Interoperability Handbook

Version: v2.0.0

November 6, 2025

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Introduction

For four decades, the **Committee on Earth Observation Satellites (CEOS)**[1] has made significant contributions to advancing the space-based Earth observation (EO) community. CEOS agencies[2] communicate, collaborate, and exchange information on EO data needs, missions, instruments, and measurements, spurring partnerships that lead to collaboration, including the launch of multi-agency missions. Such cooperative efforts have greatly benefited data users worldwide with well-curated scientific data that serves to inform decision-making and increase understanding of the Earth as an integrated system. The CEOS forum also provides an established means for mutual communication with other organizations on remote sensing developments, needs, and requirements.

Interoperability of data and services in the space-based EO domain is essential due to the importance of EO data in a wide range of applications, including agriculture, climate monitoring, disaster management, and urban planning, as well as the increasing cooperation between public and commercial space actors worldwide. To streamline such collaborative efforts, CEOS developed and published the CEOS Interoperability Handbook 1.1 in 2008. Fifteen years later, the increase in the number of EO satellites and associated complex sensors providing ever-growing volumes of data catering to complex user requirements, compelled CEOS to review the interoperability of data services in the current context and to develop the CEOS Interoperability Handbook 2.0. The CEOS Interoperability Framework was developed to guide the evolution of this handbook for EO data services. Different entities within CEOS contributed to the development of this Handbook, with the CEOS **Working Group on Information Systems and Services (WGISS)**[3] leading the overall coordination and development effort.

Purpose

This handbook will help data providers enhance the interoperability of their data and services with those of other organizations, agencies, and countries by proposing standards and best practices in terminology, structure, formats, metadata, quality, and policy. It is intended to help avoid duplication of efforts, reduce costs, and improve the interoperability of EO data and services. Interoperability also facilitates the integration of global EO data with other data sources, including geostatistics, model data, and forecasts. By combining these sources, users can gain a more comprehensive understanding of various phenomena, such as natural disasters, land use, and climate change at a global level.

Furthermore, adaptation of interoperability recommendations as discussed in this handbook will facilitate data sharing among the scientific community, governments, international organizations and other stakeholders. It can assist in creating a common understanding among users with different backgrounds, interests, and needs. Finally, interoperability goes beyond data sharing. It can foster collaboration and innovation by enabling the development of new applications, tools, and services that leverage EO data. Such advances are critical for addressing emerging challenges, such as the impacts of changes affecting the climate, natural disasters, water and food security.

[1] https://ceos.org
[2] https://ceos.org/agencies/
[3] https://ceos.org/ourwork/workinggroups/wgiss/

Scope

CEOS Interoperability Handbook Version 2.0 intends to provide guidance to organizations for development of Interoperable Data and Services and help them in measuring their maturity level.

Audience

This Handbook is intended for use as a guide by different Space Agencies, New Space Startups and Commercial Data and Service Providers to improve interoperability of data and services.

Changes with Respect to Version-1

The Handbook version 2.0 of the CEOS Interoperability Handbook represents a significant evolution from the original 2008 version 1.0. While the earlier handbook laid the groundwork for interoperable Earth Observation (EO) systems—focusing on metadata standards, catalog protocols, and service definitions, the new version responds to a transformed data landscape shaped by cloud-native architectures, open science, and global collaboration.

The Handbook Version 2.0 aims to guide EO data providers, system architects, and policy stakeholders in building interoperable data and service infrastructures. It emphasizes modularity, openness, and machine-actionability, aligning with global initiatives such as the Group on Earth Observations (GEO), FAIR data principles, and open science mandates.

In contrast, the 2008 edition focused on enabling interoperability through shared protocols (e.g., FTP, Z39.50), metadata formats (e.g., DIF, ISO 19115), and service taxonomies. It introduced foundational concepts such as the OAIS model for archiving, the CEOS Catalogue Interoperability Protocol (CIP), and the use of OpenDAP and WMS/WFS/WCS services.

Interoperability Framework

In order to guide and structure the overall Interoperability related activities within CEOS, a framework was proposed and developed. Five areas have been identified as critical 'factors' needed to move towards greater interoperability of EO data and services.

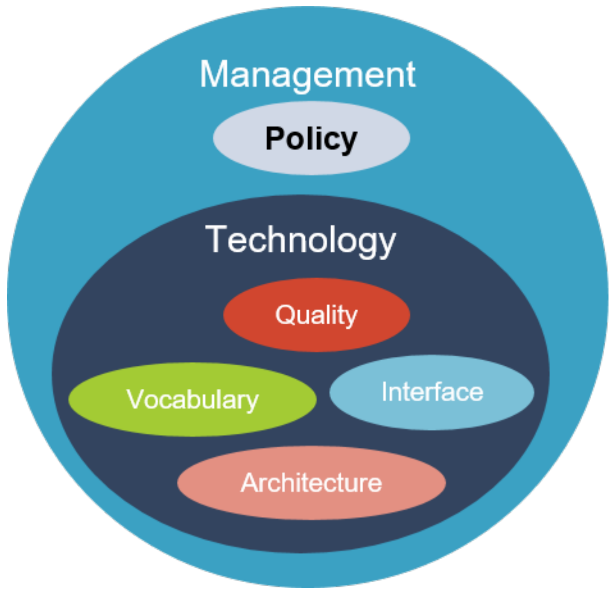

Figure 1: Interoperability factors diagram

Each factor has several components and are summarized as below.

Factor	Description
Vocabulary (Semantics)	The (narrow) semantic aspect refers to the naming and defining terms and expression. It includes developing, harmonizing, and maintaining vocabularies, concepts, and schemata supporting provision, exchange, and analysis of data, information, and knowledge regarding Earth observation. It ensures that words and language are understood in the same way by all communicating parties
Architecture	Architecture describes the organizational structure of concepts, processes, and assets, including data. It comprises of the structural aspects of models and standards that govern the collection, storage, archiving, documentation and publication of data
Interface (Accessibility)	Data exchange protocols and application interfaces, from a consumption or user perspective. These provide the means necessary to search for collections, find and access data and information contained in those collections
Quality	Indicators (parameters, metrics, etc.) for informing users of the trustworthiness (accuracy, uncertainty, consistency, etc.) of the data provided (measurands, measurements, observations, etc.).

Factor	Description
Policy	Legal frameworks, policies, rules, and strategies regulating the relation between the different stakeholders.

The factors together intend to cover all aspects that play a role in enabling interoperability of data and services. Design criteria for the factors are cohesion, independence, and modularity. Cohesion (internally) is accomplished by grouping them according to specific knowledge and competences required to tackle the respective issues. This 'separation of concerns' known from system engineering should ensure that the individual aspects are addressed in the most adequate way by experts of the respective fields without having to deal with the complexity of the entire system all the time. Independence means that specific (fundamental) aspects (e.g., data formats) should be proprietary to one factor. In this way parallel or duplicate solution development can be avoided. Modularity must ensure that all factors together build a functional ensemble in which it is clear which covers what and how they all work together.

The interoperability factors collate certain, expected-to-be related, competencies that should be considered whenever interoperability is desired or required in a project or process. Most CEOS activities are targeted at enhancing interoperability and thus they all should scrutinize their work with respect to the framework factors.

Vocabulary (Semantics)

Interoperability relies on the ability of diverse entities to communicate and exchange information seamlessly. At its core, semantics and vocabularies play a fundamental role in ensuring that data, messages, and services are not only transmitted but also correctly understood across different stakeholders. Without a shared understanding of terms, concepts, and relationships, interoperability remains limited, hampered by inconsistencies, misunderstandings, and other integration challenges.

Semantics deal with general aspects of meaning and relationships between terms and concepts in a domain, ensuring that communication is structured and interpreted consistently. As an important part of such communication, vocabularies, including thesauri, glossaries, terminologies, ontologies, taxonomies, and controlled vocabularies, provide standardized definitions that facilitate common understanding. In the context of geospatial interoperability, standardized vocabularies enable diverse entities to describe, classify, and relate data and services in a way that is human and machine-readable and reusable across the whole domain.

This section highlights the essential role of semantics and vocabularies in the CEOS Interoperability Framework. It outlines key standards, best practices for implementing semantic interoperability, and methods for aligning domain-specific vocabularies. By establishing a shared semantic foundation, stakeholders can improve data exchange, integration, service compatibility, and automated reasoning, ensuring more effective collaboration in an increasingly interconnected digital geospatial ecosystem.

ID	Semantic Recommendations
SEM#1	Terms and definitions should be collected into the CEOS Earth observation glossary[4] on GitHub.
SEM#2	Capability should be provided to enable public comment and discussion on existing and new terms and definitions.
SEM#3	Enable version control and change management at the individual term level and link to historical and alternative definitions.
SEM#4	Use of project or document specific vocabularies should be discouraged e.g., in the form of 'terms and definitions' chapters. Source (via url), maintain, and develop all terms that serve or might serve in more than one context in the online, shared repository.
SEM#5	Community members should promote the common thesaurus, including through ISO/TC 211, OGC[5], WMO, GEO and other stakeholders in Earth System Sciences, to strive for domain wide adoption.
SEM#6	Common online repositories for abbreviations and acronyms should be used. Agreed metadata fields with unified and binding lists of options should be included. Keywords from controlled vocabularies that allow lookup of keyword information via Linked Data principles, e.g., HTTP URI de-referencing or SPARQL interfaces are preferred. The use of GCMD controlled keywords is encouraged.

[4]https://github.com/ceos-org/eo-glossary/
[5]https://defs.opengis.net/prez/

Of central importance for increasing the interoperability within CEOS and across the entire geospatial domain will be a more harmonized and structured terminology. Providers and users of EO data and services will largely benefit if the definition and interpretation of terms is no longer renegotiated and amended each time projects are started, or new documents are drafted. A key finding of the terminology task force was that vocabularies should be developed as much as possible in an open and participatory way across the whole domain they are intended for. One of the main lessons learned by the CEOS terminology task force was that usability and acceptance of unified vocabularies will largely depend on consistent and comprehensive principles shared by all stakeholders and guiding their development.

ID	Thesaurus Recommendations
THES#1	The terms used in the thesaurus should be consistent and divided into classes such as Base, Core, Controversial and High Impact. The 'Base Terms' should have cross community agreement and should not have circular or ambiguous definitions. The 'Core Term' should be using the 'Base Term' consistently and can be allowed to have minor tweaks with approval from the identified committee. The 'Controversial Term' should have qualifiers attached to them with links to discussions, which led to the association of the qualifier. The 'High Impact Term' should be approved by a specialist committee and should be linked to a document providing details of the term.
THES#2	The definition of a term may not contain the term itself nor other circular definitions (e.g., where term A is defined using term B and term B is defined using term A). A clear set of base terms should be used.
THES#3	The terms used in the thesaurus should have clear and mappable relationships with other terms (parent, sibling, child). Overlaps between terms that are supposed to delineate more generic concepts (siblings) should be avoided or minimized.
THES#4	Definitions have to be kept unambiguous and short, and written in a form such that they can replace the term in a sentence.
THES#5	Explanations should be given in a separate 'Notes' sections, and Examples in a separate 'Examples' section. Both complement the definition, and should not be included as part of the main definition.
THES#6	Every definition should have an accompanying 'Sources' section, where all source documents are listed or link to register maintained by source is provided, wherever possible as urls.
THES#7	Thesaurus terms should be version controlled at the individual term level.
THES#8	Where a term is deemed 'controversial' then contradictory definitions can be provided, but only with clear links to alternative definitions and explanations as to what context a term is used in.

Architecture

Architecture plays a very important role in enabling interoperability. It describes the organizational structure of concepts, processes, and assets, including data and workflows. It comprises structural aspects of models and standards that govern the collection management, archiving, storage, documentation and publishing of data, and is the basis on which the interoperability of data and services is built on.

The Architecture factor has been divided into the following sections:

1) Preservation Architecture
2) Data and Metadata Architecture
3) Publishing Architecture

Preservation Architecture

The following list of recommendations describes the elements contributing to archive interoperability.

The primary purpose of data archiving is to preserve data over time. Preserving data over time consists in holding data in repositories in a way that enables data to be managed and accessed now and in the future. Data archiving is a complex, long-term process, with possibly many partners, including data providers supplying data to the archive, data users willing to use the archive, archive managers organizing the archive and other archives with which interoperability may be sought. Data management and archiving should consider not just the storage of data, but also the access and usage patterns of data.

ID	Recommendations
DPRES#1	Archival systems should comply with the Reference Model for an Open Archival Information System[6] (OAIS) and with the "OAIS-Interoperability Framework" to facilitate interoperability between archives.
DPRES#2	Data should be appraised and properly documented before ingestion in the archives following the CEOS Data Appraisal Procedure[7].
DPRES#3	Data and associated information should be ingested, archived and preserved following internationally recognized standards and best practices (e.g., those produced by WGISS[8] and Producer-Archive Interface Methodology Abstract Standard[9]) with any tailoring documented.
DPRES#4	Periodically perform archival system/media upgrade to the most adequate proven technology to ensure data and information long term preservation. Perform migration, with an integrity check, of archived data from old to new systems.
DPRES#5	Archive and preserve the information, code and software needed to handle the archived data, following the CEOS guidelines[10].

[6] https://ccsds.org/wp-content/uploads/gravity_forms/5-448e85c647331d9cbaf66c096458bdd5/2025/01/650x0m3.pdf

[7] https://ceos.org/ourwork/workinggroups/wgiss/documents/

[8] https://ceos.org/ourwork/workinggroups/wgiss/documents/

[9] https://public.ccsds.org/Pubs/651x0m1.pdf

[10] https://ceos.org/ourwork/workinggroups/wgiss/documents/

ID	Recommendations
DPRES#6	When performing archived data and information repackaging and/or reformatting, for example to comply with new standard formats and/or exchange formats, properly document changes made to the archived data and ensure data integrity.
DPRES#7	Periodically verify the integrity of the archive collection/content through integrity check on a representative set of the archived data.
DPRES#8	Manage evolution of archived data collections according to the Shared Collection Lifecycle Management Principles for EO Data[11] best practice.
DPRES#9	Keep archives equipment (hardware and software) up-to-date and in conformance with vendor recommendations to preserve data and associated information integrity and facilitate interoperability between archives.

Data and Metadata Architecture

This section covers the core recommendations for collection management functions including data production, management, packaging and documentation.

ID	Recommendations
DATA#1	CEOS-ARD Framework[12] should be used as a starting point for development of Analysis Ready Data.
DATA#2	CEOS-ARD Product Family Specifications (PFS) should be used for development and assessment of ARD products, including both self-assessments and peer review.
DATA#4	The ISO 19115[13] series of standards (or similar) should be used to produce geospatial metadata.
DATA#5	A Collection of data should have all granules packaged consistently and produced with consistent quality.
DATA#6	Collection-specific metadata formats may be used, but packaging should also include STAC documents at the Collection and Granule/Item level. Refer to the CEOS EO collection and granule discovery best practices with STAC[14].
DATA#7	Checksums for all files in a packaged granule should be available, to ensure integrity.
DATA#8	Where pixel-level metadata is available, such as scene quality masks, these should be clearly documented with a reference to lookup tables.
DATA#9	File names and folder or path structures should be consistent and include appropriate information to distinguish the specific granule. This could include the platform, time and date of acquisition, band(s), and product version.

[11] https://ceos.org/ourwork/workinggroups/wgiss/documents/
[12] https://ceos.org/ard
[13] https://www.iso.org/standard/53798.html
[14] https://github.com/ceos-org/stac-collection-and-granule-discovery-best-practices

ID	Recommendations
DATA#10	Assign a Persistent Identifier to data archived and published to users and ensure the availability of all associated information in the relevant Landing Page following the CEOS Persistent Identifiers Best Practice[15].
DATA#11	The CEOS supported Open Data Cube[16] family of software can be taken as a reference Datacube implementation.

Publishing Architecture

Publishing recommendations involve the final stage in making data accessible to external organizations or individuals. These recommendations are aimed at facilitating both access to data as well as maintaining a replica of part or all of a collection of data, including to be used when managing data for interoperability on the cloud.

ID	Recommendations
PUBLISH#1	Each data collection that is published as a publicly-accessible product should include a public granule-level notification including for when a granule is added, updated and deleted/archived. This supports management and maintenance of replicas collections.
PUBLISH#2	A collection should have a full listing of all available granules in a standard format, preferably cloud optimized. For example, STAC-geoparquet[17] is used by some providers.
PUBLISH#3	Granule data stored in the cloud should be accessible in cloud-optimized formats, e.g., Zarr[18] or Cloud-Optimized GeoTIFF (COG)[19].
PUBLISH#4	Granules should not be zipped when stored in the cloud, so that cloud optimized data formats can be leveraged.
PUBLISH#5	Where possible, cloud providers' standard interfaces should be used in preference to self-developed solutions, enabling interoperability of tools that work with that cloud provider.

[15] https://ceos.org/ourwork/workinggroups/wgiss/documents/
[16] https://opendatacube.org
[17] https://stac-utils.github.io/stac-geoparquet/latest/
[18] https://zarr.dev/
[19] https://cogeo.org/

Interface (Accessibility)

Interfaces allow diversified resources within and across the organization to seamlessly communicate, discover and exchange data. Interfaces are realized in the form of services and follow standards. Interfaces enable data users to have easy and efficient ways of discovering and accessing data and associated services through the exploitation of standard protocols and the harmonizing of search and data retrieval processes

Data Discovery

ID	Recommendations
DISC#1	Collection and granule discovery interfaces should comply with the CEOS STAC Collection and Granule Discovery Best Practices[20] (preferred) or CEOS OpenSearch Best Practices[21].
DISC#2	Service and tool discovery interfaces should comply with CEOS Service Discovery Best Practice[22].
DISC#3	Collection and granule metadata obtained via the discovery interfaces should advertise the existence of the corresponding file-level online data access and subfile or pixel-based access services and endpoints (e.g., OGC WCS, WMTS, WCPS, OGC API Maps, OGC API Tiles, etc.).
DISC#4	Granule metadata obtained via the discovery interfaces should include the online data access URL to the granule (in full resolution) and to a low resolution representation (i.e., quicklook or thumbnail). The low resolution representation should be provided in Web-friendly format, e.g. JPEG or PNG, and may be a static file or an OGC WMS/WMTS or API Maps/Tiles response.
DISC#5	Discovery interfaces should be accessible and return responses without requiring authentication.
DISC#6	Collection and granule metadata obtained via the discovery interfaces should advertise the existence of the corresponding authentication endpoint for human and machine access to the data (if required).
DISC#7	Resource metadata including keywords should link each keyword to its URI and to the appropriate thesaurus (i.e., controlled vocabularies).
DISC#8	Resource metadata should contain the persistent identifier (e.g., DOI) of the corresponding resource.
DISC#9	Collection metadata should refer to the level of maturity with respect to the WGISS Data Management and Stewardship Maturity Matrix[23].

[20] https://github.com/ceos-org/stac-collection-and-granule-discovery-best-practices/tree/v1.0.0

[21] https://ceos.org/document_management/Working_Groups/WGISS/Documents/WGISS%20Best%20Practices/CEOS%20OpenSearch%20Best%20Practice.pdf

[22] https://ceos.org/document_management/Working_Groups/WGISS/Documents/WGISS%20Best%20Practices/CEOS-Service-Discovery-Best-Practices_V1.1.pdf

[23] https://ceos.org/document_management/Working_Groups/WGISS/Interest_Groups/Data_Stewardship/White_Papers/WGISS%20Data%20Management%20and%20Stewardship%20Maturity%20Matrix.pdf

ID	Recommendations
DISC#10	For facilitating discovery and access, data shall be organized in collections according to the principles outlined in the Shared Collection Lifecycle Management Principles for Earth Observation Data[24].

Data Access

ID	Recommendations
DACC#1	Granule data stored in the cloud should be accessible directly via a web-based protocol, for example the S3 (Simple Storage Service) and HTTP(S).
DACC#2	Data access should support file-level access and subfile or pixel-based access. Data download interfaces over HTTPS should support "Range Requests" to allow clients to request a portion of a file. Typical use case: access to a portion of a Cloud-Optimized GeoTIFF (COG)[25] file.
DACC#3	In case a granule consists of many individual assets (files), it shall be possible to access each asset individually and it is recommended to provide access to all sub-components of a granule with a single request.

Authentication and Authorization

ID	Recommendations
AUTH#1	Authorization should be available at a file level for both human and machine-to-machine access.
AUTH#2	Authentication interfaces should comply with open standards, such as the OpenID Connect[26] protocol.
AUTH#3	HTTPS requests for data access that require authorization will support well known methods for both human and machine-to-machine interface, such as those specified in the OpenAPI 3.0[27].

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[24] https://ceos.org/document_management/Working_Groups/WGISS/Documents/Shared%20Collection%20Lifecycle%20Management%20Principles%20for%20Earth%20Observation%20Data_March2025.pdf

[25] https://cogeo.org/

[26] https://openid.net/developers/how-connect-works/

[27] https://swagger.io/docs/specification/v3_0/authentication/

Quality

Quality informs users of the trustworthiness of Earth observation data and products. Multiple Calibration and Validation (Cal/Val) groups/venues exist as forums for the exchange of information about understanding, expressing, and improving data quality, along with influencing the interoperability between multiple datasets and products.

Calibration and Validation

Calibration is the process of quantitatively defining a system's response to known and controlled signal inputs. Validation, on the other hand, is the process of assessing, by independent means, the quality of the data products derived from those system outputs.

Cal/Val Recommendations

ID	Recommendations
CALVAL#1	Data providers should engage and participate in community calibration/validation groups, such as CEOS WGCV[28] (and its subgroups), WMO GSICS[29], JACIE[30] and VH-RODA[31].
CALVAL#2	The Measurand and Uncertainty to a reference (ideally SI traceable) of stated values should be included within all products, as they are key to communicating and understanding data quality.
CALVAL#3	All products should have associated quality indicators, to allow users to assess usability of the data for their applications.
CALVAL#4	Post-launch, Level-1 products should be calibrated/validated using reference measurements, such as CEOS Fiducial Reference Measurements (CEOS-FRM)[32].
CALVAL#5	Community endorsed Cal/Val sites and reference network should be used for satellite cross-comparison, such as CEOS Cal/Val sites[33], RadCalNet[34] and/or SARCalNet[35] .
CALVAL#6	The Quality Assurance Framework for Earth Observation QA4EO[36] developed by The Group on Earth Observations (GEO) and endorsed by CEOS should be followed to enable interoperability and quality assessment of Earth Observation data.

[28] https://ceos.org/ourwork/workinggroups/wgcv/
[29] https://gsics.wmo.int/site/global-space-based-inter-calibration-system-gsics
[30] https://www.usgs.gov/calval/jacie
[31] https://earth.esa.int/eogateway/events/vh-roda
[32] https://calvalportal.ceos.org/web/guest/frms-assessment-framework
[33] https://calvalportal.ceos.org/web/guest/calvalsites
[34] https://www.radcalnet.org
[35] https://www.sarcalnet.org/
[36] https://qa4eo.org/

ID	Recommendations
CALVAL#7	The ESA/NASA/USGS Mission Quality Assessment Framework[37] should be used for reporting metrics related to quality.
CALVAL#8	The Joint Agency Commercial Imagery Evaluation (JACIE) Best Practices document[38] should be used as the guideline for performing standard calibration and validation activities.
CALVAL#9	CEOS CAL/VAL portal[39] should be used as the reference site for accessing community agreed good practices and CAL/VAL protocols for interoperability for Earth observation calibration and validation activities.

[37] https://earth.esa.int/eogateway/activities/edap

[38] https://doi.org/10.3133/ofr20241023

[39] https://calvalportal.ceos.org/

Policy

Policy is a statement of intent, which provides guidance for implementation of processes and procedures in an organization. Policies can be at organization/local level or at the government/center level and may have legal bindings. The government level policies take precedence over the organization policies. Institutional mechanism is required to ensure compliance of policies in an organization. The policies are the guiding document for decision making processes in an organization.

Policy is one of the most important factors and forms the basis of interoperability. Following are interoperability recommendations for the policy factor.

ID	Recommendations
POL#1	Data providers should participate and engage in relevant community groups/events, such as CEOS, GEO and CGMS, and their respective working groups. Interoperability requires collaboration and coordination between all actors within the sector.
POL#2	Identify policies in your organization/country related to data and services and conduct periodic check/audit for compliance to these policies. Identify policies which may be barriers to interoperability of data and services and flag them for resolution. Ensure the policies are clearly communicated to stakeholders.
POL#3	**EO Capabilities:** Publish and periodically update information about present and planned Earth observation Satellites in online databases, preferably the CEOS MIM Database[40]. This will help in planning and overall coordination among different EO stakeholders.
POL#4	**Open Standards and Specifications:** Ensure your organizations implement open standards and specifications such as those published by the Open Geospatial Consortium (OGC)[41] for data and services. Drafting of new specifications for data formats, metadata formats and service APIs should be preferably done along with standards organizations, or developed by the open source community.
POL#5	**Open Data:** Organizations should ensure that Earth observation data is discoverable, accessible and proactively made available for use, reuse and redistribution to users in human and machine readable form, under an open license (see **POL#8**).
POL#6	**Open Source Software:** Where possible, share software applications as open source software, enabling others to use the same tools as are used internally to process or transform data products or to demonstrate the use of standards to access your data and services. An example of a preferred license is Apache 2.0.
POL#7	**Open Science:** Open Science policies should be implemented to ensure open access to data, software, and research publications, thereby facilitating collaboration, transparency, and reproducibility in support of interoperability.

[40]https://ceos.org/mim-database
[41]https://www.ogc.org/standards/

ID	Recommendations
POL#8	**Data Licensing:** Organizations sharing open and unrestricted data should license the data using an open license, consistent with their organization's policy. A Custom license can restrict access for users. The GEO data licensing Guidance[42] can be referenced for examples, including Creative Commons Zero 1.0 Universal Public Domain Dedication (CCo), Open Data Commons Public Domain Dedication and License (PDDL) v1.0, or Creative Commons Attribution 4.0 International (CC BY 4.0). CC BY 4.0 is preferred.
POL#9	**Data Procurement from third party:** Organizations planning to procure/outsource Earth Observation data, to possible extent should ensure that the data complies with CEOS recommendations, including those outlined in this handbook.
POL#10	**Data preservation:** Organizations should ensure that Earth observation data is archived and preserved according to CEOS best practices[43].
POL#11	**Purge Alert:** Organizations should use the purge alert service[44] provided by CEOS WGISS before data and information removal from archives.
POL#12	Follow the FAIR[45] (findable, accessible, interoperable, and reusable) principles to ensure data and metadata interoperability

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[42] https://gkhub.earthobservations.org/packages/p0zg8-02b56
[43] https://ceos.org/ourwork/workinggroups/wgiss/documents/
[44] https://ceos.org/ourwork/workinggroups/wgiss/preservation/data-purge-alert/
[45] https://www.go-fair.org/fair-principles/

Conclusions

The Interoperability Handbook Version 2.0 introduces a five-factor Interoperability Framework that replaces the protocol-centric structure of the Version 1.0:

Vocabulary (Semantics) The new edition emphasizes harmonized, version-controlled vocabularies developed collaboratively across the EO community. It promotes open thesauri, Linked Data principles, and GitHub-based governance. This builds on the 2008 recommendation to use shared glossaries and controlled keywords but adds mechanisms for transparency, participation, and traceability.

Architecture The architecture component is now divided into three layers: Preservation, Data & Metadata, and Publishing. It reaffirms OAIS compliance but expands to include lifecycle management, persistent identifiers, and cloud-optimized formats like STAC, COG, and Zarr. The Version 1.0 focused more narrowly on archiving technologies and metadata formats like DIF and ISO 19115.

Interface (Accessibility) The version 2.0 modernizes data discovery and access by recommending STAC, OpenSearch, and OGC APIs. It discourages zipped data in cloud environments and promotes direct access via HTTP(S), S3, and byte-range requests. In contrast, the 2008 edition emphasized FTP, OpenDAP, and Z39.50, which are now considered legacy or limited in scalability.

Quality Quality assurance is expanded through integration with CEOS WGCV, QA4EO, and traceable uncertainty metrics. The Version 1.0 recommends using CEOS-FRM, RadCalNet, and SARCalNet for calibration and validation. The Version 1.0 introduced Cal/Val concepts but lacked the infrastructure and community maturity now available.

Policy The policy section now includes open data licensing (e.g., CC BY 4.0), open-source software practices, and open science principles. It encourages alignment with GEO data sharing guidelines and the FAIR principles. The 2008 edition focused more on data exchange principles and metadata compliance, without addressing licensing or reproducibility.

Future Scope

The CEOS Interoperability Handbook Version 2.0 reflects a strategic shift from protocol-level interoperability to ecosystem-level interoperability. It recognizes that modern EO systems must support distributed, cloud-native, and user-driven architectures. The emphasis is on enabling seamless integration across agencies, platforms, and applications—rather than simply connecting catalogs or services.

The new version of the handbook is both a continuation and a transformation. It honors the legacy of the previous version by preserving its core principles—such as openness, standardization, and collaboration—while equipping the EO community with the tools and frameworks needed for the next generation of data systems.

Interoperability Maturity Matrix will be developed using the recommendations provided in this handbook. The Maturity Matrix will help users to measure the maturity of Interoperability of data and services in their organizations and will also allow them to monitor the interoperability implementation with time.

Interoperability Demonstrators will also be developed using the Interoperability Handbook. These demonstrators will help the end users to understand the barriers in implementing the interoperability and will act as use-cases for Interoperability.

Document source

This document is managed in the CEOS Interoperability Handbook GitHub repository[46].

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[46] https://github.com/ceos-org/interoperability-handbook
[47] https://creativecommons.org/licenses/by/4.0/