A Long Term Preservation Framework For Earth Observation Space Data

LTDP Guidelines

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LTDP Guidelines

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Issue no: Version 2.0

Date of issue: 03 May 2013

CHANGE LOG

Reason for change	Issue	Date
New document	Issue 1.0	30 September 2010
Better alignment with OAIS standard and ISO Certification RAC Metrics.	Issue 2.0	03 May 2013

CHANGE RECORD

Issue 1.0

Reason for change	page(s)	Paragraph(s)
New document	All	All

Issue 2.0

Reason for change	page(s)	Paragraph(s)
Update Document, better alignment with OAIS standard and ISO Certification RAC Metrics.	All	All

Table of Contents

1. INTRODUCTION

1.1 Long Term Data Preservation – the issue

The GEOSS community represents a wide variety of disciplines, which utilise a multitude of different Earth Observation (EO) data and products. Timescales of needed data and products can be totally different depending on the specific application and Societal Benefit Area. Monitoring of global change processes for example has lead to increasing demand for long-term time series of Earth Observation data spanning 20 years, or more. These data are necessary to support international activities such as the United Nations Framework Convention on Climate Change (UNFCCC).

EO data truly represents an information base of lasting value. No other resource provides as much repetitive continuous, regional, national, and global and synoptic data from a single source. EO data are a reliable and unbiased source of information that constitute a baseline chronology of change, both natural and anthropogenic, that make it truly invaluable for scientific assessment and prediction for the benefit of the world. Further, content of EO space data archives is extending from a few years to decades and their scientific value is continuously increasing.

The need is well recognized to preserve the archived EO data without time limitation and to keep them well accessible and exploitable as they constitute a comprehensive, historical, permanent, and impartial record of the Earth's behavior and change. To preserve these digital assets is the aim of digital long-term preservation.

Information technology is changing rapidly and this change also affects digital data from Earth Observation missions. Because of this rapid technological change, the long-term preservation of digital assets has to deal with specific risks and challenges. Among these risks are the corruption of the bit-stream, obsolescence of the file format, extant hardware and operating environments that make data unreadable on the physical and logical level but also insufficient documentation of data, the inability to discover data, or service compatibility can prevent their re-use. In addition to direct damage, data can also become damaged or destroyed by indirect actions, such as a breach of security of the data centre or physical damage of its structure by accidents or natural hazards. Besides the risks mentioned above, not all challenges to the long-term preservation of digital assets are technical in nature. Risks may also arise from organisational issues such as insufficient financial or human resources.

Long term data preservation includes the consolidation and technical evolution of archives to the technology supported in the market, including both archive management systems and data access systems to guarantee the basic data preservation and proper data accessibility. Beyond and even more importantly, archived data can be used only if the processing chains, the algorithms and the data access technology are maintained and evolve such that users can actually receive and process the data products with up to date technology. Archive management includes the long-term management, preservation, and upgrading of EO data; and ensuring for timely ready access to all parties requesting data, as well data security and interoperability across archives.

The large amount of new Earth Observation missions upcoming in the next years will moreover lead to a major increase of EO data volumes. This fact, together with the increased demands from the scientific user community, marks a challenge for Earth Observation space data owners and archive holders regarding coherent data preservation and optimum availability and accessibility of the different data products. Cooperation, sharing and identification of commonalities are key aspects to be pursued for the benefit of the user community and for costs and efforts optimisation.

1.2 Background

The Group on Earth Observation (GEO) identified the need "to develop a GEO strategy based on a set of guidelines for the preservation of EO data in the long term, starting with space-based observations and possibly evaluating its applicability also to in-situ observations and other EO derived products, taking into account existing work in the area". Such a strategy and a cooperative and harmonised collective approach in the field of Long Term Data Preservation are needed to guarantee the preservation and access in the long term of EO data available in GEOSS for the benefit of its users while at the same time reducing the overall costs of data preservation. Reduction of operation costs will also reduce the risk that old archived data are discarded by commercial operators because the reduced commercial interest may in some cases not justify the effort to further archive these data. The strategy should be based on a set of LTDP guidelines recommended for application by Earth Observation space data owners and archive holders to guarantee the preservation of the owned archived data.

The European Space Agency (ESA), active since some years in cooperation activities in the LTDP field with the involvement of several space agencies and EO space data owners in Europe (see R.1 and R.2) under the supervision of the Ground Segment Coordination Body (GSCB, R.3), proposed in 2009 a task named "Long Term Preservation of Earth Observation Data" (DA-09-01c) for inclusion in the GEO 2009-2011 work-plan and took its lead, in partnership with other European Space Agencies and the United States Geological Survey (USGS), to carry out the activities starting from EO space data. LTDP activities are now included in the GEO 2012-2015 work-plan [R.4] under Component C1 - Advances in Life-cycle Data within Task IN-02 "Earth Data Sets". By taking a generic approach and building on existing work in the area, these organizations intend to encompass the needs of the wider GEO community in a single LTDP framework.

1.3 LTDP Guidelines scope and purpose

The LTDP Guidelines contained in this document are intended to cover the planning and implementation steps of the preservation workflow described in the following sections and have been defined on the basis of a high-level risk assessment performed on the Preserved Data Set Content [R.5], defined by the GSCB/LTDP WG, and its composing elements.

The LTDP guidelines and the underlying data preservation approach should be applied not only to future missions, where they can be easily and systematically included in the mission operations concept starting from the early phases with consequent cost savings and better achievable results, but also to the missions currently in operation or already disposed. In those last cases their application and the recovery of the full EO PDSC content could be trickier and not completely achievable and tailoring might be necessary. For current and not operational missions in any case, an incremental application approach should be pursued; the approach should consist in auditing the archives versus the LTDP Guidelines and PDSC document to be followed by the implementation of the highest priority guidelines (according to the levels defined in the next section) and by the recovery of critical missing data/information. Details on the LTDP guidelines assumptions and application are provided in the following Sections.

In the field of Earth Observation, the data landscape is complex and there will naturally be different user communities with divergent needs for the long-term reuse of the data. In case a more specific designated user community has to be addressed wrt the one defined in Section 1.4, more specific preservation objectives and PDSC composition should be defined and the LTDP Guidelines contained in this document might need to be refined and augmented accordingly. In those cases it is recommended to follow the steps identified in Section 1.4 using the PDSC document and the LTDP guidelines as starting point for the definition of a more specific approach to be properly documented in the form of "preservation approach and strategy" documents.

1.4 Preservation analysis workflow

Preservation of Earth Observation data should rely on a set of preservation actions properly planned and documented by data holders and archive owners, and applied to the data themselves and to all the associated information necessary to make those data understandable and usable by the identified user community. Data holders and archive owners should follow the "Preservation Analysis Workflow" procedure described in Annex 1 to define the proper preservation strategy and actions for their Earth Observation data collections. The result of the procedure application should consist of a set of documents[1] describing the preservation strategy, implementation plan and activities for each individual mission dataset. Such document(s) should refer to the LTDP guidelines and clearly define current compliance and future plans to improve adherence. The procedure consists of the following steps:

- Definition of preservation objective and designated user communities
- Definition of Preserved Data Set Content (PDSC) for Earth Observation missions
- Creation of PDSC Inventory for each EO mission/instrument dataset
- Risk assessment, preservation planning and actions, risk monitoring

These steps are applicable to any digital data repository and are shortly described below for a generic Earth Observation case:

1. The preservation objective considered here for an Earth Observation data holder and archive owner consists in maintaining the full data holdings accessible and usable today and in future, theoretically for an unlimited time, for its designated user communities. Long-term accessibility and usability of Earth Observation data requires that not only sensed data but also the associated knowledge (e.g. technical and scientific documentation, algorithms, data handling procedures, etc) is properly preserved and maintained accessible. This implies the availability and archiving of metadata and data products at all levels specified by each mission or the capability to generate them on user request through proper processing. Data products need moreover to be provided with known quality to end-users together with the information necessary to understand and use them.

   Different designated user communities are addressed through the preservation objective defined above. Earth Observation data users are today, as an example and among others, Scientists and Principal Investigators, researchers, commercial entities, value adders, and general public. These communities can be further differentiated on the basis of the respective application domain and area of interest (e.g. ocean, atmosphere) and generally have different skills, resources and knowledge. The data product levels and the information associated to the data necessary for their understandability and use is different for each of the above communities and even for individuals inside each community. Earth Observation data holders and archive owners generally serve today more than one user community and therefore need to be able to address the needs of all of them in terms of data and associated information availability and access. In addition, the preservation objective includes the utilization of the data products also in the future by user communities that might have completely different skills and knowledge base wrt the ones identified today but also different objectives for the use of the data. This means that the best approach for Earth Observation data holders and archive owners today would be to consider a "designated user community" generic and large enough so that the identified content to be preserved in the long term for that community will allow also other users, not considered at the time preservation was initiated, to make use of the data

[1] Single documents could address multiple datasets in case of commonalities.

in the future. The generic designated user community is assumed to be able to understand English, to work with personal computers and basic programs provided with them, and to analyse and interpret the data products when available together with the full amount of additional information (see point 2 below) necessary to understand them without additional support from the archive.

2. In Earth Observation, the "Preserved Data Set Content" should be comprised as a minimum, in addition to the EO data, of all information which permit the designated user community to successfully interact, understand and use the EO data as mandated by the preservation objective. The "Earth Observation Preserved Data Set Content" [R.5] has been defined on the basis of the preservation objective and generic designated user community defined above and is summarised in Section 2.
3. For past and current missions, the next stage to be implemented by data holders and archive owners is to tailor the "Preserved Data Set Content" for each EO mission/instrument, and to appraise each of the resulting elements comprised in the preserved data set content in terms of physical state, location and ownership. The result is the mission/instrument inventory document. For future missions, the definition of the "Preserved Data Set Content" shall be initiated during the mission definition and implementation phases and continuously maintained in the following phases.
4. Risk assessment in terms of capability of preservation and accessibility for each element of the inventory should be then performed and the most appropriate preservation actions identified and planned for implementation. The result of this activity should consist of one or more "preservation strategy and approach" documents. These documents could be drafted with different levels of detail and should generally contain Preservation Networks for each EO mission data collection consisting of all the PDSC Inventory elements, the elements on which they are dependent or necessary to understand and use them (e.g. the operating system underlying an EO data processor) and the associated preservation actions identified for each of them. Preservation networks should also identify the preservation state of each element of the PDSC inventory as described in Annex 1. Such document(s) should refer to the LTDP guidelines and clearly define current compliance and future plans to improve adherence. The identified preservation actions should be then implemented and the risks associated with inventory elements preservation properly and continuously monitored.

1.5 LTDP Guidelines Content

The scope of Long Term Data Preservation as intended in the LTDP Guidelines is not limited to the preservation of the data in the archives but includes also the capability to generate mission products (Dissemination Information Packages) from the archived data and to make them accessible to users. Consequently "Long Term Data Preservation" includes not only archiving but also access and usability aspects of the EO space mission data. The LTDP guidelines are not intended to cover programmatic and regulatory aspects (e.g. LTDP organisation, availability of LTDP dedicated programmes or budgets within organisations) or data policy aspects associated with EO data to be preserved through the application of the guidelines.

The document addresses eight main LTDP "themes" consisting of "guiding principles" and a set of "key guidelines" that should be applied to guarantee the preservation of EO space data in the long term ensuring also accessibility and usability. The eight themes are the following:

1. Preserved data set content definition and appraisal
2. Archive operations and organization
3. Archive security

4. Data ingestion
5. Archive maintenance
6. Data access and interoperability
7. Data exploitation and re-processing
8. Data purge prevention

The LTDP guidelines defined in this document constitute a basic reference for the long term preservation of EO data. Their application by Earth Observation space data holders and archive owners is fundamental in order to preserve EO space data. The application of the identified guidelines is not a requirement or a must but is strongly recommended along with following a step-wise approach starting with a partial adherence. To this end different levels of adherence (Levels A, B, and C) have been assigned to each key guideline in this document (See Table 1 and Annex 2).

Level A has been defined as the entry level and, accordingly, Level A key guidelines should be the first ones to be addressed and implemented in order to guarantee a basic level of security, integrity, and accessibility of the archived data.

Adherence Level	Description	Condition for adherence
Level A	Basic data security, integrity and access.	Implementation of all high priority key guidelines.
Level B	Medium data security, integrity, access and interoperability.	Implementation of all high and medium priority key guidelines.
Level C	High level of data security, integrity, access and interoperability.	Implementation of all key guidelines.

Table 1 – Levels of adherence to the LTDP Guidelines

The implementation of all the Level A key guidelines corresponds to a level of adherence to the LTDP Guidelines as a whole equal to Level A. The implementation of all Level A and Level B key guidelines correspond to a level of adherence equal to Level B whilst the implementation of all the key guidelines (Level A, B and C) corresponds to a level of adherence equal to Level C. The levels of adherence can also be utilized to follow a step-wise approach for the implementation of the key guidelines starting from the basic ones to reach full adherence in the long term.

A comparative analysis carried out between the LTDP Guidelines and the "Audit and Certification of trustworthy digital repositories" CCSDS recommended practice also referred as "RAC metrics" and now available as ISO standard [R.6] has shown a full compatibility between the two approaches. The RAC metrics are an audit and certification method that tests the trustworthiness of all types of digital repositories. The LTDP guidelines are on the other hand a set of practical recommendations specifically addressing Earth Observation data archives and covering in most of the cases the RAC metrics. Due to the fact that the LTDP Guidelines are not addressing on purpose financial, policy and legal/organizational aspects of Earth Observation archives, a full matching with the RAC metrics is not achieved as shown in Table 2. From the

table it can be derived that an Earth Observation archive adhering to the LTDP guidelines at Level A, B or C is also automatically satisfying the RAC metrics respectively at 32%, 60% and 72% where the not covered part is mostly dealing with financial/legal and contractual aspects. This means that adherence to the LTDP Guidelines for Earth Observation data holders and archive owners can also be intended as a first step towards the certification of their digital repositories according to the ISO 16363 standard [R.6]. Results of the more detailed comparative analysis between the LTDP guidelines and the RAC metrics are given in Annex 6.

Adherence Level to LTDP Guidelines	Coverage of RAC metrics %
Level A	**32 %**
Level B	**60 %**
Level C	**72 %**

Table 2 – Matching between adherence to LTDP Guidelines and RAC metrics

The key guidelines should be intended as a living practice and as such might evolve following specific research and development activities (e.g. outcome of cooperation in LTDP in the framework of GEO workplan tasks). Each key guideline could also have associated a set of technical procedures, methodologies or standards providing technical details on the recommended practical implementation of the guideline. These standards, methodologies and procedures are contained in an outlined box below the associated key guideline. Their selection has been made considering the results of cooperation activities in the framework of GEO workplan tasks and the outcomes of the Standards and Interoperability Forum (SIF) activities with the goal to favour convergence in GEOSS on the LTDP approach and implementation.

Similarly to the key guidelines, these procedures or standards could be further evolved and improved with time or even developed or defined if missing. The document can therefore also be intended as a starting point to support the establishment, and aid the implementation, of such detailed procedures or methodologies when missing, favouring active cooperation in GEOSS in the LTDP field. In such a case this document provides the overall LTDP principles and key guidelines considered necessary to initiate this process and enable more detailed, specific and technical guidelines to be established by appropriate technical experts. The LTDP Guidelines document will be updated in case of need to reflect the advances of activities carried out in the LTDP area.

It is hoped that the endorsement and encouragement of use of such guidelines and methodologies will lead to the set-up of a GEOSS LTDP Framework to coordinate and optimize efforts in the LTDP field and will ultimately result in the preservation of all the data available to GEOSS with a coherent and homogeneous approach for the benefit of all GEOSS users in the different social benefit areas. Funding organisations that oversee the development and execution of EO programs are responsible for implementing the LTDP Guidelines for the preservation of data products for their sphere of influence. A dedicated LTDP secretariat serves as a point of contact for LTDP activities (secretariat.ltdp@esa.int).

1.6 Acronyms used in LTDP Guidelines

Acronym	Description
AIP	Archival Information Package
CAL/VAL	Calibration and Validation
CCSDS	Consultative Committee for Space Data Systems
CEOS	Committee on Earth Observation Satellites
CSW	Catalogue Services for the Web
DIP	Dissemination Information Package
EO	Earth Observation
EROS	Earth Resources Observation and Science
ESA	European Space Agency
HMA	Heterogeneous Mission Accessibility project
GML	Geography Markup Language
GSCB	Ground Segment Coordination Body
ISO	International Organization for Standardization
LTDP	Long Term Data Preservation
OAIS	Open Archival Information System
OGC	Open Geospatial Consortium
PAIMAS	Producer Archive Interface Methodology Abstract Standard
PAIS	Producer Archive Interface Specification
SAR	Synthetic Aperture Radar
SIP	Submission Information Package
SW	Software
TBC	To Be Confirmed
TBD	To Be Defined
UNFCCC	United Nations Framework Convention on Climate Change
USGS	U.S. Geological Survey
WGISS	Working Group on Information Systems and Services

Table 3 - Acronyms

The Glossary of the terms used in the current document and their relation with the corresponding OAIS terms is reported in Annex 4.

1.7 References

R. 1 LTDP Workshop 2008, http://earth.esa.int/gscb/ltdp/LTDP_Agenda.html

R. 2 LTDP Workshop 2011, http://earth.esa.int/gscb/ltdp/presentations-workshop2011.html

R. 3 GSCB website, http://earth.esa.int/gscb

R. 4 http://www.earthobservations.org/

R. 5 "Earth Observation Preserved Data Set Content (PDSC)", LTDP-GSEG-EOPGRD-11-0003 VERSION 4.0, http://earth.esa.int/gscb/ltdp/

R. 6 Recommendation for Space Data System Practices, Audit and Certification of trustworthy digital repositories, Recommended practice, Magenta book CCSDS 652.0-M-1. ISO 16363 - Space data and information transfer systems -- Audit and certification of trustworthy digital repositories.

R. 7 ISO 14721 - OAIS standard (ISO reference model for Open Archival Information System) Pink Book, Consultative Committee for Space Data Systems, Greenbelt, MD. August 2009.

R. 8 Quality Assurance Framework for Earth Observation (QA4EO) http://qa4eo.org/index.html

R. 9 Producer Archive Interface Specification (PAIS): CCSDS 651.1-R-1 http://cwe.ccsds.org/moims/docs/MOIMSDAI/Draft%20Documents/651x1r0[pre-CESG Poll-jgg-20111223

R. 10 ISO 20652: Space Data and Information Transfer Systems -- Producer Archive Interface - Methodology Abstract Standard (PAIMAS). Also CCSDS 651.0-M-1.

R. 11 Heterogeneous Mission Accessibility (HMA) specifications and Cookbook Version 0.9.9.7, 02 February 2012): http://wiki.services.eoportal.org/tikiindex.php?page=HMA%20Wiki

2. THEME 1: PRESERVED DATA SET CONTENT DEFINITION AND APPRAISAL

Definition

The "preserved data set content" defines a consistent and complete set of data and information enabling current and possible future understanding and utilization of the preserved data by the designated user community. Therefore the goal is to preserve and make accessible this complete dataset including information required to determine a "Quality Indicator" as required by [R.8]. The relations to rules and standards which can be applied to the "preserved data set content" are being considered in the guidelines related to this theme.

Guiding Principle

All elements necessary to access, use, understand, and process EO mission data, and the associated Quality Indicators are to be preserved and made accessible to the user. Products to be delivered to users, in the form of Dissemination Information Packages (DIPs), shall contain all these elements or at least information on how additional elements, not contained in the DIP, can be accessed.

Key Guidelines

GUIDELINE 1.1 – Preserved Data Set Content - (Level A)

Identify and archive the following set of data content for each Earth Observation space mission or instrument[2] according to the "Earth Observation Preserved Data Set Content" document [R.5]:

a) Data Records: these include Raw data[3], Level 0 data and higher-level products[4], browses, auxiliary and ancillary data, calibration and validation data sets[5], and metadata.

b) Processing Software: this includes all the software used in the product generation, quality control, and the product visualization and value adding tools.

c) Mission Documentation[6]: this includes among others mission architecture, products specifications, instruments characteristics, algorithms description, calibration and validation procedures, mission/instruments performances reports, quality related information [R.8], etc.

- ✓ Earth Observation Preserved Data Set Content [R.5]
- ✓ Quality Assurance Framework for Earth Observation (QA4EO) [R.8]

GUIDELINE 1.2 – Preserved data set inventory - (Level A)

[2] Identification and archiving of all this information will probably not be achievable for old missions. A tailoring between what is required and what is available or generated for a mission (past, current and future) will be in any case necessary.
[3] Raw data shall be preserved whenever conversion to Level 0 can not be adequately certified.
[4] When systematically generated as part of the mission requirements and/or reprocessed.
[5] Including processing/reference validation data sets.
[6] Mission Documentation shall include Representation Information, Packaging Information and Preservation Descriptive Information according to OAIS information model [R.7] .

Generate and maintain a complete inventory of the archived Preserved Data Set Content defined for each mission/instrument with the following items as a minimum:

- ✓ Description and availability of the data records, processing software and mission documentation (specifying all elements identified in guideline 1.1).
- ✓ Time span and volumes of the data records.
- ✓ Physical locations of the data records and provenance information.
- ✓ Media of storage and archive formats.
- ✓ Processing Software (if maintained or simply archived) information: versioning, IPR/licenses, etc.
- ✓ Mission Related Documentation: versioning, repository, etc.

GUIDELINE 1.3 - Bi-directional linkages - (Level B)

Create bi-directional physical linkages between archived Data Records and the associated Mission Documentation and Processing Software necessary to understand and use it.

GUIDELINE 1.4 - Preserved data elements - (Level B)

Assess and harmonize the format of all the "preserved data set content" elements (see Guideline 1.1) with the archive's standards in order to make the adopted formats understandable and sustainable.

- ✓ PAIS (Producer Archive Interface Specification): implementing PAIMAS standard (in the process of becoming a CCSDS Red Book), **[R.9]**

GUIDELINE 1.5 – Archived data records format - (Level B)

Adopt a common standard archive format for data records.

List of recommended archive formats:
- ✓ SAFE – Standard Archive Format for Europe (http://earth.esa.int/SAFE/index.html)
- ✓ Others TBD

GUIDELINE 1.6 – Archived data records exchange format – (Level B)

Adopt a common standard format for the exchange of archived data.

- ✓ Archived data exchange format: TBD

GUIDELINE 1.7 – Mission Documentation format - (Level B)

Adopt a common Mission Documentation standard format suitable for long-term preservation.

List of recommended formats:
- ✓ PDF/A
- ✓ Others TBD

GUIDELINE 1.8 – Data appraisal procedure - (Level A)

Perform a "Data Appraisal" to assess and document the value and prospects of each Preserved Data Record.

✓ Data Appraisal Procedure: Annex 3 to the LTDP Guidelines.

3. THEME 2: ARCHIVE OPERATION AND ORGANIZATION

Definition

Archives operations consist of all daily activities which are carried out to run and monitor the archive system (execution and control of the applications, system monitoring, anomaly reporting, error recovery, activity reporting and statistics, etc). An organizational structure is appropriate and needed to meet the goals and perform the tasks and processes of the digital long-term archives.

Guiding Principle

Archives automation should be pursued at the maximum extent and operations should be performed by trained personnel following consolidated operational procedures.

Key Guidelines

GUIDELINE 2.1 – Reference model for archive operation - (Level A)

Adopt a common standard reference model for the archives.

- ✓ ISO 14721 - OAIS standard (ISO reference model for Open Archival Information System) [R.7].

GUIDELINE 2.2 – Operations procedures - (Level A)

Perform archive operations following a set of approved and consolidated documented operational procedures.

GUIDELINE 2.3 – Archives equipment maintenance - (Level A)

Keep archives equipment in conformance with manufacturer recommendations.

GUIDELINE 2.4 – Archives automation - (Level A)

Implement automation of the archives (e.g. utilizing automatic robot libraries and software to ensure homogeneous tasks performances) to minimize the number of operations requiring operators' intervention.

GUIDELINE 2.5 – Archives organisation - (Level A)

Establish an appropriate archive organisational structure based on a sufficient number of qualified staffs with clear roles and responsibilities. Archive operation is governed through the organisational structure that oversees the planning and operation of preservation tasks.

GUIDELINE 2.6 – Archives Legal and Contractual aspects (Level B)

Legal aspects and contractual rules related to data ingestion, archive operations and data access and dissemination should be in place.

GUIDELINE 2.7 – Archive configuration management - (Level A)

Maintain under configuration control the archived Data Records, Mission Documentation and Processing Software including their internal dependencies and linkages.

GUIDELINE 2.8 – Archive AIPs identifiers - (Level A)

Define and use a convention that generates unique identifiers for Archive Information Packages (AIPs).

GUIDELINE 2.9 – Archive AIPs persistent identifiers - (Level C)

Define and use a convention that generates unique **persistent** identifiers for Archive Information Packages (AIPs).

GUIDELINE 2.10 - Archive preservation planning and actions - (Level A)

Generate and maintain one or more documents describing the adopted preservation strategy, planning and actions relevant to the archive holdings and clearly defining current compliance to the LTDP guidelines and future plans to improve adherence.

GUIDELINE 2.11 – Archive content monitoring - (Level C)

Put in place and maintain mechanisms for monitoring the understandability and usability of the archive content.

GUIDELINE 2.12 – System infrastructure risks - (Level A)

Identify and manage the risks associated with system infrastructure which could affect the preservation objectives (e.g. monitor end of life of technologies).

4. THEME 3: ARCHIVE SECURITY

Definition

This theme encompasses all the activities dedicated to the implementation of security measures for data access and storage in order to guarantee confidentiality, integrity and availability of the archived data.

Guiding Principle

Security of archived data should be guaranteed through the implementation of appropriate security measures in three main areas:

- ✓ Physical Security
- ✓ Information Security
- ✓ Staff Security

Key Guidelines

GUIDELINE 3.1 – Archives security requirements - (Level B)

Base archive security requirements on international standards and policies. The archive infrastructure should put into practice the specifications for handling the preserved data and content on the technology and security levels.

GUIDELINE 3.2 – Controlled access to archive facilities - (Level A)

Implement controlled access to facilities, sites and equipment to avoid physical intrusion by unauthorised persons. Allow access to core functions only to identified personnel provided with appropriate security clearances.

GUIDELINE 3.3 – Local risk mitigation infrastructure - (Level A)

Implement local risk mitigation infrastructure measures to safeguard the archives from external factors (e.g. floods, fire, disasters in general).

GUIDELINE 3.4 – Protection from external intrusion - (Level A)

Implement security mechanisms to avoid external intrusion that could harm core equipment functionalities and cause information loss.

GUIDELINE 3.5 – Information loss risk mitigation infrastructure - (Level A)

Implement measures to protect core equipment functionalities and mitigate against the risk of information loss as a consequence of internal unintentional or deliberate human actions, and of technical imperfection.

5. THEME 4: DATA INGESTION

Definition

Data Ingestion encompasses the services and functions that, according to OAIS standard [R.7] accept Submission Information Packages (SIPs) from data producers, prepare Archival Information Packages (AIPs) for storage, and ensure that Archival Information Packages and their supporting descriptive information are stored in the archive system.

Guiding Principle

Common methodology has to be adopted to properly plan preservation activities and to define the interfaces and metadata models between the data producers and the archives in order to propose a predictive and reusable approach in the Data Ingestion activity.
Standardization of Archival Information Packages has to be considered in order to improve the coherency and the compatibility of the data sets stored in the archive systems and to facilitate the exchange of data.

Key Guidelines

GUIDELINE 4.1 – Data ingestion process - (Level A)

Carry out data ingestion according to relevant standards with adequate tailoring and definition derived from the generic activities described in the standards.

- ✓ ISO 20652 - PAIMAS Standard (Producer Archive Interface Methodology Abstract Standard), [R.10]
- ✓ PAIS (Producer Archive Interface Specification): implementing PAIMAS standard (in the process of becoming a CCSDS Red Book) **[R.9]**

GUIDELINE 4.2 – Metadata generation - (Level A)

Define a descriptive set of metadata for archived data and generate them as part of the ingest process or when archived data content is updated. The resulting metadata should be formatted according to relevant standards.

List of recommended standards:

- ✓ EO collection metadata: ISO 19115 Geographic Information - Metadata **[R.11]**
- ✓ EO product metadata: OGC's GML 3.2.1 Application Schema for EO Products (OGC-07-036) **[R.11]**
- ✓ ISO 19100 Series
- ✓ OAIS Information Model for Descriptive Information (e.g. Quality Information) [R.8]
- ✓ Others TBD

GUIDELINE 4.3 – Routine quality check - (Level A)

Perform routine quality check on acquired data before ingestion in the archive.

- ✓ ISO 20652 - PAIMAS Standard (Producer Archive Interface Methodology Abstract Standard) [R.10]
- ✓ PAIS (Producer Archive Interface Specification): implementing PAIMAS standard (in the process of becoming a CCSDS Red Book) **[R.9]**

GUIDELINE 4.4 – Transcription quality check - (Level A)

Perform quality check on acquired data after transcription on media in the archive to verify correct transcription of the acquired data on the media

- ✓ Technical Procedure for quality check: TBD.

GUIDELINE 4.5 – Ingestion process record - (Level B)

Document the ingestion process of all archive content (as defined in guideline 1.1).

6. THEME 5: ARCHIVE MAINTENANCE

Definition

Archive maintenance consists of all the activities aimed at guaranteeing the integrity of the archived data. Data integrity assures that the archived data are complete and unaltered through loss, tampering or data corruption. Archive maintenance is based on the storage of equipment, media and hard disk arrays in secured and environment controlled rooms and a set of defined activities to be performed on routine basis like migration to new systems and media, in accordance to the technology and consumer market evolution, data compacting and data format packaging conversion.

Guiding Principle

Earth Observation space data owners and archive holders should design a maintenance scheme for their archives to guarantee the integrity of the archived data.

Key Guidelines

GUIDELINE 5.1 – Archived data refreshment - (Level A)

Perform periodically a migration of the archived data ("media refreshment") to the most adequate proven technology[7] for data storage ensuring data access preservation[8].

GUIDELINE 5.2 – Archived data formats description and converters - (Level B)

Provide formal description of old archiving formats and provide converters to new standard formats to increase technical compatibility and to reduce diversity of formats and interfaces between archives.

GUIDELINE 5.3 – Archived data repackaging/reformatting - (Level C)

Perform archived data repackaging and/or reformatting to comply with new standard formats and/or exchange formats to increase technical compatibility and to reduce diversity of formats and interfaces between archives[9].

GUIDELINE 5.4 – Archived data duplication

Maintain identical copies of all archived data applying one of the security levels defined below:

a) dual copy in the same geographical location (but different buildings) to avoid data loss due to media degradation or obsolescence. **(Level A)**

or

[7] Technology selection should not only be based on technical and cost aspects but also aim at the minimization of environmental impact (e.g. in terms of power consumption, thermal dissipation, etc..).

[8] Currently data and system migrations are performed at least every five/six years.

[9] Repackaging and/or reformatting should be performed together with archive media migration.

b) dual copy in the same geographical location (but different buildings) based on different technology to avoid technology based principle failures. This guideline extends Guideline 5.4.a. **(Level B)**

or

c) dual copy in two different geographical locations to safeguard the archive from external hazards (e.g. floods and other natural disasters, technological hazards, etc.). This guideline extends Guideline 5.4.a. **(Level B)**

or

d) dual copy in two different geographical locations and based on different technologies to avoid technology based principle failures. This guideline extends Guideline 5.4.b and 5.4.c. **(Level C)**

GUIDELINE 5.5 – Archive system components migration (hardware) - (Level A)

Perform periodical migration of archive system components to new hardware platforms[10].

GUIDELINE 5.6 – Media readability and accessibility tests - (Level B)

Perform periodical test for media readability and accessibility on a representative set of the archived data.

GUIDELINE 5.7 - Archive content integrity - (Level B)

Periodically verify the integrity of the archive collection/content through integrity check on a representative set of the archived data.

GUIDELINE 5.8 – Obsolete media disposal - (Level A)

Organize the disposal of obsolete media in conformance with national and international environmental regulations.

✓ List of regulations to be applied: TBD

GUIDELINE 5.9 – Archiving systems common approach - (Level C)

Pursue a harmonized approach within the Earth Observation community for the future development of archiving systems to improve compatibility of services provided by different organizations (e.g. exchange of specifications, application software, best practices, etc).

[10] Currently data and system migrations are performed at least each five/six years.

7. THEME 6: DATA ACCESS AND INTEROPERABILITY

Definition

Data access corresponds to the services and functions which make the archival information holdings and related services visible to consumers. Interoperability is related to the possibility of accessing data in a common and standardized way despite the intrinsic differences between the data sets on one hand and the accessed systems on the other hand.

Guiding Principle

Archived data, when preserved, need to be made accessible to users. They need to be retrieved and delivered to users (generally after some processing) in the form of Dissemination Information Packages (i.e. products). Data access is a fundamental element of the data preservation and should be ensured and facilitated for all archived data. In order to ensure data access, the required services and functions have to be available, maintained and evolved. Standardization has to be carefully considered to offer common access procedures and data formats, to facilitate the extension to new data sets, and to share software and tools. Interoperability and harmonization of data access should be pursued to favour an easy and cost-effective access means to heterogeneous EO mission data.

Key Guidelines

GUIDELINE 6.1 – Preserved data set content discovery - (Level A)

Ensure continuous EO missions' preserved data set content discoverability through the following activities:

a) Provide and maintain mechanisms to search and discover archived data records.

b) Provide and maintain a searchable metadata and browse image catalogue of archived data records.

c) Provide and maintain mechanisms to search and discover Mission Documentation and value adding/visualization tools relevant for the designated user community.

GUIDELINE 6.2 – On-line access and delivery - (Level A)

Provide and maintain preserved data set content dissemination capabilities through ordering and delivery and/or direct access (without ordering).

GUIDELINE 6.3 – On-line access and delivery - (Level B)

Ensure on-line direct access and on-line delivery services for the preserved data set content.

GUIDELINE 6.4 – Preserved data set content access and use conditions - (Level A)

Provide transparency and visibility of preserved data set content access and use conditions to users.

GUIDELINE 6.5 – Controlled preserved data set content access and dissemination - (Level A)

Implement preserved data set content controlled access and dissemination mechanisms in accordance to applicable access and use conditions (see guideline 6.4) to avoid unauthorized visibility and access.

GUIDELINE 6.6 – Preserved data set content access interfaces and delivery formats - (Level B)

Adhere to standard interfaces, services and delivery formats (See Guideline 6.9) to allow easy and cost-effective discovery, access and dissemination of heterogeneous EO mission (different missions, new & old) preserved data set content: interfaces for discovery, catalogue access, ordering, access and dissemination, user management and administration, etc.

List of standards **[R.11]:**

- ✓ Collection and service discovery (Advertisement): OGC's Cataloguing of ISO Metadata using the ebRIM profile of CS-W (OGC 07-038)
- ✓ Catalogue Service: OGC's Catalogue Services Specification 2.0 Extension Package for ebRIM Application Profile: Earth Observation Products (OGC 06-131)
- ✓ Ordering from Catalogue: OGC's Ordering Services for Earth Observation Products (OGC 06-141)
- ✓ Feasibility Analysis (Programming): OGC's Sensor Planning Service Application Profile for EO Sensors (OGC 07-018)
- ✓ Online Data Access: OGC's WMS EO Extension (OGC 07-063), OGC WCS 2.0 extension for EO.
- ✓ Identity (User) Management: OGC's User Management Interfaces for Earth Observation Services (OGC 07-118)
- ✓ Others TBD

GUIDELINE 6.7 – Common approach for data set content access systems - (Level C)

Pursue common approach for the Earth Observation data set content access systems to improve compatibility of different systems (e.g. sharing of specifications, application software, etc.) in order to enable across-archive content discovery, viewing, and access.

GUIDELINE 6.8 – Preserved data set content access interfaces and discovery mechanisms - (Level C)

Adhere to standard interfaces and services to pursue harmonization of preserved data set content discovery, access and dissemination with domains different from the Earth Observation one.

GUIDELINE 6.9 – EO products harmonization - (Level B)

Pursue harmonization of EO products (Dissemination Information Packages, DIPs) specifications (quality and content) and delivery formats (e.g. GeoTIFF) for different missions.

- ✓ Delivery formats and specifications for the different types of products (Dissemination Information Packages, DIPs): TBD

GUIDELINE 6.10 - EO products realignment - (Level C)

Realign products' (Dissemination Information Packages, DIPs) characteristics and delivery format of old missions to established[11] harmonized ones.

GUIDELINE 6.11 – Archive search capability - (Level C)

Enhance archives search capability and harmonize key features extraction methods by contents and metadata values (e.g. Quality Thresholds).

✓ Search capabilities and feature extraction methods: TBD

Guideline 6.12 – Authenticity - (Level B)

Apply policies and procedures that enable the dissemination of EO products that are traceable to the source data, with evidence supporting their authenticity.

[11] i.e. used by a large community of users for a sufficient period of time.

8. THEME 7: DATA EXPLOITATION AND RE-PROCESSING

Definition

This theme covers all activities related to the exploitation of archived data by data processing and reprocessing, regeneration or enhancement of the catalogues (e.g. through data mining), integration of new services (e.g. through service work-flow orchestration) and quality assessment of the products and services.

Guiding Principle

Archived data represent a unique information source in the long term and can provide valuable inputs for several exploitation programmes. To guarantee and facilitate the reuse of archived data it is necessary to:

- ✓ Maintain the capability to generate missions' products during mission lifetime and even after mission end of life depending on mission requirements and strategy.
- ✓ Reprocess, during mission lifetime or after according mission requirements and strategy and processing chains availability, entire preserved data sets to obtain mission products and associated quality indicators (a) in case new approved algorithms are implemented, (b) in case of availability of updated auxiliary data, (c) to respond to specific requirements from the user community and (d) to ensure availability of coherent data sets.
- ✓ Facilitate archived data exploitation through several actions like generating thematic data sets, implementing tools for high-level processing and information extraction, etc.

Key Guidelines

GUIDELINE 7.1 – Products generation active missions - (Level A)

Provide and maintain products generation capability (systematic or through ordering) including maintenance of the processing chains and quality control tools for active EO missions. This includes the validation of models, algorithms and software.

GUIDELINE 7.2 – Products generation non-active missions - (Level B)

For non-active missions, provide and maintain missions' products generation capability (systematic or through ordering) including maintenance of the processing chains and quality control tools or in alternative perform, before dismantling the processing chains, bulk generation and archiving of all products levels according to mission requirements.

GUIDELINE 7.3 – Processing software[12] environment - (Level B)

Actively monitor the evolution of the environment (e.g. hardware and software operating systems) used to run "Processing Software" and perform hardware migration and software porting when necessary to maintain the original capabilities.

[12] Including quality control, product visualization and value adding tools

GUIDELINE 7.4 – Processing software[13] virtualization - (Level C)

Virtualize mission specific Processing Software to minimize dependency on the underlying environment (e.g. hardware and software operating systems).

GUIDELINE 7.5 – COTS software monitoring - (Level B)

Actively monitor the evolution and availability of commercial software (COTS) used as processing chains libraries and for implementation of missions products visualization and value adding processing. Apply the countermeasures defined in the risk assessment phase.

GUIDELINE 7.6 - Reprocessing - (Level A)

Provide and maintain the capability to reprocess archived data records to generate new coherent versions of missions' products according to missions' requirements and strategy[14]. Products obtained with previous algorithm versions should be maintained after reprocessing depending on missions' requirements and strategy.

GUIDELINE 7.7 – Processing/reprocessing capacity for long term data series - (Level B)

Provide the processing/reprocessing capacity to respond to missions' requirements and to projects requiring long-term data series.

GUIDELINE 7.8 – Higher level applications - (Level C)

Provide reference data sets, including Quality Indicators, to facilitate the development of higher-level applications (e.g. for information extraction).

GUIDELINE 7.9 – Earth Observation data/products quality - (Level A)

Provide Quality Assurance of EO space data during the mission lifetime (e.g. through the application of international standards or guidelines) using Quality Indicators and performing validation of models, algorithms and software.

- ✓ A Quality Assurance Framework for Earth Observation - Guidelines Framework (QA4EO), endorsed by CEOS in November 2008, www.qa4eo.org. [R.8]

GUIDELINE 7.10 – Facilitation of data exploitation - (Level C)

Pursue simplification of the workload for the users by reducing their global data handling time and cost through implementing the following measures:

1) Data adaptation to specific post-processing and applications.
2) Hosting and executing user algorithms.
3) Providing capability for data fusion across EO sensors.
4) Providing the capability to perform across disciplines data searches and integration (e.g. Earth Observation, in-situ geologic data, etc).

[13] Including quality control, product visualization and value adding tools
[14] E.g. when new approved algorithms or auxiliary data are available or according to user community needs

GUIDELINE 7.11 – Information extraction - (Level C)

Allow information extraction from low-level EO products through data mining and value adding services.

GUIDELINE 7.12 – Data Content Integrity - (Level A)

Ensure that the content of the archived data and associated information remains unchanged and, if changes are made, that these are documented and that this documentation is preserved and made available as well (provenance information).

9. THEME 8: DATA PURGE PREVENTION

Definition

"Data Purging" (Annex 3) is intended as the deletion or removal of EO data from an archive. This theme defines a set of procedures to be applied with the objective to prevent, or minimize, EO space data loss and to ensure resources are applied towards EO data preservation and access activities through a management approval process. This theme is of particular importance when an Earth Observation space data holders and archive owners, for whatever reason, can no longer preserve the data.

Guiding Principle

EO data are episodic data and cannot be recorded again at some point in the future. EO data constitute a humankind asset fundamental for the future of science and for the activities of the scientific community and therefore should be preserved. In some cases, entities may be obliged, or might choose, to discontinue the preservation of their data. In these cases, defined and controlled procedures have to be put in place to avoid the loss of any EO data and to allow the handover of responsibility for the preservation of these data to another data centre.

Key Guidelines

GUIDELINE 8.1 – Data purging alert procedure - (Level A)

Apply, when intending to dispose an Earth Observation data set and before any purging of the data, a "Data Purging Alert Procedure" to inform other Earth Observation data holders and archive owners with the goal to trigger a possible transfer of responsibility for the data set preservation to another interested entity. The complete description of the preserved data set content (Guideline 1.2), the results and documentation of the data set appraisal (Guideline 1.8) and proposals to facilitate data ingestion should be made available together with the data purging alert.

- ✓ Data Purging Alert Procedure: Annex 3 to the LTDP Guidelines

GUIDELINE 8.2 – Purging alert response time - (Level A)

Respond to a received "Data Purging Alert" within one month from the reception of the alert if interested in the possibility to take over the responsibility of the data set preservation.

GUIDELINE 8.3 – Archived data handover - (Level A)

Provide support, when intending to dispose an Earth Observation data set and before any purging of the data, to interested entities that responded to the purge alert message to allow them to assess the value and prospects of the data set and to carry out the handover of the responsibility of their preservation.

ANNEX 1 – PRESERVATION ANALYSIS WORKFLOW FOR EARTH OBSERVATION SPACE DATA

The Preservation Analysis Workflow defines a procedure for the preservation of digital data with the goal to optimize their reuse in the long term. The procedure consists of the set of actions shown in Figure 1 and has been tailored in this section for the specific case of Earth Observation space data. It should be applied by Earth Observation data holders and archive owners at mission data collection level to the full content of their archives. The result of the procedure application should consist of a set of documents[15] describing the preservation strategy, implementation plan and activities for each individual mission dataset. Such document(s) should refer to the LTDP guidelines and clearly define current compliance and future plans to improve adherence. The preservation analysis workflow procedure should be applied to past, current and future missions. In the latter case, the definition of long-term preservation strategies and implementation aspects during the mission preparation phases would lead to optimal results in terms of data and information availability and usability in the future with minimum associated costs. For future missions therefore, long-term preservation planning should be part of the mission preparation phase.

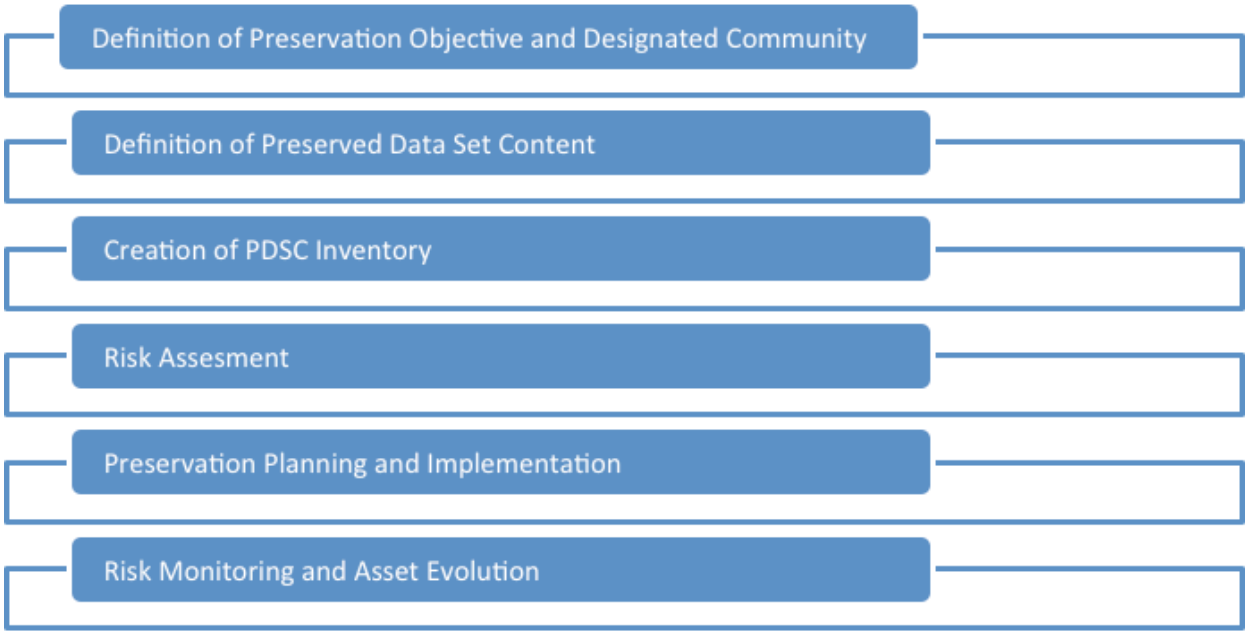

Figure 1 – Preservation Analysis Workflow

Definition of Preservation Objective

A preservation objective defines the minimum level and type of reuse which an archive wishes to maintain to for its user community. The objective should concisely describe the guaranteed level and mode of engagement supported by the archive. Typically this would cover areas such data processing, visualization, analysis and interpretation of data. However any clearly stated mode of interaction may be considered for preservation purposes. A preservation objective should be:

[15] Single documents could address multiple datasets in case of commonalities.

- Specific, well defined and clear to anyone with a basic knowledge of the domain.
- Measurable to be able to know when the objective has been attained in order to assess if any preservation strategy developed is adequate.
- Achievable, realistic and time related.

A common preservation objective for any Earth Observation data holder and archive owner consists in maintaining the own full data holdings accessible and usable today and in future, theoretically for an unlimited time, for its designated user communities. Long-term accessibility and usability of Earth Observation data requires that not only sensed data but also the associated knowledge (e.g. technical and scientific documentation, algorithms, data handling procedures, etc) is properly preserved and maintained accessible. Earth Observation data holders and archive owners need therefore to maintain the capability to provide access to the full Earth Observation data products holdings and also to all the associated information and knowledge necessary to understand and use them. This implies the availability and archiving of metadata and data products at all levels specified by each owned mission or the capability to generate them on user request through proper processing. Data products need to be provided with known quality to end-users.

Definition of Designated Community

The definition of a designated user community should be done in association to the preservation objective in order to meaningfully contain the scope of what is covered. The definition of designated user community should specify the skills, resources and knowledge base a community has access to. Definition of these attributes is critical as they set the limits to the amount of information which must necessarily be preserved in the long term. In order to do this the definition of the designated user community must be:

- Clear with sufficient detail to permit meaningful decisions to be made regarding the composition of the data set to be preserved to allow requirements for effective re-use of the data.
- Realistic and stable in so far as there is reasonable confidence in the persistence of the knowledge base resources and skill set.

Different designated user communities are addressed through the preservation objective defined above. Earth Observation data users are today, as an example and among others, Scientists and Principal Investigators, researchers, commercial entities, value adders, and general public. These communities can be further differentiated on the basis of the respective application domain and area of interest (e.g. ocean, atmosphere) and generally have different skills, resources and knowledge.

The data product levels and the information associated to the data necessary for their understandability and use is different for each of the above communities and even for individuals inside each community. Earth Observation data holders and archive owners generally serve today more than one user community and therefore need to be able to address the needs of all of them in terms of data and associated information availability and access. In addition, the preservation objective includes the utilization of the data products also in the future by user communities that might have completely different skills and knowledge base wrt the ones identified today but also different objectives for the use of the data. This means that the best approach for Earth Observation data holders and archive owners today would be to consider a “designated user community” generic and large enough so that the identified content to be preserved in the long term for that community will also allow other users, not considered at the time preservation was initiated, to make use of the data in the future. The generic designated user community is assumed to be able to understand English, to work with personal computers and basic programs provided

with them, and to analyse and interpret the data products when available together with the full amount of additional information (see next point below) necessary to understand them without additional support from the archive.

It is appreciated that in the field of Earth Observation the data landscape is complex and that there will naturally be divergent community needs for the long term exploitation of data. This should present itself in the form of more specialist preservation objectives.

Definition of Preserved Data Set Content (PDSC) for Earth Observation

Once the objective and community have been identified and described, an archive should be in a position to determine the information and data to be preserved to achieve the objective for this community. In Earth Observation, the "Preserved Data Set Content" should be comprised as a minimum, in addition to the EO data, of all information which permit the defined community to successfully interact, understand and use the EO data as mandated by the preservation objective.

The "Earth Observation Preserved Data Set Content" has been defined on the basis of the Preservation Objective and Designated Communities described above and is summarised in Section 1.4. Additional details are provided in [R.6].

Creation of PDSC Inventory for own EO missions/instruments datasets

For future missions, the definition of the "Preserved Data Set Content" as well as of an appropriate storage solution shall be initiated during the mission definition and implementation phases and continuously maintained in the following phases. For past and current missions, the next stage to be implemented by data holders and archive owners is to tailor the "Preserved Data Set Content" for each EO mission/instrument, and to appraise each of the resulting elements comprised in the preserved data set content in terms of physical state, location and ownership. The result is the mission/instrument inventory document. The resulting EO PDSC inventory should include among others:

- **Information:** description of each PDSC element for the specific mission/instrument dataset required to satisfy the preservation objective for the designated user community.
- **Location information:** information required by the end user to physically locate and retrieve the PDSC elements as they can be distributed and managed within different information systems. This tends to be the case when data is in active use with resources moving in dynamic environments. Note the difference between being able to locate and retrieve information and having control (ownership) of it. This information is also necessary for the planning of the preservation action.
- **Physical state**: description of the form of the PDSC element. It should contain sufficient information relating to the version, instance or format.
- **Ownership**: Intellectual property rights should be listed at this point.

Risk Assessment

Each element of the EO PDSC Inventory should undergo a risk assessment with the goal to identify all potential risks and dependencies and be appraised in terms of:

- **Semantic Risk**: do any of the PDSC elements contain any critical information which is not defined formally or can be potentially subject to "semantic drift" over time?

- **Technical Risk**: is there any PDSC element consisting of software or dependent on software exposed to technical risks?
- **Organisational Risks**: does any PDSC element exist in distributed locations and under different organisational custody? Is suitability and stability of such environments guaranteed?
- **IPR related Risks**: Is there any impediment to the supply or use of PDSC elements due to legal restrictions?
- **Resourcing Risks**: Is there any impediment in the use of any PDSC element due to resources limitations (e.g. costs or skills)?

Preservation Planning and Implementation

The preservation approach for the full EO Preserved Data Set Content need to be planned through the definition of a set of actions to be performed for each composing element according to the identified risks. Preservation actions are determined by cost, benefits and risk burden which is acceptable for an archive and could take one of the following forms:

- Risk Acceptance (referencing): risk is accepted, referenced and continuously monitored.
- Description: PDSC element is further described in an easily understandable form for the designated user community according to evolution of its knowledge base.
- Transformation: PDSC element is transformed in a different format to facilitate preservation.

The most appropriate preservation actions need to be identified to guarantee the preservation and future usability of each element composing the PDSC Inventory defined in the previous steps. The result of this activity should consist of one or more "preservation strategy and approach" documents. These documents could be drafted with different levels of detail and should generally contain Preservation Networks for each EO mission data collection consisting of all the PDSC Inventory elements, the elements on which they are dependent or necessary to understand and use them (e.g. the operating system underlying an EO data processor) and the associated preservation actions identified for each of them. Preservation networks should also identify the preservation state of each element of the PDSC inventory. An example of preservation network for the ESA Envisat MERIS N1 File Level 0 data is given below:

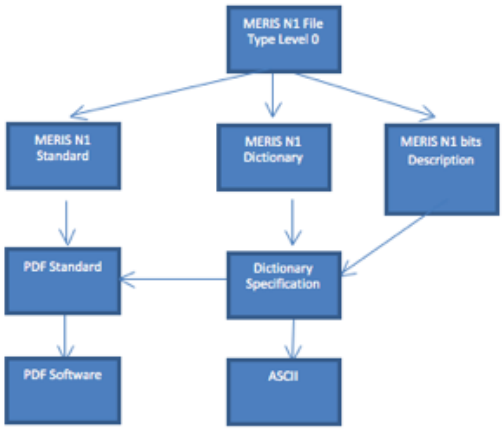

Figure 2 – Preservation Network Model for Envisat MERIS N1 File Level 0 data

Such document(s) should refer to the LTDP guidelines and clearly define current compliance and future plans to improve adherence. The identified preservation actions should be then implemented and the risks associated with inventory elements preservation properly and continuously monitored (see following step below).

Risk Monitoring and Asset Evolution

As no preservation solution is permanent or necessarily appropriate in the long term, the EO PDSC Inventory and its composing elements must be monitored for stability and suitability. In order to do so the accepted risks/dependencies within the preservation strategy must be monitored, as does the preservation objective and description of designated user community. It is then a goal of the preservation plan to "follow" the needs and evolution of the original user community, and make the appropriate changes (risk assessment).

ANNEX 2 – KEY GUIDELINES PRIORITY AND LEVELS OF ADHERENCE TO THE LTDP GUIDELINES

A level of adherence (Levels A, B, C) has been associated to each key guideline identified in this document. Level A has been defined as the entry level and guidelines for Level A should be the first to be addressed and implemented in order to guarantee a basic level of security, integrity and accessibility of the archived data. The different levels of adherence to the LTDP Guidelines have been defined in detail in the introductory section to the LTDP Guidelines (Section 1.5). The priority level of the key guidelines is summarised in Table 4.

Theme	Key Guideline	Level
1. Preserved Data Set Content	1.1	A
	1.2	A
	1.3	B
	1.4	B
	1.5	B
	1.6	B
	1.7	B
	1.8	A
2. Archive operations and organization	2.1	A
	2.2	A
	2.3	A
	2.4	A
	2.5	A
	2.6	B
	2.7	A
	2.8	A
	2.9	C
	2.10	A
	2.11	C
	2.12	A
3. Archive security	3.1	B
	3.2	A
	3.3	A
	3.4	A
	3.5	A
4. Data ingestion	4.1	A
	4.2	A
	4.3	A
	4.4	A
	4.5	B
5. Archive maintenance	5.1	A

	5.2	**B**
	5.3	**C**
	5.4a	**A**
	5.4b	**B**
	5.4c	**B**
	5.4d	**C**
	5.5	**A**
	5.6	**B**
	5.7	**B**
	5.8	**A**
	5.9	**C**
6. Data access and interoperability	6.1	**A**
	6.2	**A**
	6.3	**B**
	6.4	**A**
	6.5	**A**
	6.6	**B**
	6.7	**C**
	6.8	**C**
	6.9	**B**
	6.10	**C**
	6.11	**C**
	6.12	**B**
7. Data exploitation and reprocessing	7.1	**A**
	7.2	**B**
	7.3	**B**
	7.4	**C**
	7.5	**B**
	7.6	**A**
	7.7	**B**
	7.8	**C**
	7.9	**A**
	7.10	**C**
	7.11	**C**
	7.12	**A**
8. Data Appraisal and Purge Prevention	8.1	**A**
	8.2	**A**
	8.3	**A**

Table 4 – Key Guidelines Priority

ANNEX 3 – DATA PURGING ALERT AND DATA APPRAISAL PROCEDURES

Data Purging Alert Procedure

CEOS has established a "Purge Alert" service to help ensuring the long-term preservation of valuable EO space data. This initiative enables data archive managers to advise other archives of EO data holdings scheduled to be disposed of, and offer these data to other archive centers. To contact the Purge Alert members and start the purge alert procedure, an e-mail should be sent to purgealert@wgiss.ceos.org.

More information can be found at: http://wgiss.ceos.org/purgealert/ Organisations whose missions match the type of records being disposed, and who are willing to take on the responsibility for their preservation, will be able to respond to the purge alert message and start negotiations with the alert initiator.

Data Appraisal Procedure

The data appraisal procedure consists in performing an assessment of an EO space data set under evaluation (for example in case of possible preservation discontinuing) through answering to a set of categorized questions extracted from the USGS EROS Appraisal Online Tool (http://eros.usgs.gov/government/ratool/) or from the CEOS online questionnaire http://wgiss.ceos.org/archive/index.html.

The list of questions should cover:

- ✓ Mission relevancy
- ✓ General policy (ISO Standard)
- ✓ Physical properties (Media)
- ✓ Metadata
- ✓ Cost / benefit analysis.

When performing the appraisal, an appraisal report should be produced in order to properly document the different steps performed in the appraisal procedure and the final results. The appraisal report should be provided, in case of purge decision, to other data holders and archive owners together with a description of the data set when applying the data alert procedure.

A link to a template document containing the list of questions and to generate the appraisal report is provided hereafter: http://eros.usgs.gov/government/ratool/export.php?blank

ANNEX 4 – GLOSSARY OF TERMS

Term	LTDP Guidelines Definition	OAIS Definition
Ancillary Data	Ancillary data can be broadly defined as those used to determine when (and how) an instrument was acquiring data, where an instrument was located, where an instrument was pointed and what it targets (e.g. a surface or atmospheric feature), how those targets would appear at the time of observation and what else of potential significance to science data analysis was occurring. Examples of ancillary data are spacecraft ephemeris or attitude. Ancillary Data are part of the Secondary Data as defined in Key Guideline 1.1.	Ancillary data can be considered as a **Digital Data Object (**object composed of a set of bit sequences) part of a **Content Information,** related to other digital objects **(i.e. Primary Data)** through **Context Information** (the information that documents the relationships of the **Content Information** to its environment; this includes why the **Content Information** was created and how it relates to other **Content Information** objects) or as a compound digital object which contains a mixture of **Provenance**, **Context** and **Representation Information** related to a Primary Digital Data Object.
Archival Information Packages (AIP)	An Information Package, consisting of the Content Information and the associated Preservation Description Information (PDI), which is preserved within an OAIS.	An Information Package, consisting of the Content Information and the associated Preservation Description Information (PDI), which is preserved within an OAIS.
Archive	An archive is to be intended as a complete system, which includes people and facilities within an organization aimed at storing data in the long term guaranteeing their integrity, usability and allowing their retrieval.	**Archive**: an organization that intends to preserve information for access and use by a **Designated Community**.
Archives Operations	Archives operations consist of all daily activities which are carried out to run and monitor the archive system. They include the execution and control of the applications, system monitoring, anomaly reporting, error recovery, activity reporting and statistics, etc. Maintenance of an archive is also generally associated to operations.	**Administration Functional Entity:** The OAIS functional entity that contains the services and functions needed to control the operation of the other OAIS functional entities on a day-to-day basis.
Archives Organization	The organizational structure of an archive based on a sufficient number of qualified staff with clear roles and responsibilities.	**Open Archival Information System**: an **archive**, consisting of an organization of people and systems that has accepted the responsibility to preserve information and make it available for a **Designated Community**. It meets a set of responsibilities that allows it to be distinguished from other uses of the term 'archive'.
Auxiliary Data	Auxiliary data are all data files used to generate a product, other than the direct measurements of the instrument. Auxiliary data include calibration data measured on-board but not part of the main measurements of the instrument, external calibration files from sources other than the satellite, processor configuration files, and any other files needed by instrument processors. Auxiliary Data are part of the Secondary Data as defined in Key Guideline 1.1.	Auxiliary Data can be considered as a **Digital Data Object (**object composed of a set of bit sequences) part of a **Content Information,** related to other digital objects **(i.e. Primary Data)** through **Context Information** (the information that documents the relationships of the **Content Information** to its environment; this includes why the **Content Information** was created and how it relates to other **Content Information** objects).or as a specialist type of **Representation Information** related to a Primary Digital Data Object.
CAL/VAL Data	CAL/VAL Data are data needed to calibrate the satellite instruments and to monitor data quality (also determining the parameters, corrections, etc.., to be applied to measurements). CAL/VAL Data are part of the Secondary Data as defined in Key Guideline 1.1.	CAL/VAL Data can be considered as a **Digital Data Object (**object composed of a set of bit sequences) part of a **Content Information,** related to other digital objects **(i.e. Primary Data)** through **Context Information** (the information that documents the relationships of the **Content Information** to its environment; this includes why the **Content Information** was created and how it relates to other **Content Information** objects) or as a specialized type of Provenance and Representation Information related to a Primary Digital Data Object.

Term	LTDP Guidelines Definition	OAIS Definition
Catalogue	The cataloguing function provides search and retrieve capabilities for product metadata and browse images. It supports data management functionality based on references to corresponding data products stored in an archive. Products can be organized in collections with restricted access depending on product type and users. Cataloguing can occur in several areas of an Earth Observation mission Ground Segment: user services, central product/order handling and archiving/inventory.	**Data Management Functional Entity:** the OAIS functional entity that contains the services and functions for populating, maintaining, and accessing a wide variety of information. Some examples of this information are catalogs and inventories on what may be retrieved from **Archival Storage**, processing algorithms that may be run on retrieved data, Consumer access statistics, Consumer billing, **Event Based Orders**, security controls, and OAIS schedules, policies, and procedures.
Data Access	Data access is intended as the services and functions which make the archival information holdings accessible to users. This includes services for data search, discovery, retrieval, and dissemination.	**Access Functional Entity:** the OAIS functional entity that contains the services and functions which make the archival information holdings and related services visible to **Consumers**.
Data Level	**Raw Data:** The physical telemetry payload data as received from the satellite, i.e. a serial data stream without de-multiplexing. These data are not computer compatible. **Level 0:** Reconstructed unprocessed data at full space-time resolution with all available supplemental information to be used in subsequent processing (e.g. ephemeris, health and safety) appended. **Level 1A:** Reconstructed unprocessed data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and geo-referencing parameters (e.g. ephemeris) computed and appended but not applied to the Level 0 data. **Level 1B:** Radiometrically corrected and calibrated data in physical units at full instrument resolution as acquired. **Level 1C:** L1B data orthorectified, re-sampled to a specified grid. **Level 2:** Derived geophysical parameters (e.g. sea surface temperature, leaf area index) at the same resolution and location as Level 1 source data. **Level 3:** Data or retrieved geophysical parameters which have been spatially and/or temporally re-sampled (i.e. derived from Level 1 or 2 products), usually with some completeness and consistency. Such re-sampling may include averaging and compositing. **Level 4:** Outputs or results from models using lower level data as inputs and, thus, not directly derived from the instruments.	Data in each level **(e.g. Raw Data)** are **Digital Objects** part of a **Content Information,** related to other digital objects **(e.g. Secondary Data)** through **Context Information** (the information that documents the relationships of the **Content Information** to its environment; this includes why the **Content Information** was created and how it relates to other **Content Information** objects). Data level can be intended as **Provenance Information** described in the **Preservation Descriptive Information**.
Data Search and Discovery	The procedure to search an archive based on specific search criteria and to obtain information on available products. Data search and discovery is enabled by generating and maintaining searchable metadata and browse image (when applicable) catalogs and by mechanisms to retrieve the information contained therein.	**Finding Aid:** a type of **Access Aid** that allows a user to search for and identify **Archival Information Packages** of interest.
Data Set Description	A data set description consists of a set of information identifying an archived dataset from a long term preservation perspective. It includes a description of the spatial mission and payload, the composition of the data set itself and its availability, the data set time span, volume, storage media and archiving format. The data set description is fundamental for data set appraisals and to support the purposes of data preservation and archiving.	**Descriptive Information**: the set of information, consisting primarily of **Package Descriptions**, which is provided to **Data Management** to support the finding, ordering, and retrieving of OAIS information holdings by **Consumer**s.
Dissemination Information Packages (DIP)	A Dissemination Information Package (DIP) is the Information Package, derived from one or more AIPs (Archival Information Package), supplied to the Consumer in response to a request to the OAIS.	**Dissemination Information Package** (DIP): the **Information Package**, derived from one or more **AIP**s, received by the **Consumer** in response to a request to the **OAIS**.

Term	LTDP Guidelines Definition	OAIS Definition
EO Space Data	Earth Observations Data generated by spaceborne missions or instruments owned by public or private organisations.	**Content Data Object:** the Digital Data Object that together with associated Representation Information is the original target of preservation.
EO Space Data Holders and Archive Owners	This category is intended to include all entities dealing with the archiving of EO space data and responsible for their preservation in the long term. It includes data providers, data and mission owners, archive holders, etc...	**Management**: the role played by those who set overall OAIS policy as one component in a broader policy domain.
EO Space Data Producers	Producers of Earth Observation data derived products. This category includes private and public institutes which are responsible for space missions and the companies/institutes participating to the programs which produce the different levels of data to be preserved.	**Producer:** the role played by those persons, or client systems, who provides the information to be preserved; this can include other OAISs or internal OAIS persons or systems.
EO Space Data Users	User communities interested in various application areas heavily benefiting from the availability of Earth Observation space data and products.	**Consumer**: the role played by those persons, or client systems, who interact with OAIS services to find preserved information of interest and to access that information in detail. This can include other OAISs, as well as internal OAIS persons or systems.
Metadata	Metadata is intended as information describing significant aspects of a resource (Earth Observation space data in this context). They are created for the purposes of data search, discovery and access management and may exist at various levels, typically from data collection through to the individual variables of each data file in a collection.	**Descriptive Information:** the set of information, consisting primarily of Package Descriptions, which is provided to Data Management to support the finding, ordering, and retrieving of OAIS information holdings by Consumers.
Migration of archived data ("Media Refreshment")	Data migration is a means of overcoming technological obsolescence by periodically transferring archived data from an hardware/software environment to a different one in order to exploit new technologies for the purposes of data preservation for future use.	**Digital Migration**: the transfer of digital information, while intending to preserve it, within the OAIS. It is distinguished from transfers in general by three attributes: - a focus on the preservation of the full information content; - a perspective that the new archival implementation of the information is a replacement for the old; - an understanding that full control and responsibility over all aspects of the transfer resides with the OAIS.
Packaging Information	A description of the package which allows the user to understand the structure of the information package.	**Packaging Information**: the information that is used to bind and identify the components of an Information Package.
Preservation Descriptive Information	Preservation Descriptive Information consists of: 1. **Reference Information**, which enumerates and describes identifiers assigned to the content information such that it can be referred to unambiguously, both internally and externally to the archive. 2. **Provenance Information**, which documents the history of the content information (e.g., its origins, processing history, chain of custody, preservation actions and effects) and helps to support claims of authenticity and integrity. 3. **Context Information**, which documents the relationship of the content information to its environment (e.g., why it was created, relationships to other content information). 4. **Fixity Information**: documents authentication mechanisms used to ensure that the content information has not been altered in an undocumented manner (e.g., checksum, digital signature). 5. **Access Rights:** Access Rights provide the terms of access, including preservation, distribution, and usage of Content Information.	**Preservation Description Information** (PDI): the information which is necessary for adequate preservation of the **Content Information** and which can be categorized as **Provenance, Reference, Fixity, Context information and Access rights**.
Preserved Data Set Content	The composition of the data set to be preserved in the long term defines a consistent and complete set of data	One or more **Archival Information Packages** (**AIPs**): an AIP is an **Information Package**,

Term	LTDP Guidelines Definition	OAIS Definition
	enabling current and possible future utilization of the Mission data and knowledge preservation. It consists of Primary Data, Secondary Data and all associated Preservation Description Information, Packaging Information and Representation Information. It includes also Metadata for discovery and Browse images when available.	consisting of the Content Information and the associated **Preservation Description Information (PDI)**, which is preserved within an OAIS.
Products, Mission Products	Products are intended as the Earth Observation data set generated and delivered to EO space data users according to mission requirements. They are composed of metadata and data structured into one or more product components.	**Dissemination Information Package (DIP):** the Information Package, derived from one or more AIPs, received by the Consumer in response to a request to the OAIS.
Reference Model	A framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment. In this context the Reference Model is a conceptual framework for an archival system dedicated to preserving and maintaining access to digital information. It addresses a full range of archival preservation functions including ingest, archival storage, data management, access and dissemination.	**Reference Model**: a framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment. A reference model is based on a small number of unifying concepts and may be used as a basis for education and explaining standards to a non-specialist.
Reformatting of data	A process to convert data holdings in a different format from the original one. During the process certain fields can be relocated from a positional standpoint and/or dropped or the data can be reorganized within fields. Other steps can be incorporated in the reformat, such as insertion of data from a second input file. Reformatting shall use well-described transformation rules without deterioration of information content.	**Transformation:** a Digital Migration in which there is an alteration to the Content Information or PDI of an Archival Information Package. For example, changing ASCII codes to UNICODE in a text document being preserved is a Transformation.
Repackaging of data	Repackaging is a digital migration in which there is an alteration in the Packaging Information of the AIP.	**Repackaging**: a **Digital Migration** in which there is an alteration in the **Packaging Information** of the **AIP**.
Representation Information	Representation information facilitates the proper rendering, understanding, and interpretation of a digital object's content. It consists of structure and semantic information. Structure information describes the format or data structure concepts to be applied to the dataset to transform it into meaningful values in their spatial and temporal context. Semantic information describes the meaning of the measurement values, e.g. the physical property observed. Both should be made available together with the Primary Data as part of the preserved data set composition.	**Representation Information**: the information that maps a **Data Object** into more meaningful concepts. An example is the ASCII definition that describes how a sequence of bits (i.e., a **Data Object**) is mapped into a symbol.
Submission Information Package (SIP)	A Submission Information Package (SIP) is an Information Package that is delivered by the Producer to the OAIS for use in the construction of one or more AIPs.	**Submission Information Package (SIP)**: an **Information Package** that is delivered by the **Producer** to the **OAIS** for use in the construction of one or more **AIP**s.

Table 5 – Glossary of terms: LTDP Guidelines vs OAIS definitions

ANNEX 5 – LTDP RELEVANT STANDARDS

OAIS-ISO 14721

The **OAIS-ISO 14721** standard has been used in the definition of the structure of the LTDP Guidelines document. The purpose of this standard is to define the Reference Model for an Open Archival Information System (OAIS). An OAIS is an archive, consisting of an organisation of people and systems, which has accepted the responsibility to preserve information and make it available for a designated community. OAIS is made up of a functional model and an information model. The functional reference model can be met with different architectures and physical implementations of the Earth Observation missions Ground Segments. Physical architectures of OAIS compliant archives may therefore not be identical for different organisations. As the OAIS standard document encompasses every domain concerned by information preservation, it has to be adapted specifically to Earth Observation Satellite Data. Scope of this section is to briefly clarify some aspects of the OAIS standard and to define the relation with the LTDP Guidelines.

The OAIS standard identifies the responsibilities of an organisation in charge of an OAIS system. First, the community of users of the OAIS system has to be identified and defined. Secondly, the information delivered to this community has to be "independently understandable without the help of experts who produced the information". In Earth Observation space missions, often raw data are basically archived through an archival function in charge to guarantee the integrity of the data and processors necessary to obtain from the archived data the mission products which correspond to the information required by the users. Raw data cannot be considered in any case as "independently understandable information". It is therefore clear that both archived data and processors have to be considered to deal with an OAIS system in this domain even if the standard does not detail these issues. It is also important to consider that an OAIS system can evolve: the trade-off between archiving the products or processing the preserved data to obtain these products can give different results at different times due to technology improvements and evolution of users capabilities. Two additional functional entities are specific to the Earth Observation Satellite Data exploitation context: the Ingest entity and the Access entity. The Ingest entity function of OAIS defines the transfer conditions of the data from the producer to the archive. The access entity function of OAIS is to be considered during and after the mission duration and deals with the users management, the catalogue access and products delivery. In general a single organization covers all the aspects and functions identified within the OAIS standard but in some cases different entities might be in charge of different functions.

Audit and Certification of Trustworthy Digital Repositories - ISO 16363

The ISO standard on **Audit and Certification of Trustworthy Digital Repositories** (**ACTDR**), established by the Consultative Committee for Space Data Systems (CCSDS), also have an important role to play in conjunction with the LTDP guidelines. Having been generated by CCSDS, to which several national space agencies contribute as members, they are relevant for the operation of Earth Observation data archives.

The LTDP guidelines and the trustworthiness audit and certification metrics, contained in the ACDTR standard, have different functions. The guidelines are recommended to be applied by EO data holders to ensure that data are properly preserved and that their accessibility and usability is facilitated. The guidelines are intended for use in the Earth Observation domain even if they could be, at least in part, applicable and valuable also in other domains dealing with digital data preservation. The audit and certification standards and technical metrics are intended to assess the trustworthiness of a generic digital repository which is not an identical but nevertheless a complimentary goal.

Producer Archive Interface Specification (PAIS)

The **Producer Archive Interface Specification** (PAIS) also is a CCSDS recommendation. It is the implementation of the PAIMAS and provides a standard method for formally defining the digital information objects to be transferred by an information producer to an archive, and for effectively packaging these objects in the form of Submission Information Packages (SIPs). This supports effective transfer and validation of SIP data. It thus aims at overcoming the many difficulties encountered during transactions between information Producers and the Archives. This recommendation should enable:

- The Producer to have a very precise, unambiguous definition of the different Digital Objects to be produced, of the form and possibly the order in which they should be delivered,
- The Archive to be sure that the Digital Objects which are to be transferred to it will enable it to build **Archival Information Packages** which have all of the characteristics defined in the OAIS Reference Model,
- The respective Managers of the Producer and the Archive to be fully aware of all details of their commitments in terms of human and financial resources.

Regarding the Transfer Phase, this Recommendation should enable a high degree of automation and verification of the transfer process (recognize the schedule for the Data Submission Sessions, guarantee that the operation runs well technically, etc.). Regarding the Validation Phase, this Recommendation should enable the use of tools for systematically validating that the objects received are those expected, and that they conform to the level of detail previously agreed.

PAIMAS-ISO 20652 standard - Producer Archive Interface Methodology Abstract

The **PAIMAS-ISO 20652 standard - Producer Archive Interface Methodology Abstract** identifies and provides a method to manage an archival project and the interactions which take place between an information producer and a deposit archive in order than they reach a submission agreement for data ingestion, transfer and validation. The standard covers the first stages of the ingest process defined by OAIS. It identifies the phases required for transferring information, and defines objectives, actions and expected results for each phase. It provides a methodological framework for achieving the phases and forms the basis for identifying and developing standards and technologies to support their delivery. This includes the definition of the implementation required to design the long term archival (data model and tools), the risk analysis and the preservation planning.

Quality Assurance Framework for Earth Observation (QA4EO)

The **Quality Assurance Framework for Earth Observation** (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”. 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: Accessibility/Availability and Suitability/Reliability. 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, 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.

ANNEX 6 – KEY LTDP GUIDELINES VS RAC METRICS

This annex provides the detailed relation between key LTDP guidelines and RAC metrics. Compliance to one key LTDP guideline can result in automatic satisfaction of one or more RAC metrics. This is indicated in more detail in the following Table 6.

Key Guideline #	Level (A, B, C)	RAC Metrics #	Compliance (full, partial)
1.1	A	4.1.1	Full
1.2	A	4.1.2	Full
1.3	B	5.3 & 5.4	Full
1.4	B	3.3.1	Partial
1.5	B	4.2.1	Full
1.6	B	4.2.(2-3)	Full
1.7	B	3.3.1	Partial
1.8	A	3.1.3	Partial
2.1	A		
2.2	A	3.3.2 & 3.3.3	3.3.2 (Full) &3.3.3 (Partial but full in conjunction with other guidelines)
2.3	A	3.3.3	Partial but full in conjunction with other guidelines
2.4	A	Not covered by metrics	
2.5	A	3.2.1	Full
2.6	B	3.4.2 & 3.5.2	Full
2.7	A	4.16	Full
2.8	A	4.2.4	Partial but full in conjunction with other guidelines
2.9	C	4.2.4	Partial but full in conjunction with other guidelines
2.10	A	4.3.1	Full
2.11	C	4.3.3	Full
2.12	A	4.3.2	Full
3.1	B	5.2.2 ,5.2.4 & 3.3.6	(5.2.2 &5.2.4)Full & 3.3.6 (Partial)
3.2	A	5.2.1	Partial but full in conjunction with other guidelines
3.3	A	5.2.1	Partial but full in conjunction with other guidelines
3.4	A	5.2.1	Partial but full in conjunction with other guidelines
3.5	A	5.2.1	Partial but full in conjunction with other guidelines
4.1	A	4.1.3,4.1.4,4.1.5, 4.1.6 & 4.1.7	Full
4.2	A	4.2.6	Full
4.3	A	Not covered by metrics	
4.4	A	3.3.5	Partial
4.5	B	4.1.8	Full
5.1	A	5.2.1	Partial but full in conjunction

			with other guidelines
5.2	B	4.2.5 & 4.3.1	Full
5.3	C	Not covered by metrics	
5.4a	A	5.2.1	Partial but full in conjunction with other guidelines
5.4b	B	5.2.1	Partial but full in conjunction with other guidelines
5.4c	B	5.2.1	Partial but full in conjunction with other guidelines
5.4d	C	5.2.1	Partial but full in conjunction with other guidelines
5.5	A	5.2.1	Partial but full in conjunction with other guidelines
5.6	B	5.2.1	Partial but full in conjunction with other guidelines
5.7	B	4.2.9	Full
5.8	A	Not covered by metrics	
5.9	C	Not covered by metrics	
6.1	A	Not covered by metrics	
6.2	A	Not covered by metrics	
6.3	B	Not covered by metrics	
6.4	A	4.6.2	Partial
6.5	A	4.6.1	Full
6.6	B	Not covered by metrics	
6.7	C	Not covered by metrics	
6.8	C	Not covered by metrics	
6.9	B	Not covered by metrics	
6.10	C	Not covered by metrics	
6.11	C	Not covered by metrics	
6.12	B	4.6.2	Full
7.1	A	4.2.5	Partial
7.2	B	4.2.5	Partial
7.3	B	4.2.4	Partial
7.4	C	Not covered by metrics	
7.5	B	4.2.5	Partial
7.6	A	4.2.5	Partial
7.7	B	4.2.5	Partial
7.8	C	4.2.5	Partial
7.9	A	3.3.5	Full
7.10	A	Not covered by metrics	
7.11	C	Not covered by metrics	
7.12	A	4.2.6 & 4.2.10	Partial but full in conjunction with other guidelines
8.1	A	3.1.2	Partial
8.2	A	3.1.2	Partial
8.3	A	3.1.2	Partial

Table 6 – LTDP key guidelines vs RAC metrics