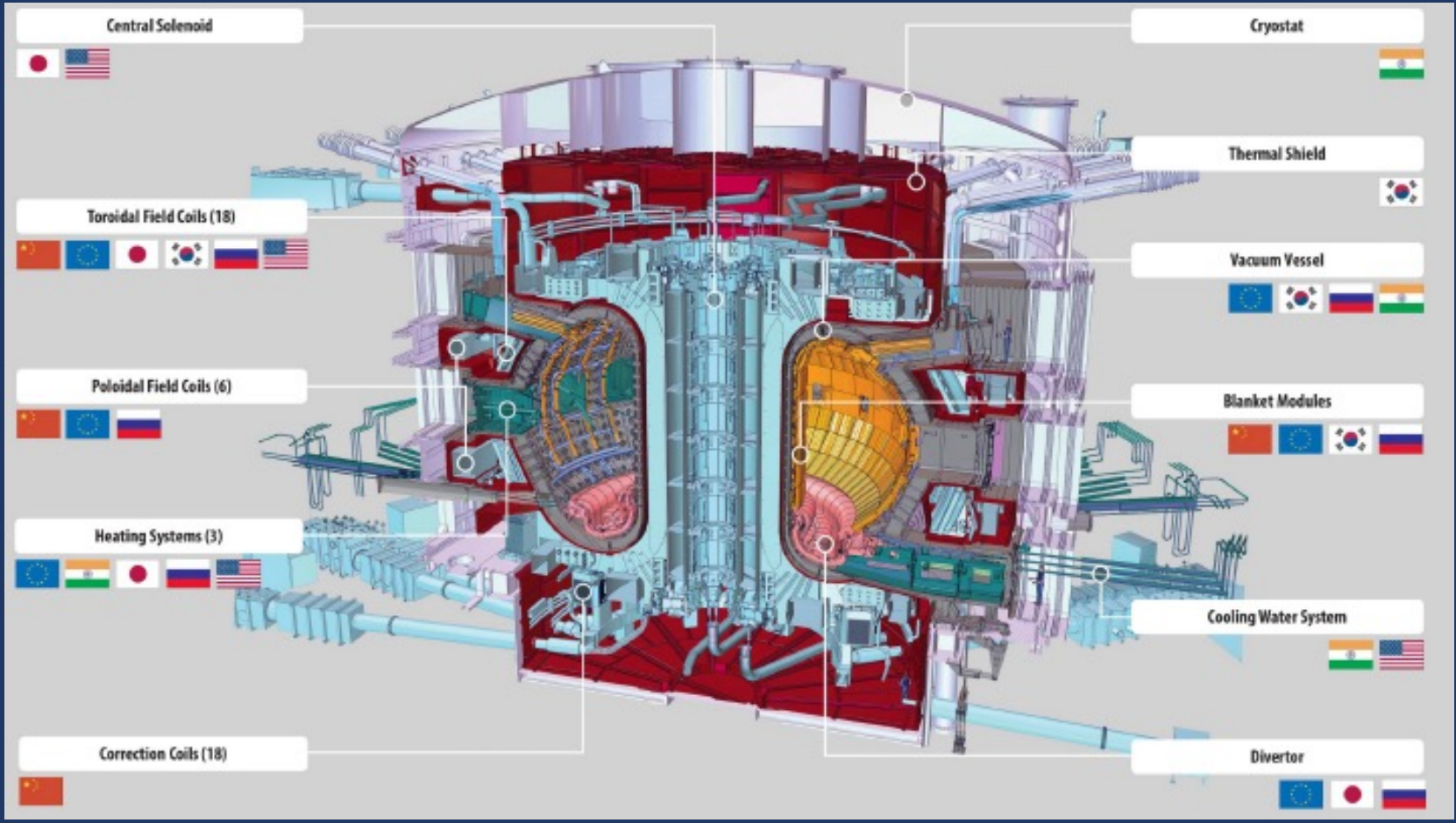
A platform open to the world for fusion science / technology / human resources



Members contribute "in-kind" (80-90%)

More than 1 million components.

Who manufactures what?



The ITER Members share all intellectual and industrial property

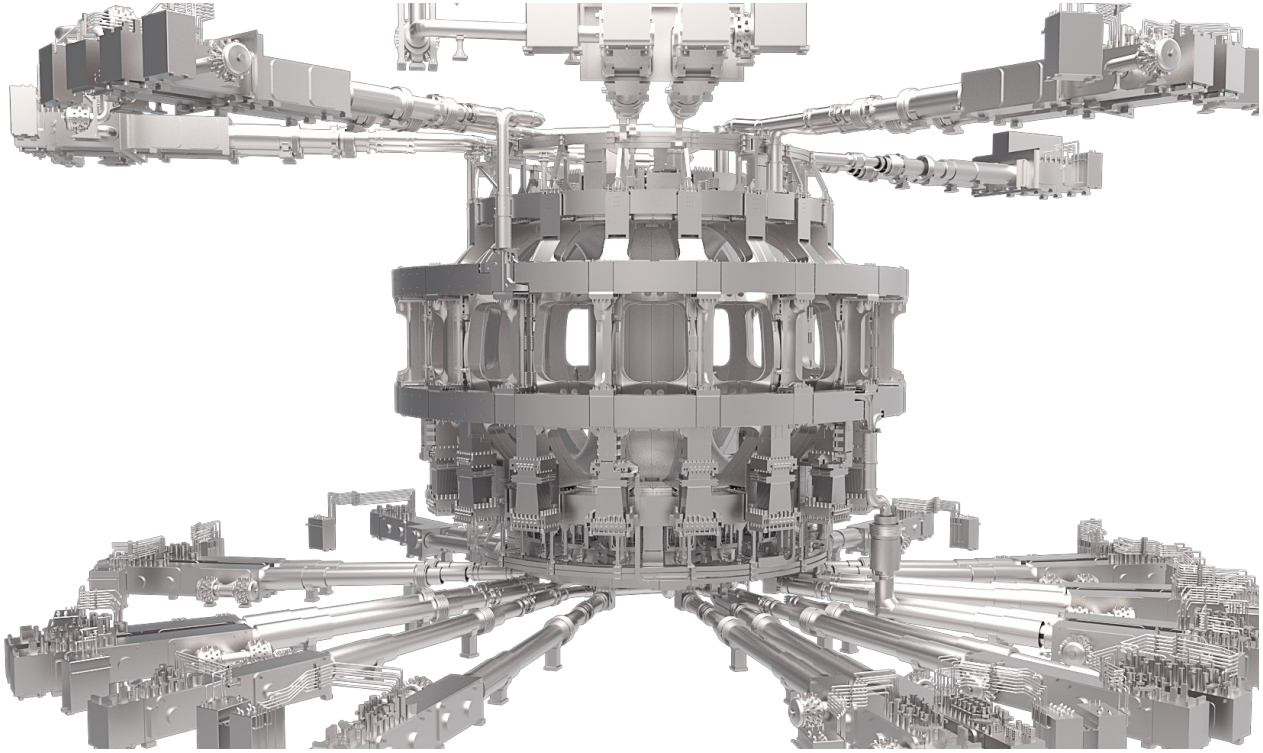

Toroidal Field Coils
17m
All 19 coils Manufacture completed
CryoPlant completed, => commissioning
Magnet Power Conversion completed
April 2021: PF6 placed in pit
85% of civil works now completed.
Jun. 2024
May 2022: The First Sector Module placed in pit
Now under repairment
All 6 coils Manufacture completed
Poloidal Field Coils
ITER New Baseline
2035: DD fusion operation
2039: DT fusion operation
Heat Rejection System completed

THE ITER MAGNET SYSTEM

The most sophisticated superconducting magnet system ever designed with a record stored energy of 51 GJ.

Total weight: 10.000 t
- **18 Toroidal Field (TF) Coils,**
- **a 6-module Central Solenoid (CS),**
- **6 Poloidal Field (PF) Coils,**
- **18 NbTi Correction Coils (CCs).**

The magnet Feeders include
- NbTi CICC busbars (MB & CB),
- Ag-Au(5.4%) BiSCCO 2223 HTS current leads.

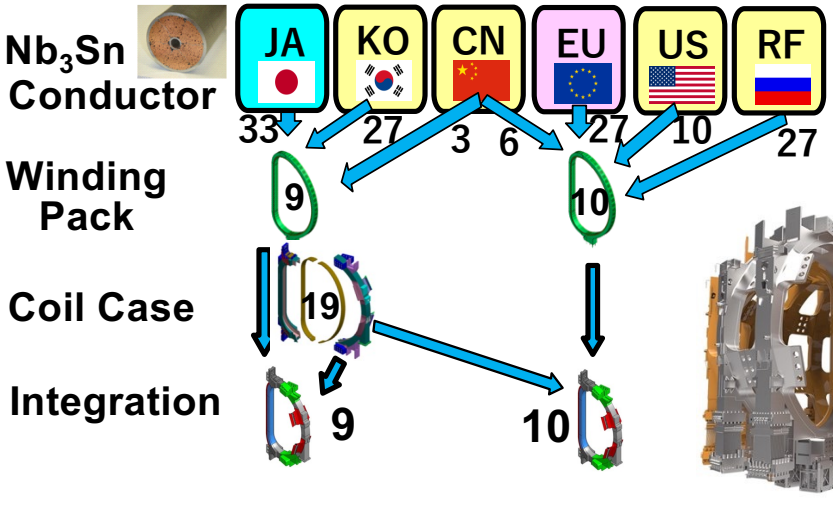


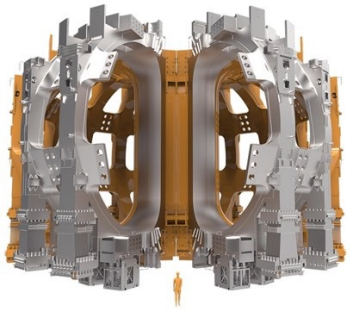
TOROIDAL FIELD COILS

Nb3Sn, 11.8 T, 68kA, 41 GJ,
9 x 17 m, 360 t each

‘Manufacture Completed !’
All 18 + 1 (spare) coils on site (EUx10, JAx9)
~30years’ big effort

‘Supply chain + mass production’
have been already established.



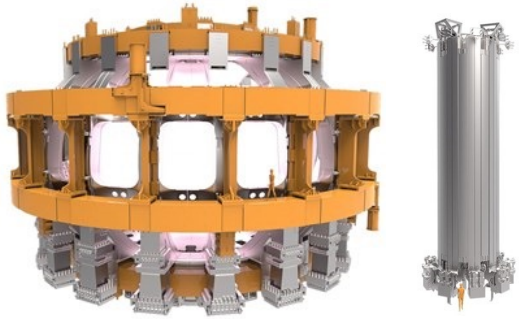


POLOIDAL FIELD (PF) COILS

NbTi, 6T, 45kA, the largest coil 24 mϕ
the heaviest 400 t.

‘Completion’

PF6 (CN) & PF5 (EU) installed;
PF1 (RF) on site
PF2 ,PF3 , PF4 (EU) on site



1000 t

PF3 Manufacture Completion May 2024

CENTRAL SOLENOID

Nb3Sn, 13.5T, 42kA, (US)
A total of six modules => 20m height

‘Manufacture on going’

The 3rd module installed
The 4th module delivered

PLANT SUPPORT SYSTEMS : OPERATIONAL or IN COMMISSIONING

ITER site Power Supply System under steady operation

Cooling water system fully installed and commissioned

Magnet power conversion equipment largely installed

Cryogenics plant: under operation. Liquid He production started !

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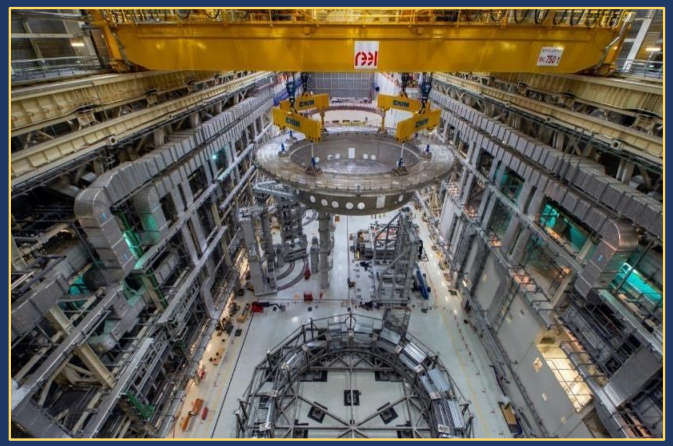
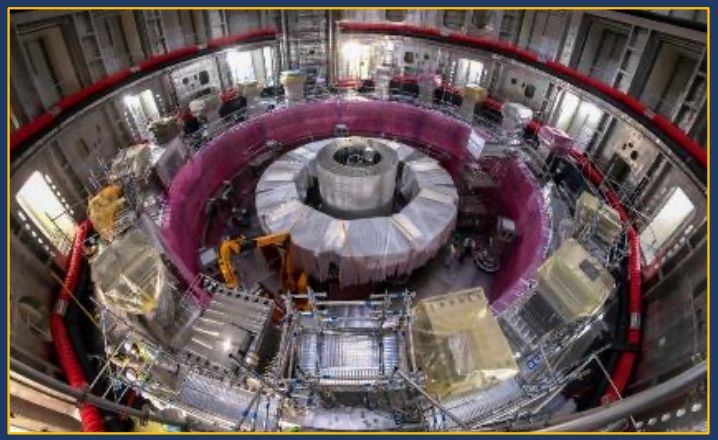
Assembly progress



Cryostat Base (1350t) (May 2020)

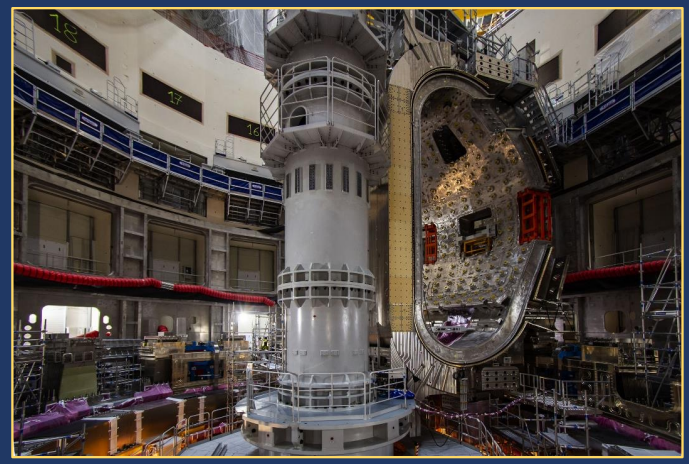
Cryostat Lower Cylinder (Aug.2020)

Lower thermal shield (Jan.2021)



Poloidal field coil # 6 (Apr. 2021)

Poloidal field coil # 5 (Sep.2021)



1st VV Sector Module (May.2022)

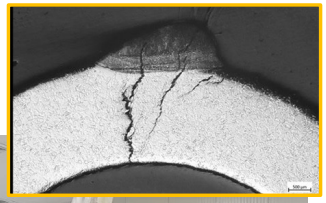
CHALLENGES OF FIRST-OF-A-KIND COMPONENTS

Vacuum Vessel (VV) sectors have geometric non-conformities in the field bevel joints.

- **Repair work has started based on successful R&D.**

Thermal shield have issues of chloride stress corrosion and galvanic corrosion.

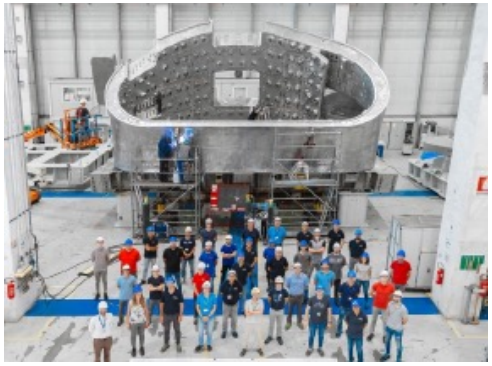
- **All Ag-plating will be removed**
- **repair onsite, repair offsite, &new fabrication.**



Vacuum Vessel Sector: VV#7 & #6 repairment completed (Sep.& Nov.)

=> #7 & #6 Sector Module Sub Assembly (SMSA) started.

VV#5 & #1 arrived at the site (Oct. & Nov).



S5 Completion Ceremony
24 Sep 2024

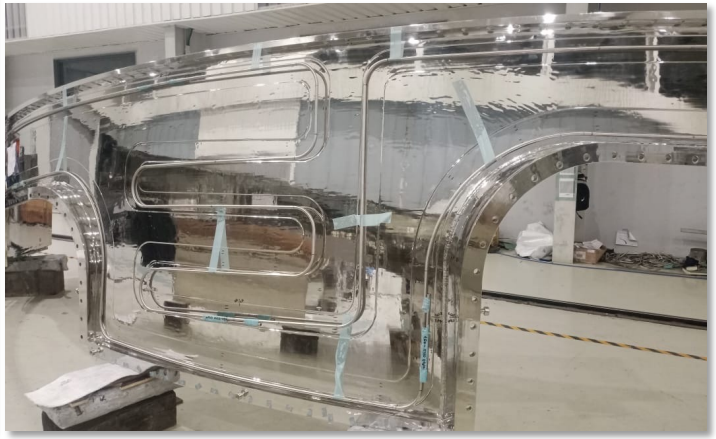
VV Thermal Shield (TS) Repair & remanufacture progressing satisfactorily

Repaired VVTS #7 and #6 were handed over to Sector Module Sub Assembly (SMSA) contractor;

Repaired Panel Assembly at IO

Re-assembly of Outboard #7

Repair (at INOX)

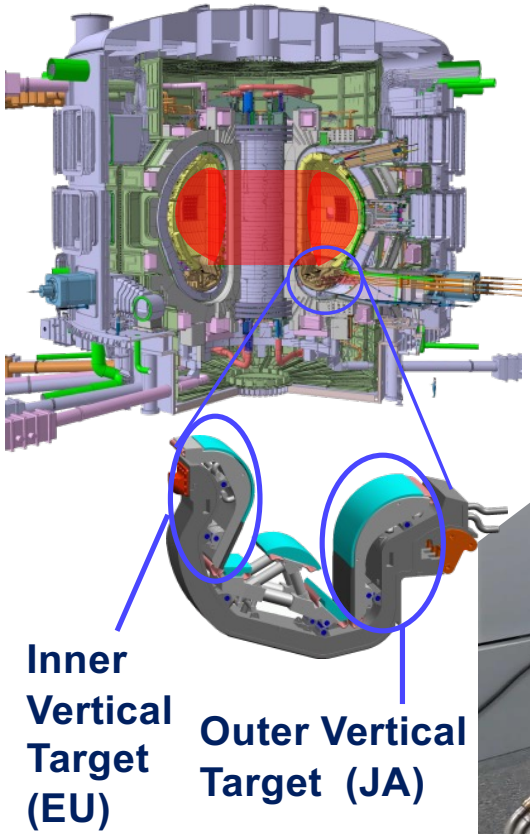


OB #8 Panel buffing completed

Re-Manufacturing (at SHM)

Outboard Fabrication

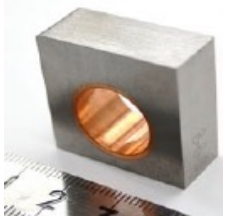
Divertor Outer Vertical Target (OVT) Prototype Delivered



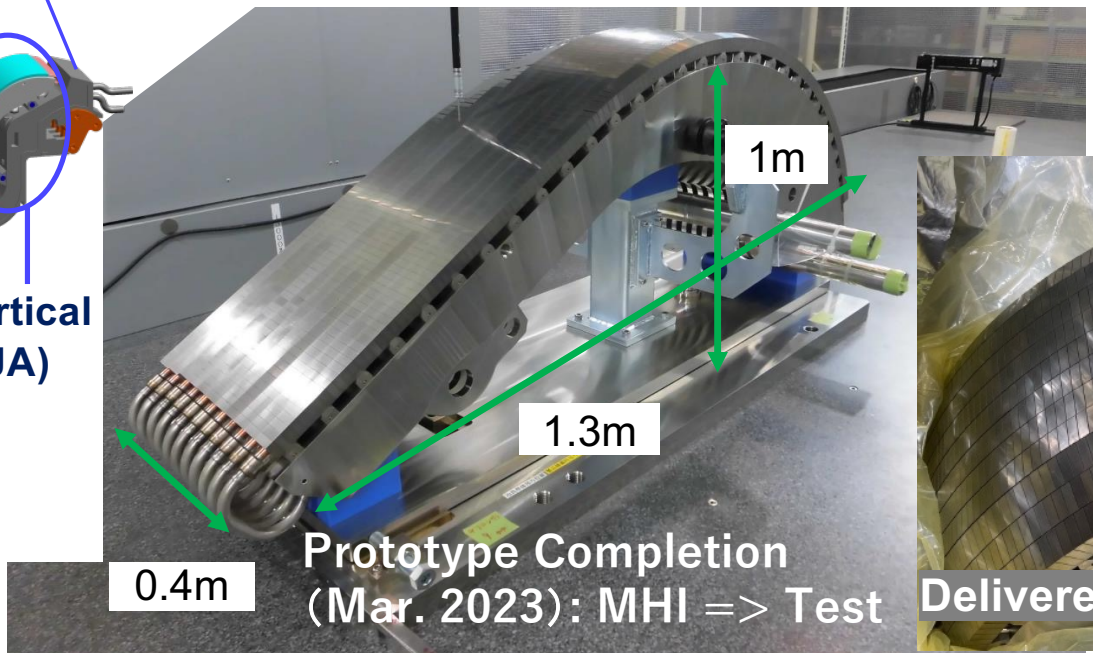
Divertor Cassettes (54 in total)

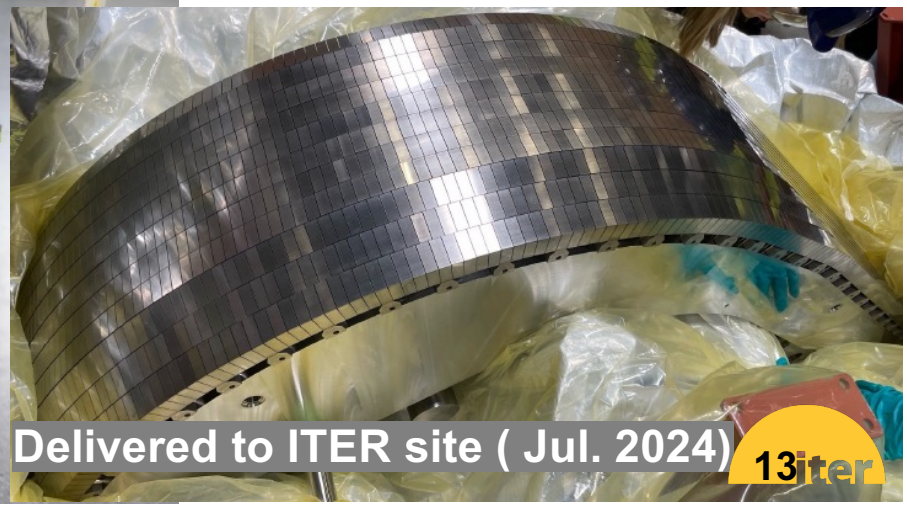
Extremely severe parts receiving a large heat flux from the plasma (20MW/m^2) :
One of the most challenging technologies for DEMO

Tungsten Monoblock (1600 pieces)
Manufactured & assembled with 0.3mm tolerance



Final needs:
200,000 pieces





New Baseline proposed to the ITER Council (IC)
IC-35 (Nov. 2024) endorsed the overall approach.

A comprehensive and feasible plan for assembly, integrated commissioning and operation developed so to keep to the already agreed final project goals and focussed to deliver the key objectives of ITER as early as possible.

Realistic Schedule

Based on all past delays caused by the Covid-19 pandemic, manufacturing and assembly difficulties for first-of-a-kind components, and repair works on key components.

Stepwized Safety Demonstration:

Stepwise safety demonstration and licensing approach as the FOAK industrial-scale DT fusion device far exceeding the dimensions and parameters achieved in present devices:
Results of DT-1(the total fluence of neutron ~ 1% of the end-of-life) => License for DT-2

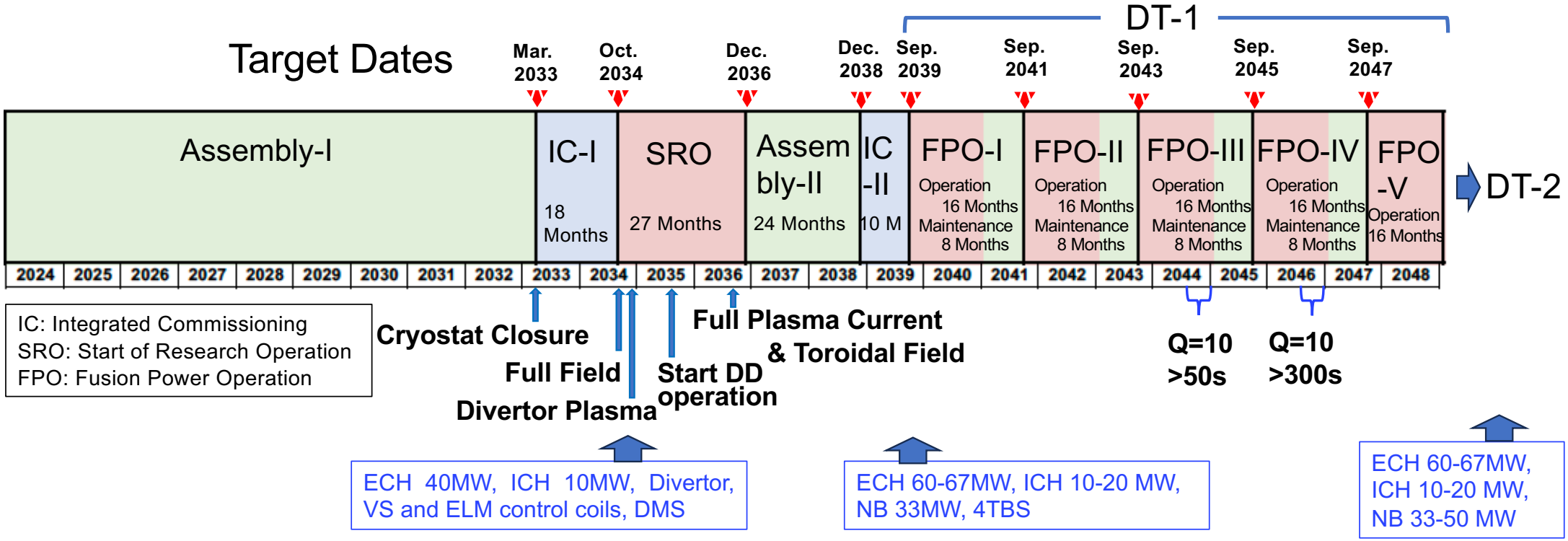
Meaningful First Operation Phase:

Establishing the first operation phase as a scientifically meaningful research phase with sufficient heating power and divertor. Starting DD nuclear operation. Demonstrating the integrated fusion system with the nominal magnetic energy.

Based on the most updated knowledge:

Optimizing the systems based on the most updated scientific knowledge, such as change of the first wall armor material from Be to W, reinforcement of the wall conditioning system, increase of heating power, optimization of plasma diagnostics etc.

New Baseline: Overall Project Schedule

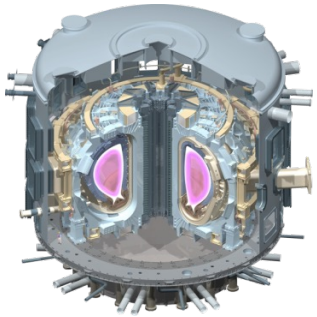


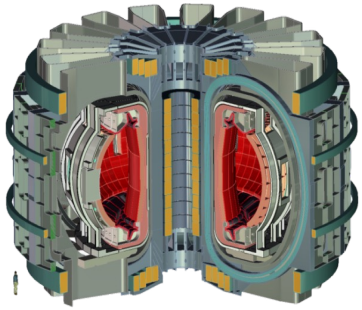
Contingency to be added to the target dates:
2 years for Assembly-I , 6 months for IC-I, 6 months for SRO, 6 months for Assembly-II, 3 months for IC-II

ITER: Contributions to Fusion Power Plants

Science & Technology, Code & Standard, Experience, Human Resources

ITER
~ 500 MWth





Power Plants
~2000MWth
(mid 2040s)

Collaboration with world Fusion Science & Engineering community

Fusion Technology	implementation	evaluation
Manufacture	◎	◎
Assembly and system integration	◎	◎
Plasma Operation	◎	◎

⇔

Fusion
Regulation
Code & Standard

The ITER Project supports private sector fusion companies.

THE ITER MISSION (Project Specification) : Values of ITER

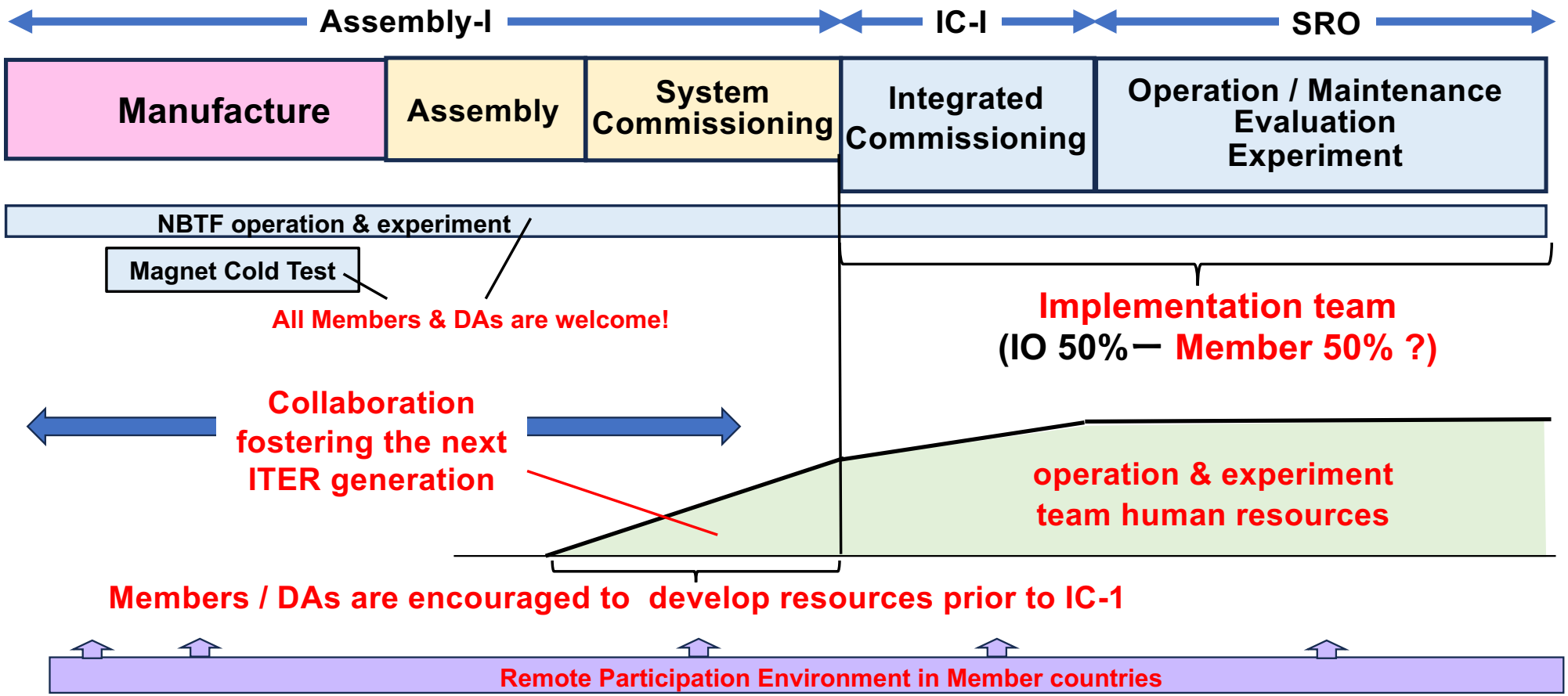
Demonstrate the scientific and technological feasibility of fusion power for peaceful purposes at the reactor-scale: ONLY ITER can accomplish.

Controlled fusion plasma with DT Fusion gain : Q = 10, Fusion Power 500MW

Availability and integration of technologies essential for a fusion reactor = Integrated Fusion Engineering System

ITER brings Fusion Energy from Science to Industry.

ITER needs enhanced collaboration & Future Team Members



Integrated Plasma Control needs to be Developed

key = Diagnostics and Data Science

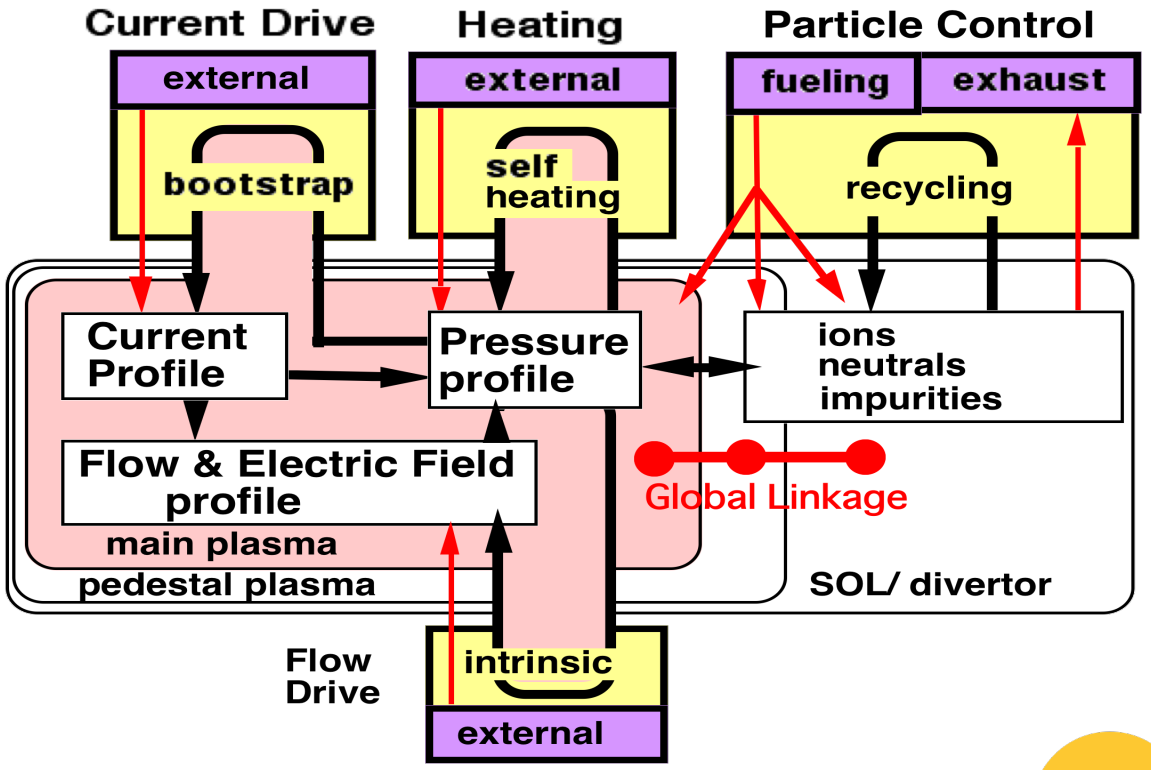
Fusion Plasma = a highly self regulating non-linear combined system governed by strong linkages among j(r), p(r) and v(r) in core & pedestal.
& strong spatial linkage : Core – Pedestal – SOL – Divertor plasmas

Study controllability & Plasma response

Determine minimum set of diagnostics, actuators & logic.
+
control margin against operation boundaries

Prediction, Benchmark

- **World Tokamaks**
- **ITER**
- **DEMO**



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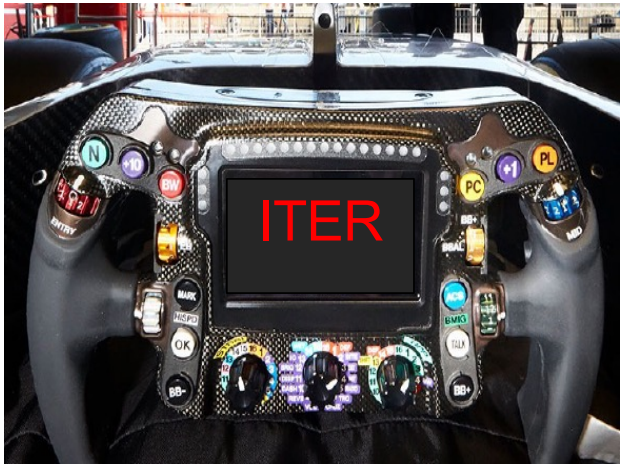
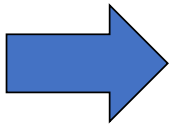
Controllability: Practical in DEMO ?





Your work !

PUBLIC-PRIVATE WORKSHOP *27-29 May 2024, @ ITER site*

Co-hosted by ITER and the IAEA
participants: ~ 350
from 30 start-ups
+ 80 component manufactures

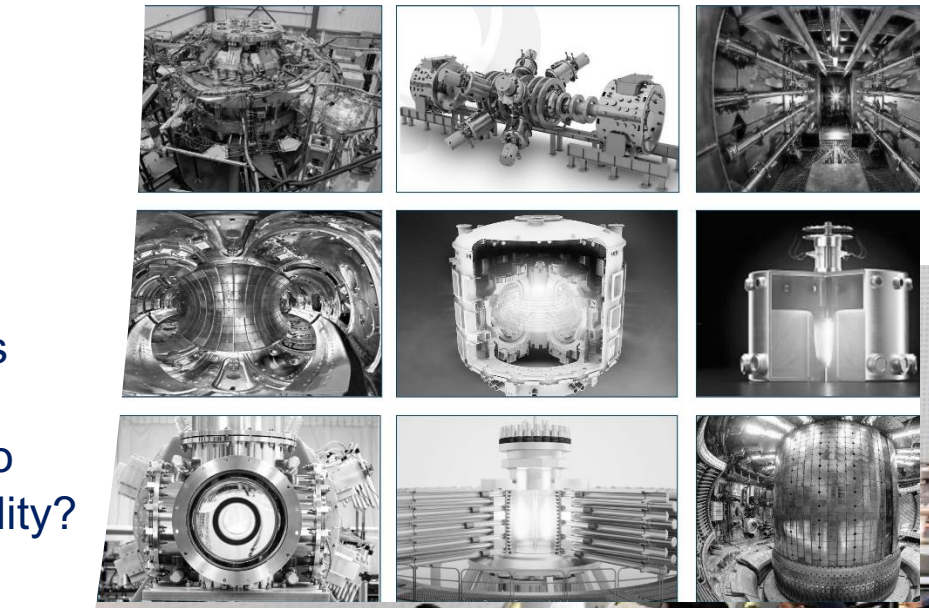
Private fusion presentations:

What innovations and breakthroughs have you achieved?

- What are the remaining hurdles to bring your fusion approach to reality?
- How can ITER help?

Poster session with discussion
ITER site tours

ITER Goal: to establish priorities and formulate plans for how to engage with private sector fusion companies going forward




‘Mutual Trust’ is the core of team building.
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