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Technical Specifications (In-Cash Procurement)

Technical Specification of the FWC for the Tokamak Systems Monitor Implementation

Framework contract for 55.GT implementation phase, covering MRR, manufacturing, CODAC integration, FAT, SAT and commissioning.

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1 Preamble

This Technical Specification is to be read in combination with the General Management Specification for Service and Supply (GM3S) – [Ref 1] that constitutes a full part of the technical requirements.

In case of conflict, the content of the Technical Specification supersedes the content of Ref [1].

2 Purpose

This document specifies the requirements for the framework contract "Tokamak Systems Monitor Implementation". It defines the scope of the services to be provided, the execution and the deliverables associated. This is a framework contract, where each task order is a free self-standing activity with its own budget.

3 Acronyms & Definitions

3.1 Acronyms

The following acronyms are the main one relevant to this document.

Abbreviation	Description
CCP	Common Components Procurement Project
CODAC	Control, Data Access and Communication
Contractor	The supplier of the services to which this Call for Nomination applies
CRO	Contract Responsible Officer
CWP	Construction Work Package
DA	Domestic Agency
EWP	Engineering Work Package
FDR	Final Design Review
FEA	Finite element analysis
FEM	Finite element method
FTE	Full-time equivalent
GM3S	General Management Specification for Service and Supply
I&C	Instrumentation and Control
IMAS	Integrated Modelling Analysis Suite
IMD	Imaging and Monitoring Diagnostics Project
IO	ITER Organization
MRR	Manufacturing Readiness Review
OPI	Operator Interface
PBS	Plant Breakdown Structure
POZ	Plant Operation Zone
PRO	Procurement Responsible Officer
TSM	Tokamak Systems Monitor
XPOZ	External to POZ
WP	Work Package

3.2 Definitions

Contractor: shall mean an economic operator who have signed the Contract in which this document is referenced.

Imaging and Monitoring Diagnostics (IMD) Project is also part of the Diagnostics Programme, grouping more specialized optics-based diagnostics.

POZ: A collection of computer or hardwired networks, and of plant system equipment connected to those networks, required for integrated plant operation.

XPOZ: A part of CODAC located outside the POZ boundary. Used for dissemination of experiment results, remote participation, as well as for CODAC activities not directly related to plant operation.

Engineering disciplines: This term denotes distinct fields of interest for various Tokamak Systems. These fields encompass electromagnetic, structural static, thermal-hydraulic, thermal-mechanical, structural dynamic, accumulated structural damage, and thermal & electrical contacts.

Tokamak systems: The subset of ITER PBS under the scope of the TSM: PBS 11 Magnets, PBS 15 Vacuum Vessel, PBS 16 Blanket System, PBS 17 Divertor, PBS 24 Cryostat, PBS 27 Thermal Shield, PBS 55 Diagnostics (Port Plugs and Plasma Diagnostics), PBS 52 Electron Cyclotron Heating & CD System, PBS 53 NB Heating & CD System.

Monitoring function: A TSM software procedure that derives the status of a tokamak system or component using instrumentation variables as inputs.

Reconstruction function: A type of monitoring function which derives global output parameters of a generic tokamak system or component for a specific engineering discipline. It calculates the response of non-directly measured variables of a system based on the values provided by the machine instrumentation through an algorithm based on the representation of the system (e.g., transfer functions computed using a finite element model).

POZ monitoring application: Software that runs a specific monitoring function integrated in the CODAC environment consuming from and feeding data to different networks (e.g., PON, DAN). It corresponds to the instantiation of a generic monitoring (e.g., reconstruction) function with the specific parameters required to its application to a system or component: algorithm parameters, system data, etc.

Synchronous monitoring application: A TSM POZ monitoring application which delivers outputs at the same pace as the inputs are received.

Note: In previous TSM task orders, this concept was referred to as 'online', which is now obsolete.

Asynchronous monitoring application: A TSM POZ monitoring application that does not necessarily deliver outputs at the same pace as the inputs are received.

> *Note: In previous TSM task orders, this concept was referred to as 'offline', which is now used for XPOZ.*

XPOZ monitoring application: Offline Software that implements a specific monitoring function or group of functions using the archived values of the machine instrumentation.

Tokamak Simulator: TSM software running in POZ which manages the state and execution of the sync and async monitoring applications. It also interfaces with SUP for configuration and automation purposes. It makes available the configuration of the system as a whole as well as the configuration of the different Monitoring Applications.

4 Applicable Documents & Codes and standards

4.1 Applicable Documents

This is the responsibility of the Contractor to identify and request for any documents that would not have been transmitted by IO, including the below list of reference documents.

This Technical Specification takes precedence over the referenced documents. In case of conflicting information, this is the responsibility of the contractor to seek clarification from IO.

Upon notification of any revision of the applicable document transmitted officially to the contractor, the contractor shall advise within 4 weeks of any impact on the execution of the contract. Without any response after this period, no impact will be considered.

Ref	Title	IDM Doc ID	Version
1	General Management Specification for Service and Supply (GM3S)	82MXQK	1.4
2	Sub-System Requirement Document sSRD-55.GT: Tokamak Systems Monitor	WYWPGS	1.4
3	CODAC Core System Overview	34SDZ5	7.5
4	Plant Control Design Handbook	27LH2V	7.1
5	SEQA-45 – Software Engineering and Quality Assurance for CODAC	2NRS2K	3.2

4.2 Applicable Codes and Standards

This is the responsibility of the contractor to procure the relevant Codes and Standards applicable to that scope of work. TSM software shall be compatible with CODAC environment [3]. Operator interfaces must follow the PCDH guidelines [4].

5 Scope of Work

The implementation of the PBS 55.GT Tokamak Systems Monitor [2] covers the phase between the Final Design Review and the Commissioning of the system, requiring very specific skills from numerical algorithms to integrated FEA modelling I&C software development. The TSM is designed to provide a comprehensive overview of the Tokamak's state by using optic-fibre and resistive instrumentation measurements, mixed with other monitoring diagnostics data such as electromagnetic diagnostics and infrared cameras. The TSM algorithms compare the current state with reference design values, detects anomalies, and manages the health and lifetime of the Tokamak.

It has been identified that the following groups of activities will be required to complete the implementation of the system:

- Algorithms specialization:
  - Reconstruction algorithms for structural integrity, electromagnetic identification, as well as thermohydraulic and thermomechanical disciplines;
  - Limits and lifetime monitoring,
  - Anomaly detection,
- POZ software development and CODAC integration, and
- XPOZ software development and events database integration.

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This framework contract focusses on maximizing the value of the engineering developments, technologies and processes required and shared by these activities for completing the TSM implementation through the manufacturing, CODAC integration, deployment, acceptance testing and commissioning phases.

5.1 Work description

The Tokamak Systems Monitor (TSM) is a software suite that uses available discrete sensor data to reconstruct critical information not directly available from the implemented sensors. It is designed to provide an integrated view of the ITER's Tokamak from an engineering standpoint. The TSM is responsible for reconstructing global engineering parameters (Thermo-hydraulic, Thermomechanical, Structural Static, Structural Dynamic, and Electromagnetic) and evaluating margins and lifetime, detecting anomalies, reporting, analysing operational data, and verifying and calibrating numerical engineering models.

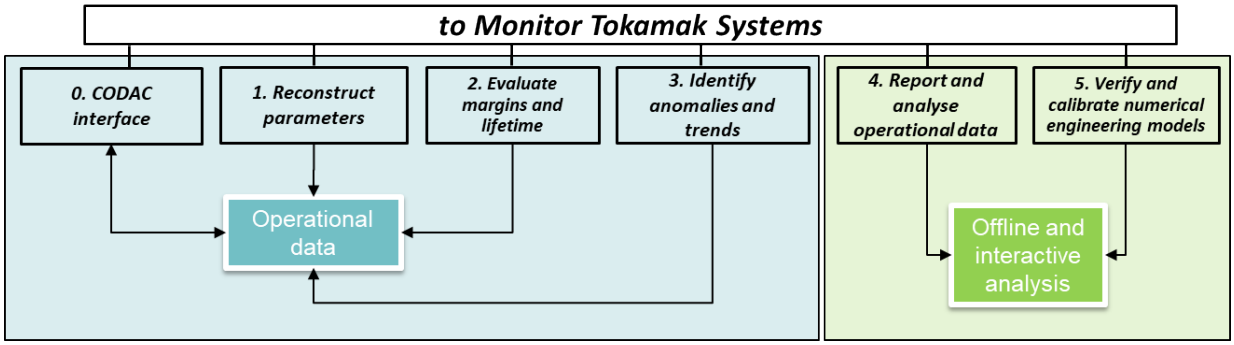

Figure 1: Top-level functions of 55.GT TSM

This framework contract will provide specialist engineering expertise in order to successfully implement the TSM, ensuring the manufacturing, CODAC integration, testing and installation activities are completed on time and to high levels of quality.

In more detail for the different areas (note that these are indicative activities and not intended to cover all but most of the activities to be performed):

Algorithms specialization:

- Specialization of TSM reconstruction algorithms for Start of Research Operations (SRO) scenarios, including configuration of system-specific parameters, operational envelopes and reference cases.
- Completion and consolidation of monitoring algorithms for structural integrity, thermo-hydraulic, thermo-mechanical, structural dynamic and electromagnetic disciplines relevant to SRO operation.
- Definition and implementation of SRO-specific limits, margins, warning thresholds and lifetime indicators for Tokamak systems and components monitored by the TSM.
- Implementation of anomaly detection functions adapted to SRO operational phases, including validation against expected transient behaviour and representative abnormal conditions.
- Integration of supplier, analytical and finite element models into the ITER system databases and TSM configuration files required for operational execution.
- Verification and validation of algorithm inputs, outputs, units, data quality rules and failure modes before deployment in the CODAC environment.

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- Preparation of synthetic and archived test cases to demonstrate algorithm behaviour under representative SRO pulses, commissioning scenarios and degraded instrumentation conditions.
- Implementation and testing of algorithm workflows within the Integrated Modelling Analysis Suite (IMAS), including mapping of reconstructed quantities to the appropriate IDS variables.
- Support to POZ deployment of synchronous and asynchronous monitoring applications, including interface definition with CODAC, data streams, configuration management and execution control.
- Executing Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT) when needed.
- Supporting TSM commissioning and integrated commissioning activities.
- Preparation of technical documentation, verification reports and acceptance evidence demonstrating readiness of the TSM algorithms for SRO operations.
- Planning and realizing any of the previous activities in preparation for DT operations.

POZ software development and CODAC integration

- Development and completion of TSM POZ monitoring applications for synchronous and asynchronous execution within the ITER CODAC environment.
- Implementation of the application software architecture required to instantiate generic TSM monitoring functions with system-specific configuration data, algorithm parameters and operational limits.
- Integration of TSM POZ applications with CODAC services, including data acquisition, data publication, configuration management, timing, supervision and execution control interfaces.
- Definition and implementation of input and output interfaces with the relevant CODAC networks and data streams, including PON and DAN connections where applicable.
- Implementation of data mapping between CODAC variables, TSM internal data structures and IMAS IDS variables (if needed) as required for monitoring, reconstruction and reporting functions.
- Development of the Tokamak Simulator functions required to manage application states, execution modes, configuration loading, automation sequences and interaction with the CODAC SUP layer.
- Implementation of robust error handling, data quality checks, alarm conditions, fallback modes and diagnostic information required for POZ operation.
- Integration and testing of SRO-specific monitoring workflows in the POZ environment using synthetic signals, archived data and representative CODAC test benches.
- Verification of application performance, latency, synchronization, data throughput and resource consumption against the requirements of synchronous and asynchronous monitoring functions.
- Preparation and execution of software integration tests, Factory Acceptance Testing and Site Acceptance Testing in coordination with CODAC and TSM stakeholders.
- Support to deployment, configuration control, version management and release procedures for TSM POZ applications during manufacturing, integration and commissioning phases.
- Support to TSM system commissioning activities, including verification of installed software baselines, configuration files, CODAC connectivity, data acquisition chains, supervision interfaces and end-to-end execution of monitoring applications in the commissioned plant environment.

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- Support to Tokamak integrated commissioning phases by executing and analysing representative commissioning scenarios, confirming the correct interaction of TSM POZ applications with plant systems, CODAC services, operational procedures and SRO-readiness criteria.
- Preparation of software design documentation, interface control documentation, test procedures, test reports and acceptance evidence demonstrating readiness for CODAC-integrated POZ operation.
- Support to commissioning and troubleshooting of the TSM POZ applications during integrated CODAC tests, SRO preparation activities and subsequent evolution towards DT operations.

XPOZ software development and events database integration

- Development and completion of TSM XPOZ monitoring applications dedicated to offline analysis, calibration and post-processing of archived Tokamak monitoring data.
- Integration of XPOZ applications with the Events Database to retrieve, organize, query and correlate archived monitoring data with pulses, operational phases, events, alarms and commissioning scenarios.
- Implementation of data access workflows allowing TSM-ThermaVIP to load, process and visualize archived instrumentation data, reconstructed quantities, monitoring outputs and associated metadata.
- Development of post-processing functions to replay monitoring algorithms on archived data, compare POZ results with offline recalculations and support detailed investigation of abnormal or unexpected behaviour.
- Implementation of calibration workflows using archived monitoring data to adjust algorithm parameters, sensor mappings, reference cases, engineering limits and model-based reconstruction coefficients.
- Integration of TSM-ThermaVIP with the Events Database for event-driven analysis, including selection of relevant time windows, retrieval of contextual information and generation of analysis-ready datasets.
- Development of tools for trend analysis, data mining, statistical assessment and long-term evolution of reconstructed quantities, margins, lifetime indicators and anomaly detection results.
- Implementation of interfaces for importing and exporting datasets, configuration files, calibration parameters, analysis results and reports between TSM-ThermaVIP, the Events Database and other ITER data systems where applicable.
- Verification of data consistency, traceability, units, timestamps, synchronization and metadata completeness across archived signals, reconstructed outputs, events and analysis products.
- Preparation of representative offline analysis cases using synthetic data, archived commissioning data and SRO operational scenarios to validate XPOZ workflows and post-processing functions.
- Support to model validation and improvement by comparing archived measurements with analytical models, finite element model outputs and reconstructed engineering parameters.
- Implementation of user-oriented analysis functions, visualisation views and reporting templates enabling engineering teams to review monitoring results, calibration outcomes and post-event analyses.
- Preparation and execution of software integration tests, verification tests and acceptance tests for XPOZ applications, TSM-ThermaVIP workflows and Events Database interfaces.

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- Support to deployment, configuration control, version management and release procedures for XPOZ software components and associated analysis workflows.
- Preparation of software design documentation, interface control documentation, user guidance, test procedures, test reports and acceptance evidence demonstrating readiness for offline TSM analysis and calibration activities.
- Support to system commissioning and Tokamak integrated commissioning by performing post-shot analysis, calibration updates, event reconstruction and feedback to POZ monitoring applications and SRO-readiness assessments.
- Planning and realization of XPOZ analysis, calibration and post-processing capabilities required to support the progressive evolution from SRO operation towards DT operation.

5.2 Indicative Work packages

The following activities are foreseen as indicative work packages. The indicative work packages are not task orders by themselves and only define some span of work expected within the current Framework Contract. The work is to be performed predominantly off-site, with occasional visits.

Three different categories of activities are foreseen:

- Category 1 – for activities which can be spread in time, i.e. those with workloads less than 0.5 person per day or less of 0.5 full-time equivalent (FTE).
- Category 2 – for activities which will be the main occupancy for a person during some period, i.e. workloads between 0.5 to 1.0 person per day, and total allocation of at least 0.5 FTE.
- Category 3 – for those activities involving for sure more than one person, i.e. those with workloads higher than 1.0 person per day, and total allocation of at least 0.5 full-time equivalent (FTE).

The work packages (WPs) will use the previous classification along with an estimate of total hours. The contractor will then add the proposed details of the delivery and the price for this work package. Some indicative WPs are listed in the following table.

Indicative work package	Category & duration	Hours
Complete the implementation of the dynamic structural algorithm for the equatorial port plug:	Cat 1, 6 months	820
- FEM model processing: inclusion of sensors and definition of loading parameters		200
- Generation of system data files		250
- Sensitivity analysis for defining best combination of algorithm parameters		200
- Analysis of the test cases for defining the accuracy of the algorithm		80
- Study of the sensitivity to sensor noise and failure rate		90

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Indicative work package	Category & duration	Hours
Integration of POZ application with CODAC SUP: - Define the SUP integration implementation steps for the TSM POZ application, including application states, commands, configuration parameters, supervision variables, alarms and execution modes to be exposed to CODAC SUP. - Implement the TSM interface with CODAC SUP to manage monitoring application start-up, shutdown, state transitions, configuration loading, automation sequences and execution control. - Configure and validate the exchange of supervision data between the TSM POZ application and CODAC SUP, including status publication, command reception, error reporting, alarm handling and diagnostic information. - Perform integration and regression testing on CODAC test benches using representative synchronous and asynchronous monitoring workflows, including nominal, degraded and failure scenarios. - Prepare the interface documentation, test procedures, test reports and acceptance evidence required to demonstrate readiness of the TSM POZ application for operation under CODAC SUP supervision.	Cat 3, 12 months	2300 200 600 500 400 600

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Indicative work package	Category & duration	Hours
Integrate the Events Database with the ThermaVIP interface application:	Cat 2, 9 months	1500
- Define the Events Database and ThermaVIP integration requirements, including archived data access, event metadata, query mechanisms, user permissions, bidirectional control commands and the information required by anomaly detection workflows.		200
- Implement the bidirectional interface allowing ThermaVIP to retrieve events, signals, tags and contextual information from the Events Database, and to write back analysis results, calibration updates, user annotations, derived events and post-processing status.		300
- Implement tagging and traceability functions for archived monitoring data, including pulse identification, operational phases, anomaly labels, calibration versions, algorithm versions, data quality flags and links to engineering analysis cases.		300
- Implement the MLOps support required by anomaly detection algorithms, including dataset preparation, feature extraction, model version tracking, training and validation metadata, inference result storage, performance monitoring and feedback from expert review.		500
- Perform integration, regression and acceptance testing of the ThermaVIP–Events Database workflows using representative archived data, including nominal analysis, calibration updates, anomaly review, tag editing and failure-recovery scenarios.		200

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6 IO Documents

All technical documentation is already available within the 55.GT folders in IDM:
55.GT-Tokamak Systems Monitor

7 List of deliverables and due dates

The implementation details of deliverables and priorities will be agreed between the Contact Persons under each separate Task Order. No element of work or activity shall begin without the prior written notification by the ITER Organization in the form of a "Task Order" signed by both Parties.

The deliverables will depend on the type of a task, but they shall be well defined before the start of the Task order in question and shall be based on the expertise requested in Section 5 of these Technical Specifications. The examples of the deliverables include, but are not limited to, the following items:

1. Reports or minutes of the kick-off meeting including list of all input information and requirements.
2. Progress reports containing:
    a. Summaries of meetings and decisions,
    b. Drafts of material to be used in final reports,
    c. Issues that have arisen in the course of the work, along with suggested approaches to addressing these issues.
3. Deliverables of Task orders in the form of:
    a. Report,
    b. Technical note,
    c. Any other relevant documents.
4. Reports or minutes of the meeting for completion of the task order containing:
    a. Deliverables acceptance statement,
    b. Report on outstanding issues identified during Task Order execution, forward action plan,
    c. Summary of the Task Order outcome.
5. Delivery on ITER site (or other agreed location) of prototypes and components manufactured under this contract.

8 Quality Assurance requirements

Software delivered in scope of this Framework is classified as SWIL-2 (ITER Quality Class 3). Quality validation defined in SEQA-45 Guidelines [5] applies in accordance with the chosen quality classification level. The Quality class under this contract is therefore QC3, [1] GM3S section 8 applies in line with the defined Quality Class.

9 Safety requirements

No specific safety requirement related to PIC and/or PIA and/or PE/NPE components apply.

10 Special Management requirements

Requirement for [Ref 1] GM3S section 6 applies in full.

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10.1 Work Monitoring

The work on individual task orders shall be started by dedicated kick-off meetings and managed by means of Progress Meetings. It is expected that Progress Meetings will be held as frequently as required, generally bi-weekly, written progress reports are required monthly.

The main purpose of the Progress Meetings is to allow the ITER Organization/Diagnostics Division and the Contractor Technical Responsible Officers to:

a. Allow early detection and correction of issues that may cause delays;
b. Review the completed and planned activities and assess the progress made;
c. Permit fast and consensual resolution of unexpected problems;
d. Clarify doubts and prevent misinterpretations of the specifications.

In addition to the Progress Meetings, if necessary, the ITER Organization and/or the Contractor may request additional meetings to address specific issues to be resolved.

It is expected that on occasion the Contractor will be required to make a presentation to Topical Technical Meetings either by videoconference or in person. If a presentation in person at an off-site meeting is required, the ITER Organization will reimburse travelling expenses.

For all Progress Meetings, a document (the Progress Meeting Report) describing tasks done, results obtained, blocking points and action items shall be written by the Contractor. Each report will be stored in the ITER IDM in order to ensure traceability of the work performed.

10.2 CAD design requirements

This contract requires for CAD activities, [Ref 1] GM3S section 6.2.2.2 applies.

10.3 Specific requirements and conditions

Successful performance is mandatory.

It shall be noted that Contractor's personnel visiting the ITER site shall be bound by the rules and regulations governing safety and security.

The Contractor shall have and maintain the necessary equipment and licenses to run the software tools required to carry out the tasks and produce the deliverables in accordance with the tools adopted by the IO. This concerns the CAD, FEA simulation software and any complementary tool. The Contractor shall ensure that experts are adequately supported and equipped. The official language of the ITER project is English. Therefore, all input and output documentation relevant to this Contract shall be in English. The Contractor shall ensure that all the professionals in charge of the Contract have an adequate knowledge of English, to allow easy communication and adequate drafting of technical documentation. This requirement also applies to the Contractor's staff working at the ITER site or participating in meetings with the ITER Organization.

Documentation developed shall be retained by the Contractor for a minimum of 5 years and then may be discarded at the direction of the IO. All source code required to run, configure, test and calibrate the algorithms and TSM applications will be uploaded to the TSM repository along with the numerical models, scripts and simulations supporting the configuration of the algorithms.