THE 2024 NEW BASELINE ITER RESEARCH PLAN

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1. INTRODUCTION

The 2024 new baseline has been developed by the ITER Project to ensure a robust achievement of the Projects' goals, in view of past challenges. The 2024 baseline includes modifications to the configuration of the ITER device and its ancillaries (e.g. change from beryllium to tungsten as first wall material, modification of the heating and current drive mix, etc.) as well as additional testing of components (e.g. toroidal field coils) or phased installation (start with inertially cooled first wall before later installation of the final actively water-cooled components) to minimize operational risks [1,2]. In the new baseline, the ITER Research Plan (IRP) scientific exploitation will be divided into three main phases:

a) Start of Research Operation (SRO) with 40 MW of ECH and 10 MW of ICH, which will focus on the demonstration of 15 MA operation in L-mode, commissioning of all required systems, including disruption mitigation, and the demonstration of H-mode plasma operation in deuterium at 2.65 T.

b) First deuterium-tritium phase (DT-1) with 60-67 MW of ECH, 33 MW of NBI and 10-20 MW of ICH, which will demonstrate robust operation in high confinement H-mode plasmas in DT to $Q \geq 10$ and for burn durations ≥ 300 s within an accumulated fluence of 3.5 10^{25} neutrons (~ 1% of the ITER machine's lifetime total)

c) DT-2, with up to 67 MW of ECH, up to 50 MW of NBI and up to 20 MW of ICH, with ITER tokamak and ancillaries in their final configuration to demonstrate routine operation in DT plasmas at high Q and the Q = 5 long-pulse and steady-state scenarios to the final neutron fluence (0.3 MWy/m^2 or 3.0 10^{27} neutrons).

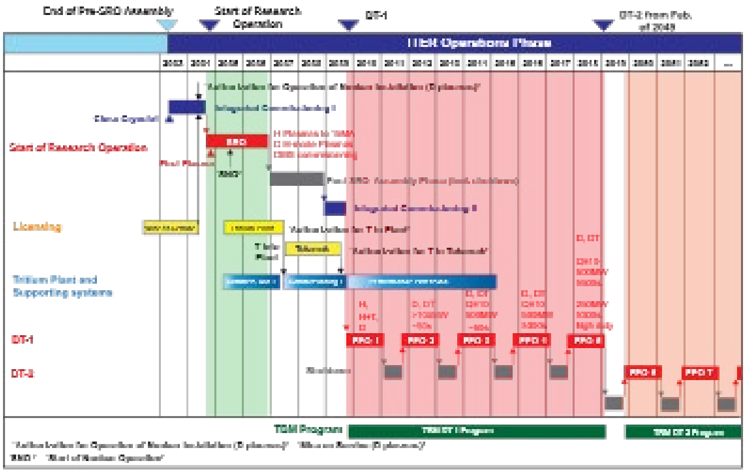

Figure 1. Operational plan for the execution of the 2024 new baseline ITER Research Plan to the demonstration of the $Q \geq 10$ 500 MW fusion power goal in the 1st Deuterium-Tritium phase and the initial campaigns of the 2nd Deuterium-Tritium phase.

The 2024 baseline IRP has been developed with strong involvement of experts from all ITER Members, including the International Tokamak Physics Activity, under the coordination of the ITER Organization. The IRP describes the objectives, scientific and technical deliverables for each of the three operational (as well as the integrated commissioning) phases. It includes the experimental strategy proposed to be followed to the achievements of the Project's goals in consistency with the configuration of the ITER device together with its ancillary and plant systems and the required licencing steps in every phase (see Fig. 1).

2. START OF RESEARCH OPERATION

The objective of this phase is to develop the operational basis for the plasma scenarios to be later employed for fusion power production in DT-1 and to commission the plasma key systems required to support them (e.g. Plasma Control System (PCS), Advanced Protection System (APS), Central Interlock System (CIS), Disruption Mitigation System (DMS), etc.). This phase starts with the demonstration of the first tokamak plasma, which requires all tokamak, plant, and auxiliary systems to operate in an integrated way under the PCS satisfying their respective requirements for plasma operation. In the following part of the SRO phase, tokamak operation up to the nominal plasma current and field of 15 MA / 5.3T will be demonstrated in low confinement mode (L-mode). High confinement mode (H-mode) scenarios will be explored up to 7.5 MA at 2.65 T, both in diverted plasma configurations. This requires commissioning of the available H&CD systems (ECH and ICH) up to their nominal plasma coupled power levels for durations of up to 50 s. Most plasmas will be performed in hydrogen (H or D, with helium-3 (^{3}He) as minority species for ICH) with a specific

‡ See "The new ITER Baseline, Research Plan and open R&D issues", A. Loarte, et al., Proc. 50th EPS Conference, submitted to Plasma Physics and controlled fusion

set of experiments carried out in deuterium plasmas (D, with H as minority species for ICH) to address the exploration of H-mode scenarios and to test ICH; this will mark the Start of Nuclear Operations in ITER. The use of H and D plasmas allows the execution of the experimental programme with low production of neutrons and tritium by fusion reactions required to enable post-SRO assembly activities. The configuration of SRO systems (final or temporary/partial) has been defined to simplify first assembly and facilitate the achievement of its objectives with minimum operational risks, such as those associated with disruption loads and their mitigation. Of particular importance is the use of an inertially cooled W wall in SRO since this minimizes the risks associated with the development of disruption mitigation severely impacting operation [3]. While superficial damage of wall PFCs may not be avoided, no in-vessel leak of water vessel will occur in such events.

3. FIRST DEUTERIUM-TRITIUM PHASE (DT-1)

The objective of the first Deuterium-Tritium (DT-1) phase is to achieve the first Project's goal in the demonstration of the scientific and technological feasibility of fusion power production foreseen in the ITER Project. For the fusion power production goal, this is the demonstration of 500 MW of fusion power production with $Q \geq 10$ for burn lengths longer than 300 s. To meet these goals, the research programme in this phase addresses key scientific and technical issues for the demonstration of nuclear fusion as an energy source, including the self-heating of deuterium-tritium plasmas by alpha particles from the fusion process, the demonstration of operation with efficient tritium management, the demonstration of tritium-breeding by performing the TBM Research Program [4], the validation of assumptions in the nuclear safety licence in DT-1 and the provision of the operational basis to define the licence details for the second Deuterium-Tritium (DT-2) phase. The DT-1 phase is divided into five two-year operational cycles with 16 months of plasma operation followed by 8 months of long-term maintenance plus commissioning periods.

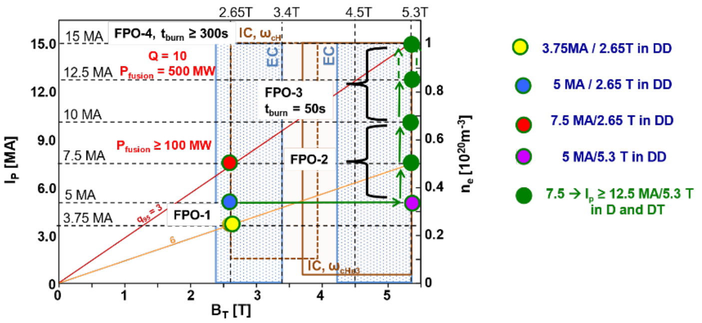

Figure 2. Sequence of H-mode plasma scenarios to be explored in DT-1 in DD and DT plasmas in terms of plasma current, toroidal field and electron density, assuming a typical value of ~ 85% of the Greenwald limit.

The achievement of the DT-1 goals requires installation of new systems or upgrades, in addition to those already available in SRO, particularly of the H&CD systems (ECH, ICH and NBI), the water-cooled W first wall, diagnostics and the TBMs with their ancillary systems. In particular, an extensive set of diagnostics to characterize fusion products will be available.

The DT-1 H-mode scenario development path is shown in Fig. 2 together with the corresponding campaigns in which they will be demonstrated. Emphasis is given to the achievement of $Q \geq 10$ plasmas as soon as possible (i.e. in short ~ 50 s burn lengths) in FPO-3 and, once demonstrated, to the extension of high Q scenarios to, at least, 300s burn in FPO-4. Scenarios will be first developed in D and then reproduced in DT in order to maintain low neutron fluence consumption and ensure the achievement of the $Q \geq 10$ goal within the approved DT-1 fluence.

4. SECOND DEUTERIUM-TRITIUM PHASE (DT-2)

The objective of this phase is twofold:

a) To demonstrate all the Project's fusion power production goals. These goals are the demonstration of 500 MW of fusion power with $Q \geq 10$ for lengths of 300-500 s, in high duty operation, and of long pulse and non-inductive steady-state scenarios with $Q \geq 5$ and burn lengths of 1000 s and 3000 s, respectively. They are presently foreseen to be achievable with the DT-1 H&CD mix at 12.5 MA for the 1000s goal [5] but will require the upgrade of the 3rd NBI for the demonstration of steady-state operation at 10 MA [6], and;

b)To support the ITER Members' demonstration fusion reactor programmes including both scenario development issues (e.g. heat flux exhaust), design basis/operational issues (e.g. optimum H&CD mix, minimum sensor and actuator set for fusion reactors, etc.) and their TBM programmes, in principle, up to neutron fluences of, at least, 0.3 MWyear/m2 (3 10^{27} neutrons), assuming this is confirmed by the licence for DT-2. We note that variants of the ITER long-pulse and steady-state scenarios to address the Project's fusion power production goals above are presently considered as prime candidate operational scenarios for several demonstration fusion reactors and, thus, the research in this area is not only to fulfil the Project's goals but also to support the ITER Members' demonstration fusion reactor programmes.

The logic, physics basis and the modelling and experimental evaluations carried out to support the new baseline and the associated IRP will be described in the paper.

REFERENCES

[1] P. Barabaschi et al., submitted to Fusion Eng. and Design 2025.
[2] A. Loarte, et al., submitted to Plasma Phys. Control. Fus. 2024.
[3] A. Loarte, et al., this conference.
[4] L. Giancarli, et al., Fusion Eng. and Design 203 (2024) 114424.
[5] S.H. Kim, et al., 2016 Nucl. Fusion 56 126002.
[6] A.R. Polevoi, et al., 2023 Nucl. Fusion 63 076003.