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# QUALITY ASSURANCE PLAN FOR THE SCADA SYSTEM OF THE CHERENKOV TELESCOPE ARRAY OBSERVATORY

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*Abstract*

The Array Control and Data Acquisition (ACADA) software is a crucial part of the Cherenkov Telescope Array (CTA) Observatory and requires the definition of an appropriate Software Quality Assurance (SQA) process. This activity is necessary to ensure the development and maintenance of a high-quality product, throughout the construction stage and the whole lifetime of the Observatory. Software Development, Software Management, and Software Verification and Validation Plans are the mainstays of the SQA activities documented in the SQA Plan (SQAP). The Scope of this paper is to describe the SQAP proposed for the ACADA work package, which includes all the necessary actions planned to guarantee process and product conformance to the ISO/IEC 25010:2011 standard.

## INTRODUCTION

The Cherenkov Telescope Array (CTA) is the next-generation atmospheric Cherenkov gamma-ray observatory. It will be the world's largest ground-based facility for gamma-ray astronomy at very-high energies. The observatory will be composed of more than 100 telescopes and different types of calibration devices that need to be centrally managed and synchronized to perform the required scientific and technical activities.

The operation of the array requires the presence of a complex Supervisory Control and Data Acquisition (SCADA) system, named Array Control and Data Acquisition (ACADA) [1]. The quality level of the ACADA work package is crucial for maximizing the efficiency of the CTA operations.

An appropriate SQA activity is fundamental to ensure the development and maintenance of a high-quality ACADA product. Furthermore, it will help to improve reliability, maintainability, and cost-saving through the prompt discovery of problems.

In the next sections, we will describe the SQA organization and planned activities. We will show how the defined roles and tasks are coherently scheduled and organized with the ACADA Management Plan, Software Development Life Cycle (SDLC) Plan [2]. We will present the quality models and the related metrics defined to comply with the required quality standards. Finally, we will describe the procedures and methods applied to guarantee that, for each phase of the project, the required level of quality in the design, implementation, testing, integration, configuration, usage and maintenance of the ACADA product are met.

## QUALITY ASSURANCE MANAGEMENT ORGANIZATION

This section describes relevant roles and responsibilities applicable to the ACADA-SQAP, together with the software quality tasks to be performed.

### *Roles and Responsibilities*

The ACADA SDLC follows an iterative and incremental model which is based on the ISO/IEC 12207:2017 standard [3]. The roles and responsibilities of the personnel assigned to the ACADA quality assurance activity are listed in Table 1. They are individuated based on the roles and responsibilities defined in the ACADA Management Plan and ACADA SDLC [4]. Depending on the level of responsibility of the QA activity to be performed, four main bodies have been defined[1].

ACADA SQA Management Body is responsible for the organization and implementation of the SQA activities related to the definition of the program and associated budget and personnel needs. This body is also responsible for the supervision and control of the planned activities for the product and maintenance quality assurance.

The quality aspects of the ACADA system in the global quality framework of the whole CTA project involve the presence of the SQA Top Management Body, responsible for the top-level tasks of the quality process assurance.

The SQA Professional Body is responsible for the technical implementation of the measurable quality quantities (metrics) and the execution of the tests. This body is mainly composed of designers, developers, and testers.

The validation and verification activities are performed by the SQA Validation and Verification Body, which can be composed of external and internal members of the project (e.g. ACADA Coordinator, stakeholders). This body is in charge to supervise the quality tests of the product and to organize audits to evaluate the related quality reports.

## PRODUCT ASSURANCE

The quality models adopted for ACADA are two, as recommended by [5]: Product Quality Model and Quality in Use Model. They are related to the definition of the quality

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[1] These bodies are organization roles covered by already existing or planned personnel from the CTA project organization chart.

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level of the product (Product Quality Model) and the quality level of the outcomes of interaction with the specific users (Quality in Use Model) [5].

Table 1: ACADA QA Roles and Responsibilities

| Roles | Responsibilities |
|---|---|
| SQA Top Management Body (SQA -TMB) | • Assure ACADA compliance with stakeholders' requirements<br>• Approval of SQA activities program and budget<br>• Ensure availability of resources for ACADA SQA activity<br>• Ensure that the QA objectives for ACADA system are established and accomplished<br>• Assure the quality of ACADA maintenance service |
| SQA Management Body (SQA -MB) | • Preparation of SQA program and budget<br>• Periodic control of the SQA planned activities<br>• Provide planning and oversee implementation of changes necessary to adapt the SQA activity to major internal and external changes.<br>• Determine the adequacy of the manpower and resources for SQ activities<br>• Interface with Safety, Reliability, and Verification & Validation personnel on SQA activities<br>• Identify and document non compliances<br>• Identify lesson learned that could improve processes for future products<br>• Presentation of the SQA issues to the top management |
| SQA Professional Body (SQA -PB) | • Implement SQA metrics defined<br>• Implement and Perform SQA tests<br>• Produce Test Reports<br>• Implement design Specifications |
| SQA Validation and Verification Body (SQA-VVB) | • Perform Internal SQA audits<br>• Perform External SQA audits |

The Product Quality Model focuses on the quality of the ACADA package, which can be evaluated by measuring the quantities related to the internal and external metrics. The internal metrics refer to static analysis, which aims to measure the internal quality properties of the product. The quality of the software behaviour while in execution is quantified by the external metrics. Appropriate internal properties of the software are a prerequisite for achieving the required external behaviour. Appropriate external behaviour is a pre-requisite for achieving quality in use. For this reason, the Product Quality activity must be coherently applied at each stage of the SDLC, as shown later in the paper.

### *Product Quality Model and Metrics*

The attributes which define the ACADA Product Quality Model are:

- Functional Suitability
- Performance Efficiency
- Compatibility
- Usability
- Reliability
- Security
- Maintainability
- Portability

Based on these quality attributes and the related sub-characteristics (as reported in [5]) the measurables quantities (metrics) have been defined in the ACADA SQAP. For each metric, the information for the correct implementation, testing, and stage of applicability in the development process have been provided.

As an example below is shown one of the internal metrics defined for the Installability, a sub-characteristic of the Portability attribute.

- <u>Metric Name:</u> Installation Effort
- <u>Purpose:</u> Measure the level of effort required for installation.
- <u>SDLC Stage:</u> Integration & Verification
- ISO/IEC 12207 Reference: Verification
- <u>Users of Metrics:</u> Tester, SQA Internal Executor
- <u>Method of Application:</u> SQA Internal Executor counts the number of implemented installation automated steps, performed by the tester, and compare it to the number of prescribed installation steps.
- <u>Formula:</u> $X = A/B$
- A = Number of automated installation steps confirmed in review
- B = Number of installation steps required
- <u>Interpretation:</u> $0 \le X \le 1$ (closer to 1 the easier)

The outcome of the metrics is evaluated by a comparison of performance data (X) with the related indicators. The indicators are quantitative reference values defined based on:

- Defined software quality standards
- Quality targets

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- Average quality levels achieved by other teams applying the same development tools in similar development environments
- Average quality achievements of the organization
- Best Practices from the Industry practices for meeting quality requirements

### *Quality in Use Model and Metrics*

The Quality in Use Model focuses on the whole ACADA system and it is applied when the product is in the use phase. The attributes which define the ACADA Product Quality model, as reported in [4] are:

- Effectiveness
- Efficiency
- Satisfaction
- Freedom from risk

The quality in use measures are related to the impact of the system on stakeholders. They measure intrinsic properties of the ACADA system, which can include software, hardware, communications, and users.

## PROCESS ASSURANCE

A good project organization with realistic planning and schedule and good documentation of the intermediate work steps is fundamental to guarantee a good quality of a product. Our SQA activities take care also of the quality of the process defined for the realization of ACADA. The following process assessments [6] are conducted, based on the development activity schedule, as shown in the next section:

- Supervision of the SQA activities
- Supervision of periodic reports to assess the achievement of quality objectives
- Review of progress of the SQA activity
- Final approval of the quality of software products

### *Process Metrics*

The measurable quantities related to the software development process belong to three main categories. For each category, proper metrics have been defined. These metrics aim to monitor simultaneously the quality of the on-going process, departures from the planned schedule and the error removal trend [6]:

- <u>Software process quality metrics</u> measure the quality of the ACADA developing process based on the errors detected per volume of software.
- <u>Software process Timetable metrics</u> measure the trend of the objectives of the project reached based on the ACADA schedule.
- Error removal effectiveness metrics measure the effectiveness of error removal after a period of regular operation of the system (usually 6-12 months).

## QUALITY ASSURANCE LIFE CYCLE

This section describes how the process and product SQA tasks are performed coherently with the different stages of the ACADA SDLC.

As suggested by the adopted ISO standard [5], an ACADA Software Quality Life Cycle (SQLC) model has been defined. The SQLC is strictly related to the development process as follows:

- The product under development phase is the subject of internal measures of the software quality (internal metrics of the Product Quality Model).
- The product testing phase is the subject of the external measures of software quality (external metrics of the Product Quality Model).
- The product in use is the subject of the quality in use (metrics of the Quality in Use Model).

The different stages of ACADA SQLC and the relationship with the SLDC phases are presented in Figure 1.

Each phase of the SQLC must provide the verification and validation of a specific set of quality requirements. The requirements are related to the software aspects (software product quality requirements) to the software and the hardware (system product quality requirements) or the usage of the overall product (system quality in use requirements).

The association between the different SQA tasks, the actors involved and the different stages of the SQLC is summarized in Table 2 and described below.

**Quality Assurance Objective Specifications** The first step of the SQLC is part of the Requirement Analysis stage of the SDLC, which defines the set of requirements based on which the system will be designed, implemented, integrated and verified. As shown in Table 2 this phase must define the quality assurance activities, schedule, and budget. The quality attributes of the systems, which specify the criteria for a qualitative description of how the system must operate and perform a given function, must be defined here. At the end of this stage, the Quality Assurance Plan (defined by the SQA Management Body and approved by the SQA Top-Management Body) and the Qualification test specifications (defined and approved by SQA Management Body) must be produced.

**Architecture Peer Review** This stage aims to assess the quality of the architecture defining the system structure. This is performed through the organization of internal and external peer reviews involving SQA Validation and Verification Body. At the end of this stage, an ACADA architecture quality report must be provided.

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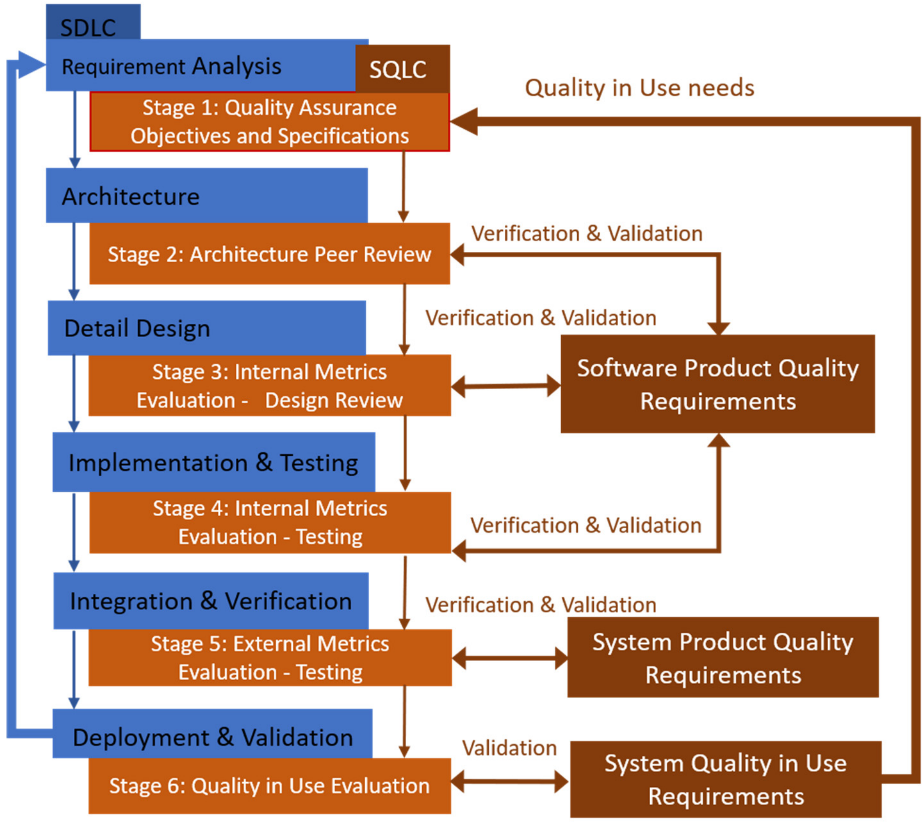


Figure 1: Software Quality Life Cycle (blue boxes) and Software Development Life Cycle (orange boxes) stages defined for ACADA, based on ISO/IEC 25010:2011 and their relationship. At each stage, a specific SQ activity must be performed. As a result, the verification and validation of software product quality requirements (stage 2, stage 3 and stage 4), system product quality requirements (Stage 5) and system quality in use requirements (step 6) must be performed.

**Internal Metrics Evaluation - Design Review** The quality of the detailed design of the ACADA components is evaluated based on internal metrics defined in the Product Quality Model. The method of application is the design review peers. The actors involved are the SQA Professional Body, as the producer of the technical materials, and the SQA Validation and Verification Body for internal audits. At the end of this stage, design quality reports should be produced.

**Internal Metrics Evaluation – Testing** The quality attributes of the ACADA implementation are estimated by applying the internal quality metrics which provide the execution of quality tests. The tests are performed by a member of the SQA Professional Body (developer), under the supervision of the SQA Internal Executor, as part of the SQA Validation and Verification Body. At this stage also the software process quality metrics regarding the code error density and severity are evaluated, with the help of automatic tools such as Jenkins [7] and SonarQube [8]. The results (internal quality test reports) are evaluated via dedicated audits involving different members of the SQA Validation and Verification Body. At the end of this stage, the compliance with the software product quality requirements is assessed.

**External Metrics Evaluation – Testing** The external metrics evaluation of the SQLC is applied during the Verification stage of the SDLC, after the conclusion of the integration phase. The external metrics can verify the System Product Quality Requirements of the current iteration process. The QA personnel involved are the SQA Internal Executor and Tester, belonging respectively to the SQA-VVB and the SQA-PB. The outcome of the test must generate a system quality test report. As for the internal metrics execution even in this case the results are evaluated and approved by a dedicated audit.

**Quality in Use Evaluation** The final stage of the SQLC provides the validation of the quality in use requirements and must be applied after the deployment stage of the SDLC. In this case, the QA Validation and Verification Body can involve the presence of external stakeholders either for the testing than for the audit phases. A Quality in Use test report must be provided.

The SQLC activity described here applies for each iteration of the SDLC. The fulfilment of the quality requirements in each stage of the process represents a pre-condition to proceed to the next phase of the SDLC.

Table 2: ACADA Software Quality Life Cycle

| SQLC | QA Body | Activities |
|---|---|---|
| Stage 1 | SQA TMB | Approval of SQA activities program and budget |
| | | Ensure availability of resources for ACADA SQA activity |
| | SQA MB | Preparation of SQA program and budget |
| | | Determine the adequacy of the manpower and resources for SQ activities |
| Stage 2 | SQA-VVB | Internal SQA audits |
| | | External SQA audits |
| Stage 3 | SQA-PB | Implement Design Specifications (developers) |
| | SQA-VVB | Internal SQA audits |
| Stage 4 | SQA-PB | Implement and test internal SQA product and process quality metrics (developers) |
| | SQA-VVB | Supervise tests (SQA Internal Executor) |
| | | Internal SQA audits |
| Stage 5 | SQA-PB | Implement and test external SQA metrics (Developers) |
| | SQA-VVB | Supervise Tests (Internal SQA Executor) |
| | | Internal SQA audits |
| Stage 6 | SQA-VVB | Perform Test and Produce test Reports |
| | | External SQA audits |

As part of the process assessment, the ACADA SQA Management Body should interface with the SQA-VVB to evaluate the results of the on-going activities and provide dedicated reports to assess the achievement of the target quality level. Identified non-compliances must be properly documented and appropriate solutions should be defined. In case of serious inconsistencies, the SQA – MB must report the SQA issues to the top management.

At the end of each iteration of the SDLC, the new software version is deployed and validated, ready to be used. At this point the process timetable metrics must be determined and evaluated based on the ACADA schedule, performing audits organized by the SQA MB. After six months of usage of the new software version, the error removal effectiveness metrics should be applied by the ACADA team and evaluated by the SQA MB.

## CONCLUSION

The SQA activities described in this paper illustrate how the quality aspects of the ACADA software package have been considered for both the product and development process aspects. The product assessment guarantees the quality of the product from a technical and functional point of view. On the other hand, the assessment of a good process, including intermediate work products and documents, is as important as the product itself and becomes the main criterion for a reliable product. The SQLC approach adopted, applied coherently with the different stages of the SDLC, is an efficient mechanism for evaluating the status of compliance with the product, system, and usage quality requirements. This approach provides also a good method for the discovery of problems in the early stages of the development process. In this way, an efficient and cost-saving development and maintenance of consistently high-quality ACADA product can be guaranteed.

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https://www.cta-observatory.org/consortium_acknowledgments/

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