

## INTRODUCTION

The Quality Assurance Framework for Earth Observation (QA4EO; <http://QA4EO.org/>) was established and endorsed by the Committee on Earth Observation Satellites (CEOS; <http://ceos.org/>) as a direct response to a call from the Group on Earth Observations (GEO; <http://earthobservations.org/>). GEO had identified the requirement to establish an internationally harmonised Quality Assurance (QA) strategy to enable interoperability and quality assessment “at face value” of EO data. QA4EO encompasses a framework and set of ten key guidelines, derived from best practices and with example templates included to aid implementation. Each GEO stakeholder community is responsible for its own overall governance within the framework. QA4EO provides guidance to enable individual organisations to document, in a consistent manner, the necessary evidence of compliance, thereby allowing those commissioning the work to assess its adequacy and “fitness for purpose”. QA4EO-compliant processes would unequivocally assure data quality and would encourage harmonisation across the whole GEO community.

## BACKGROUND

QA4EO has been endorsed by CEOS as a contribution to facilitate the GEO vision for a Global Earth Observation System of Systems (GEOSS). The aim of GEOSS is to deliver comprehensive and timely knowledge / information products worldwide to meet the needs of its nine “societal benefit areas” (figure 1). This can only be achieved through the synergistic use of data derived from a variety of sources (satellite, airborne and *in situ*) and the coordination of the resources and efforts of the GEO members.

To accomplish this vision, starting from a system of disparate systems that were built for a multitude of applications, requires the establishment of an internationally coordinated operational framework to facilitate interoperability and harmonisation. The success of this framework, in terms of data, is dependent upon the successful implementation of two key principles:

1. Accessibility / Availability and
2. Suitability / Reliability.

Success also requires effective communication of these principles to all stakeholders.



**Figure 2: First Workshop of Cal/Val experts in 2007 hosted by GEO in Geneva**

To implement these principles in a harmonised manner, CEOS (the space arm of GEO), through discussion with calibration and validation experts from around the world (see figure 2), established QA4EO to facilitate interoperability of GEO systems. QA4EO is based on the adoption of guiding principles, which are implemented through a set of key operational guidelines derived from best practices, for implementation by the GEO community. Although these guidelines were originally developed to meet the needs of the space community, they have been written with the aid of national metrology institutes of the UK and the USA and, where appropriate, are based on best practices of the wider non-EO

community. They should therefore be readily adoptable by all GEO communities as a top-level framework that can subsequently be translated and implemented to serve each specialist need.

## KEY PRINCIPLES

If the vision of GEOSS is to be achieved, **Quality Indicators** (QIs) should be ascribed to data and, in particular, to delivered information products, at each stage of the data processing chain - from collection and processing to delivery. A QI should provide sufficient information to allow **all** users to readily evaluate a product’s suitability for their particular application, i.e. its “**fitness for purpose**”. To ensure that this process is internationally harmonised and consistent, the QI needs to be based on a documented and quantifiable assessment of evidence demonstrating the level of **traceability** to internationally agreed (where possible SI) **reference standards**. Such standards may be manmade, natural or intrinsic in nature. The documented evidence should include a description of the processes used, together with an **uncertainty** budget (or other appropriate quality performance measure). The guidelines of QA4EO provide a template and guidance on how to achieve this in a harmonised and robust manner.

One of the key guiding principles of QA4EO is **appropriateness** underlain by a community desire to:

- Achieve **consistency** amongst peers,
- Provide advice and training for newcomers,
- Provide transparency of approach, *and*
- Improve efficiency.

**The QA4EO process and its implementation should NOT be judgemental, bureaucratic or costly.**



**Figure 1: GEOSS & the nine stakeholder societal benefit areas**

**KEY DEFINITIONS**

**Quality Indicators:** a means of providing a user of data or derived product (which is the result of a process) with sufficient information to assess its suitability for a particular application. This information should be based on a quantitative assessment of its traceability to an agreed reference or measurement standard (ideally SI), but can be presented as numeric or a text descriptor, providing the quantitative linkage is defined.

**Traceability:** property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations each contributing to the measurement uncertainty.

**Reference (measurement) standard:** realisation of the definition of a given quantity, ideally with a stated uncertainty, which can be used as a reference; it can be individual or community defined.

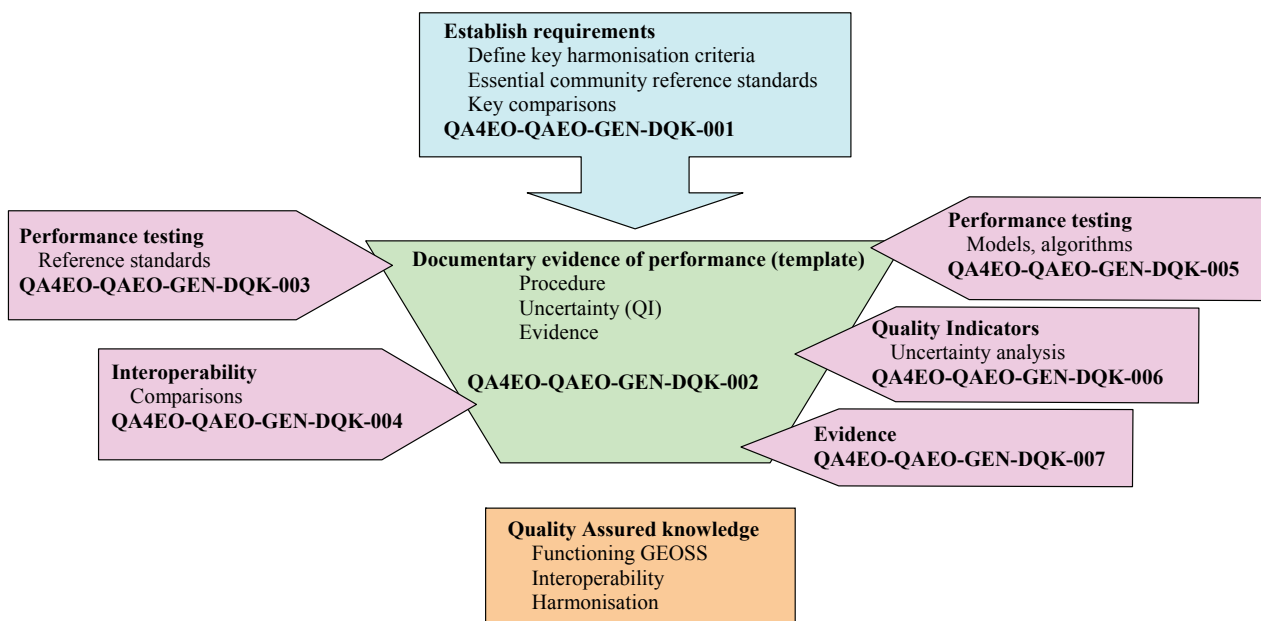
**Uncertainty:** non-negative parameter characterising the dispersion of the quantity values that are being attributed to a measurand (quantity), based on the information used. Where possible this should be derived from an experimental evaluation but can also be an estimate based on other information, e.g. experience.

**QA4EO GUIDELINES**

The Quality Assurance Framework for Earth Observation consists of ten distinct key guidelines linked through an overarching document - the **GUIDELINES FRAMEWORK**. The naming convention of the guideline documentation is fully explained in guideline **QA4EO-QAEO-GEN-CEK-001** and collates the guidelines in terms of more specific functions, e.g. Data Quality (DQ), Data Policy (DP) and Communication and Education (CE).

Guideline **QA4EO-QAEO-GEN-DQK-002** (“A guide to content of a documentary procedure to meet the Quality Assurance requirements of GEO”) is essentially the core requirement for QA4EO (see figure 3). If processes are carried out in full compliance of this fundamental guide, a user can have confidence in any resultant output. **QA4EO-QAEO-GEN-DQK-002** provides the template to guide the user through the process, aided by the other nine key guidelines for specific technical details, but in principle this guide provides all the information needed to be compliant.

In considering issues of interoperability and international harmonisation within any specific GEO community it is often helpful to start with a review of generic activities and from these define key requirements that drive the QA process. For example, in the space sector all derived information products originate from a measurement made by a satellite sensor. Thus, a set of key activities for every sensor could be defined for implementation during its development and operation. Guideline **QA4EO-QAEO-GEN-DQK-001** provides this satellite-based example to illustrate the process. This example shows how the top level requirements drive the need for community references, indicate critical generic deliverables for bias evaluation through comparisons and act as a starting point for more detailed technical procedures to underpin the top level requirements.



*Figure 3: Schematic summary of the data quality aspects of the QA4EO process*

## DOCUMENTATION

The QA4EO **GUIDELINES FRAMEWORK** provides the background to QA4EO and introduces the key guidelines:

- **QA4EO-QAEO-GEN-DQK-001** A guide to establish a Quality Indicator on a satellite sensor derived data product
- **QA4EO-QAEO-GEN-DQK-002** A guide to content of a documentary procedure to meet the Quality Assurance requirements of GEO
- **QA4EO-QAEO-GEN-DQK-003** A guide to “reference standards” in support of Quality Assurance requirements of QA4EO
- **QA4EO-QAEO-GEN-DQK-004** A guide to comparisons – organisation, operation and analysis to establish measurement equivalence to underpin the Quality Assurance requirements of QA4EO
- **QA4EO-QAEO-GEN-DQK-005** A guide to establishing validated models, algorithms and software to underpin the Quality Assurance requirements of QA4EO
- **QA4EO-QAEO-GEN-DQK-006** A guide to expression of uncertainty of measurements
- **QA4EO-QAEO-GEN-DQK-007** A guide to establishing quantitative evidence of traceability to underpin the Quality Assurance requirements of QA4EO
- **QA4EO-QAEO-GEN-CEK-001** A guide to facilitate Procedure and Documents Management
- **QA4EO-QAEO-GEN-DPK-001** A guide on Cal/Val data sharing principles and data exchange
- **QA4EO-QAEO-GEN-DPK-002** A guide for providing Cal/Val data: content and metadata

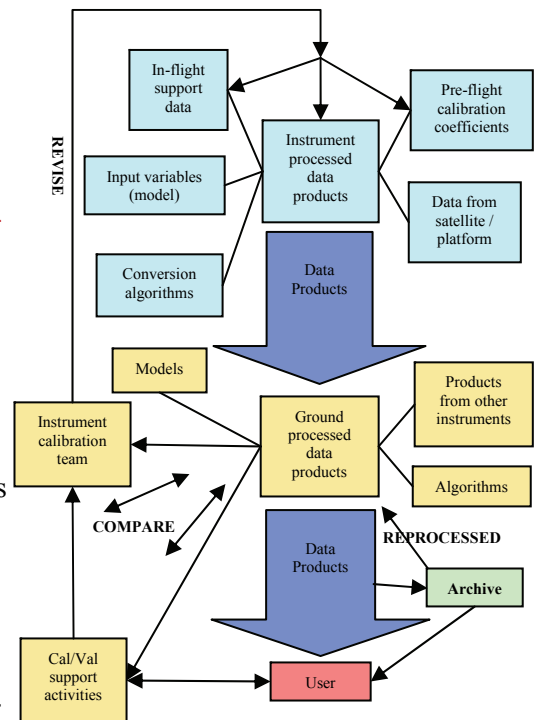
## IMPLEMENTATION

The QA4EO guidelines offer a flexible approach to allow the effort for compliance to be commensurate with the final objectives. For example, although it is a fundamental requirement of QA4EO that the result of any process must have associated with it a QI derived from a quantitative assessment of uncertainty, this value can be high or low and in some cases based on an estimation of an individual. Guideline **QA4EO-QAEO-GEN-DQK-006** provides a summary and link to the ISO guide to the expression of uncertainty of measurement (GUM) to aid the user in this process. It is for the final user (customer) of the information to determine if the information, with its associated QI, is suitable for their requirement. They must therefore have the ability to trace back to the origin of any resultant QI, or in practice have confidence that those responsible for accepting the results of each of the earlier steps in any process chain have undertaken an adequate review. The key guidelines and templates of QA4EO are designed to facilitate this in a harmonised manner.

The processing chain can be considered as a set of linked activities / processes (e.g. data collection, correction / conversion algorithm, dissemination, etc.) some operating in a direct linear path and others providing ancillary information to aid the next processing step. The objective of QA4EO is to assign a QI to the result of every step in an EO information product processing chain. Figure 4 provides a schematic data processing chain for a satellite sensor, where the complexity and interdependency of the various activities in the process chain can be visualised. Each activity can be considered as:

- a measurement – the use of an instrument to obtain information about an entity *or*
- a process – the transformation of information from one form to another. This may involve the combination of other information and/or the use of theoretical models.

The value assigned to each QI must be supported by documentary evidence commensurate with its criticality to any eventual knowledge information product derived from it. The basis for deriving each QI and the evidence to support the assigned value must be transparent, internationally consistent and independent (in terms of definition) of any specific community. By considering the data production process in this way (as a set of linked tasks each with a documented procedure and uncertainty) the interfaces of these individual tasks naturally become Quality Control points.



**Figure 4: Schematic representation of a data process chain of a satellite sensor and the interdependencies of activities**

**REFERENCE (MEASUREMENT) STANDARD KEY PROPERTIES & EXAMPLES**

- Must be characterised (and documented) for the property for which they are a reference
  - ◇ At level commensurate with application
  - ◇ Temporally stable over the period of use
  - ◇ If assigned a value must be SI traceable or community agreed
- Can take any form: data, artefact, gas, natural, man-made, methodology, ....
- Can be formally endorsed for “community” use
- Must be accompanied by procedure on use



**PERFORMANCE TESTING**

In terms of Quality Assurance the only unequivocal evidence that can be used to support a QI of the result of an activity is a direct comparison against something (a reference standard) with a known result (i.e. calibration). Guideline [QA4EO-QAEO-GEN-DQK-003](#) provides guidance on the selection and use of reference standards. The reference standard can take any form - artefact, dataset, manmade, natural, physical law, etc., and its properties can be known intrinsically or through a reference to another standard. In some cases, reference standards may be community defined and do not necessarily have to be assigned a value, if only to evaluate biases. For more routine performance testing, individuals or organisations can select their own, providing they can demonstrate that its characteristics are suitable for its intended use.

Where there is no obvious answer, QA4EO recommends a comparison with peers to establish the degrees of equivalence between similar activities. Guideline [QA4EO-QAEO-GEN-DQK-004](#) provides guidance with examples on how to organise, perform and analyse comparisons.

In an ideal world, all performance testing (QI evaluation) would involve calibration or comparison of every activity and involve, in the case of calibrations, independent review of the process. However, this is often neither practical nor necessary within the EO community. Guideline [QA4EO-QAEO-GEN-DQK-007](#) provides advice to stakeholders on determining the level and type of evidence that would be adequate for their purpose. Guideline [QA4EO-QAEO-GEN-DQK-005](#) recognises the special case of algorithms, models and software and provides guidance through links to other best practice documents on assessing performance so that a reliable QI can be assigned.

**GOVERNANCE**

QA4EO was established and is operated under the auspices of GEO to facilitate interoperability and harmonisation. Any QA process requires some form of governance to operate successfully and for QA4EO this is coordinated through appropriate GEO recognised community representative bodies and organisations. The current list of these bodies can be found on the QA4EO website: <http://QA4EO.org/>.

Individual communities are responsible for detailed administration and implementation of the QA4EO guidelines in their sphere of influence, tailored to their own specific needs. This is likely to require adaptation of some of the key guidelines (e.g. [QA4EO-QAEO-GEN-DPK-001](#) and/or [-002](#)) into a form commensurate with their need and organisational structure. In some cases an update of the key QA4EO guidelines themselves will be required (e.g. “acceptable evidence” in [QA4EO-QAEO-GEN-DQK-007](#)). On request, the QA4EO management board will provide guidance on generic implementation and provide support during the early phases of implementation.

The key QA4EO guidelines only provide guidance and templates; it is for each individual organisation to document their specific activities, following the guidelines, and for those commissioning the work to consider their adequacy and compliance. Where possible, such documents should be made publicly accessible through the QA4EO secretariat and via any other appropriate community specific portal. Guideline [QA4EO-QAEO-GEN-CEK-001](#) provides a description of the document management process together with a universal indexing taxonomy.

**COMMUNICATION**

One of the key aspects of QA4EO is to encourage accessibility and openness amongst all stakeholders. This would require some commonality in terms of formats for presentation of information or at least commonality in terms of the content and the means of accessing the content, i.e. metadata accompanying data and derived products. Guideline [QA4EO-QAEO-GEN-DPK-002](#) provides guidance on how this should be accomplished, referencing appropriate ISO standards. The concept of openness also requires a code of practice to ensure that efforts of individuals and organisations providing information or services are appropriately acknowledged and referenced. Guideline [QA4EO-QAEO-GEN-DPK-001](#) provides guidance on a code of practice for use in the context of QA4EO and GEO. It is noted that many organisations and communities have widely varying data access policies and this guideline can be adapted to take account of this.

**For further information contact the QA4EO Secretariat ([secretariat@QA4EO.org](mailto:secretariat@QA4EO.org)) or visit the QA4EO website (<http://QA4EO.org/>)**