

REPORT NO.

ITR-IEBH-108-2 v1.0

TITLE

ITER Engineering Basis Handbook

Vol. 1: Genesis, Design and Evolution

Chapter 8 - Managing the Design and Construction of ITER

Section 2 - Quality Assurance and Quality Control

CHIEF EDITOR

Dr. Gianfranco Federici

CHIEF EDITOR'S EMAIL

gianfranco.federici@euro-fusion.org

September 19th, 2026

About the ITER Basis Engineering Handbook

This handbook consists of two volumes which describe the ITER design from its inception up to the design, construction and assembly in 2025.

The handbook is not designed to be read as a continuous sequence of chapters. Instead, it is composed of focused, self-contained sections that address specific topics. Each chapter can be read and understood independently, allowing readers to engage with the material most relevant to their needs without requiring familiarity with preceding chapters. As a result, the reader will find certain overlapping content in chapters.

It is to be noted that at the time of writing, the design for some systems is still on-going. Therefore, the reader should consider that whilst there is significant value of this important point-in-time study, an update would be required as the Project progresses.

A broad Project overview is given in the first volume, to provide the reader with background information necessary to understand the context in the subsequent more-detailed chapters of the second volume, dedicated to the individual systems composing ITER.

For the overall table of contents of the Handbook and to access each one of the chapters, please refer to <https://www.iter.org/scientists/iter-technical-reports>.

Authors and Contributors of this Chapter

This chapter is authored by Chun Young Jung, Juan Knaster and Miia Tiainen-Paquaux; and co-authored by the Handbook Editors Federico Casci, Stefano Chiocchio Gianfranco Federici, Richard Hawryluk, John How, Akko Maas, Masanori Onozuka, René Raffray, Gabriella Saibene, and Bill Spears.

Volume 1**GENESIS, DESIGN AND EVOLUTION****Chapter 8****MANAGING THE DESIGN & CONSTRUCTION OF
ITER****Section 2****QUALITY ASSURANCE AND QUALITY CONTROL****Table of Contents**

8.2	Quality Assurance and Quality Control.....	2
8.2.1	ITER Project Quality Assurance Framework	2
8.2.2	ITER Management and Quality Program (MQP).....	4
8.2.3	ITER Quality Assurance Program (QAP).....	5
8.2.4	Quality Classification, Quality Supervision (QS) testing and Quality Control (QC)....	7
8.2.5	Quality management in regards of ITER risks and opportunities	9
	Glossary	11
	References	12

Chapter 8

MANAGING THE DESIGN & CONSTRUCTION OF ITER

8.2 Quality Assurance and Quality Control

8.2.1 ITER Project Quality Assurance Framework

At the onset of the ITER Project, the DAs' perception of several Procurement Arrangements (PA) was that the IO was acting as a demanding customer asking for excessive requirements without considering the costs of manufacturing. The ambitious design with a limited focus on workability during the EDA phase turned out to be extremely challenging if not impossible to meet by industrial players. This could result in the disregard by industry of the specified tolerances without properly understanding the implications. In parallel, both the IO and the DAs needed to develop optimal quality management practice in terms of quality assurance requirements and methods to perform and monitor quality control, arguing about disruptions on the on-going work in domestic industry or about the need to pay for additional storage of massive items that required special storage conditions.

The ITER Agreement in its Section 6.5 Common Understandings on ITER Management and Procurement [\[1\]](#) stipulates that the IO maintains the overall responsibility for the technical

performance and management of quality issues and interfaces of ITER, in close collaboration with the DAs.

Thus, whilst the IO is the overall integrator and nuclear operator of the ITER Facility and responsible for the quality compliance of the ITER facility, in turn, each DA shall:

- a) “Establish internal project management and Quality Assurance systems meeting the Organisation’s project management and Quality Assurance requirements to ensure full implementation and delivery of the Party’s contributions to the Organization”.
- b) “Ensure that each of its suppliers performs in full compliance with the Quality Assurance requirements”.

In other words, the IO holds the role to mandate processes and methods for Project-wide Quality Assurance (QA) and Quality Supervision (QS) practices, however, all the Project Execution Entities (PEE), i.e. the IO, the DAs and their respective supply chains, are jointly responsible for the quality of the delivered items and activities. Unfortunately, especially during the first years of machine installation activities, the IO’s technical or offsite QS resources would not systematically be present during the Factory Acceptance Tests (FAT) of the equipment before being shipped.

Later, driven by the need for a rigorous control of budget mandated by the Governance especially during the first years of machine installation activities, a severe restriction of the missions of IO staff to monitor the in-kind procurement was in place. This was a decision that reduced the role of the IO in offsite QS. Either because of the IO’s budgetary restrictions or because of access issues at some Suppliers’ facilities, the IO’s technical or offsite QS resources would not systematically be present during the Factory Acceptance Tests (FAT) of the equipment before being shipped.

The cumulative effect of a series of decisions that progressively reduced the ITER Project’s ability to ensure effective, prioritised, and coordinated upstream QS proved increasingly challenging. This was compounded by technical non-conformities identified only upon the arrival of items at the ITER site, while the clarity of project ownership and accountability continued to diminish. The ITER 2016 Baseline schedule pressure led to disregarding apparent non-conformities and 'accept as is' components with downstream quality, repair and cost consequences.

A new collaboration platform, the IO-DA Quality Leadership Team (QLT), was established in 2024. Thanks to this new approach, constructive teamwork has led to jointly setting focused targets that are formalized in ITER Quality Culture Improvement Roadmap [2]. Dedicated QLT swim lanes address short term improvement initiatives and have already at the time of writing this chapter brought major improvements both in terms of QA and in-field QS with annually revised targets¹ that are linked to ITER Project milestones. The purpose of the Road Map is to:

¹ The Road Map formalizes necessary activities in three improvement areas: QS, QA, Quality Culture and Awareness. Within each improvement area, the actions relate to different elements such as: Execution methods and work instructions, Availability of tools and equipment, Competences and skills, Availability of resources, Requirement clarifications and procedure definitions.

- Minimize the occurrence of non-conformities and quality issues throughout the ITER supply chain in all project phases;
- Mobilize suitable and qualified competences with world class quality management methods and tools, adapted for each project phase;
- Deploy an integrated quality management approach by the IO and the seven DAs to optimize resource allocation and effectiveness, and to ensure highquality products.

8.2.2 ITER Management and Quality Program (MQP)

The ITER Management and Quality Program (MQP) is maintained by the IO in close collaboration with the DAs. The MQP is understood as the “management baseline”, alongside with the “technical baseline” (scope) and “performance baseline” (schedule and cost). Each PEE is responsible to set their respective internal controls system, thus their respective Senior Management hold the responsibility and authority to ensure the effectiveness, suitability and sufficiency of the MQP, and to develop, procure, manufacture, operate and maintain equipment in accordance with it. The DAs are suggested to follow the ITER MQP, alternatively they are to set up an equivalent domestic MQP that satisfies the same MQP principles. The DAs are obliged to submit to the IO such domestic quality management system/quality assurance program for acceptance.

Whereas the responsibility to meet the ITER Project quality requirements remains with the contracting PEE, any contractual documentation package derived from the Procurement Arrangements (PA) of the DAs, shall contain information about applicable quality requirements.

The MQP has been developed as a four-level framework, as shown in Figure 8.2-1:

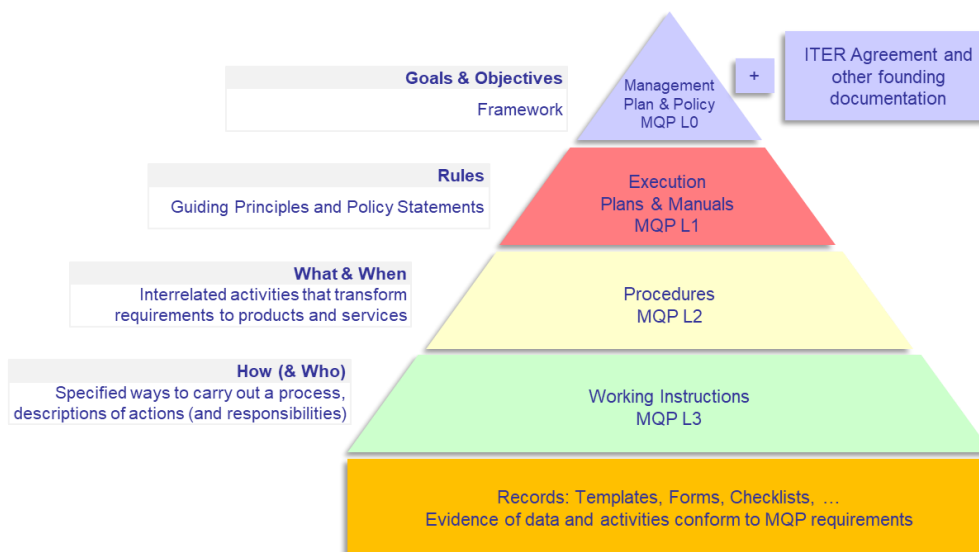


Fig. 8.2-1: Pyramidal representation of ITER Management and Quality Program (MQP)

At a certain moment over 700 documents comprised the MQP. Asking the DAs for full compliance was unaffordable and efficient propagation of requirements was impossible. A focussed effort to rationalize, eliminate redundancies and focus on essential things was deployed in 2024-2025. The IO is responsible to maintain and keep accessible an MQP process map and applicable MQP documents in a central and accessible location [3]. In turn, the PPEs are jointly responsible for continuous maintenance of the MQP alignment matrix. Since 2025, the DAs have been set responsible to simply inform the IO about the MQP document versions they use for each individual Procurement Arrangement (PA) so that the IO can centrally maintain an MQP alignment matrix. Applicable versions of the MQP documents used by the DAS are agreed within the IO-DA QLT.

8.2.3 ITER Quality Assurance Program (QAP)

The ITER Quality Assurance Program (QAP) lies beneath the overall framework of the MQP and addresses the organization for the implementation of the MQP. The QAP is established and maintained based on the principles listed in:

- IAEA General Safety Requirements.
- The French Order dated 7 February 2012 relating to the general technical regulations applicable to INB.
- ISO 9001 Quality Management Systems Requirements.
- ITER MQP Level 0 Project Management Plan (PMP) [4].
- World Association of Nuclear Operators (WANO) guidelines
- French Decree 2015-799
- ESPN Order dated 30 December 2015
- Pressure Equipment directive 2014/68/UE
- ISO 14001 International standard for environmental management system
- ISO 45001:2018 Occupational health and safety management systems- Requirements with guidance for use
- OHSAS 18001 Standard for Occupational Health and Safety management system

The QAP formalizes the quality level at which the activities of the ITER Project shall be executed by all PEEs. Therefore, it is to be followed by all technical and administrative units within the IO and the DAs to ensure that equipment is designed, procured, fabricated, transported, installed, assembled, and tested to conform to established and documented technical, safety and administrative requirements and attaining the level of quality necessary to accomplish the ITER Project mission and objectives.

To reach the objectives of the QAP, PEEs' management is responsible for

- Aligning and cascading the QA requirements described in the QAP in their ITER Project related quality management systems,

- Providing assurances that the activities they manage, execute and procure
 - In conformance with established requirements; and
 - In a fully traceable manner; and
- Collecting information on the effectiveness of their QAP.

The relationship between the IO and the DAs has been subject to extensive discussions over time, with different formulations for IO-DA integration and efforts to avoid duplication of documental effort. The multiplicity of documents, often redundant, and excessive lead to confusion. This is discussed in Sec. 7.2.

The Quality Assurance (QA) is performed not only on physical items but also on quality processes. Within that scope, various activities are performed in support of the ITER Construction Project (CP) and the DAs: the implementation of annual quality audit programs and follow-up on findings, provision of expertise and necessary technical support to Non-destructive testing (NDT) activities on ITER site and at the DAs' and manufacturers' premises, quality receiving inspections at the reception at ITER worksite, Non-Conformity management and Quality training.

The QA activities applied to an item are to be correlated with its relevance to the safety, reliability, and performance of the ITER Facility. To prevent the specification of insufficient or inadequate requirements, quality classification using a graded approach is assigned to all items. This classification scheme is used:

- to establish a basis on which a stepwise hierarchy of quality requirements can be developed, and
- to identify items that require less stringent quality requirements with consequential cost saving.

Due to the nuclear characteristics of ITER and its first-of-a-kind nuclear facility for the fusion community, the requirements were defined by nuclear safety experts with expertise in nuclear fission safety. This led to demanding requirements biased by the requirements for fission reactors, which despite the commonalities, exhibit substantial differences that were not duly considered. The Nuclear Regulator was satisfied with the rigour shown, however this impacted the in-kind procurement of the DAs in terms of cost and schedule and put in risk the success of ITER. A good example of the latter is the consideration of the Vacuum Vessel as nuclear pressurized equipment, as if it was the reactor pressure vessel, though it is a vacuum vessel. Although the nuclear consideration is undisputable given the presence of tritium and activated materials (including dust and cooling water), the main mechanical design is not driven by the possible pressure in the vessel or cooling water but by electromagnetic loads during accidental events. However, the consideration of the VV as a fission reactor pressure vessel under French ESPN categorization led to zero-defects requirements in the welding of the 60 mm double wall structure in a complicated geometry difficult to measure and to meet along the many kilometres of weldments. This bias from nuclear fission world was also apparent on the efforts to assess the risks of a Loss of Coolant Accident, the worst possible event in a fission reactor (despite the residual heat in ITER could hardly create such a problem). This rigorous initial approach led to include in the design provisions

to rapidly vent ITER, that could damage the equipment at cryogenic temperatures inside the Cryostat, like magnet or thermal shield, in case a drastic change of temperature would take place. However, this risk has become during the construction of ITER and a deeper understanding less relevant.

Quality Assurance (QA) activities shall be implemented throughout the lifecycle of the equipment. The PEEs are to check and guarantee the compliance of data and material to the requirements along the consecutive gate reviews, as depicted in Figure 8.28.2-2 below.

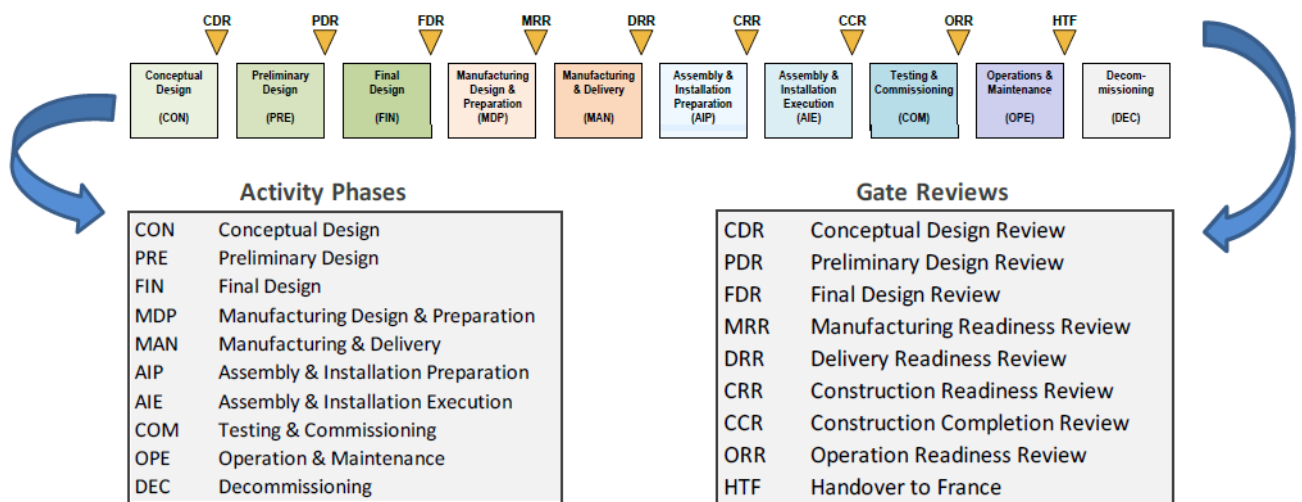


Fig. 8.28.2-2: Activity phases and gate reviews.

The readiness of an activity or a phase of an activity to proceed to the next phase or to the next follow-on activity needs to be assessed and agreed upon prior to proceeding.

Lessons learnt and quality management improvements advised to set an IO-DA joint Quality Audit Program scheduling audits on an annual basis to provide coverage of ongoing activities, based on their status and relevance. On top of this, additional unplanned audits are deployed of specific subjects when perceived necessary.

8.2.4 Quality Classification, Quality Supervision (QS) testing and Quality Control (QC)

The main responsibility of the manufacturing and thus quality of the ITER key components remains with the DAs; however, the IO Responsible Officers (ROs) may implement Quality Supervision (QS) including physical inspections directly at manufacturers' sites jointly with DAs to ensure that there are no quality issues. This was a lesson learnt after difficulties faced and lack of ownership of the ITER observed in the DAs as described above that led to the acceptance of non-conformities during the FAT. Thus, the Quality Control (QC) of the DAs' in-kind deliveries are

carried jointly by the IO and DAs. In some cases, or for specific systems, under European and French regulations applicable to ITER, the manufacturer:

- Shall perform installation or fabrication tasks as well as the related QC at the ITER Site; and
- Has the ultimate responsibility for the conformity of the product to the applicable regulations and shall therefore perform technical control of all tasks and certify the construction reports.

The rigour in this exercise correlates with its relevance.

QS is performed on physical items through execution of quality processes. Within that scope, the following activities are executed in support to the construction of ITER on site and the DAs' in-kind procurements at their contractor's facilities.

- Quality Independent Assessments, inspired by PBS items, to check compliance with applicable quality requirements in the implementation of MQP procedures by the IO Performers covering both IO as DAs activities [5]. This includes documentation review, technical support and participation to gate reviews from tendering to handover to operation, with the aim to prevent non-conformities.
- QS and QA to check compliance with applicable quality and process requirements during manufacturing, pre-fabrication, assembly and installation. This includes QS inspections to monitor Manufacture Inspection Plans (MIP) and Inspection and Test Plans (ITP) execution, namely:
 - Off-site QS inspections to check products/items/services at suppliers' facilities; and
 - On-site QS inspections to monitor execution of inspection plans vs. activities on ITER worksite.
- Maintenance of MQP Inspection and testing process, including verification of competences of QS inspectors and maintenance of QS inspectors' lists.

Special precautions are in place for transportation. This was particularly important when the IO had reduced their QS on the DAs' in-kind procurement. Accelerometers became an indispensable tool to identify possible issues during the long trips to ITER site.

All equipment of ITER, as nuclear device, is assigned a particular Safety Importance Class (SIC) that is based on the consequences of their failure. The top-level criteria for the identification are

- SIC-1, the equipment required to bring to and to maintain ITER in a safe state; and
- SIC-2 the equipment used to prevent, detect or mitigate incidents or accidents, but not SIC-1, i.e. not required for ITER to reach a safe state

All other components are described as "non-SIC". However, some components, while not being SIC, may have some relevance to safety. These components are labelled 'Safety Relevant' (SR).

This leads to a Quality Classification in three categories, where all SIC-1 are Quality Class 1. SIC-2 and SR components are assigned to a Quality Class determined by the impact either Adverse (Quality Class 2) or Moderate (Quality Class 3) with a weighted formula considering various aspects being operational performance, environmental impact and cost and schedule impact being the heaviest.

Prior to launching an activity, in case a Contractor would notice a need or an interest to execute a work package in a different manner than what is described in applicable procedures and instructions, they may open a formal Deviation Request (DR) for the IO review. In case a deviation is observed after performing the given activities, a non-conformity report (NCR) shall be recorded to initiate the formal NCR process. Each nonconforming item or work would be prominently identified, tagged, or uniquely identified and, when practical, segregated to prevent its use. Given that the time and effort involved in the evaluation of non-conformances is substantial, a graded approach is applied to ensure that the most intensive evaluation is reserved for the problems of highest significance. This grading follows an assessment on risks on safety, quality and performance leading to two categories: major NCR or minor NCR. The depth and rigor of details necessary and the magnitude of resources required to manage the NC are commensurate with the relative importance of the detected NC in terms of risks on safety, quality and performance. The categorization is agreed between the performer (DAs TRO in case of PA implementation/ supplier / contractor) and IO-RO (IO TRO / IO CRO) with IO QARO support considering the level of impact.

Any personnel who are involved with the dispositioning of non-conformances is to be competent in the technical areas in question and knowledgeable of the intended application of the item or work being dispositioned.

8.2.5 Quality management in regards of ITER risks and opportunities

Risk and Opportunity (R&O) management [6] on continuous basis is central to effective baseline management and successful delivery of any project. As the ITER Project is an international and multi-party project with challenges related to its scientific, manufacturing, delivery and installation aspects, it is essential to have effective and proactive IO-DA coordination towards risk identification, assessment and mitigation, and a rigorous focus on significant unknown and uncertain variables.

An MQP Procedure dedicated to defining the process for the identification, assessment, analysis, mitigation/exploitation and management of ITER Project R&O is established to be maintained throughout the project lifecycle. To properly address risks and benefit from new opportunities, decision-making authority and sufficient resources for risk mitigation are empowered to the lowest possible level whilst keeping the rest of the organization informed with transparent data to prevent hidden and/or cross-cutting risks becoming an issue. Substantial efforts have deployed from lessons learnt along the years to reinforce IO-DA collaboration and transparency on R&O management.

Nevertheless, an issue with difficult solution in ITER is that the delays faced by the project makes useless the 2-years warranty period typically stipulated in the PAs. It could happen that often the Site Acceptance Tests (SAT) could only be done years after the expire time of the warranty periods. Then, in case of a non-conformity detected in the equipment, with even possibly the DA technical responsible person is not even available anymore, who is responsible of the resolution of the non-conformity. Concerns are the magnet system of ITER. Power supplies, feeders and magnets themselves are delivered but several of them will remain untested before the cryostat is closed and in cold operational conditions. Efforts are going on to keep the teams in the DAs involved together with the experts in domestic industries. Further, an approach to the management of QA issues related to component failures beyond commercial warranties was developed and the principles agreed by the ITER Council in 2025, whereby the IO and DAs should reinforce their full commitment to quality, DAs should be engaged in integrated commissioning and operation of their in-kind components as appropriate, and the Members, through their DAs shall remain responsible until the end of SRO for the cost of repairs resulting from defects and other non-conformities associated with in-kind technical specifications originally warranted in PAs, which are demonstrated to have occurred during manufacturing and could not have been identified with state of the art NDE during the SAT.

The principal practice for quality improvement is adequate up-front task planning and timely monitoring. Whereas the IO-DA QLT coordinates the maintenance of an ITER Quality Culture Improvement Road Map [7], all involved personnel from the IO, the DAs and involved industry are encouraged and required to transparently report problems to appropriate management for correction and to make recommendations for improvements. Those closest to the working level of an activity are considered being the most knowledgeable of the activity and its problems, risks or shortfalls. The following steps are essential in the ITER Quality Culture.

- To identify problems is the necessary first step in getting them fixed and preventing their recurrence;
- To expedite opportunities for improvement, recommendations shall be considered at the lowest appropriate organizational level;
- To prevent reoccurrence and waste, root cause analysis (RCA), corrective actions and lessons learned shall be utilized in a focused manner to improve management, quality and safety of systems, resourcing, communication and working methods.

Indeed, experience highlighted some challenges in the way non-conformities were identified, reported, and addressed across the Project. In certain instances, deviations were not brought forward or addressed through the appropriate channels as promptly or transparently as expected. These aspects have since been addressed through the Road Map referred to above. Moreover, increasing efforts have been deployed to prevent counterfeit and fraudulent items. A systematic endeavour is in place by the IO-DA QLT to harmonize the behaviour of IO-DAs staff and Contractors to ensure adherence to ITER project quality standards. To support positive transformation, a generic reference to all ITER Project Executing Entities was suggested by the IO-DA QLT, leading to an ITER Policy on Safety, Security, Quality and Environment Protection being signed by the DG and the Heads of all seven DAs in July 2025.

Glossary

AIE	Assembly & Installation Execution
AIP	Assembly & Installation Preparation
CCR	Construction Completion Review
CDR	Conceptual Design Review
CP	Construction Project
CRR	Construction Readiness Review
DEC	Decommissioning
DR	Deviation Request
DRR	Delivery Readiness Review
FAT	Factory Acceptance Test
FDR	Final Design Review
ITP	Inspection and Test Plan
MAN	Manufacturing & Delivery
MDP	Manufacturing Design & Preparation
MIP	Manufacture Inspection Plan
MQP	Management and Quality Program
MRR	Manufacturing Readiness Review
NCR	Non-Conformity Report
NDT	non-destructive testing
OPE	Operation & Maintenance
ORR	Operation Readiness Review
PA	Procurement Arrangement
PDR	Preliminary Design Review
PMP	Project Management Plan
PRE	Preliminary Design
QA	Quality Assurance
QAP	Quality Assurance Program
QC	Quality Control
QLT	Quality Leadership Team
QS	Quality Supervision
R&O	Risk and Opportunity
RCA	Root cause analysis
RO	Responsible Officer
SAT	Site Acceptance Test
SIC	Safety Importance Class
SR	Safety Relevant
VV	Vacuum Vessel
WANO	World Association of Nuclear Operators

References

- [1] Common Understandings on ITER Management and Procurement (2F9UJS)
- [2] ITER Quality Culture Improvement Road Map (AM2TRZ)
- [3] See: <https://portal.iter.org/baseline/Pages/MQPmap.aspx>
- [4] MQP Level 0 Project Management Plan (PMP, AVAMQG)
- [5] Terms of Reference (ToR) for Quality Management Division (QMD) (E9JIM4)
- [6] MQP Level 2 Risk and Opportunity Management Procedure (22F4LE)
- [7] ITER Quality Culture Improvement Road Map (AM2TRZ)