CI QUALITY ASSURANCE / QUALITY CONTROL PLAN

Version 2-00
Document Control Number 2010-00002
4/14/2011

Consortium for Ocean Leadership
1201 New York Ave NW,
Washington DC 20005
www.OceanLeadership.org

in Cooperation with

University of California, San Diego
University of Washington
Woods Hole Oceanographic Institution
Oregon State University
Scripps Institution of Oceanography

Document Control Sheet

Version	Date	Description	Originator
1-00	August 14, 2008	Initial release	Kleinert, J
1-01	October 13, 2008	Incorporated Comments	Kleinert, J
2-00	April 14, 2011	General Update	Kleinert, J

Table of Contents:

1 Introduction

1.1 Scope

This Quality Management Plan (QMP) presents a coherent road map to meet the Quality Assurance (QA) and Quality Control (QC) requirements of the Ocean Observatories System Cyberinfrastructure (OOI/CI) Program. This QMP is consistent with the umbrella of best practices invoked by the Ocean Leadership (OL) Quality Assurance Plan (QAP) and provides the CI contribution to OL's integrated quality management system.

Addressed in this plan is this QMP's relationship to other project plans; the QM organization; subcontracting; required staff resources, qualifications, and responsibilities; schedule for activities; and QM activities and practices, including corrective actions, security, tools, metrics, and records. Responsibility for ensuring that an adequate CI QM Program is implemented rests with the CI Program Manager.

1.2 Identification

This Quality Management Plan (QMP) is developed to support the Ocean Observatories Initiative (OOI) Cyberinfrastructure (CI) Program. This document is maintained by version number to reflect significant changes as the CI Team tailors the QMP to meet the evolving needs of the Ocean Observing community's needs. The CI QMP shall be identified as 2010-00002_QA_QC_Plan_CI, with the date and version number updated as the document is formally changed. The CI Program Manager is the final change approval authority.

1.3 CI Overview

Next generation studies of dynamic, interacting processes in the Earth-ocean-climate system require new in situ approaches to complement the more traditional ship-based, expeditionary science that has dominated oceanographic research for the past century or more. Routine, long-term measurement of episodic oceanic processes is crucial to continued growth in our understanding and predictive modeling of complex natural phenomena that are highly variable and span enormous scales in space and time. This access is enabled by innovative ocean observatory facilities providing unprecedented levels of power and communication to access and manipulate real-time sensor networks deployed within the ocean. These facilities empower entirely new approaches to science and enable education and outreach capabilities that dramatically impact the general understanding of, and public attitude toward, the ocean sciences.

To accomplish this paradigm shift, ocean scientists require at least seven infrastructural capabilities that they do not have now. They must be able to:

- Fully and quantitatively characterize selected volumes of the ocean, the atmosphere overhead and the lithosphere beneath;
- Receive information about all interrelated components of the system simultaneously, in real-time;
- Recognize departures from the norm and observe emergent phenomena to conduct interactive experiments within the environment;
- Reconfigure observational-sampling systems in response to events;
- Assimilate in situ data efficiently into models that expand the space/time view of them and feed back onto the measurement protocols;
- Continue and expand this in real-time;
- Interact with the oceans for decades.

The Ocean Sciences Division of the National Science Foundation has implemented the Ocean Observatories Initiative (OOI) to focus on science, technology, education, and public awareness activities

needed to develop and deploy a network of science-driven ocean observing systems that implement this vision. This will provide users with the means to characterize the oceans for decades.

1.4 Document Overview

Quality is a critical CI attribute inherent in all processes that span the project's development life cycle. Consequently, failure to achieve specified quality thresholds injects unacceptable technical, schedule, and/or cost risks that could ultimately jeopardize success. Accordingly, quality management concepts and methodologies addressed in this QMP act as a "quality barometer" to, hopefully, avoid or, as a minimum, mitigate these risks.

The CI QMP addresses all areas that impact the project's system quality. This approach ensures that prescribed quality is built into system development processes and products (including supporting documentation and non-deliverable system), and is in total compliance with relevant Ocean Leadership QA requirements, policies, and standards. These are identified and thoroughly defined in the plan. Also included are essential practices and procedures to be implemented to constantly measure and verify system quality requirement compliance. General CI QM Program goals are to:

- Increase system product quality
- Reduce overall project risk
- Reduce system product and life cycle cost
- Maintain system product integrity through objective verification in each phase of the CI design and development life cycle
- Ensure that the project meets its acceptance requirements

Generally accepted QM concepts are fully incorporated in the QMP and will be routinely implemented throughout all CI system development efforts. All CI QM activities are conducted in accordance with this QMP. CI QMP objectives to achieve these goals are to:

- Ensure compliance with specific QM contractual terms and conditions, including acceptance criteria
- Ensure establishment of documented project quality-related requirements and standards for products
- Provide QM management visibility and oversight of the status of the quality of products and companion documentation
- Provide QM management visibility and oversight of the status of adherence to stated plans and procedures
- Provide and/or coordinate qualified personnel resources to support the QM Program
- Ensure that this QMP complements companion CI plans.

Specifically, this QMP describes scheduled and controlled CI system QM concepts, processes, procedures, and events. The events integrate all necessary system QM inspections, test observation and monitoring, peer reviews, formal reviews (LCO, LCA, IOC, and PRR), product and process audits, QM trend and risk analyses, and corrective action implementation and tracking. These QM events are essential to ensure superior system quality from initial system design through development, testing, certification, and final acceptance of CI system products and supporting documentation.

This QMP also addresses the QM organization and philosophy; QM staff resource requirements, qualifications and responsibilities; and emphasizes the "independent" relationship of the QM staff to other CI Project entities.

1.4.1 Quality Management Philosophy and Practices

The following sections describe CI's overall QM philosophy and practices. QM is perceived to be highly interrelated with the project’s process improvement and training activities. Therefore, the CI QM Manager

will identify training and process improvement needs and ensure their satisfaction. The principles and practices identified in this QMP will be applied to all CI management and technical processes.

1.4.1.1 Quality Management Philosophy

Effective Quality Management (QM), as an engineering discipline, is accomplished by ensuring that all areas affecting product quality are identified and defined, and that adequate plans and procedures are implemented to measure and ensure compliance with baselined requirements. CI QM philosophy emphasizes prevention rather detection by focusing on "doing it right the first time". QM of all program processes and products is firmly embedded in CI's management philosophies to the extent that each project team member is responsible for the quality of the system products they develop and services they provide. This philosophy embodies our strategic concept of linking QM with focused and disciplined individual professionalism, as the mere imposition of QM procedures alone will not automatically inject quality into a system product, process, or service. In support of this philosophy, this QMP has been developed to address every aspect of our commitment to consistently provide quality CI system products. QM of CI products and processes will, therefore, focus on:

- Establishing a set of system quality assurance criteria and procedures to guide the system development effort
- Sequential refinement of development processes and procedures to constantly improve the quality of system products
- Product and process reviews and audits to ensure compliance with agreed upon standards and procedures
- Periodic trend analyses to alert management to impending problems, issues, and risks.

In this manner, effective quality assurance procedures cascade downward through the entire CI organization, enabling efficient integration of QM into all system engineering and development activities. Staff are empowered to accept this responsibility and appropriately trained to enable their satisfactory performance.

1.4.1.2 QM Practices

CI's QM practices serve both to prevent and detect product defects and process deficiencies, thereby reducing costs and risks, while simultaneously increasing product quality. Of the two types of QM, prevention and detection, prevention is by far the most cost-effective, since system defects or deficiencies can be avoided or corrected early in the development process with corresponding cost and time savings.

In practice, each process and sub project is monitored, audited, and reviewed on a continuing basis by QM representatives to assure that current QM processes and techniques are effectively implemented and efficiently administered. These reviews provide CI management and Ocean Leadership with a comprehensive measure of product and service quality, while permitting timely corrective action of detected quality anomalies. Additionally, CI QM Program feedback mechanisms monitor procedural effectiveness and can encourage modification of procedures, as required. In this manner, both products and the associated processes undergo continual refinement and improvement.

1.4.1.3 Quality Assurance (QA) Versus Quality Control (QC)

Quality Management (QM) can be broken into two distinct areas, Quality Assurance and Quality Control.

- **Quality Assurance (QA)** is a *process*-focused *Preventive* activity. It is a staff function that ensures quality is defined & agreed upon, ensures processes exist to produce & measure quality products, ensures continuous improvements, and provides objective analyses.

- **Quality Control (QC)** is a *product*-focused *Detective* activity. It is a mainline activity that is the responsibility of the system developers utilizing mechanisms to ensure that products meet requirements (inspections, testing, etc)

This QMP addresses both aspects of Quality Management in two separate sections, Section 4, Quality Assurance (QA), and Section 5, Quality Control (QC).

1.5 Relationship to Other CI Plans and Documents

The CI QMP relates to other major CI and OOI process-related and functional planning documents. These plans, and the level and extent of QM interface, are described below:

1.5.1 OOI System Engineering Management Plan (SEMP)

The OOI SEMP is a consolidated document that embraces all of the OOI Implementing Organizations (IOs), CI does not maintain a separate and subordinate SEMP. The OOI SEMP defines the detailed methods, procedures, and strategy used in system development processes, as applied to the Systems that comprise the OOI System of Systems and for the CI System the application software and hardware that comprise the CI Subsystems. The QMP is written in support of the OOI SEMP, and thereby constitutes components of that plan relative to its discussions of quality assurance. The QMP provides QM guidance for overall CI System product quality verification, ensuring that CI System products and documentation meet applicable requirements and standards.

1.5.2 OOI Quality Assurance / Quality Control Plan

The OOI QA/QC Plan provides high level QA guidance for all of the OOI Implementing Organizations (IOs). However, because the CI is a software-intensive system, the CI Program has elected to maintain a separate, subordinate, and consistent QMP. The CI QMP is written to address the unique aspects of software development while complying with the guidelines provided by the OOI QA/QC Plan.

1.5.3 CI Configuration Management Plan (CMP)

The CI CMP describes the development, implementation and maintenance of configuration management controls for CI System product development. It describes primary functions of identifying and controlling system changes, status accounting, and auditing. QM activities described in the QMP related to verification of configuration controls and baseline management are consistent with the approach and procedures defined in the CI CMP.

1.5.4 CI Integration, Test, and Verification Strategy

The CI Integration, Test, and Verification (ITV) Strategy plan describes and invokes the specialized role of formal system testing in the Incremental Spiral Development Lifecycle that has been selected by the CI Program. Because of the unique demands imposed by the project's system development standards, processes, and precision procedures, documentation and reviews are established for comprehensive product test and evaluation. The CI (ITV) Strategy plan integrates testing into system development processes through a cohesive, well planned and rigorously controlled test program. QM's test oversight activities monitors development and adherence to the CI (ITV) Strategy plan; verifies test baselines, validates CI requirements compliance; and confirms system product reliability, suitability, and usability, as demonstrated during formal system product testing.

1.5.5 Work Breakdown Structure (WBS)

QM's role in relation to the proposed WBS is to assist project management to evaluate its contents and ensure that all significant products and services, and requisite activities to produce those products and services, have been accounted for.

2 Referenced Documents

The documents referenced in this QMP are applied only to the extent specified in this plan.

Reference	Title
ANSI/EIA- 632-1998	Processes for Engineering a System
ANSI/EIA-731.1	Systems Engineering Capability Model
DoDAF Version 1.0	DoD Architecture Framework, Volume 1: Definitions and Guidelines, Volume II: Product Descriptions, & Deskbook, August 15, 2003
IEEE Std 1220-2005	Systems Engineering – Application and Management of the Systems Engineering Process
IEEE/EIA 12207	Standard for Information Technology, April 1998
ISO 9001	Quality Management Systems – Requirements
ISO 9004	Quality Management Systems – Guidelines for performance Improvements
IEEE Std 15288-2008 1100-00000_SEMP_OOI	Systems and Software Engineering – System life Cycle processes Ocean Observatories Initiative (OOI) System Engineering Management Plan (SEMP)
1003-00000_QA_QC_Plan_OOI	Ocean Observatories Initiative (OOI) Quality Assurance / Quality Control Plan

3 Quality Planning

CI Quality Management begins at the highest levels of the executive staff and extends downward to the program level. The QM organizational structure reflects a commitment to "assured delivery" of the highest quality products and services, by providing management visibility and oversight of all QM activities.

3.1 Project Organization

The standard process to be applied to the CI project assumes a "Concurrent Engineering" methodology in accordance with IEEE/EIA 12207, Standard for Information Technology. Concurrent Engineering invokes the concept of multi-disciplinary teams, also known as Integrated Product Teams (IPTs), and ensures QM, as a specialty engineering discipline, will have a prominent role on each IPT. As part of project kickoff, project roles, responsibilities, and interrelationships are identified, including the relationship of QM to other project functions. The relationships provide effective QM oversight and control.

QM functions are planned and structured in such a manner as not to encumber individual project processes nor stifle the creativity or resourcefulness of the developers. QM personnel, however, maintain a close working relationship with the CI staff to monitor technical progress and influence the evolving technical and administrative processes.

3.1.1 CI QM Independent Reporting

The cornerstone QM principle is independence of the quality management organization. The CI QM organization is specifically organized to be independent of influences from the Program Manager. The CI QM function is organizationally a part of the CI project, but independent of all development and administrative activities. The CI QM Manager reports directly to the Deputy Project Director who is

Figure 1. Independent QM organization

responsible for periodically reviewing QM activities against plan. The CI QM Manager also reports directly to the OOI QM Manager as a member of the OOI QM Organization.

This independent organizational structure provides the CI QM Organization with sufficient detachment from the direct jurisdiction of project management to assure CI product quality requirements and standards are not compromised or influenced by other contract-related functions and pressures. This arrangement optimizes CI Program Executive responsiveness to overall CI quality assurance issues, including corrective action status reviews and necessary QM resource support.

3.1.2 CI QM Responsibilities

Project QM is generally responsible for:

- Verifying the CI Team has the required capabilities and resources to perform the requested work
- Providing inputs to, reviewing, and concurring with project plans and procedures to ensure compliance with contract provisions, and CI policies and procedures
- Ensuring compliance with SOW requirements
- Ensuring adequacy of proposed processes and other quality provisions
- Conducting reviews of project products to ensure conformance with standards
- Conducting audits of project processes during each project stage to ensure adherence to the project's plans and written procedures
- Documenting and tracking product and process deficiencies to closure
- Participating in selected scheduled one-on-one peer reviews, formal inspections, and formal reviews, and ensuring that deficiencies identified are documented and tracked to closure
- Participating in regularly scheduled project status reviews and ensuring that problems and action items are documented and tracked to closure
- Ensuring that system components to be tested have been built from system components that are under configuration control
- Ensuring that formal tests are conducted on the basis of procedures and data that are under configuration control
- Witnessing test conduct to ensure adherence to approved test procedures and accurate reporting of test results
- Collecting project metrics in accordance with the OOI SEMP, CI PEP, CI QMP, and analyzing data for developing trends and patterns
- Conducting final inspections of all project deliverables prior to delivery and tracking deficiencies identified to closure

3.1.3 QM Manager's Responsibilities

Organizationally, the Deputy Project Director delegates project QM program implementation and administration to the QM Manager. The delegated responsibility for acceptance or rejection of system products is therefore independently vested in the QM Manager. Consequently, the QM Manager is specifically responsible and accountable for monitoring compliance with specified quality requirements and standards of project products, and the processes that produce these products. In discharging these responsibilities, the QM Manager is vested with well-defined authority. The QM Manager directs quality assurance related tasks, establishes standards of quality acceptability, controls implementation of inspection tasks, monitors test activities, and assesses the system's quality impact on CI technical, schedule, and cost risks. The QM Manager is also empowered with sufficient independence and organizational freedom to aggressively identify and evaluate project quality problems. For example, the QM Manager has authority to initiate, recommend, and/or obtain solutions, or initiate corrective actions to issues and problems generated as the result of the QM oversight. The QM Manager reports his activities on a monthly basis to the CI Deputy Project Director.

In the act of administering and controlling the QM Program, the QM Manager applies quality evaluation procedures to scrutinize products and improve processes associated with on-going system development

efforts. The quality assurance procedures describe specific measures for assuring products and processes meet agreed-upon quality requirements and standards. The results of periodic reviews, audits and other measures of performance are used to continually refine and improve the QM process.

To effectively control and administer the QM Program, the QM Manager specifically establishes or customizes quality evaluation procedures to scrutinize and improve processes and products associated with on-going system development efforts. Quality Management procedures describe specific measures to assure products and processes meet specified quality requirements and standards. Associated reviews and audits refine these procedures, as warranted. The QM Manager's responsibilities to effectively achieve the QM Program goals and objectives are to:

- Define, implement, and administer the project QM Program to be fully compliant with contract requirements, and CI quality assurance policies, standards, and procedures
- Verify, through reviews and audits, that configuration control and corrective action processes are in place and functioning in accordance with the CMP
- Establish QM standards for product acceptability
- Ensure availability of sufficiently trained QM resources and budgets to fully implement the CI QM Program
- Ensure visibility of QM activities by both CI Executive management and Ocean Leadership senior management
- Tailor and apply organizational procedures which ensure continuous QM review of CI system development activities
- Verify contract requirements compliance at each major stage of system development
- Accumulate, retain, and protect Verifiable Objective Evidence (VOE) that QM has performed its function (status reports, quality evaluation analyses and reports, formal reviews, audit reports, etc.) and ensure that artifacts and records from other program activities are retained and protected for subsequent use by the program and other similar projects.

The QM Manager also has the authority and responsibility for ensuring that all defective and/or immature non-developed materials and/or non-deliverable products are 1) identified and 2) either rejected, reworked or other appropriate corrective action instituted. The CI QM Manager is empowered to convene and supervise special one-time, ad hoc audits for the purpose of inquiring into any aspect of project performance or product integrity whenever a measure of quality uncertainty exists.

3.2 Resources

QM is responsible for verifying that each developmental phase of the CI system development follows a defined process, which is in conformance with applicable contractual requirements and the CI system development and maintenance policy and processes. Specifically, QM's responsibility is to ensure that the implementation of system quality standards and practices provide system quality procedures, instructions, and adequate QM training to ensure that CI system complies with established OOI and CI quality policy requirements and standards.

CI QM activities are primarily performed at the UCSD facilities in La Jolla, CA. The System development team is a distributed team and QM activities may be performed through remote access or site visits. Through these facilities QM personnel have access to the Internet, access to several IBM PCs, printers, fax machines, and copiers. The software packages commonly used includes Microsoft Word, Excel, PowerPoint, Exchange, and similar software packages in the performance of QM activities.

3.2.1 Qualifications

General requirements for personnel supporting the CI QM function include the ability to:

- Support Group and project management functions with a QM Program that ensures product quality integrity

- Evaluate quality requirements to ensure establishment of a tailored QM Program that spans all development and administrative activities
- Oversee quality audits and reviews and provide adequate QM resource support
- Create and maintain a coherent management oversight methodology to adequately monitor and analyze CI QM Program effectiveness
- Evaluate the overall impact of the CI QM Program.

3.2.2 QM Training

In meeting objectives of resource support to QM requirements, the QM Manager is responsible for providing internal QM training for members of the CI technical staff and, if and when required, additional QM staff and subcontractors, as appropriate. Training will focus on familiarity with CI QM policies, practices, and standards; OL QM standards; and the potential impact of the QM function on project system development processes, procedures, and end products. Internal QM training subject matter will include:

- Applicable Ocean Leadership QA and CI QM policies and standards
- Audit and review processes and procedures
- Trend analysis procedures
- Test monitoring responsibilities
- Integration and coordination with CM activities
- Individual QM reporting responsibilities.

QM staff personnel are also required to have selected training for all other project positions, so that they are at least familiar with the system engineering and management practices currently being advocated. In addition, a general orientation is presented to emphasize project QM and specific services to be provided. This is to ensure that all project system developers and managers are aware of essential compliance aspects and the critical significance of the QM Program.

3.3 Schedule

The following paragraphs describe the typical scheduling of QM activities, emphasizing the relationship of these activities to other project and organization activities.

3.3.1 CI QM Schedule

All CI QM activities provide maximum benefit towards achieving the common project goal of producing and delivering quality products on time and within budget. Because of the potential volume of products to be produced and multiple processes to be exercised during distinct CI System releases, it is impractical to depict exact schedules of QM activities. However, the general relationship between development of system products and product/process evaluation activities is as follows:

a) Pre-development testing occurs as soon as it is determined that a particular software component is a candidate for reuse--typically during systems or software requirements analysis, but no later than architectural design.
b) Peer Reviews are scheduled as products become available, which prevents further development on the basis of unusable and/or unmaintainable products. Peer Reviews may be performed when predefined entry criteria have been satisfied and previously scheduled reviews have been successfully completed.
c) QA product reviews are conducted upon product availability. All corrections must be verified by QA before any scheduled delivery.
d) QA process audits are performed upon completion of a particular process.
e) Integration testing takes place only after all modules scheduled for integration have been successfully unit tested. QA monitors integration testing.

f) Validation testing takes place only after the product has been successfully integration tested. QA monitors Validation testing.
g) Formal testing occurs before delivery to Ocean Leadership. QA monitors Formal testing.

3.4 CI Processes and Procedures

Quality Management ensures that the project will employ all processes needed to meet requirements and monitors specific project results to determine whether they comply with relevant quality standards and indentifying ways to eliminate causes of unsatisfactory results. Stated in a slightly different manner, QM for a software-intensive system concentrates on the processes and procedures that produce products that comprise or enable the system and on the products themselves. The Cyberinfrastructure Program recognizes this imperative and has established an Integrated Process Architecture.

The Cyberinfrastructure Project has selected the Integrated Product Team (IPT) as its organizational model, which is designed to accommodate integrated product development, and consists of IPTs whose membership spans required engineering disciplines and functions to produce products and services for delivery. The team organization is integrated with the Cyberinfrastructure product hierarchy as defined in the WBS, with WBS elements the primary responsibility of a single IPT. This enables IPTs to identify clear and measurable outputs plus necessary interfaces.

The Cyberinfrastructure Program has selected the Incremental Spiral Development Life Cycle, which is described in the Cyberinfrastructure PEP, and is based on the spiral development management model that is widely used for software intensive systems. Each Spiral includes an inception phase, an elaboration phase, a construction phase, and a transition phase. Each phase terminates in a milestone review.

Each phase is comprised of two month “Iterations” consisting of a two week design period, a five week build period, and a one week wrap-up period. Written procedures have been developed to guide the activities of the IPTs within each of these periods. Within the context of an Integrated Process Architecture, multi-disciplinary members of an IPT continue to follow the procedures of their individual disciplines but the individual procedures are integrated in a cohesive manner to execute the activities in each phase and iteration of the Spiral Development Life Cycle.

4 Quality Assurance (QA)

Quality Assurance (QA) is a process-focused Preventive activity. It is a staff function that ensures quality is defined & agreed upon, ensures processes exist to produce & measure quality products, ensures continuous improvements, and provides objective analyses.

QA is a systematic approach to the prevention of errors. The discovery and prevention of defects early in the development lifecycle offers the OL program a significant return on investment. Quality Assurance focuses on that preventive mission with auditing and other quality management reporting functions. The goal of quality assurance is to provide management with the data necessary to be informed about product quality and program status—from the customer’s viewpoint.

All QA activities fall into one of two general categories: project phase-dependent or -independent activities. Phase-dependent activities are specific to a particular phase of project activity. Phase-independent activities are conducted independently of any particular product development or project phase and may occur one or more times throughout the life of the project.

The following paragraphs describe the actual QA processes performed in execution of project responsibilities, the tools supporting those activities, and the records maintained to document project activities.

4.1 Phase-Dependent Activities

Phase-dependent QA activities are conducted at the conclusion of specific development activities related to a particular process or product. Project phase-dependent QA activities are identified and described in the following paragraphs.

4.1.1 Pre-Development Testing

Pre-development testing is conducted whenever open source system components are considered candidates for incorporation into the CI System to ensure that such components are sufficiently mature to make reuse feasible and practical. Candidates for reuse are typically determined during requirements analysis or architectural-level design. Test Engineering develops procedures specifically designed to exercise a cross section of claimed functionality. Discrepancies are documented, which then become reuse evaluation factors.

Project QA monitors the planning and conduct of pre-development testing to ensure that sufficient testing is conducted to make a sound judgment regarding individual component maturity and suitability. QA is also responsible to ensure that all identified deficiencies are documented and formally presented for resolution as early in the life cycle as possible.

4.1.2 Review of Plans and Procedures

CI QA is responsible for ensuring that appropriate plans and procedures are put in place early in the life cycle to encourage CI startup on a solid basis and maintained during the entire system life cycle. Project QA is involved in development and maintenance of the CI Project Execution Plan (PEP), OOI System Engineering Management Plan (SEMP), CI Configuration Management Plan (CMP), CI Quality Management Plan (QMP), and associated procedures, and minimally reviews all project plans and procedures. The chief system quality concerns address these issues:

- Are system requirements well understood and unambiguous?
- Does the project organization and selected life cycle make sense in light of the tasking?
- Are the required resources available in the right time frames?
- Are methods compliant with CI Processes and Procedures and appropriate for the tasking?
- Have risks been identified and is there at least one viable mitigation recourse for each?
- Have associated cost drivers been identified and accounted for in the budget?
- Have all of the Cross Product Dependencies been identified and accounted for in the schedule?

All major project planning activities are performed in accordance with documented procedures. Individual procedure exit criteria (documented in the procedure prolog) determine whether the procedure has been completed. QA process audits follow the completion of all planning-related procedures to ensure that all planning activities have been satisfactorily completed and establish a reasonable level of confidence that the project is not proceeding at risk.

4.1.3 One-On-One Peer Reviews & Formal Inspections

Defect/anomaly detection and prevention is accomplished through the use of Peer Reviews that include both One-on-One Peer Reviews and Formal Inspections. Periodic Peer Reviews provide CI program management and OL with the early visibility needed to keep the project on track. QA participates in a subset of each category of peer review, which is selected on the basis of the risk associated with the items being reviewed. Known risk areas are given greater emphasis. The peer review process is widely regarded as the single, highest-payback activity that can be infused into the system and software engineering process. Peer reviews not only reduce risk, but shorten the development effort by greatly reducing the amount of rework incurred and the magnitude of the test effort. Formal reviews keep OL

informed of program progress and enable reevaluation of technical directions, issues, and problems at appropriate points in the project life cycle.

Peer review entry criteria are minimally:

1. Successful completion of all related, previously scheduled reviews
2. Availability of the targeted products (review objects) in a condition suitable for review

Exit criteria typically stipulate that no severe defects/deficiencies may exist. Further, there is usually some upper limit established on the number of other defects and problems that may exist. Note that where exit criteria have not been satisfied, additional reviews may be necessary. In the strictest of development environments, peer reviews are not only project milestones, but also control gates used to prevent subsequent development until such time as the deficiencies are cleared.

4.1.4 Formal Reviews

Formal Reviews (LCO, LCA, IOC, & PRR) are conducted at the end of each major phase. CI QA is responsible to see that the CI Program is ready for the review; conducts the review; communicates an accurate assessment of program status, problems, issues, and risks; and incorporates comments on an appropriate and timely basis.

4.1.5 Independent Process Audits

Process audits are conducted to ensure that stated procedures are followed. Audits of project processes are conducted to ensure adherence to written procedures. Where a particular procedure is performed more than once during the course of a task (e.g., detailed design, code walkthrough, etc.), QA selects a representative sample of process instances to audit. Experience suggests that an audit of 20 percent of the processes performed is a reasonable goal.

All process audit findings are documented via checklists, distributed to the responsible parties (including project management and the responsible IPT Lead), and tracked to closure by QA. The QA Manager identifies the engineering and management processes targeted for audit during execution of a typical Spiral phase and activity, including specific engineering and management procedure references. QA typically audits a subset of these processes based on associated risks and impacts on other dependent processes.

4.1.6 Independent Product Reviews

Product reviews are conducted to ensure that developed products comply with imposed standards, including OL style guides, when the product is a document. Every project product is evaluated by one or more QA techniques: Peer Reviews, formal QA Reviews, and ad hoc reviews where there are no specific standards applied to a product. Independent Product Reviews are performed on all developed materials for which there are documented standards using a predefined checklist that focuses on the quality concerns for the particular product. When there are many items for a particular product, QA selects a representative sample of the items for review with emphasis on the higher risk elements of the system. The percentage is determined by the QM Manager and coordinated with the Project Manager and System Development Manager and documented as part of the review report.

The purpose of product reviews is to ensure that invoked standards (contract and program) are followed, allocated requirements are satisfied, and materials meet or exceed standards for professional quality. All product reviews are conducted by QA staff immediately following closure of any related Peer Review comments and before product delivery (if the product is a CDRL item) or subsequent, related development efforts. All product review findings are documented via checklists, distributed to the responsible parties (including project management and the responsible line manager), and tracked to closure by QA.

4.2 Phase-Independent Activities

Phase-independent activities are conducted without regard to particular program phases. Project quality assurance activities that typically fall into this category are those activities that are conducted on a fairly continuous basis, such as trend analyses; repetitive activities during the life cycle, such as receipt inspection of materials; or on a somewhat random basis, such as the CM process, corrective actions, security activities, and project repository audits. The following paragraphs describe the phase-independent QA activities to be conducted during CI performance.

4.2.1 Periodic Audits

The following paragraphs describe the Project QA audits performed periodically throughout the life of the project and the Group QA audits performed as requested or as needed.

4.2.1.1 Configuration Management Audits

Project QA is responsible for performing periodic CM audits. CM audits are performed on an intentionally random basis, with minimal notice, to ensure that stated procedures are being followed and records are maintained up to date. Periodic CM audits are necessary to ensure that the integrity of developing products is being preserved:

a) Interim products are being placed under control at appropriate points in the life cycle.
b) Changes to controlled items are being correctly and completely documented, reviewed, and approved.
c) CM is being applied in accordance with the CMP.
d) The status of each controlled item can be readily determined at any point in time. All discrepancies are documented, distributed to CM, and tracked to closure by QA.

4.2.1.2 System Development Library Reviews

Project QA conducts periodic reviews of the project System Development Library (Engineering, CM, and project document libraries) to ensure that the contents and status of contents match configuration management records. All discrepancies are documented, distributed to CM, and tracked to closure by QA.

4.2.1.3 Security Audits

Project QA is also responsible for ensuring that invoked security requirements/standards have been addressed throughout system development and deployment. Accordingly, QA performs periodic audits of: 1) development environment security procedures adherence, and 2) invoked security standards adherence in project materials, such as requirements and design documentation. As the system is developed and tested, QA will also ensure that test procedures include verification of built-in system security features. The goal is to ensure that: 1) development environment security requirements are not violated, and 2) sensitive application certification may be issued before system deployment.

4.2.2 Trend Analysis

QA collects and analyzes project metrics data for significant negative trends and patterns at least once during each major step in a process. Project metrics are collected and reviewed to evaluate key characteristics of the software being developed; processes employed; and associated management indicators of progress. If a metric indicates a major defect in a process, it is immediately corrected with the input and concurrence of affected IPT Leads. Specific metric data to be collected is identified in:

- OOI SEMP Section 4.1.2.4, System Engineering Metrics, which includes the Technical Performance Measures (TPMs)

- CI PEP Section 2.4.2, Project Metrics Strategy, which includes the Earned Value Management metrics

All significant emerging trends, deficiencies, and patterns are: 1) reported to the Software Development Manager and the responsible IPT Lead, or if necessary, line management, for resolution; 2) documented in the project corrective action data base; and 3) tracked to closure. The CI project maintains a repository of process data and periodic project QA trend analysis continues into system Operation & Maintenance.

4.2.3 Evaluation of the QA Function

CI QA activities are reviewed with project management on both a periodic and event-driven basis. The Program Management assesses the results of product and process audits, the root causes of any process-related problems, and any QA-identified developing trends and patterns, in addition to general project activities, cost and schedule status.

Senior line management is responsible for periodically reviewing the QA plans and actual activities. At least once a quarter, the senior line manager, or designee, reviews the performance of project QA to ensure that all planned QA activities are being performed on a consistent, timely, and cost effective basis. The purpose of this review is to determine whether project QA is performing the required functions, has the training and experience required to perform the tasks at hand, and has sufficient resources to provide the level of support required. All deficiencies noted in the QA services provided are discussed, and any necessary commitments to corrective action on the part of QA or management are agreed upon. In addition, project QA periodically meets with senior line management to discuss the status of planned activities and resulting findings

4.2.4 OOI Evaluations of Implementing Organizations

In accordance with the OOI QA/QC PLan, OL QM may conduct direct objective audits of the IOs. The OL procedures direct the IO QM staff to prepare and deliver the audit package and support the OL QM staff during the audit. The OL QM staff conducts the audit, documents the results of the audit in the OL quality assurance database and reports the results of the audit to the IO QM Manager who in turn reports the results to the appropriate point of contact in the IO functional area.

OL QM may also conduct indirect objective audits of the IOs by requesting the IO QM organizations to perform Process Audits and Product Reviews against items of specific interest. In these instances, the IO QM organization prepares the audit package, conducts the audit, documents the results of the audit in the IO's quality assurance database and reports the results of the audit to the OL QM Manager and the appropriate points of contact in the IO functional areas.

When an IO publishes a new process and/or procedure, OL QM evaluates the procedure and assists in the development of an audit strategy. The start-end, frequency, duration and audit criteria are determined to demonstrate an acceptable level of quality for the process and/or procedure. New processes and procedures should be operational long enough to have an established baseline of performance before it is subject to a quality audit. Examples of the IO processes that are subject to direct and indirect evaluations:

- **Program Management**
  - Program Planning
  - Program Monitoring and Control
  - Risk Management Process
  - Subcontractor Control
  - Corrective action
- **Systems Engineering**

- Configuration Management Processes (Hardware and Software)
- Change Control Board Processes
- Functional Configuration Audits
- Physical Configuration Audits
- First Article Tests
- Decision Analysis and Resolution Process
- Requirements Development Process
- Requirements Management Process
- Data Management Process

❖ **Software Design, Development, Test and Maintenance**

- Software Inspection and Acceptance Process
- Build requirements planning
- System Acceptance Test Plans
- Software Integration and Test Plans
- Correction of Software Discrepancies

❖ **Operations and Maintenance**

- Establish controls in the Maintenance Phase of the lifecycle.
- Maintenance schedules
- Establishment of Service Level Agreements to maintain levels of quality during O&M.

4.2.5 Material Receipt

Project QA is responsible for ensuring that appropriate procedures for receipt and evaluation of materials are followed. All materials received are inspected by QA for general condition, correctness, completeness, and conformance. Damaged, missing, and wrong items are immediately reported to the responsible party. All non-conforming items are separated from conforming items to prevent accidental incorporation or usage. QA is also responsible for all re-inspection necessary to determine non-conformance correction. Records of such inspection are documented and maintained by CM. CM also ensures that each item is properly identified, logged, and controlled to preserve its integrity.

4.2.6 Corrective Action System Evaluation

Throughout the system development effort, QA is responsible for ensuring that all issues, action items, and adverse trends and patterns are properly documented and acted upon in a timely fashion. QA conducts periodic audits of CM status accounting reports to verify SPRs are addressed in accordance with the following suggested turnaround time frames as functions of problem severity.

Table 4. Problem Severity and Turnaround Time Frames

Severity:	Problem Description	System Development
1	System displays abnormal termination	2 to 3 days
2	Component displays abnormal termination	4 to 7 days
3	Component malfunction	7 to 14 days
4	Cosmetic defect detected	14 to 30 days

Project QA attends all regularly scheduled project status meetings and ensures that all technical and contractual issues identified result in action items that are documented completely, assigned to an identified responsible individual, entered into the action item data base, fully resolved, and closed out within the established suspense period (based on the perceived criticality of the particular action item). Furthermore, Project QA is responsible for ensuring that any adverse trends and patterns identified are

analyzed for root causes, and appropriate process corrective actions and tracking measures instituted (e.g., process modifications, additional training, and/or education).

Deficiencies related to program corrective-action activities are documented, brought to the attention of management, and tracked to closure. Where problems persist and/or corrective actions are inadequate or ill timed, the QM Manager has latitude to exercise the independent reporting chain to line management.

4.3 Tools

Project QA typically uses a DBMS, a word processing package, and a spreadsheet tool to plan, execute, and document QA activities. CI Quality Assurance has adopted Microsoft Word, Microsoft Project, Excel and PowerPoint as the standard tools to be used in the production of QA products.

4.4 Records

The following paragraphs describe the records that QA typically maintains to substantiate the performance of its activities and track required corrective actions.

4.4.1 Audit Records

For each audit that project QA conducts, a checklist is completed that guides the conduct of the audit and documents the results. Where necessary to clarify audit findings, QA may elect to attach an audit memo. Standard checklists for QA are established based upon contract standards and OL guidance. Copies of completed checklists are forwarded to the responsible IPT Lead and, if necessary, the Project Manager. One copy of all audit results is maintained in the QA files.

4.4.2 Test Records

Records of unit test results are documented as a part of each unit test plan by the author/developer responsible for the system module and the testing. Component integration test results are also documented and maintained by the System Development Manager in the Engineering Library; however, problems identified are formally documented and tracked to closure.

During the Construction Phase, the Software Development Manager is responsible for scheduling and tracking the development and conduct of formal and system-level tests and the Chief Systems Engineer takes over this responsibility during the Transition Phase. The CI Test Plan documents the approach to test materials development and evaluation, as well as test conduct. Results of formal tests are documented in formal test reports. Unsuccessful tests are tracked by the Test Engineering Manager and QA through defect removal and retesting to closure.

4.4.3 Test Observation Reports

Project QA performs sampling surveillance of test procedures and results conducted by the project Test Team. Included is software code and unit testing performed by developers and integration testing. QA will also monitor system verification testing. In these later test sequences, QA reconfirms that requirements and test baselines have remained stable and controlled through CM procedures throughout the development cycle. Project QA will also conduct an informal test readiness reviews for each system version or build element.

QA's selective witnessing of developmental tests is based upon the degree of risk associated with each item being tested. At the end of each series of tests, a summary test report is produced. QA minimally reviews the test report and signs off as an indication of concurrence.

4.4.4 Evaluation Records

Records are kept of each product evaluation conducted to ensure that all issues, problems, and deficiencies identified can be tracked to closure. Copies of all peer review materials, audit records, and witnessed tests results are maintained by the QA organization. Records of other tests conducted are maintained by the Test Engineering Manager, and records of system development audits are maintained. The OOI QM Manager is invited to review product evaluation records at any time. All such requests should be directed to the CI QM Manager.

4.4.5 QA Summary and Corrective Action Reports

At the conclusion of a QA review, audit, or surveillance activity, a standard QA Summary Report is completed. This report provides uniform recording of QA findings, observations, identified problems, and recommendations for appropriate corrective actions. For reviews identifying anomalies, a Corrective Action Report is also generated, attached to the Summary Report, and distributed by the CI QM Manager for resolution. Copies of the entire report, including source documentation, are retained in the CI QA database.

4.4.6 QA Status Report

Once a month, project QA prepares a status report for the CI Project Manager, CI Deputy Project Director, and OL QM Manager that summarizes activities performed, the general results of those activities, and significant developing trends and patterns.

4.4.7 Peer Review Results

When a One-on-One Peer Review or a Formal Inspection is conducted to evaluate a developed work product, a copy of the results is forwarded to project QA for the QA file, whether or not QA participates in the particular review or inspection. QA tracks review and inspection results to closure, and uses these results as an input to periodic trend analyses.

4.4.8 Corrective Action Data Base

Project QA maintains a corrective action database that logs and tracks all program issues requiring some form of corrective action. QA documents problems, issues and action items as memos and maintains a file of those memos.

4.4.9 Product Acceptance

At the conclusion of successful testing, project QA validates and certifies that system products are ready for integration and test. It then conducts surveillance of the Transition Phase activities. This QA phase verifies the completeness and readiness of deliverables and adherence to all invoked product standards.

4.4.10 Site Support

QA representatives continue to monitor the receipt, installation, post-installation operational testing and final acceptance of the system products by OL.

5 Quality Control (QC)

Quality Control (QC) is a product-focused Detective activity. It is a mainline activity performed by members of the engineering organizations utilizing mechanisms to ensure that products meet requirements (one-on-one peer reviews, formal inspections, testing, etc).

QC is the testing and assessment portions of the system development process. QC provides project management with a realistic, fact-based assessment of OL hardware, software and telecommunication systems during all phases of the project life cycle. From the design and development phase through the implementation and deployment phase and during the Operations and Maintenance phase, QC verifies, validates and documents the quality of the OL systems and their requirements. Quality control includes security testing when required.

5.1 System Product Evaluation

The specific processes and procedures used by the system development groups to evaluate system products and documents are described in the OOI SEMP as an integral part of the discussion of other technical, management, and quality activities. In particular, the OOI SEMP describes the overall management and technical processes and procedures for the CI project and discusses system engineering techniques, methodologies, and evaluation procedures used during each system development phase, including formal qualification test procedures. Many of these activities are considered Quality Control (QC) types of activities.

QC of developed system-related materials is an IPT responsibility. Everyone, for example, participates in the One-on-One Peer Review and Formal Inspection processes, which are QC activities. System Engineering, Test Engineering is primarily responsible for performing QC on system products in the form of validation and verification activities. System Engineering is responsible for validating that the system meets its functional and performance requirements. Test Engineering verifies that all system requirements have been satisfied. QA is responsible for verifying that each configuration item and the overall system meet OL's specifications and acceptance criteria. Product QC is accomplished through design analysis and simulation, review and/or inspection, demonstration, and test and/or audit at various points in the development cycle to ensure compliance with agreed-upon requirements. Demonstration and test verify required performance of all critical characteristics. Design analysis and simulation are used to complement, not replace, demonstration and test. Tests will include system effectiveness evaluations. Where total verification by test is not feasible, testing will be used to verify key characteristics and assumptions used in the design analysis or simulation. As a part of the development process, each CI IPT performs QC activities that include:

- Verifies the traceability of functional and performance requirements to each level of the physical architecture (including interfaces) from the lowest level up to the total system
- Generates evidence (review/inspection results, audit reports, test results, etc.) necessary to confirm that configuration items meet their requirements
- Evaluates candidate technologies for use in people, product, and process solutions with respect to cost, schedule, performance, and risk using agreed-upon criteria.

QC Techniques and tools vary depending on the specific products to be evaluated. Our product QC approach relies heavily on a few proven techniques (i.e., One-on-One Peer Reviews, Formal Inspections, product reviews, and independent testing) that we have found to be very effective for detecting defects early and preventing major defects. Previous sections have described QM's criteria for selecting samples for product reviews and process audits, as well as planned sample sizes. Selection criteria for other evaluation test techniques such as peer reviews, are discussed throughout the OOI SEMP. This Section outlines the life-cycle activities and documents the full range of products that will be produced. For each work product, references are provided for the procedures to be employed and general QC criteria to be applied.

5.2 System QC Criteria

This section describes System QC Criteria to be applied to hardware, system, and documentation product QC, which falls into the general categories described in Table 5.

Table 5, System Product Evaluation Criteria

QC Criteria	Description	Applicability		
		HW	SW	DOC.
Form (F)	Adherence to standards for: form, format, appearance, technical content (includes adherence to code and design standards)	X	X	X
Correctness (TC)	Contents are technically correct	X	X	X
Traceability (TR)	Contents are traceable to allocated requirements	X	X	X
Understandability (U)	New terms or uses are defined, rules in the OL Style Guide are followed, standard abbreviations are used, new acronyms and abbreviations are defined, acronyms and abbreviations are spelled out the first time, tables and figures are called out in the text before they appear		X	X
Internal Consistency (IC)	No two statements contradict each other, terms are used consistently, items and concepts are described with the same name and description	X	X	X
Consistency with Other Documents (CI)	No two statements contradict each other, terms are used consistently, terms and concepts are described with the same name and description			X
Techniques Used (AT)	Complies with techniques called in contract and SDP	X	X	
Allocation of Timing and Sizing Resources (AA)	Appropriate allocation of timing and sizing resources—amount of memory allocated to an element does not exceed constraints, the sum of the allocation to sub-items does not exceed overall allocation for the item	X	X	X
Interoperability (I)	The ability to exchange information or services directly	X	X	
Security (S)	Meets security requirements	X	X	X
Test Coverage (AC)	Every requirement is tested at least once, test scenarios cover both average and boundary conditions, test scenarios cover out-of-bounds conditions, test scenarios exercise combinations of functions			X
Quality (Q)	Tradeoffs between quality factors have been considered, methods for measuring compliance have been identified			X*
Testability (T)	Testability of requirements			X*
Data Consistency (DC)	Consistency between data definition and data usage			X**
Adequacy of Tests (A)	Adequacy of test procedures and test cases			X***

LEGEND: * Applies to System Requirements Documents
** Applies to design documentation
*** Applies to test cases and test procedures

5.3 QC Activities

This section describes system QC activities, highlighting specific development Procedures and related QC procedures. In general, if not stated otherwise, it is assumed that 100% of the developed products are Quality Controlled via the activities and methods identified in Table 6. The first two columns in the table provide a mapping between the development activities and the full range of work products to be produced (based on known tasks and other projected activities). Column 3 provides the QC method that will be employed (i.e., QA Audit (A), Automated Method (AM), QA Review (R), Peer Review (PR), and/or Test (T)). Column 4 references the specific criteria to be applied, which were described in Table 5.

Table 6, Summary of Product Evaluation Activities

Development Activity	Product Evaluation Activities	Method	Criteria
Generating Software Builds	Evaluate Engineering Load build	A	CI, TC, TR
System Requirements Analysis	SDP, SSS, IRS, RTM	PR, A, R	F,TC, TR, R, U, IC, AT
System Architecture Design	SDD, RTM	PR, A	F, TC, TR, R, U, IC, CI, AT, AA, I, S, DC
Software Requirements	SRS, IRS, RTM, Data Dictionary	PR, A, R	F, TC, TR, R, U,

Analysis			IC, CI, AT, T, Q
Reuse Analysis – Designs & Source Code	Make/Buy/Use Analysis documents, Reusable system or COTS	PR, R, T	F, TC, TR, R, U, IC, CI, AT
Reuse Analysis – COTS Products	Make/Buy/Use Analysis documents, Reusable system or COTS	PR, R, T	F, TC, TR, R, U, IC, CI, AT
Software Architecture Design	SSDD, RTM	PR, A, R	F, TC, TR, R, U, IC, CI, AT, AA, I, S
Designing System Interfaces	IDD	PR, A	F, TC, TR, R, U, IC, CI, I
Database Data Structures	DBDD	PR, R	F, TC, TR, R, U, IC, CI, AT, AA, S, DC
Algorithm Design	SDD, SDFs,	PR, A	F, TC, TR, R, U, IC, CI, AT, AA, S, DC
Coding	Software units, Unit test plans, SDFs	PR, A	F, TC, TR, R, U, IC, AC, CI, AT, S
Conducting Unit Tests	Conduct unit tests, Evaluate unit test results, updated software, design, requirements, and System Development Files (SDFs)	T, A	F, TC, U
Developing the Integration Test Plan	System Test Plan, System Test Description, System Test Procedures, System Test Report, SEE, STE	PR, A, R	F, TC, TR, R, U, IC, CI
Conducting Integration Tests	Conduct tests, Evaluate test results, SPCRs	T, A	F, TC, U
Conducting System Test	Conduct tests, evaluate the results of tests to test fixes	T, A	F, TC, TR, R, U, IC, CI, AT
TE-07 Conducting System Test	Conduct tests, evaluate STR and new SPCRs	T, A	F, TC, U, IC, AT, I

5.4 Test Observation

As hardware and software system components are evaluated via formal test, Quality Control is responsible for witnessing a reasonable subset of those tests. The purpose of test observation is to ensure that tests are conducted in accordance with the approved test procedures, test results are accurately documented, and allocated requirements are satisfied.

Project QM plans to observe approximately 100% percent of the formal CI system tests and will continue this test support until such time as the criteria for system acceptance has been met. QM will maintain copies of test reports as a record of test results. During testing, QC ensures that all requirements agreed to have been satisfied and are signed off by the OL QM Manager.

5.5 Physical Configuration Audit (PCA)

CI QM provides support to Systems Engineering in the area of Configuration Management (CM) in planning for and participating in the physical configuration audit. QM helps to conduct the audit, assists in accumulation of data and participates in verification activities. Systems Engineering plans, leads the audit, assigns discrepancies, coordinates closure of issues and discrepancies, reports and presents the audit statistics at program reviews.

5.6 Functional Configuration Audit (FCA)

The objective of the functional configuration audit is to verify that the deliverable's actual performance complies with its requirements and interface specifications. Functional Configuration Audits for the OL project are satisfied by QM inspection of the acceptance test results. This inspection confirms the acceptance test results have been properly mapped to requirements, that they are reported, and that deficiency reports are properly accounted for.

6 Metrics

The core set of metrics listed in Table 7 provides guidance on implementing the project's metric program. For the purposes of metrics collection, each individual release is considered a separate and distinct project. This approach permits the metrics gathered on previous releases to be used to predict the productivity on future releases.

6.1 Metrics Evaluation

Product and process metrics are analyzed by QA to determine trends and effectiveness of the review process, process implementation, problems areas, and delivery status of system products.

6.2 Project Metric Planned/Estimation

The formulae to develop the "Planned" metrics are shown in the Planned/Formulas column of Table 7. These formulae require estimates to be made based on data that was collected, reviewed, and analyzed from previously completed projects.

6.3 Collecting and Analyzing the Data

The lead engineer responsible for executing a particular procedure is responsible for collecting the metric data associated with that procedure. The lead engineer is responsible to ensure all the metrics are properly collected as one of the exit criteria from a specific procedure.

The Quality Assurance organization is responsible for performing the analysis on the metrics collected. The data collected will be analyzed to determine if past performance was acceptable and within the planned estimated baseline. If there is a better way to estimate, collect, review, or accomplish the analysis submit lessons learned for strengths and improvements. All Analysis Reports are reviewed by QA to determine trends and effectiveness of reviewed processes before they are given to the PM. The PM will ensure the project's metrics analysis are briefed and reviewed by the project personnel.

Table 7, Core Metric Collection Set

Metric	Definition	Collection Method
System Requirements	Itemized count of functional and performance requirements (shalls or equivalent) allocated to the CI System.	If an automated tool is used, the number of requirements that are automatically developed will be the number of requirements that establish the initial project baseline. Otherwise, review the SSS and count the number of requirements to establish the initial baseline.
System Requirement Changes	Number of new, modified, or deleted requirements identified after the initial requirement count.	All adds, modified, and deletes will be estimated by multiplying the initial baseline of requirements by a percentage of change for each phase based upon previous builds.
Design Size	Number of objects to be designed and implemented.	Count each object as one design entity to establish the initial baseline.

Metric	Definition	Collection Method
Design Size Changes	Number of new or deleted design objects.	All adds, modified, and deletes are estimated by multiplying the initial baseline of design objects by a percentage of change for each phase based upon previous builds.
Software Size	Number of new, adapted, modified, or rehosted source lines of code (SLOC), function points, feature points, or object points.	Count each SLOC without comments. Include all error code and non-deliverable support code
Software Size Changes	Magnitude of software size changes between any estimate/update and actual values.	All adds, modified, and deletes are estimated by multiplying the initial baseline of software size by a percentage of change for each build based upon previous builds. Actuals are obtained by counting each addition, deletion, and modification. Total changes are the sum of these three.
Number of Unit Tests Developed	Number of test cases, procedures, or steps planned and executed.	Manual count of each test case, procedure, or step.
Number of Unit Tests Changed	Magnitude of test size changes between any estimate/update and actual values.	All adds, modified, and deletes are estimated by multiplying the initial baseline of test questions by a percentage of change for each build based upon previous builds.
Number of Unit Tests Executed	(Self explanatory)	The number of test questions successfully completed divided by the total number of test questions in the current baseline.
Defects Found During Unit Test	Number of errors detected during formal reviews, peer reviews, inspections, tests, and operations that cause rework of a work product.	Total number of defects categorized by Major, Minor, and Cosmetic.
Number of Integration Tests Developed	Number of test cases, procedures, or steps planned and executed.	Manual count of each test case, procedure, or step.
Number of Integration Tests Changes	Magnitude of test size changes between any estimate/update and actual values.	All adds, modified, and deletes are estimated by multiplying the initial baseline of test questions by a percentage of change for each build based upon previous builds.
Number of Integration Tests Executed	(Self explanatory)	The number of test questions successfully completed divided by the total number of test questions in the current baseline.
Effort	Number of personnel hours expended (actual vs. planned) on the development of the system.	Planned and actual values are derived from labor tracking system
Cost	Cost (actual vs. planned) associated with the system development contract.	Planned and actual values are derived from labor tracking system
Milestone Completions	Milestones are planned dates for the completion or occurrence of key activities. These include key system development and test activities as well as activities related to CM, QA, peer review, subcontract management, and process improvement. The milestone completion metric measures the actual completion date against the planned completion date.	Planned milestones and actual milestones completed are derived from the scheduling system.
Defects	Number of errors detected during formal reviews, peer reviews, inspections, tests, and operations that cause rework of a work product.	Total number of defects categorized by Major, Minor, and Cosmetic.

Metric	Definition	Collection Method
Critical Computer Resource Utilization	For systems with critical computer performance requirements, measures of the critical computer resource utilization are required. Measurements include the amounts available, allocated, and used.	Use of automated tools.