INTERNATIONAL ENERGY AGENCY
TECHNOLOGY COLLABORATION PROGRAMME

STELLARATOR-HELIOTRON
IMPLEMENTING AGREEMENT

Annex II

JOINT ANNEX ON COORDINATION ON INTERNATIONAL CHALLENGES ON LONG DURATION OPERATION (CICLOP)

A Joint Task of the Co-operation on Tokamak Programmes (CTP) and Stellarators and Heliotrons (SH) Technology Collaboration Programmes (TCPs)

1. Background:

Controlling fusion plasma for long periods, while gaining experience in steady state and/or long-pulse operation with superconducting magnets and active cooling systems that can maintain the plasma facing components at a stable temperature, is essential for the success of ITER, fusion demonstration power plants and fusion reactors.

To facilitate the coordination on these challenges, a network of experts for **C**oordination on **I**nternational **C**hallenges on **L**ong duration **Op**eration (CICLOP) was established in 2020. The objectives of the CICLOP group are to promote activities, collect and disseminate information on the physics and engineering issues of long-pulse operation for tokamaks and stellarator facilities, by sharing best practice, operational procedures, experimental data, simulation programme and coordinating experiments between the fusion-related IEA Technology Collaboration Programmes (TCPs) in close cooperation with the IAEA Technical Meeting on Long-Pulse Operation of Fusion Devices.

This joint annex describes the objective, goals and organisation of the international CICLOP network. The activities of the CICLOP group will be performed jointly under the TCPs on "Co-operation on Tokamak Programmes" (CTP-TCP) and "Stellarators and Heliotrons" (SH-TCP). Indeed, to successfully implement the CICLOP objectives a joint international effort and coordination are required between tokamaks and stellarators/heliotrons programmes to increase synergies towards the development of long-pulse operation for an efficient fusion reactor operation.

2. Objective:

Long-pulse operation in tokamaks and stellarators is addressing control of stable plasma for duration well above the plasma confinement time and approaching plasma-wall integration timescales where physics processes may evolve on very long timescales (e.g. first-wall erosion process). Long-pulse operation is referring to the "Grand Challenge" for fusion science that requires pushing the limits of physics and technology integration in a nuclear environment for fusion reactor applications. To address

these challenges, long-pulse operation developments require a coordinated worldwide effort that encompasses:

(1) experimental programme on existing short- (physics development or proof of principle experiments) and long-pulses facilities either on tokamaks or stellarators;
(2) technology R&D programme (e.g. actively cooled plasma unit components, super-conducting magnets);
(3) control methods and recovery techniques, to maintain a fusion burning plasma within a safe and stable operating domain, 'transferable' to ITER and to the thermonuclear fusion reactor.

International collaboration and consensus on developing and managing all aspects of long-pulse operation with the ultimate goal of delivering stable electricity on the grids with fusion power plants will facilitate/promote the achievement of the overarching objectives described above where joint programme on tokamaks and stellarators will be mutually benefit.

The group will address the physics and engineering issues of long-pulse operation for tokamak and stellarator facilities. These objectives will be achieved by sharing best practice, operational procedures, experimental data, simulation programme and coordinating experiments between the fusion-related IEA TCPs in close cooperation (by joint meetings and workshops) with the IAEA Technical Meeting on Long Pulse Operation of Fusion Devices.

3. Goals:

The main goals of the joint tasks are detailed as below:

- collect, compare and disseminate information on steady-state and long-pulse operation (e.g. set-up a web site for sharing information and communication with updated information on facilities addressing long-pulse operation issues);

- set-up a high level network of contact persons for tokamaks and stellarators addressing long-pulse issues including future facilities;

- liaise with the relevant topical groups set-up under the International Tokamak Physics Activity (e.g. the Integrated Operational Scenarios group for the development of the long pulse scenarios);

- strengthen the synergy between tokamaks and stellarators;

- identify gaps in physics and technology of long-pulse operation or limiting factors in duration and propose actions plan to address the identified gaps or limiting factors for tokamaks and stellarators;

- propose action plans to address long-pulses issues as, for instance, identified in the latest version of the ITER research plan (c.f. ITER specific R&D topics for the effective implementation of the ITER Research Plan);

- develop a roadmap of activities to be carried-out for long-pulse operation of a fusion thermonuclear reactor including physics, technology, engineering, control and, modelling/theory;

- promote experimental and simulation programmes to address key issues specific to long-pulse operation for ITER and DEMO within the frame of the relevant TCP agreements;

- facilitate exchange of staff, codes, tools procedure and operational practices within the frame of the relevant TCP agreements.

To reach these main goals, the joint Task performed within the CICLOP group has the following objectives:

- to set-up, develop, update and maintain a multi-machine database that includes tokamaks and stellarators data with the summary of the most recent results and possible limiting factors;
- to promote exchanges between tokamaks and stellarators on long-pulses operation physics: experiments, modelling, simulation tools, large data processing tools, operational procedures;
- to promote exchanges between tokamaks and stellarators long-pulses operation technology, engineering and RAMI (Reliability, Availability, Maintainability, and Inspectability) issues: superconducting magnets, actively cooled plasma-facing components, real-time integrated control, CW heating and current drive systems, CW fuelling and pumping systems, CW power supplies, diagnostics, large data acquisition and management, real-time wall monitoring and protection systems (e.g. infrared imaging);
- to promote exchanges of staff, software & hardware between tokamaks and stellarators on topics relevant for long-pulses operation physics and engineering issues for ITER and the fusion power plants.

4. Approach/Means:

The general approach/methodologies to be employed in this joint task is as follows:

- Provide relevant experimental 0-D data for assessing progress towards tokamak long-pulse operation for the CICLOP multi-machine database [jointly with CTP TCP]
- Provide relevant experimental 0-D data for assessing progress towards stellarator long-pulse operation for the CICLOP multi-machine database [jointly with SH TCP]
- Agree on experts for tokamaks [CTP TCP] and stellarators [SH TCP] to attend the CICLOP group meeting for addressing long-pulse issues in present and future facilities;
- Update the gaps in physics and technology of long-pulse operation or limiting factors [CTP TCP & S-H TCP]
- Promote experimental and simulation programmes to address key issues specific to long-pulse operation for ITER and DEMO within tokamak [CTP TCP] and Stellarators [SH TCP] ;
- Facilitate exchange of staff, codes, tools procedure and operational practices for topics relevant of long-pulse operation within the frame of the relevant TCP agreement [CTP TCP and SH TCP];
- Facilitate joint research activities between tokamaks and stellarators [CTP TCP, S-H TCP].

5. Sub-Tasks and Objectives:

- **Sub-task 1 (ST1)**: Collect and disseminate information on steady-state and long-pulse operation

- ST1.1: The group will set-up and maintain a web site for sharing information and communication within the CICLOP group with updated information on facilities addressing long-pulse operation issues and on the high-level multi-machines database combining physics and technology for long-pulse operation.

- ST1.2: The CICLOP chair and Co-chair will set-up and coordinate a network of contact experts for tokamaks and stellarators addressing long-pulse issues.

- ST1.3: The chair or co-chairs of the CICLOP group will attend the annual International Tokamak Physics Activity (ITPA) Coordinating Committee (ITPA-CC) and the CICLOP group members will liaise with the relevant topical group of the International Tokamak Physics Activity;

- **Sub-task 2 (ST2)**: Set-up, maintain and expand a high-level multi-machine database combining physics and technology for long-pulse operation

    - ST2.1: A validated 0-D multi-machine database combining up to date data from tokamaks and stellarators stored on the CICLOP group web page.

- **Sub-task 3 (ST3)**: Contribute to the scientific programme of the IAEA Technical Meetings on Long-Pulse Operation of Fusion Devices. The event aims to review, discuss and address scientific and engineering issues related to steady-state and long-pulse operation of fusion devices, which are essential for ITER and future fusion reactors.

    - ST3.1: Scientific programme of the IAEA Technical Meetings on Long-Pulse Operation of Fusion Devices featuring contributions from the CICLOP group members.

- **Sub-task 4 (ST4)**: Identify gaps in physics and technology of long-pulse operation or limiting factors in duration/performance and propose actions plan to address the identified gaps or limiting factors;

    - ST4.1: List of limits towards long-pulse and high performance operation for tokamak and stellarators maintained by the CICLOP group.

- **Sub-task 5 (ST5)**: Promote experimental and simulation programmes to address key issues specific to long-pulse operation for ITER and DEMO within the frame of the relevant TCP agreement;

    - ST5.1: The CICLOP group members will identify possible exchange of staff, codes, tools procedure and operational practices within the frame of the relevant TCP agreement that will address long-pulse topics.

6. Communication/reporting

- Coordination meeting will be organised among the CICLOP participants at a level of minimum two video-conference meetings per year. During these meetings, report on progress towards the development of long-pulse operation will be provided by the CICLOP members acting as contact person within their relevant facilities.

- The chair or Co-Chair will provide a written report and an oral presentation at the annual IEA Fusion Power Co-ordinating Committee (FPCC) and to the relevant Executive Committees.
- Chair and co-chairs will participate to the ITPA-CC, and members of the CICLOP group to the relevant ITPA meeting and TCP meetings when deemed useful to promote activities (experiments, data exchange, hardware), collect and disseminate information on long-pulse operation issues.
- Chair and co-chairs will liaise on a regular basis with the chairs of the CTP and SH TCPs.
- In conjunction to the IAEA Technical Meeting on Long-Pulse Operation of Fusion Devices, the CICLOP group will meet to review the activity and progress made.
- CICLOP members will promote the group activity by participating in conferences, workshop, meeting, public event and will write relevant publications.

7. Task Manager(s):

Chair and the two co-chairs of the CICLOP group are jointly nominated for three years with ideally one expert coming from the tokamak community while the other one is from the stellarator community.

The chair and co-chair of the CICLOP group will jointly manage this joint task of TCPs on Tokamak Programmes (CTP TCP) and on Stellarators and Heliotrons (SH TCP) by liaising on regular basis when deemed necessary with the chairs of the two TCPs.

8. Responsibilities of Task Manager(s):

The CICLOP chair as Task Manager shall be responsible for co-ordination of this Joint Task. The Task Manager shall:

(a) Develop, in co-operation with the Participants and CICLOP group members, a detailed work programme, a framework for the Final Country Report and a timetable for all the activities carried out under this Joint Annex, including methodology;

(b) Provide periodic reports to both Executive Committees describing the progress of the work being accomplished under this joint Annex, once per year orally for each ExCo (focusing on results, achievements and/or successes), twice a year a written management report and once a year a contribution to the annual report. For the avoidance of doubt, the Task Manager can provide the same reports to each Executive Committee and is not required to separately report to each.

(c) Manage delivering the results as described in Deliverables;

(d) Provide to the Executive Committee, within six months after completion of all work under the Joint Task, a Final Report for approval;

(e) In co-ordination with the Participants, use its best efforts to avoid duplication with activities of other related programs and projects implemented by or under the auspices of the IEA or by other competent bodies;

(f) Provide the Participants with necessary guidelines for the work they carry out, assuring minimum duplication of effort;

(g) Co-ordinate the efforts of Participants and ensure the flow of information within the Joint Task;

(h) Co-ordinate the work to ensure the compulsory deliverables to the respective participating TCPs' Newsletters/Magazines and to their websites;

(i) Provide general administration; and

(j) Carry out any and all responsibilities as an Task Manager, as required by the TCP Implementing Agreements of the respective TCP.

9. Funding:

All participants will bear their own costs in carrying out the Joint Task.

10. Time Schedule:

This Joint Task shall remain in force up to the renewal of the relevant TCPs.

11. Specific obligations and responsibilities of the Participants:

(a) Each Participant shall nominate representatives to participate in the work under this Joint Task.

(b) Each Participant will actively contribute to this Joint Task, including participating in biannual coordination meetings and in Sub-Tasks as relevant.