

QA4E

**A Quality Assurance Framework
for Earth Observation**

Principles

A Quality Assurance Framework for Earth Observation: Principles

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ACRONYMS

Cal/Val	Calibration and Validation
CEOS	Committee on Earth Observation Satellites
DQ	QA4EO nomenclature label for documentation relating to Data Quality
EO	Earth Observation
GEN	QA4EO nomenclature label for a generic guideline
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
KI	Knowledge Information
QA	Quality Assurance
QA4EO	Quality Assurance Framework for Earth Observation
QI	Quality Indicator
SBA	GEO's Societal Benefit Area
SI	International System of Units
VIM	Vocabulary of International Metrology
WGCV	CEOS Working Group on Calibration and Validation
WMO	World Meteorological Organization

1 Executive Summary

The Global Earth Observation System of Systems (GEOSS) must deliver comprehensive and timely “knowledge / information products” worldwide to meet the needs of its nine Societal Benefit Areas (SBAs). The GEOSS community represents a wide variety of disciplines, which utilise a multitude of monitoring methodologies and procedures. These all require the association of a quality metric to their outputs to enable them to be reliably integrated into the various systems and services that support the Earth Observation (EO) needs of Society. The fundamental principle of the Quality Assurance Framework for Earth Observation (QA4EO) - "that all EO data and derived products has associated with it a documented and fully traceable quality indicator (QI)" - addresses this core requirement and is universally applicable to all disciplines. This principle is not in itself novel and is already being practised by many. QA4EO seeks to ensure it is implemented in a harmonious and consistent manner throughout all EO communities to the benefit of all stakeholders. The end-user – "customer" – is the driver for any specific quality requirements and should assess if any supplied information, as characterised by its associated QI, are "fit for purpose".

QA4EO Principle

Data and derived products shall have associated with them a fully traceable indicator of their quality

Quality Indicator

A Quality Indicator (QI) shall provide sufficient information to allow all users to readily evaluate the “fitness for purpose” of the data or derived product

Traceability

A QI shall be based on a documented and quantifiable assessment of evidence demonstrating the level of traceability to internationally agreed (where possible SI) reference standards

The QI needs to be unequivocal in its interpretation and derivation, yet sufficiently flexible, to be implemented across the full range of EO activities that are coordinated through the Group on Earth Observations (GEO) - QA4EO was established to achieve this task. A set of documentation is available (from the QA4EO website – <http://qa4eo.org/>) to assist the community in interpreting and implementing QA4EO into their specific working arena. This framework document provides information on the essential principles and concepts that underpin the QA4EO philosophy. This is complemented by a set of key guidelines to assist the adoption of the QA4EO ethos into operational working. These are further enhanced by numerous (and ever-evolving) detailed community-specific guidelines and “best practises” that provide assistance in the practical implementation of QA4EO at the working level.

Funding organisations that oversee the development and execution of EO programs are responsible for implementing the QA4EO principles in the generation and delivery of data products for their sphere of influence. Data users (at all stages) are responsible for the utilisation of QA4EO to assess the adequacy and level of evidence

supporting the QI associated with their data and/or any resultant information product according to the needs of their specific applications, i.e., its “fitness for purpose”. They are also responsible for adhering to the data sharing principles outlined in the GEO data sharing principles.

The QA4EO task team is currently being augmented to include representatives from other GEO tasks and all SBAs. The augmented team will not regulate but will provide a coordination role, monitor progress and provide a guidance, harmonisation and capacity building function. In addition a dedicated QA4EO secretariat serves as a point of contact for QA4EO (sec@qa4eo.org) and the QA4EO website contains all the latest information and guidelines (<http://qa4eo.org>).

2 Background

The Group on Earth Observations (GEO; <http://earthobservations.org/>) was founded in 2003 following calls for action from the World Summit on Sustainable Development and the G8 of leading industrialised countries. These high-level meetings recognised that international collaboration is essential to exploit the growing potential of Earth Observations to support decision making in an increasingly complex and environmentally stressed world.

GEO is a voluntary partnership of governments and international organisations that provides a framework for the coordination of effort and strategies to address common goals. In 2005 it launched a ten-year implementation plan to establish its visionary goal of a Global Earth Observation System of Systems (GEOSS [1]). The key objective of GEOSS is to deliver comprehensive and timely “knowledge information products” worldwide to meet the needs of its nine Societal Benefit Areas (SBAs). This will be achieved through the synergistic use of data. Data may be derived from a variety of sources (satellite, airborne and *in situ*) at all scales – global, regional and local – through the coordinated resources and efforts of the GEO members. As this is a voluntary process, “adaptor plugs” must be developed to accept **all** (properly documented) data. GEOSS aims to allow the provision of, and the access to, *the Right Information, in the Right Format, at the Right Time, to the Right People, to Make the Right Decisions*.

GEO identified the need ‘to develop a GEO data quality assurance strategy, beginning with space-based observations and evaluating expansion to *in situ* observation, taking account of existing work in the area’ (GEO task DA-06-02 [2], now DA-09-01). Calibration and validation (Cal/Val) is critical to data quality assurance (QA) and therefore data usability. The Committee on Earth Observation Satellites (CEOS)’s Working Group on Calibration and Validation (WGCV), in partnership with the Institute of Electrical and Electronics Engineers (IEEE), were therefore natural leads to carry out this task for space-based observations. By taking a generic approach and building on broad-based, non EO-specific QA best practices that utilise, amongst others, the expertise of the national standards laboratories of the UK and USA, these organisations sought to encompass the needs of the wider GEO community in a single QA framework. That framework is evolving to take account of the needs of the SBAs

and to involve the wider community in the evolution and implementation of QA4EO into GEOSS.

This document presents the conclusion of a community-derived process to establish an international QA framework to facilitate harmonisation and interoperability of EO data, derived products and the various tools and assets required to achieve them. The principles and operational details were debated with representatives at the *GEO / CEOS workshop on quality assurance of calibration and validation processes: Guiding Principles*, held in Geneva in October 2007, and its subsequent workshop partner, *Establishing an Operational Framework*, held in Gaithersburg in May 2008. The *QA4EO workshop on Facilitating Implementation*, held in Antalya, Turkey in September 2009, broadened the scope for QA4EO by involving representatives from a range of SBA communities in the process.

3 Quality Assurance Framework for Earth Observation (QA4EO)

3.1 Overview

In order to achieve harmonisation and facilitate interoperability between data type and sources, as required by GEOSS:

Data and derived products shall have associated with them an indicator of quality to enable users to assess their suitability for particular applications, i.e., their “fitness for purpose”.

To address this, a set of guiding principles was established, supported by a suite of “key guidelines” that are based on the adoption / adaptation of existing “best practises”. Together, these key guidelines define the generic processes and activities needed to establish and underpin an operational Quality Assurance Framework for Earth Observation (QA4EO). This strategy and the key guidelines were endorsed by the 22nd CEOS plenary in 2008.

The key guidelines (K) are labelled according to their thematic topic area (DQ equates to Data Quality) and their generic nature (GEN); see Annex A for guidance on the review and management of documents. For example QA4EO-QAEO-GEN-DQK-001 is labelled as a QA4EO document (QA4EO), issued under the authority of QA4EO (QAEO), it covers generic issues (GEN) for the data quality thematic topic area (DQ), it is a key guideline (K) and is the first of its kind (001). All key guidelines are written as self-contained documents. Although each is self-contained, most rely on the content of others to provide specific detailed guidance on particular aspects and so all guidelines should be viewed as a linked set.

Implementation will lead to the population of QA4EO with more detailed technical procedures and activities at all stakeholder levels, i.e., individual data providers, sensor builders and algorithm developers through to community-agreed processes recommended for wide adoption to facilitate international harmonisation. The

procedures and activities will be established by appropriate technical experts within the research and operational EO community. Many activities or procedures in common use will already be fully consistent with the QA4EO key guidelines, others may need small additions before they can be fully endorsed within the system. It is anticipated that future procedures and activities will be documented and carried out following the guidance contained within the key guidelines.

Subsequent operational guidelines, procedures and activities written by the community following the guidance contained within the key guidelines will be organised and categorised according to their principal technical domain of interest. Each GEO community will make use of its own structures to establish and approve technical and detailed procedures following the generic guidance of the key guidelines. The QA4EO task team, established by GEO to oversee the process, will be responsible for coordination between GEO communities and for ensuring that the key guidelines evolve to take account of all stakeholder needs.

The key guidelines are intended to facilitate the establishment and presentation of the documentary evidence needed to support a QI in a common and consistent manner. Individual organisations responsible for delivery of data, product or associated process are responsible for using the guidelines to enable them to establish and demonstrate a QI to their customer and/or the user. The user is responsible for assessing, based on the QI and associated evidence, that the delivered “product” is suitable for his/her application. This includes specifying the requirement to be compliant with key principles and where appropriate the generic key guidelines of QA4EO and also any community or specific organisational detailed procedures that they consider necessary.

Some organisation or community-specific activities and processes may themselves be submitted and considered by broader EO representative communities as current “best practice” but would always be seen as living documents or processes that could, with time, be improved upon. These are likely to be related to relatively generic activities that span a wide range of organisations, especially where there is a need to establish international harmonisation and interoperability. They are, in general, intended to be suggested (not required) practices that provide baseline reference material and good guidance to newcomers and to established institutions and professionals alike. It is hoped that the endorsement and encouragement of use of such “practices” will lead to improved coordination between communities and a common set of well-established procedures. These procedures could ultimately result in a reduction of overall costs and bring the prospect of a fully integrated, interoperable GEOSS closer to a reality.

An operational QA4EO will include coordinated comparisons and the establishment of “common community reference standards” to facilitate “bias evaluation”. This, together with the encouragement of openness and access to results and performance evaluation, will provide the necessary evidence to support assigned QIs. A QA4EO secretariat and task team, composed of representatives from appropriate international bodies representing key GEO technical communities and SBAs, will provide the technical administration and governance under the overall direction of the GEO membership. Implementation will be through the EO community, individual organisations and agencies, and their representative bodies (e.g. CEOS, the World

Meteorological Organization (WMO), etc.) upon which it will also depend for detailed practical support, particularly in terms of infrastructure.

3.2 Data Quality

Data quality can be considered the key to interoperability. Without at least a means to assess data quality, it would be impossible to combine or use data from different sources in any meaningful way.

The guiding principle for data quality within the QA4EO framework is that:

All data and derived products must have associated with them a Quality Indicator (QI) based on documented quantitative assessment of its traceability to community agreed (ideally tied to SI) reference standards.

All steps in the data product delivery chain (collection, processing and dissemination) must be documented with evidence of their traceability and the resulting quality information propagated through from end to end. This can be achieved by following the guidance document QA4EO-QAEO-GEN-DQK-002.

To achieve the data quality guiding principle requires a range of generic processes or activities. Key guidelines have been written to support this implementation:

- A guide to establish a Quality Indicator for a satellite sensor derived data product (QA4EO-QAEO-GEN-DQK-001),
- A guide to content of a documentary procedure to meet the QA requirements of GEO (QA4EO-QAEO-GEN-DQK-002),
- A guide to “reference standards” in support of QA requirements of GEO (QA4EO-QAEO-GEN-DQK-003),
- A guide to comparisons – organisation, operation and analysis to establish measurement equivalence to underpin the QA requirements of GEO (QA4EO-QAEO-GEN-DQK-004),
- A guide to establishing validated models, algorithms and software to underpin the QA requirements of GEO (QA4EO-QAEO-GEN-DQK-005),
- A guide to expression of uncertainty of measurement (QA4EO-QAEO-GEN-DQK-006), *and*
- A guide to establishing quantitative evidence of traceability to underpin the QA requirements of GEO (QA4EO-QAEO-GEN-DQK-007).

Figure 1 illustrates how the guidelines interact together.

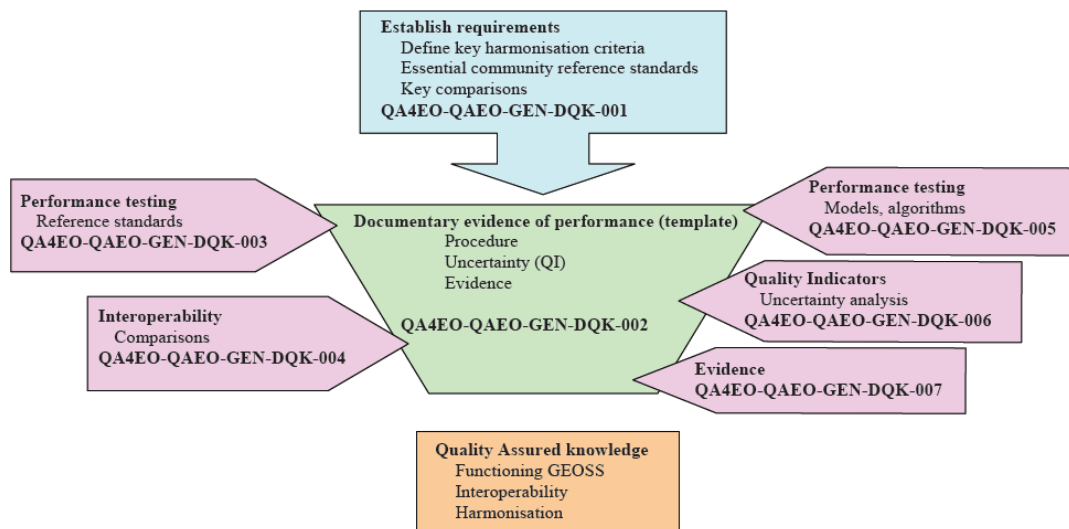


Figure 1: Schematic of the Data Quality Aspects of the QA4EO Process

The key guideline QA4EO-QAEO-GEN-DQK-001 can be considered as the “process driver” that translates the guiding principle into its top-level requirements. QA4EO-QAEO-GEN-DQK-002 provides guidance on how to document an activity, providing through its template a “checklist”. This key guideline can be considered the translation of a “requirement”, such as those highlighted in QA4EO-QAEO-GEN-DQK-001 and subsequent detailed specifications, into a task or set of tasks and how to describe them. QA4EO-QAEO-GEN-DQK-003 to -007 are the tools to aid the completion of documents that would result from implementation of QA4EO-QAEO-GEN-DQK-002, and consequently to meet the requirements identified in QA4EO-QAEO-GEN-DQK-001.

3.3 Data Management

The guiding principle for data management in the context of QA4EO is that:

The data product must be freely and readily available / accessible / useable in an unencumbered manner for the good of the GEOSS community, for both current and future users. This necessitates that all EO data and associated support information (metadata, processing methodologies, QA, etc.) is associated with the means to effectively implement a quality indicator. In return, the provider must be consistently acknowledged.

QA data management for GEO is underpinned by the GEO data sharing principles. These principles are currently undergoing final revision in preparation for potential adoption at the GEO ministerial summit in November 2010 (see <http://www.earthobservations.org/> for more details).

3.4 Documentation Management and Outreach

The guiding principle for documentation management and outreach for QA4EO is that:

Sound and effective harmonised documentation management is needed to facilitate and enhance interoperability and achieve the objectives of consistent and traceable quality information. To enable this activity, all stakeholders must have a clear understanding of the adequacy of the information that they are accessing and using for their specific application. The evidence for this clarity should ideally be accessible through a centralised portal and should be fully traceable to its origins. The traceability and interoperability process must be understandable by any appropriately trained individual within GEOSS and efforts must be made to encourage the wider usage of information and facilitate the training of GEOSS users.

To facilitate this requires:

- The use of common terminology,
- Access portal(s) as a gateway(s) to relevant data quality information (as addressed within the GEO data sharing principles),
- A document management system (see Annex A), and
- The support and facilitation of education and capacity building activities to promote the QA4EO, encourage its adoption and the uptake of best practice procedures.

The development, use and encouragement of the use of internationally agreed terminology for all EO-related fields of expertise is recommended. Duplication of documents should be avoided by harmonising and adopting those internationally agreed or endorsed dictionaries that already exist. New documents should be developed to cover all EO aspects, providing a clear and unambiguous definition for all relevant terms and parameters. The various dictionaries can independently be stored in different locations but must all be linked to, and accessible from, a common portal. Some examples of existing dictionaries are:

- ISO guide 99:2007 to Vocabulary of International Metrology (VIM; http://www.iso.org/iso/catalogue_detail?csnumber=45324)
- GEO/CEOS Cal /Val portal Terms and Definitions (<http://calvalportal.ceos.org/CalValPortal/docs/information/TermsAndDefinitions.pdf>)

A centralised web portal can act as a gateway to all relevant data and information. This portal should link to other websites that store additional quality information. The QA4EO website (<http://QA4EO.org/>) will serve to provide a link to community-specific portals. For example, the GEO / CEOS Cal/Val portal is currently the space community's portal for all Cal/Val data (<http://calvalportal.ceos.org/>). The means to access and populate the portal in a manner that is unambiguous, unencumbered but also robust is addressed further in the GEO data sharing principles.

For QA4EO to become a globally effective framework for EO data, it will be important to seek to encourage the uptake of its “best practice” methods. It will also be important to facilitate rapid entry and contribution of new groups to support global QA needs when developing or carrying out EO-related activities.

4 Summary

This document provides an introduction to a framework for establishing and demonstrating Quality Assurance for Earth Observation data and derived products. This QA4EO is based on the need to coordinate and harmonise processes and activities to enable interoperability. It is structured around a set of internationally agreed “guiding principles” that can be achieved through following the guidance contained within a suite of key generic guidelines.

QA4EO, under the auspices of GEO, will be responsible for the operation and strategic development of the process, but it will be implemented and operated at a detailed level by individual organisations and communities. It is anticipated that there will be some coordination and sharing of resource, infrastructure and knowledge between the various SBA communities to ensure that implementation can progress rapidly and in a relatively uniform manner across the globe.

As the system develops and matures, the coordination and cooperation between individual organisations and GEO communities is likely to become more structured and formalised to ensure the continued maintenance and evolution of QA4EO.

5 References

- [1] GEO, adopted 16 February 2005, [The Global Earth Observation System of Systems \(GEOSS\) 10-Year Implementation Plan](#)
- [2] GEO, 2008, v6, [GEO 2007-2009 Work Plan: Toward Convergence](#)
- [3] GEO, November 2008, 2009-2011 Work Plan, Document 12

Annex A: A guide to facilitate Review and Management of Documents

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1 Abstract

The peer review and effective management of documents within the Quality Assurance Framework for Earth Observation (QA4EO) are critical tasks to ensure that appropriate and correct information is identifiable and retrievable when needed. Therefore, guidelines are needed to identify, control and manage document preparation, review, approval, authorisation, issue and change.

2 Scope

This key guideline specifies the requirements related to the peer review and management of documents generated in the context of QA4EO. This key guideline does not describe the implementation solution responding to these requirements; this definition is left to the producer of the documents. This key guideline also describes the mechanism through which a document is officially registered as part of QA4EO. In the context of this key guideline, the word “document” is used as a generalised term incorporating other descriptors such as methodology, processes, protocol, procedures and guidelines.

3 Terminology

All terms within this document are based on internationally-agreed definitions that are, in many cases, derived directly from formal standardising bodies such as the International Organization for Standardization (ISO). These agreed definitions can be found on the QA4EO website (<http://QA4EO.org/>).

4 Context

This key guideline is written as part of a set, based on the adoption of existing best practise, to form a Quality Assurance Framework for Earth Observation (QA4EO). The QA4EO was developed to meet the current and aspirational needs of the societal themes of the Group on Earth Observation (GEO)’s Global Earth Observation System of Systems (GEOSS). It was prepared as a direct response to GEO task DA-06-02 (now DA-09-01-a) to “Develop a GEO data quality assurance strategy, beginning with space-based observations and evaluating expansion to *in situ* observations, taking account of existing work in this arena”.

5 Peer review requirements

All documents and procedures contributing to QA4EO should be peer reviewed by the entities generating them before being presented and officially registered as part of

QA4EO. The peer review process upholds the quality and validity of each document and procedure.

The details and mechanisms of the implementation solution of the review process are to be defined by the entity responsible for the documents. The peer review method could follow quality standards that already exist (e.g. ISO standards) or could follow other review processes (e.g. single blind review, double blind review or open review).

The review process should be well defined, documented and transparent.

6 Document management requirements

Beyond the document format and structure requirements described in QA4EO-QAEO-GEN-DQK-002, each entity producing QA4EO-related documents should implement an effective document management system.

The details and mechanisms of the implementation solution of the document management system are to be defined directly by the entity responsible for the documents. The method can follow standards that already exist (e.g. ISO standards) or be implemented following other document management processes.

The method used should specify document management in terms of generation, change, issue and distribution of documentation in paper or electronic forms. This includes:

- Identification, preparation and submission
- Review and Verification
- Document Issue and Release
- Document Change
- Document Distribution and Publishing

The document management solution should, as a minimum, respond to the requirements listed in the following paragraphs:

- Identify each document by a unique identifier
- Specify the document Author(s) who are responsible for drafting, completing and implementing updates on the document content.
- Specify the Document Issuing Authority who will ensure the document management process and maintain the unique identifier required. The Document Issuing Authorities are responsible for managing and providing endorsement authorisation. In addition, Document Issuing Authorities who receive documents from external sources are responsible for ensuring that these documents are adequately identified and controlled.
- Specify the document Registrar. This could be a responsibility of the Document Issuing Authority, although responsibility could equally lie elsewhere. The Document Registrar is responsible for:

- establishing and assigning unique identifier codes for sets of documents,
- maintaining the document register,
- preventing duplicate identifiers being issued,
- issuing documents and notifying changes after proper authorisation according to agreed communication channels and distribution lists,
- maintenance of document source files.

6.1 Documentation Identification

As a minimum, the following information shall be attached to each document:

- Title
- Author
- Author e-mail address
- Issuing authority
- Issue and Revision numbers
- A unique identifier or reference number
- Date of issue

6.2 Document Lifecycle

The document management system should define a clear and structured document lifecycle. An example is provided below:

Draft	Document is being generated or updated by the document Authors or is being subject to its review under the supervision of the Document Issuing Authority. Draft documents shall be identified by the word “Draft” next to the Issue / Revision / Version number.
Reviewed	Document has completed its peer review and is subject to the appropriate approval under the supervision of the Document Issuing Authority.
Issued	Document is complete, approved and authorised through signature.

6.3 Document Approval and Release by Issuing Authority

The Document Issuing Authority should seek approval and authorisation for release when they are confident of the accuracy and suitability of the document. If they are satisfied that the document contents are correct and complete, the Approvers and Authorisers should indicate their approval and authorisation as applicable, wherever possible, by physical signature of the document. The document can then be given to the Document Issuing Authority for release.

7 QA4EO Document Registration

7.1 Document Preparation

Within the framework of QA4EO, the requirement for a document can come from two different sources:

- From an independent submission of a Documentation Author *or*
- From the identification of a need by a Document Issuing Authority

Document preparation should follow the format and contents guidelines as defined in QA4EO-QAEO-GEN-DQK-002 and/or QA4EO-QAEO-GEN-DQK-003 for reference standards, and QA4EO-QAEO-GEN-DQK-004 for protocols relating to comparisons.

7.2 QA4EO Document Registration

Upon receipt, the document is given a new unique identifier for use within QA4EO, but the document can also retain local (issuing authority specific) numbering schemes for maintenance and control within their own organisation. The QA4EO Document Registrar will maintain any necessary linkage between these numbering schemes.

7.3 QA4EO Document Distribution and Applicability

QA4EO will release and distribute documents in a non-editable form only. The QA4EO Document Registrar will keep records of document issue in the Document Register. Issues of a document requiring approval and authorisation can only be changed by the Issuing Authority.

7.4 QA4EO Distribution Lists

The QA4EO Document Registrar is responsible for ensuring that all persons on the QA4EO distribution list are notified of any update of the document concerned. The distribution list may either be printed within the document or maintained as a separate record.

7.5 QA4EO Document Change

Document Change is the responsibility of the Author and the Issuing Authority. The review and authorisation processes should follow those described in section 5 of this key guideline.

7.6 Storage and Retrieval of Documents

The primary distribution mechanism for all non-confidential documents should be via electronic form. All documents should be stored, by the relevant Document Issuing Authority, in an editable form and employing a multi-user environment.

7.7 Property Rights

Documents containing commercial information limited by intellectual property rights should clearly state this in the first page of the document.

8 Conclusion

This document defines the guiding principles, in terms of content and development, for authors of “procedures” (and other relevant documents), and those using them, to ensure that they are compliant with the Quality Assurance strategy for GEO’s GEOSS. This key guideline specifies the requirements that relate to the peer review and management of documents that are generated in the context of QA4EO. It describes the mechanism through which a document is officially registered as part of QA4EO. This procedure has been written in the same style as it proposes for its users. However, as a “procedural document”, it does not contain sections on performance evaluation.