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Technical Requirements Specification

ITER Operational States

This document defines the operational states of the ITER facility and systems.
It elaborates upon the ITER Concept of Operations and is applicable to all systems

Approval Process			
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Change Log			
ITER Operational States (54L85L)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Revision Required	05 Oct 2021	
v1.1	Revision Required	03 Mar 2022	This version includes all comments from reviewers and a revised section on the GOS transitions and Access Control
v1.2	Signed	21 Jun 2022	Comments from reviewers included and some figures improved for better understanding of the mapping between Pulse and COS.
v1.3	Revision Required	28 Jun 2022	Corrected the COS numbers to align with those implemented by CODAC
v1.4	Signed	19 Sep 2022	This version addresses the comments from the reviewers. Includes clarifications where required by the reviewers. A section was added to address the failure of the GOS transition process. The concept of Pulse states is kept.
v1.5	In Work	06 Oct 2022	Comments addressed: clarification of figure 1 and allowed operation in the TCS state
v1.6	Approved	06 Oct 2022	Comments addressed: clarification of figure 1 and allowed operation in the TCS state Included link to OT appendix
v2.0	Revision Required	28 Feb 2025	See track changes in comments
v2.1	Signed	16 May 2025	New version addresses the comments from reviewers. See document with track changes in comments.
v2.2	Approved	02 Jun 2025	missing link corrected

ITER Operational States

Table of Contents

1 Purpose

This document defines the operational states of the ITER facility and systems. It elaborates upon the Project Requirements [RD1] and the ITER Concept of Operations [RD2] and is applicable to all systems.

2 Abbreviations

APS	Advanced Protection System
CIS	Central Interlock System
CODAC	Control and Data Acquisition System
CODAC-SUP	Supervisory Control System
COS	Common Operating State
CRY	Cryoplant System
CSS	Central Safety System
CVVF	Configuration, Verification and Validation Framework
ECH	Electron Cyclotron Heating System
ECWC	Electron Cyclotron Wall Cleaning
EOF	End of flat-top
EOP	End of Pulse
EPD	End of plasma discharge
GDC	Glow Discharge Cleaning
GOS	Global Operating State
ICH	Ion Cyclotron Heating System
ICWC	Ion Cyclotron Wall Cleaning
IOT	ITER operational time
LTM	Long Term Maintenance
OT	Operational Task
PCS	Plasma Control System
PF	Poloidal Magnetic Field
PFC	Plasma Facing Component
POS	Plasma Operation State
SCW	Secondary Cooling Water System
SOF	Start of flat-top
SOP	Start of pulse
SPD	Start of plasma discharge
STM	Short Term Maintenance
TCS	Testing and Conditioning State
TCW	Tokamak Cooling Water System
TF	Toroidal Magnetic Field
VV	Vacuum Vessel
VV-PHTS	Vacuum Vessel Primary Heat Transfer System

For a complete list of ITER abbreviations see: ITER_D_2MU6W5 - ITER Abbreviations
For a complete list of the level 1 System Breakdown Structure see: ITER_D_YSNQBW

3 References

[RD1] Project Requirements (27ZRW8)
[RD2] ITER Concept of Operations (S7T73E)
[RD3] ITER Research Plan (YS74S9)
[RD4] ITER Operating Limits and Conditions (54L865)
[RD5] Preliminary Safety Report (RPrS) (3ZR2NC)
[RD6] CCCF-00018-Pulse Counter Service for concurrent activities (2D3JGQ)
[RD7] Safety Requirements Roombook (KF63PB)
[RD8] Appendix to ITER_D_54L85L ITER Operational States – Operational Tasks (84VBE8)
[RD9] Operations Management Procedure (XA95GG)
[RD10] Platform design guide for PCS implementation (32M75W)
[RD11] Principles of operation for Access Control System (ACS) operation functions (23B5GX)
[RD12] I&C safety function specification for the Safety Operation State Management (N-153) (Q5VZ9M)

4 Introduction

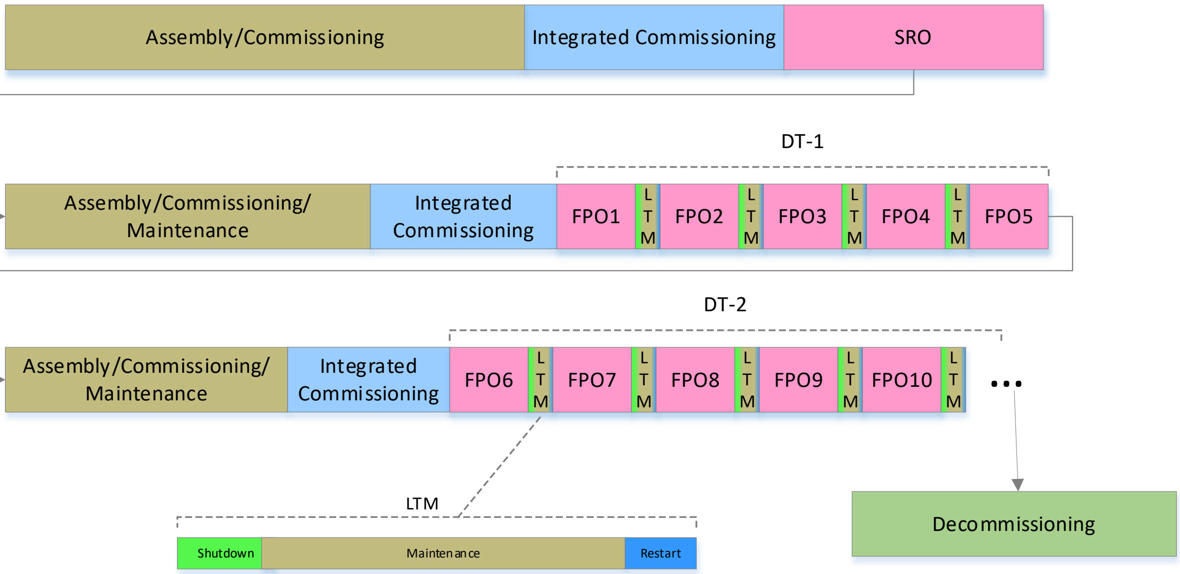

Figure 1: ITER lifecycle phases representing the steps defined in [RD1] (for illustrative purposes only)

As per the definition in the Project Requirements [RD1], the lifecycle of ITER is defined for the different phases as depicted in Figure 1. Before each DT phase, an assembly phase for upgrades and/or replacement of components is planned, hence an integrated commissioning phase to restart operations before the DT-1 and DT-2 phases (FPO1 in DT-1 and FPO6 in DT-2). From FPO-1 and FPO-6 (for DT-1 and DT-2 respectively), onwards the plant restart is planned as a short phase before the Operational Campaign and may include short periods of integrated commissioning for refurbished and upgrade of systems which do not involve the tokamak machine. The detail of the ITER lifecycle is as described in the ITER Concept of Operations [RD2] (section 4, Figure 1), and summarised in Figure 2 for convenience. The definitions and concepts in this document, including the concept of Common Operating States (COS) (see section 10) apply to all ITER lifecycle phases.

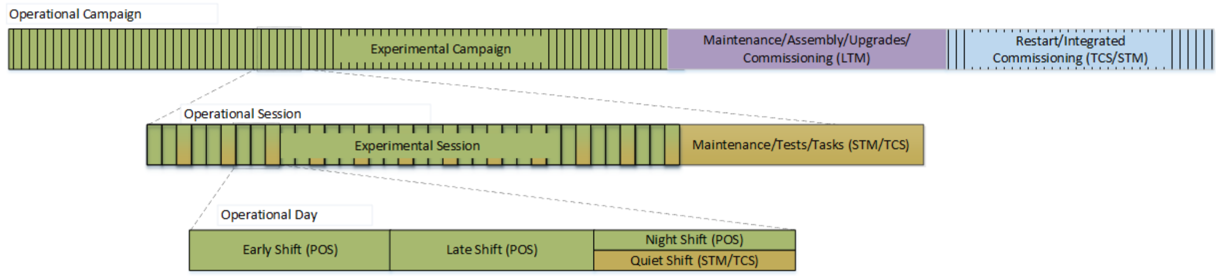

Figure 2: Cycles in Operations

In order to capture the different processes and how they relate to the GOS states and the ITER lifecycle, as defined in [RD3], the restart and shutdown concepts are defined:

- **Restart**: is defined as the phase between the end of the maintenance phase and the start of the experimental campaign. It typically starts when the VV is closed with the start of pump-down and finishes when plasma operation is permitted. Other activities required for the preparation for plasma operation and performed during this phase are: VV baking, Magnets and thermal shields cooldown, energisation of TF and test of all PF coils, conditioning of the additional heating systems, etc. The conditions/constraints and access to buildings is that of the TCS state. Note that if there is a need for commissioning of a new installed/upgraded system, this phase is called Integrated Commissioning.
- **Shutdown**: is defined as a phase at the end of the experimental campaign (start of Assembly phase) where all systems (except utilities) will be put in a specific state, after which maintenance, assembly and/or upgrade of systems can start. The de-energisation of the TF coils and warm-up if required, the decrease of the VV temperature to ambient, the venting of the VV, etc. will be performed in this phase. The conditions/constraints and access to buildings is that of the TCS or STM state. This phase can be performed across the TCS, STM and LTM phases, depending on the activities in progress to put the plant available for assembly, maintenance and upgrades.

To distinguish the plant systems which are pulse dependent or work continuously during the operational campaigns, the following definitions were introduced:

- **Continuous Systems:** these systems are initialised during the restart of operations (except those that will operate at all times) and will run continuously throughout the operational campaign until the plant shutdown is required (e.g. SCW, CRY, TCW, etc…). Although these systems are continuously running, they can be pulse-related i.e., continuous systems can be informed about pulse related activities and take appropriate actions if required (e.g. recovery of Heat Rejection System before next pulse).

- **Pulsed systems**: these systems perform their primary functions during a pulse. Pulsed systems are primarily operated during a pulse (e.g. receive configurations, apply power, inject fuel, etc.). These systems are under PCS control during a pulse (e.g. ECH, ICH, NBI, FUE, etc…).

5 Global Operating States

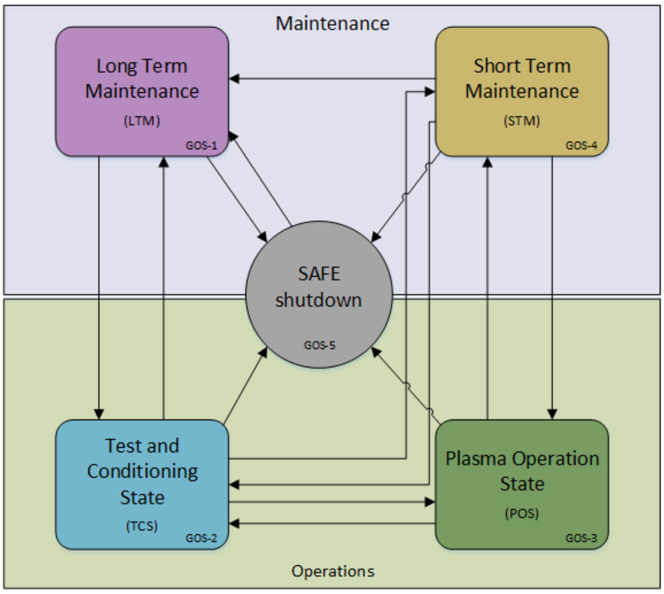

Figure 3: Global Operating States and possible transitions between states

The status of the ITER facility is described through a set of Global Operating States (GOS) shown in Figure 3. These are: Long Term Maintenance, Short Term Maintenance, Test and Conditioning State, Plasma Operation State and SAFE. A GOS is specified by a set of limits and conditions [RD4], the status of the required safety and interlock functions and requires each plant system to be operated in specific modes and configured appropriately. For all states, CODAC-SUP provides the necessary infrastructure for the coordination and orchestration of operational tasks (see section 8), including pulsed operation and the continuous monitoring of the whole plant systems.

5.1 Safe shutdown (SAFE)

The SAFE state of the ITER plant in the event of an incident/accident or crisis is defined in [RD5]. The transition to the SAFE state can be performed automatically or by the operations team following Emergency Procedures. For the case where the MCR is unavailable, the back-up control room will be used for monitoring and to maintain the Safe state.

5.2 Long Term Maintenance (LTM)

This state allows construction and maintenance activities that require operations and systems (except utilities) to be stopped. Maintenance activities are co-ordinated by the Operations team and in general only require a PtW. Coil energisation and any power injection by an additional heating system into the Tokamak is not allowed by default. Cask transfer and neutron calibration are to be performed during this state and require restrictions on access to be managed through procedures with different level of verification depending on the hazards.

5.3 Short Term Maintenance (STM)

Short Term maintenance is a state which allows planned or unplanned maintenance/intervention activities in periods within the experimental campaign. For planned maintenance, the duration of this state is either a shift (night shift) or 2-3 days after every 11-12 days of experimental campaign. For unplanned interventions which can be performed within the conditions of this state, the duration of this state will be as required by the specific work to be performed. Intentional breach of primary vacuum is not allowed, but repairs to primary vacuum can be executed. Energisation of the superconducting coils is not allowed by default, with the exception of the TF coils.

5.4 Testing and Conditioning State (TCS)

Allows coordinated timed sequences i.e. operational tasks, technical or conditioning pulses. Tasks are executed under CODAC-SUP control and the technical and conditioning pulses are executed under PCS control and require a pulse schedule. Tokamak plasma pulses are not permitted.

5.5 Plasma Operating State (POS)

Generation of radiation from the tokamak is only expected in this state resulting from tokamak plasma pulses. The PCS functionality required for a specific phase of the project is available. All the CIS and CSS functions required for plasma operation are commissioned and operational and all superconducting coils can be energised. The sequence of steps is defined and controlled by CODAC-SUP and PCS through the pulse schedule. Local activities such as conditioning of a pulsed system or other activities which do not impact the pulsed operation are allowed providing that these are authorised.

6 Access control and the GOS states

The areas of the Tokamak Complex and all other operational areas of the INB perimeter are assessed as radiological zones as defined in [RD5] [RD7]. Operational areas are sub-divided in Zones for Access Control (ZAC). In each ZAC access can be either:

- **Forbidden** due to radioprotection, occupational safety and to avoid changes to the configuration of systems which may impact operations. Access can also be forbidden due to other elements of risk, such as magnetic field or beam sources.
- **Restricted** where access can only be granted pending a hazard assessment and only qualified people to the specific required intervention. Access is granted based on procedures, with different level of verification depending on the hazards. This access is granted to a limited number of workers.
- **Procedural** in areas where no potential exposure to hazardous factors is identified. Access is granted based on procedures, with different level of verification depending on the hazards, and only to persons holding the appropriate permissions for the zone to be accessed.

Global Operating State	Radiological Mode[1]	Access to Tokamak Building – B11
POS state	Mode 0	Forbidden
TCS state	Mode 1	Restricted or Forbidden[2]
STM state	Mode 1	Restricted[3]
All LTM states except for cask deployment and neutron calibration	Mode 1	Restricted
Cask deployment and neutron calibration	Mode 2[4]	Restricted or Forbidden

Table 1: Radiological zoning and correspondence to the GOS states

All requests for access shall follow the Safety, OHS, Security and Operations rules and procedures. The process by which access to ZACs is controlled (blocking and unblocking of entrances and the

[1] Radiological modes: 0 – in operation, fusion plasma; 1 – in maintenance with human intervention in B11; 2 – in remote handling maintenance to transfer highly activated in-vessel components in B11

[2] The status depends on the on-going activity

[3] Some areas of the tokamak building might be forbidden depending on OHS risk and radiological protection

[4] Applies also in the non-active phase of the project during Neutron Diagnostic Calibration.

use of patrols) is described in [RD11]. Concerning the Tokamak Building, the correspondence shown in Table 1 between the GOS and the applicable access state is applicable.

7 Operational Time

ITER Operational Time (IOT) is identical to Coordinated Universal Time (UTC) and it is not subject to daylight savings. All data, commands, alarms, faults and events are recorded in the database against ITER Operational Time. In all human-machine interfaces, printouts and logs, ITER Operational Time is identified by suffixing the abbreviation UTC.

Where it aids to avoid confusion, the user's local time may be displayed in addition – however this shall be clearly qualified as such according to ISO 8601 standards.

8 Operational Tasks and Pulses

Requirement	Description
Excluded	The system is not required for the task and will not receive requests from CODAC-SUP or PCS. The system shall remain in an operating mode that will not cause errors or affect the execution of the task.
Included	The system may receive requests from CODAC-SUP or PCS related to the task. However, if the system does not reach its expected state during the execution of the task, or if reports error during the execution of the task, then this will not prevent the start or continuation of the task.
Required	The system must reach the expected states during the execution of the task. Any failure in doing so will abort the task.

Table 2: Systems configuration during the execution of an operational task or activity under CODAC-SUP or PCS control

For each Operational Task or activity to be performed under CODAC-SUP or Pulse performed under PCS control, a plant system is defined as being *Excluded*, *Included* or *Required* as show in **Table 2**. For the timed sequence activities, a unique identifier, (numbers and time) is defined in an analogous way to pulse numbers and time [RD6]. The time at which this increment occurs is recorded against ITER Operational Time. Several operational tasks can be requested and active in parallel if compatible among themselves. Operational tasks and pulses are mutually exclusive.

8.1 Concept of Operational Task

Key operational activities to be performed on the ITER facility under the control of CODAC-SUP and which will occur often, such as baking, cooldown, mirror cleaning, etc., are defined as Operational Tasks (non-pulsed) [RD8]. These are initiated by an operator in accordance with operating procedures and performed by manual or automatic control actions through CODAC-SUP. A non-exhaustive list of Operational Tasks is defined in [RD8] and is maintained in the Technical Procedures and change-managed by MQP [RD9]. An Operational Task can only be executed if:

- The required systems to execute the task are available and can be used
- The CIS and CSS functions identified as needed for the activity are implemented and operational

- The conditions and pre-requisites for the execution of the task are met
- The execution of the task is compatible with other activities
- Limitations and constraints to the task are known and approved

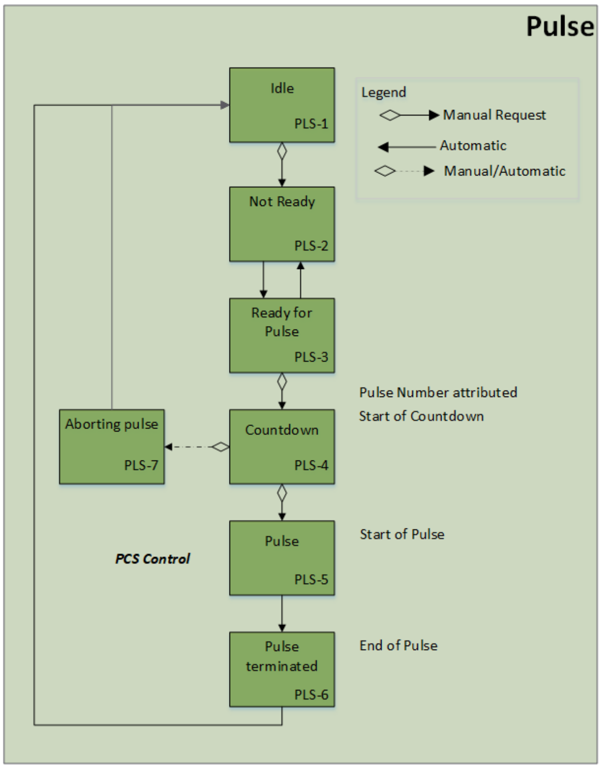

Figure 4: Pulse states

Each task is labelled by a sequential integer serial number and a label indicative of the task performed. A new number is generated at the start of the task. These numbers are never reused, even when the task is aborted.

8.2 Concept of pulse

Pulse requires co-ordinated real time control of the plant systems by the Plasma Control System. During a pulse, the PCS fully autonomously controls all pulsed plant systems needed to execute the steps defined in the pulse schedule[5]. These pulses are executed following a specific time sequence as shown in **Figure 4**. These can be a technical pulse, a conditioning pulse or a tokamak plasma pulse. Each pulse is labelled by a sequential integer serial number.

A new pulse number is generated at the transition from *Ready for Pulse* to *Countdown*. These numbers are never reused, even when a pulse is aborted or terminated. Technical and Conditioning pulses can be run in both POS and TCS states. Tokamak Plasma pulses can only be run in POS.

Pulse sub-state	Description
PLS-1 Idle	The pulse is terminated, and all pulsed systems will return to this state to wait for the next pulse. When the new pulse schedule is received, a request is sent from CODAC-SUP to the systems to transit to *Not Ready* to start the preparation/configuration of the systems for a new pulse.
PLS-2 Not ready	The plant systems marked as *Required* and *Included* for pulse have received a request from CODAC-SUP to configure the systems for the next pulse.
PLS-3 Ready for Pulse	All required systems have been fully configured and no error in the plant systems marked as *Required* is reported. This state is used to report that the countdown for the pulse can start. No specific actions are performed in this state.
PLS-4 Countdown	CODAC-SUP sends the *Initialise* request individually to each system, based upon predefined dependencies, sequences and timing. All systems report *Initialised* and *Pulse* can be triggered
PLS-5 Pulse	Control has transferred from CODAC-SUP to PCS. The task is executed in real-time by PCS according to a predefined pulse schedule. At the end of the pulse, the CS, PF, EFCC and IVC coils currents are brought to zero by PCS.

[5] Pulse schedule defines the set of parameters, and their time sequence used to configure the ITER plant systems in order to perform a pulse

PLS-6 **Pulse terminated**	Control has returned to CODAC-SUP which has issued the *Terminate* request to all plant systems. Automatic checks are performed by CODAC-SUP to all systems before returning to *Not Ready*
PLS-7 **Aborting Pulse**	The pulse has been aborted during the countdown and systems are recovering and waiting for the next pulse. This action can be either automatic or manual

8.2.1 Tokamak plasma pulse

Figure 5 shows a typical high performance (Q=10) tokamak plasma pulse (and typical stages SOP, SPD, SOF, etc. where each stage is described by one or more *segments* of a *pulse sequence*). A tokamak plasma pulse can only be executed in POS.

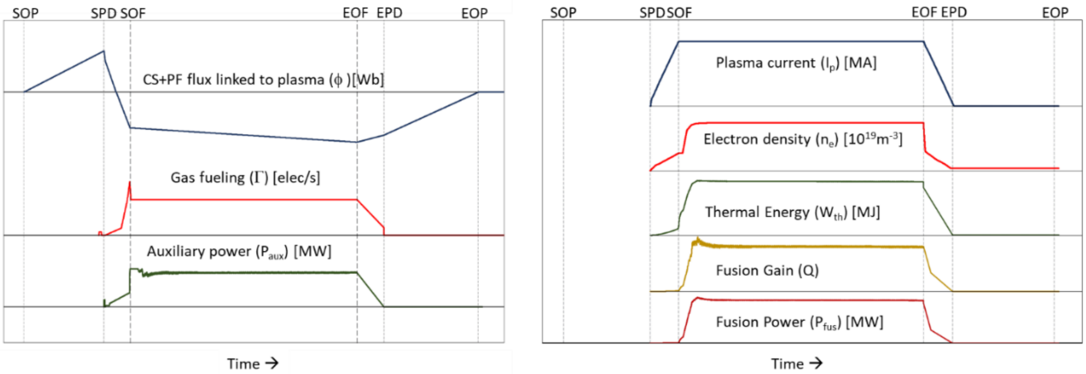

Figure 5: Typical high performance tokamak plasma pulse

8.2.2 Technical pulse

A technical pulse (or dry-run) is a pulse where plasma formation is inhibited. These pulses are normally executed to test that the coils and the gas injection system are performing according to requirements. Figure 6 shows an example of a technical pulse to test the superconducting coils, gas introduction and ECH systems without the creation of plasma. Technical pulses can be executed either in POS or TCS.

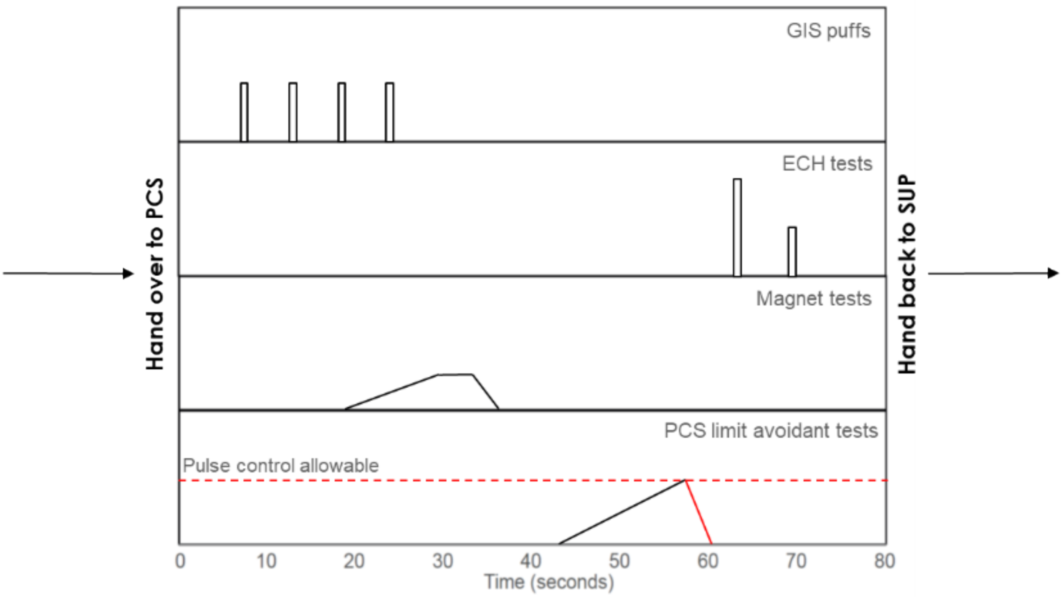

Figure 6: Example of a pulse used to test the opening of the GIS, ECH tests, and magnet tests and limit avoidance by PCS

8.2.3 Conditioning pulse using RF waves

For wall conditioning, two schemes using RF waves are available, the Ion Cyclotron Wall Conditioning (ICWC) and Electron Cyclotron Wall Conditioning (ECWC). During the operational campaign, the use of baking to remove impurities from the wall is lengthy and costly time wise and GDC is not allowed because the toroidal magnetic field will be maintained throughout the entire operational campaign. ICWC and ECWC are pulses which create a low density and temperature plasmas supported by PF coils with low current levels (no production of nuclear radiation) which can interact with the PFCs for conditioning e.g. after a large disruption, etc. These pulses can be performed in POS or during TCS overnight. Conditioning pulses and tokamak plasma pulses are mutually exclusive.

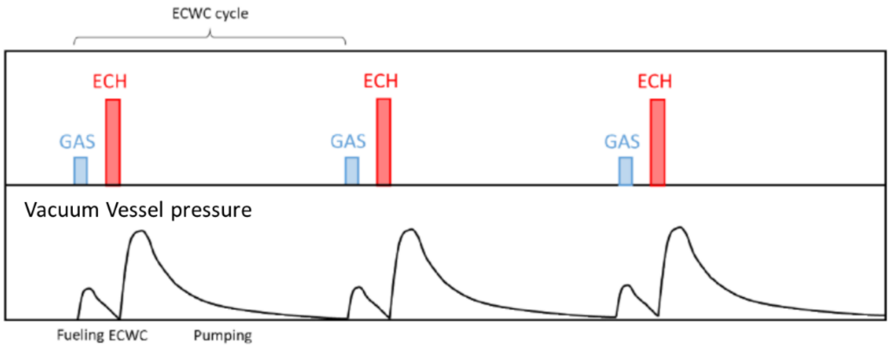

Figure 7: Example of a possible scenario for a conditioning pulse using ECH (ECWC)

8.3 Pulse Time

Pulse time is defined not as a trigger but as an administrative time, with the sole purpose to allow harmonisation between the collaborators, in different time zones, on data visualisation and processing. Pulse Time will be set by the pulse schedule and is marked in seconds and fractions of seconds. The relationship between ITER Operational Time and Pulse Time is shown in Figure 8. When a pulse countdown starts, Pulse Time is set as a pre-defined negative value ($t=-t_P$) and counts up towards zero. The Pulse Time t=0 is defined at the handover of the control of the plant from CODAC-SUP to PCS at the start of the pulse [RD10]. Note that this time coincides with the start of the central solenoid charging for tokamak pulses (Figure 5).

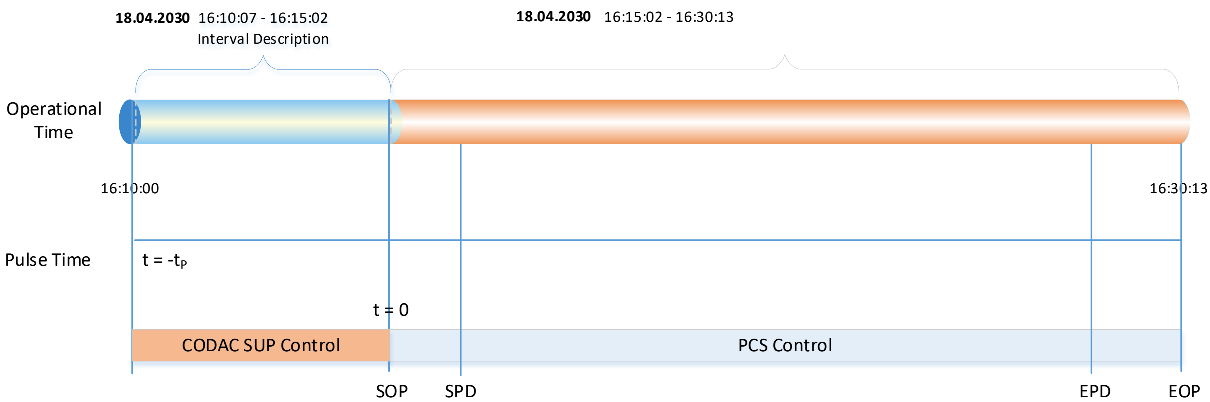

Figure 8: Relationship between Operational Time and Pulse Time

Pulse Time allows convenient references to pulse milestones, events and data, e.g. if heating is to be turned on x seconds into a pulse, it will be at t=xs, no matter at what time the pulse was run. Data values during a pulse are identified by a unique Pulse Number and by the Pulse Time and ITER

Operational Time. Data from continuous systems outside of a pulse are identified by the ITER Operational Time.

8.4 Plant Modes of Operation

Plant systems and sub-systems typically each have several defined modes of operation that represent a configuration set and programmed control behaviours. Modes are configured and activated in response to CODAC-SUP requests, associated parameters and the current GOS.

9 Transition between Global Operating States

The GOS states are driven by the activities planned for either operations or maintenance. Access constraints to the Tokamak and other buildings are in place due to the possible risks generated by the planned operations. The transitions between the different GOS states and the authorization requests are decided and controlled by the Operations Team and take into account the ITER Research Plan, the required maintenance for the different systems and the systems scarce resources. The transition from a GOS state to another is performed manually following a specific sequence [RD12] and is defined by the restrictions that apply to each state (see Figure 9). Long Term Maintenance is the less restrictive state since it allows access to most buildings and most of the systems are in local mode, i.e., disconnected from their clients but monitored by CODAC-SUP when appropriate. The Plasma Operation State is the most restrictive state since tokamak plasmas pulses are allowed (radiation levels will increase) and all systems are operational. The preparation process, once the decision is taken to change GOS state can last from seconds to some days until the request to change GOS is sent to the CSS-N operator. Once this request is issued, the transition from one GOS state to another GOS state is instantaneous.

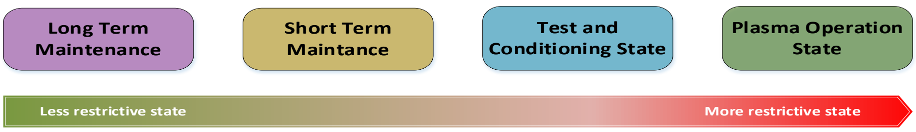

Figure 9: Hierarchy of GOS states regarding access to the systems and level of safety and investment protection functions in place

9.1 Transition from less restrictive to most restrictive states

The request to transit between GOS states is defined administratively by the Operations team, except the transition to the SAFE state which is performed automatically by CSS-N. The transition between the GOS states requires that all systems including the protection systems (CSS/CIS) are set for the change of the GOS state. For the transition, the plant systems must be in a mode of operation compatible with both states. The process to perform the transition of states follows a pre-defined set of steps (shown in Figure 10) and can only be finalised if all the steps are successfully executed.

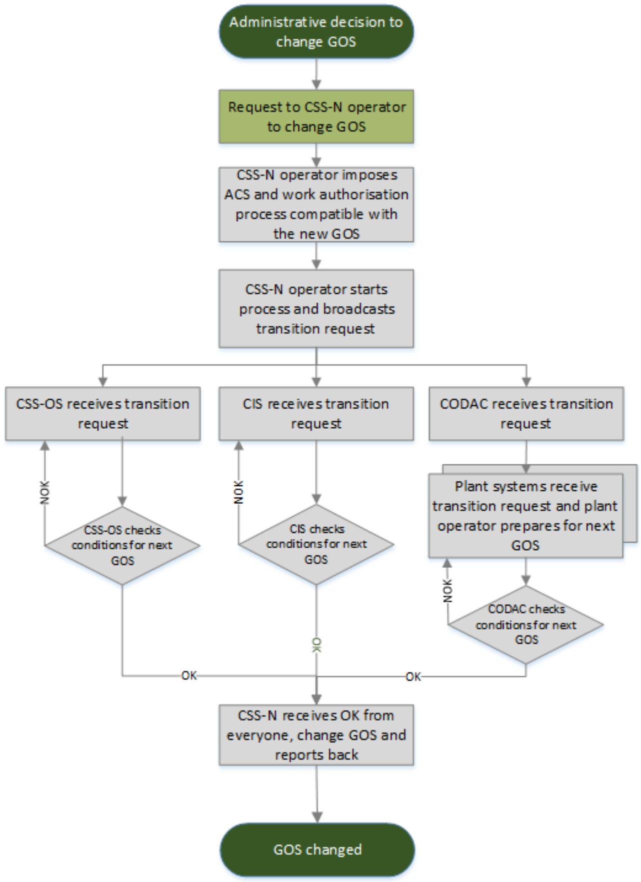

Figure 10: Flowchart showing the process to change GOS state from less to more restrictive state

The process starts with the administrative decision to change GOS state. This information is propagated to the different systems by their representatives in the decision-making process and disseminated down. The information of requested GOS state and the date/time when the planned change takes place will be available in the MCR overview screen. The next step by CSS-N imposes the access control and work authorisation defined for the GOS which the ITER plant is transitioning to.

The request is then broadcasted by CSS-N to CSS-OS, CIS and CODAC. CODAC will request all systems to configure for the next GOS state and will change the process variable related to the GOS change state, which will appear in all systems' HMIs title bar (local or central).
Once the systems are ready, these will report back to CODAC acknowledging that they are ready for the change. In parallel, the CIS and CSS-OS will enable the functions required for the next GOS. Due to the staged approach of the project, the information related to the systems and CSS and CIS functions required for the GOS change is stored in a database, to be updated when a new system is introduced in the plant.

9.2 Transition from more restrictive to less restrictive states

In order to transit from a more restrictive state to a less restrictive state, the process is similar to that above. The only difference in this case is that the change of access control and work authorisation process only changes when the CSS-N operator receives the ok from CODAC, CIS and CSS-OS.

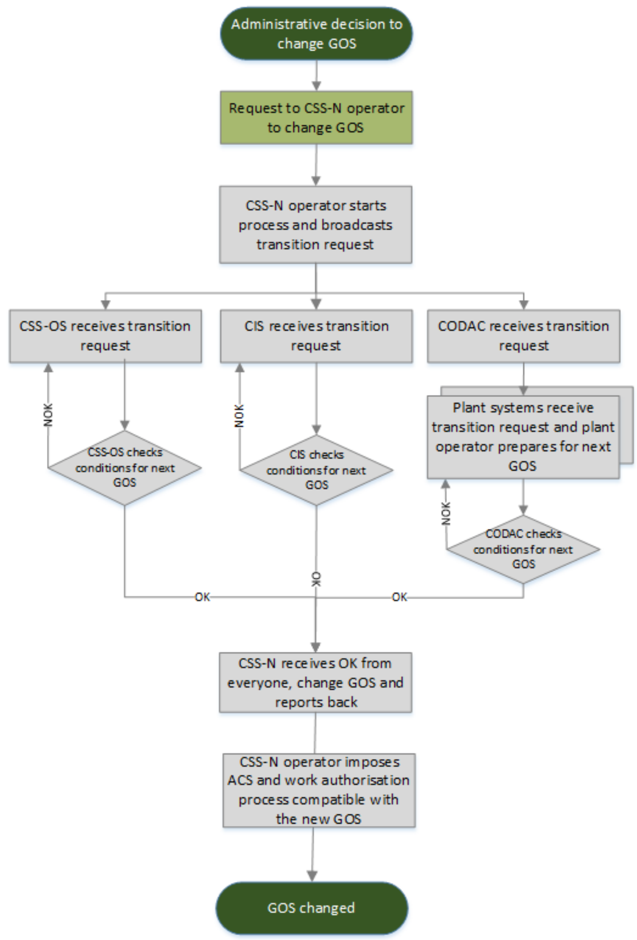

Figure 11: Flowchart showing the process to change GOS state from more to less restrictive state

Once an administrative decision to change GOS state is taken, the information is propagated to the different systems by their representatives in the decision-making process and disseminated down. Because the transition is from a more to a less restrictive state, access control and work authorisations remain those of the initial GOS state. The information of requested GOS state and the date/time when the planned change takes place will be available in the MCR overview screen. The request is then broadcasted by CSS-N to CSS-OS, CIS and CODAC. CODAC will request all systems to configure for the next GOS state and will change the process variable related to the GOS change state, which will appear in all systems' HMIs title bar (local or central).

Once the systems are ready, these will report back to CODAC acknowledging that they are ready for the change. In parallel, the CIS and CSS-OS, if required, will disable the functions not required for the next GOS. Due to the staged approach of the project, the information related to the systems and CSS and CIS functions required for the GOS change is stored in a database, to be updated when a new system is introduced in the plant.

Once CSS-N receives the confirmation from CODAC, CIS and CSS-OS that the systems are ready for the GOS transition, the change is executed and reported back to the systems. The access control and work authorisations are then updated to reflect the requirements of the present GOS state.

9.3 GOS transitions Fail Path

Emergency Operational Procedures shall be defined to address the identified possible individual and accumulated failures for the processes defined in sections 9.1 and 9.2 including the process to restore the initial state of the ITER systems.
These identified failures are:

1. CSS fails to perform an automatic transition to SAFE state
2. Loss of communication to CSS-OS
3. Loss of communication to CODAC
4. Loss of communication between CODAC and the plant systems
5. Total or partial loss of the CSS-OS, CIS and CODAC systems

10 Common Operating States

The Common Operating States (COS) showed in Figure 12 are a metric to assess the overall condition and availability of a single Plant System control in a harmonized way and applies to both pulsed and continuous systems. At all times each plant control system reports to CODAC-SUP a translation of its internal states into one COS. COS are used by CODAC-SUP and operators to display and understand the overall condition and availability of all systems. Permitted transitions between COS states are defined as either *automatic* or *requested*. Request driven transitions (shown by a diamond in Figure 12) are initiated by CODAC-SUP. The update of these states by CODAC-SUP might be pulse dependent or, for the continuous systems, task dependent. The COS is foremost a control system concept. Automatic transitions are condition based, meaning the transition is made when the required system operating mode and configuration are obtained, unless the transition is disabled or prevented. A system remains in its initial state until it is able to satisfy the conditions required to enter the target state. During this period the system is said to be *transitioning*. Transitions may be prevented by the Central Safety System (CSS) and the Central Interlock System (CIS).

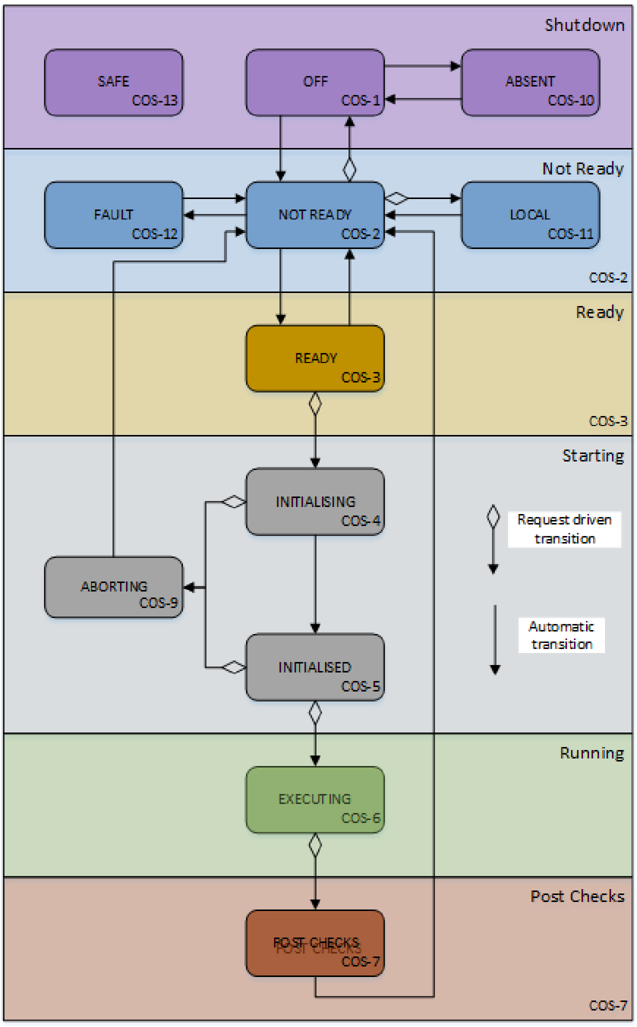

Figure 12: Common Operational States (COS) and Transitions

SHUTDOWN	
COS-13 Safe	The system is in its pre-defined safe state. This may be triggered by the Central Safety System. **(This state exists only where applicable)**.
COS-01 Off	The system is present, but it has informed the CODAC supervisory control system that it is being switched off or rebooted and will not be able to report state
COS-11 Absent	The system is not present/installed

NOT READY	
COS-12 Fault	The system has an internal fault or error and it is not available for operation.
COS-02 Not Ready	The system is operational but currently not ready to start a pulse, e.g. it may be performing system start-up tasks.
COS-11 Local	The system has been authorised to perform local control activities.

READY	
COS-03 Ready	The Plant System control is ready to be configured by CODAC-SUP. Verification of the configuration at the central level (SUP) can be done before or during this state. The configuration of the Plant System control is done during this state. All such configurations (for all required Plant System control) need to be successful for SUP to transition to POS-

	2/TCS-2 Ready (see Figure 13). Failure of configuration verification and validation during this stage does not abort the pulse but can be handled by small (allowed) changes to the pulse schedule and a re-verification cycle.

STARTING

COS-04 Initialising	The system has received the request to initialise, to change operating mode and to configure itself according to parameters transmitted by CODAC. Continuous systems will reconfigure themselves as necessary to support the task and prevent incompatible internal changes of mode.
COS-05 Initialised	The system declares that it is initialised and configured. All system circuits are energised and the systems required for the pulse or execution of a task are fully operational and ready to immediately transfer to executing state. Control actions on systems that could interrupt the pulse or execution of a task are inhibited.
COS-9 Aborting	The system has encountered an internal fault, timeout or error that prevents continuing with initialisation, or has received a manual or automatic request to abort and is executing any necessary actions.

RUNNING

COS-06 Executing	The system is operating to execute a pulse or a task.

POST-CHECKS

COS-07 Post-checks	The pulse has completed and PCS has instructed the system to perform any final actions (e.g. reduce coil current to zero) and return to CODAC control where CODAC-SUP carries checks in the systems. In the event of PCS error this Terminate request may be sent by CODAC, CIS or CSS.

11 Mapping between Pulse and COS

The mapping between the Pulse states and the Common Operational States for pulsed systems that are marked as *Included* or *Required* is summarised in Table 3 and the their sequence shown in Figure 13. Note that during TCS, tokamak plasma pulses are not allowed.

Pulse		Shutdown			Not Ready			Ready	Starting			Running	
		Safe	Off	Absent	Fault	Not Ready	Local	Ready	Initialising	Initialised	Aborting	Executing	Post-Checks
POS/TCS – Pulse													
PLS-1	Idle				✓	✓							
PLS-2	Not Ready				✓	✓		✓					
PLS-3	Ready for Pulse							✓					
PLS-4	Countdown							✓	✓	✓	✓		
PLS-5	Pulse				✓							✓	
PLS-6	Pulse Complete				✓	✓							✓
PLS-7	Aborting Pulse				✓	✓					✓		

Table 3: Mapping between the Pulse states and COS during the execution of a pulse

For pulses which require the configuration of the plant through the pulse schedule, the interaction between the Pulse states and the COS states is controlled by CODAC-SUP and the corresponding actions performed by CODAC-SUP.
For continuous systems, the assignment of the Common Operating States is specific for each plant system which can have any COS state in LTM, STM and TCS, depending on the system mode of operation. Some continuous systems may be operational even during Long Term Maintenance (e.g. cooling water systems which provide for HVAC, cryoplant, etc.) while others may only be operational during a pulse. During pulsed operation, the plant systems which operate continuously should at all times be in the *Executing* state.
For the execution of an operational task, CODAC-SUP defines the state *Task Running* to ensure that pulsed operation is not possible. In this case, when a task is required, CODAC-SUP will request the transition to the state *Task Running* which inhibits pulsed operation and allows CODAC-SUP to follow the procedure defined for the execution of the required task.

Prepare to configure	Checking of the availability of the systems, based on the information contained in the pulse schedule, is the responsibility of CODAC-SUP. CODAC-SUP will not consider a system as *COS-3 Ready* if this check fails, meaning this check will be performed either during the *COS-2 Not Ready* state or even earlier. *COS-3 Ready* will also check that the plant system control is correctly reset. Not all actions can be fully handled in a central and automated way by CODAC-SUP which means that Plant System Operators might be requested to perform manual actions. Configuration takes place after reaching COS3 Ready.
Initialise	Once the countdown is started, no changes can be made to the configuration of the Plant System control and all participating systems are requested to perform warming-up actions (this can be literally a warming-up of the system, some preliminary calibration steps, the establishment of the control loop with PCS, etc.) CODAC-SUP sends the *Initialise* request to the plant system control to indicate they should start these actions. Any failure during this stage will lead to aborting the pulse.
Execute	At the end of the countdown, CODAC-SUP hands over control to PCS and sends the *Execute* request to the plant system control to indicate they are now under control of PCS.
Terminate	When PCS indicates it has finished the pulse, SUP takes back control and signals this to the plant system control by sending the *Terminate* request and the system is set to *COS-7 Post-Checks*. This reset cycle is part of the actions taken during the *COS-2 Not Ready* state.

Table 4: CODAC-SUP actions mapping the Pulse states to COS

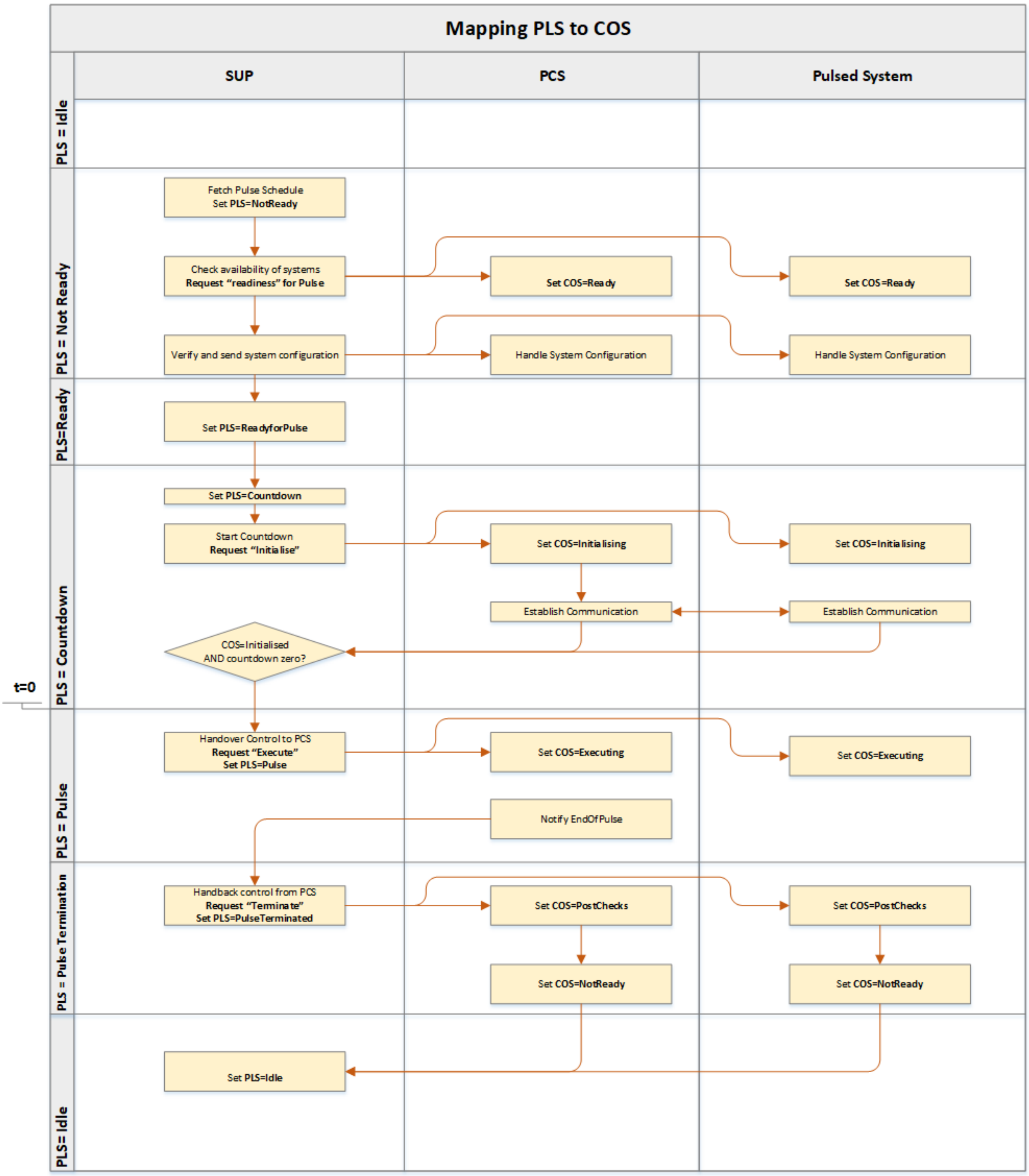

Figure 13: Mapping of the Pulse states to the COS states through CODAC-SUP requests