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OAIS: ANALYSIS OF A SUCCESS STORY IN THE LONG-TERM PRESERVATION OF DIGITAL INFORMATION

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Abstract

The OAIS Reference Model: Open Archival Information System (2024) is a standard developed by the Consultative Committee for Space Data Systems (CCSDS) and adopted by ISO as ISO 14721:2025. It defines the processes required for long-term preservation and effective access to information objects and establishes a common language to describe them. The central objective of this study is to analyse the changes introduced in the latest version of OAIS and their implications. This research employs a qualitative research design involving a comprehensive comparison between version 2 (2012) and version 3 (2024). The artcle begins by providing a brief history of the standard. Then, based on a quantitative analysis of the literature, it examines its relevance to digital preservation research and practice. Next, analyzes the changes introduced in the latest edition. Finally, it evaluates the degree of success achieved and providing possible areas for improvement.

Keywords

OAIS. Digital Preservation. Digital Archiving. Space Data Systems. Information Architecture. Standardization

1. *Introduction*

OAIS (Open Archival Information System) - where open means that it has been developed in open forums, but does not imply that access is open or unrestricted, as stated in the text (CCSDS 2024, 1.1) - is a reference model that defines the processes required to preserve and provide effective long-term access to information objects, while also establishing a common language for describing them. It is a model that represents the core functionalities and information types necessary for preservation and identifies the responsibilities and relationships among producers, consumers, and information managers (Klump, 2011).

The OAIS system is relatively easy for an archivist to understand; however, the text has one particularly notable feature: its complexity. It is a model laden with specialized terminology and acronyms that demand constant attention and almost require the creation of a table of equivalences in order not to lose track of the details. It is important to remember that this is a model, not an application, and therefore it cannot be implemented as such (Ruusalep et al. 2012). Moreover, the model applies to all types of assets, both digital and analogue, although its primary focus is on the former. Finally, it is intended for the scientific community, particularly systems and computer engineers, as well as professionals working in the field of ICT.

The model is based on the premise that preserving information in digital form is far more difficult than preserving information on media such as paper or film, because technology is affected by rapid obsolescence and by the risks of information loss (CCSDS 2024, 1.3). It also emphasizes that the model is not concerned exclusively with technology, but also with organizational, legal, industrial, scientific, and cultural aspects.

This article assumes that the reader is already familiar with the standard and therefore omits a general introductory description, which can easily be found in the many references available online and in the literature. It is nevertheless useful to establish some basic starting points in order to define what the standard is and what it is intended to do. Let us begin with its definition, which has changed substantially in comparison with previous versions: "OAIS is an Archive system consisting of hardware, software, information, and policy-based processes and procedures put in place and operated by an organization and its staff. The organization has accepted the responsibility

to preserve information and make it available to a Designated Community. The organization may be part of a larger organization. The system meets a set of mandatory responsibilities that allow an OAIS Archive to be distinguished from other uses of the term 'archive'" (CCSDS 2024, s 1.1).

Designated Community is defined in the terminology section (CCSDS 2024, s 1.6.2) as: "An identified group of potential Consumers who should be able to understand a particular set of information in ways exemplified by the Preservation Objectives. The Designated Community may be composed of multiple user communities. A Designated Community is defined by the Archive, and this definition may change over time." This definition has also changed in the third version, a matter that will be examined later in the analysis of the revisions.

Once the definition is established, we can see what its usefulness is. This reference model:

– provides a framework for the understanding and increased awareness of archival concepts needed for Long Term digital information preservation and access;
– provides the concepts needed by non-archival organizations to be effective participants in the preservation process;
– provides a framework, including terminology and concepts, for describing and comparing architectures and operations of existing and future Archives;
– provides a framework for describing and comparing different Long Term Preservation strategies and techniques;
– provides a basis for comparing the data models of digital information preserved by Archives and for discussing how the data models and the underlying information may change over time;
– provides a framework that may be expanded by other efforts to cover Long Term Preservation of information that is NOT in digital form (e.g., physical media and physical samples);
– expands consensus on the elements and processes for Long Term digital information preservation and access, and promotes a larger market which vendors can support;
– guides the identification and production of OAIS-related standards.

(CCSDS 2024, s 1.1)

What does it mean for OAIS to be a reference model? In this context, a reference model is a conceptual framework or standard that defines best practices, structures, and terminology for understanding and organizing complex systems. It serves as a point of departure for standardizing processes and facilitating communication.

2. *Origins and Evolution of OAIS*

The 1960s and 1970s marked the beginning of the space age, when many space agencies began investing substantial sums in the development of space missions. "As space exploration moved along into the 1980's, technological advances in spacecraft computation, memory and communications capabilities made it feasible to start standardizing the ways in which spacecraft and ground data systems exchanged information. At the same time, the costs of implementing and operating these more capable space missions were increasing significantly" (CCSDS 2025). In order to provide solutions based on international cooperation, the NASA-ESA Working Group (NEWG) was created in 1981 to discuss common problems relating to space information and data systems. The CCSDS emerged from this cooperation. It is currently composed of 11 member agencies, 33 observer agencies, and 141 industrial associates.

In 1991, the CCSDS entered into a cooperative arrangement with the International Organization for Standardization (ISO) as a Category A liaison, that is, among "organizations that make an effective contribution to the work of the technical committee or subcommittee for questions dealt with by this technical committee or subcommittee" (ISO 2025). Under this arrangement, CCSDS Recommendations were advanced to Subcommittee 13 within Technical Committee 20 (Aircraft and Space Vehicles), where, through the normal ISO review and voting procedures, they progressed into full International Standards.

As part of the Consultative Committee for Space Data Systems (CCSDS), the Digital Archiving and Interoperability Working Group (DAI WG) has, since its earliest discussions in 1995, sought to establish standards and best practices for the long-term storage of and access to space mission data. This has included defining reference models such as the Open Archival Information System (OAIS) and developing standards for data formats, metadata, and preservation strategies. "In the CCSDS architecture, the DAI WG is within the Mission Operations and Information Management Services (MOIMS) Area of CCSDS, which is the

applications layer of the CCSDS architecture" (Shaban, Farhan and Ahmed 2022, 176).

Work therefore began in 1994 and culminated in 2002 with the first version of the standard (ISO 14721:2003). The standard was revised in 2012 (ISO 14721:2013), with a stronger focus on verifying the authenticity of data and developing concepts relating to access rights and a security model (Flathers, Kenyon and Gessler 2017), and it was updated again in 2024 (ISO 14721:2025). The original version of the 2024 standard is freely available on the CCSDS website. It belongs to the category of Recommended Practices, which are descriptive in nature and intended to provide general guidance on how to address problems associated with supporting space missions.

The work began in 1994 at the request of ISO, in an open and cooperative working environment, as described by Lavoie in his report for the Digital Preservation Coalition (2014; the 2004 first edition is not accessible), and in greater detail by Lee in his doctoral thesis devoted to the subject (Lee 2005) and in a condensed entry in the Encyclopedia of Library and Information Sciences (Lee 2010). The Committee found that there was no generally accepted framework that could serve as a basis for regulatory development: for example, there were no shared concepts and terminology for digital preservation, no common understanding of the basic functions of a digital archive system, and no agreement on the attributes of digital information objects to which preservation efforts should be directed.

In the absence of a common framework, the CCSDS embarked on the development of a reference model that would define the basic functional components of a system dedicated to the permanent preservation of digital information, identify the key internal and external interfaces of the system, and characterize the information objects managed by that system. All this would be based on a set of well-defined terms and concepts that transcended the vocabularies of specific domains and that would specify a minimum set of requirements for an archiving system. The reference model was intended to provide a comprehensive and consistent framework for describing and analysing digital preservation projects, to constitute a solid basis for future regulatory developments, and to serve as a reference point for the industry.

In May 1997, the first draft was ready for review, and in May 1999 the second draft was released; this would be approved as an ISO draft in 2000. After eight years of work, the first version was issued in January 2002, and the second in June 2012. The first version had been included in the Recommended Standards category, which is prescriptive and specifies how space mission support infrastructures should operate and interoperate. This was corrected in the second version, when the standard was moved to the Recommended Practices category, which is descriptive and provides general guidance.

Accustomed to solving complex problems and developing pioneering solutions, the space agencies within the CCSDS decided to address digital preservation - and, indeed, the very concept of electronic archiving - in response to the challenge of storing data, whether digital or analogue, and keeping it available for as long as necessary. The solution, in the form of a reference model for the long-term preservation of digital information, is a standard: a framework, not an application. In other words, OAIS is a recommendation developed by and for a scientific audience (engineers, physicists, computer scientists, and others), for whom the challenge was not primarily technological but conceptual: how to structure an electronic archiving system as both a concept and a set of integrated processes.

OAIS is organized into six sections: introduction, concepts, responsibilities, detailed models, preservation perspectives, and archive interoperability, complemented by six annexes.

3. A Misunderstood Model? What Quantitative Analysis of the Literature Reveals

This section analyses the findings of a literature-based study focused on OAIS in order to assess both the relevance of the model and the aspects that have been most extensively studied. This is not a literature review in the strict sense, because such an approach would be of limited value for the specific purpose of the present research, namely the analysis of a recently published version of the standard.

Our analysis is based on an exhaustive search of the most relevant databases and bibliographic repositories, combining precise terms (i.e. OAIS, ISO 14721, CCSDS, Reference Model, Long Term Digital Preservation (LTDP)) restricted to the title and subject descriptor fields. The databases consulted and the results obtained are as follows (see Table 1):

Tab. 1: Databases consulted and results obtained

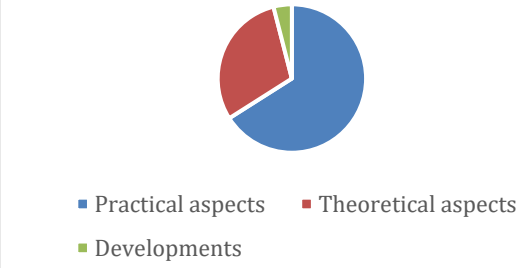
DATABASES	RESULTS
ProQuest. Advanced Technologies & Aerospace Database	275
ProQuest. Library of Science Database	274
ProQuest. LISA. Library and Information Science Abstracts	240
SCOPUS	124
ACM-Digital Library	115
Google Scholar	803/112[1]
Clarivate. Web of Science	45
ProQuest. Arts & Humanities Database	39
ProQuest. Dissertations & Thesis Citation Index	38
EBSCO. Academic Search Ultimate	25
EBSCO. LISTA. Library, Information Science and Technology Abstracts	24
IEEE Xplore	19

The time frame selected was the last ten years, from 2015 to 2024, corresponding to the period following the publication of the second version, since valuable retrospective reviews of the earlier literature already exist (Bettivia, 2016; Corujo, Revez, & Silva, 2020; Cruz & Díez, 2014; Cruz & Díez, 2016; Eschenfelder et al., 2019).

The total result was 1,330 references, from which items referring to other meanings of OAIS - such as Osteo-Articular Infectious Diseases in medicine and Outcomes and Assessment Information Set in psychology - were removed. Because of the relative unreliability of Google Scholar results, the search there was restricted to the title field. The provenance of the repositories, mainly ProQuest and EBSCO, also alerted us to the high degree of duplication in the results; accordingly, duplicates, records outside the time range, and thematically irrelevant items were eliminated. This initial refinement reduced the corpus to 419 references. A second filter was then applied, based on examination of the content, in order to exclude publications that merely cited OAIS without focusing on it. This second selection produced 75 references for close reading, after which 53 were retained. At first sight, this number appears low, amounting to just over five references per year.

In terms of content (see pie chart 1), the overwhelming majority of the studies (35 references, 66%) focus on practical aspects of the model's application, with two principal topics: scientific data repositories (18 references) and national digital preservation projects (12 references). The remainder concerns digital evidence, audiovisual archives, and general aspects of the standard. In second place are articles dealing with theoretical issues (16 references, 30%), addressing topics that became central during the reform process, such as the concepts of Designated Community, Information Model, Preservation Description Information, Significant Properties, and the connection with certification processes (ISO 16363). The remaining two works (4%) concern developments related to the standard.

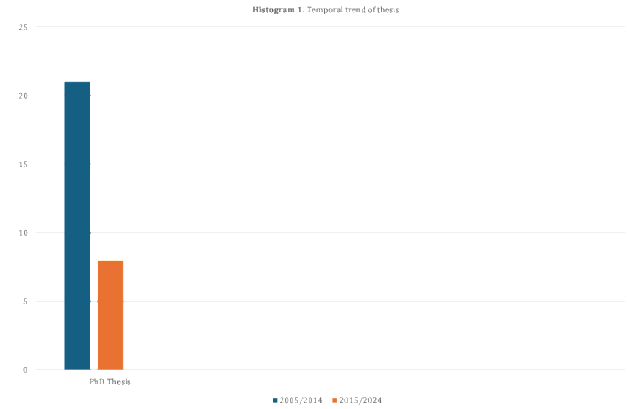
Pie chart 1. Thematic distribution of the results



A first observation arising from these figures is that the OAIS Reference Model is relatively infrequently addressed as a direct topic of research. This conclusion is reinforced by an indicator as reliable as the number of doctoral theses. After consulting the Dissertations & Theses database (Clarivate Analytics Web of Science) without time restriction, the result showed that 38 theses on OAIS had been submitted worldwide between 1969 and 2024. The starting date prompted a further search and the elimination of theses related to medicine and psychology, leaving a total of 29. Between 2005, the year in which the first thesis was submitted, and 2014, 21 theses were completed, representing 72.4% of the total, whereas only 8 theses were completed between 2015 and 2024, representing 27.6% (see histogram nº 1). This points to a clear decline in

[1] Restricted to the title: 112

scholarly interest in the standard as an object of research and reinforces our findings.



On the basis of these figures, we hypothesize that the scarcity of studies is not due to a lack of interest among researchers, but rather to the general acceptance of the Reference Model, which has become largely uncontested and unquestioned. We also consider the effect of "black-boxing" or "infrastructure normalization". OAIS has increasingly been integrated into standard repository architectures and software (e.g. DSpace, Fedora Commons, Archivematica, E-ARK). As a result, it has become a consolidated architectural pattern rather than a subject of active theoretical debate, which helps to explain its reduced visibility in recent research literature.

4. *Analysis of the Changes Introduced in the Standard*

The third version of the standard introduces structural, functional, conceptual, and formal changes. This section analyses those changes and assesses their significance. The standard itself warns, in the first Document Control note, that: "Changes from the current issue are too numerous to permit meaningful use of change bars." The 2012 version facilitated change control by marking revisions with vertical bars in the margin of the affected text. This is no longer the case in the 2024 version.

4.1 The New Features Described by the Authors

Members of the Working Group responsible for revising OAIS published a paper in 2019 reporting on the process and the progress achieved (Giaretta et al. 2019). The changes were presented as updates, based on the conviction that "the updates will not require archives that are currently conforming to the OAIS to make major changes but will instead allow such archives to provide evidence about their conformance more clearly".

In that paper, the authors explained that the changes were organized around the following aspects: concepts, functional model, information model, preservation perspectives, and archive interoperability. The updates to OAIS concepts affect Representation Information, Preservation Description Information, and Preservation Objectives, and they are explained independently, without articulating a broader logic that would interrelate them, as though they were merely incremental revisions. The changes to the Functional Model are likewise presented as minor clarifications: "There have been many small clarifications made to the various text and diagrams which make up the Functional Model, introducing unambiguous shapes for diagram entities" (Giaretta et al., 2019). The main updates to the Information Model carry forward the conceptual changes already mentioned. However, the Preservation Perspectives section underwent substantial revision, expanding the scope of preservation practices. In the previous version, the only preservation practices explicitly described were migration and emulation. The standard now adds other techniques that are not strictly technological but also organizational. In summary, the Content Data Object of the Content Information being preserved may be retained by the Archive but changed, in which case the Archive may transform the Content Data Object; it may be retained unchanged, in which case the Archive may add Representation Information to ensure that the Content Information remains independently understandable; or it may cease to be kept by the Archive and instead be handed over to another Archive, in which case the Archive may transfer the AIP (Archival Information Package) containing the Content Data Object. The Archive Interoperability section describes possible categories of archive association, based either on increasingly high levels of organizational interaction (independent, cooperating, and federated archives) or on styles of resource sharing (all in-house, shared resources, and distributed). This development is based on the recognition that OAIS has never required archives to be monolithic organizations.

As the authors note in their conclusions, "The changes add further clarity to OAIS and bring in a number of useful concepts developed by others

since version 2 of OAIS was published. They will allow repositories to be described more clearly, despite increasing complexity" (Giaretta et al., 2019).

Another issue raised in the paper is the parallel revision of ISO 16363, which was updated to maintain consistency with changes to OAIS. In this respect, version 3 "provide[s] significant clarifications and, when integrated into ISO 16363, improve[s] the auditability of repositories, for example by giving auditors specific tests to verify understandability by using the Preservation Objectives, where they are available" (Giaretta et al., 2019). As will be discussed later, the changes in the current version establish a clearer connection between OAIS and certification, which may affect its nature as a Reference Model.

Six years later, after the publication of the third version, the changes were the subject of a FAIR (Findable, Accessible, Interoperable, Reusable) implementation workshop focusing on OAIS, hosted by FAIR-IMPACT on 24 March 2025 and titled "OAIS version 3 - What does it mean for repositories?" (FAIR-IMPACT 2025). At this event, David Giaretta, a lead author of the standard, explored the recent updates to the OAIS reference model and their implications for digital repositories. In addition to the points already discussed in the 2019 paper, now presented in greater detail, the range of updated terms was expanded and some new topics were introduced:

- Updates to the Functional Model;
- the addition of a Preservation Watch function within the Preservation Planning Functional Entity;
- the replacement of annexes by online, more easily updatable documents:
  Annex A: Composite functional view marked as Informative;
  Annex B: Relationship with other standards or efforts;
- the removal of subsection 1.5 from the previous version (Roadmap for Development of Related Standards).

The links between OAIS and other standards are therefore being strengthened, including ISO 16363 and ISO 23507:2025, Space data and information transfer systems - Information preparation to enable long-term use (IPELTU), within the broader context of far-reaching digital preservation initiatives such as the FAIR principles and the idea of sustainability. The workshop concluded with a presentation of CoreTrustSeal, an international, community-based, non-governmental, and non-profit organization that promotes sustainable and trustworthy data infrastructures. CoreTrustSeal is one of three routes to certification as a Trustworthy Digital Repository (TDR), alongside ISO 16363 and the Nestor Seal, which reinforces the sense that OAIS is increasingly being clarified for certification purposes.

4.2 Our View of the Changes

The following pages present the results of our own analysis of the revisions, based on a comparison between the 2012 and 2024 texts. The current version warns of the large number of changes and the difficulty of identifying them, but we consider the effort worthwhile in view of the importance of the standard and the scope of the revisions.

For explanatory purposes, the changes have been grouped into three categories:

a) Structural: changes affecting the organization of the document through the addition or removal of sections.
b) Functional: changes affecting the functional elements of the model.
c) Conceptual: changes involving terminology or the introduction of new terms and concepts.

At the heart of the revisions lies the transformation of the very concept of OAIS (1.1 Purpose and Scope), as becomes evident when the two versions are compared:

> An OAIS is an Archive, consisting of an organization, which may be part of a larger 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 such responsibilities as defined in this document, and this allows an OAIS Archive to be distinguished from other uses of the term 'archive'. (2012)
>
> An OAIS is an Archive system consisting of hardware, software, information, and policy-based processes and procedures put in place and operated by an organization and its staff. The organization has accepted the responsibility to preserve information and make it available for a Designated Community. The organization may be part of a larger organization. The system meets a set of mandatory responsibilities that allow an OAIS

Archive to be distinguished from other uses of the term 'archive'. (2024)

The subject is now an Archive system, a more complete and comprehensive concept that encompasses organized and interrelated elements working together to achieve a common objective: preserving information and making it available to a Designated Community. The goal remains the same, but the means by which it is understood have changed. OAIS now rests on a set of mandatory responsibilities, thereby moving from a largely desiderative model towards a more prescriptive one. These responsibilities are described in subsection 3.2 and coincide with those of the 2012 version, but with one substantial difference: subsection 3.2 is now normative and establishes the mandatory responsibilities that an organization must discharge in order to operate an OAIS Archive.

In this sense, OAIS has undergone a profound transformation. Whereas the 2012 version treated only Annex A, Composite Functional View, as normative, that annex is now informative, described as "a recommended design or implementation ... useful for discussing concepts and comparing systems". The normative part of the standard now extends beyond subsection 3.2 and includes:

1.6.2 Terminology

2.3 OAIS Information

3.2 Mandatory Responsibilities

4.3 Information Model.

The significance of this change is reinforced by section 1.5.5, Normative Text, which explains the conventions applicable to normative specifications. Accordingly, the words shall and must indicate a binding and verifiable specification; should indicates an optional but desirable specification; may indicates an optional specification; and is, are, and will indicate statements of fact.

4.2.1 Structural Changes

One revision affects the entire standard: the addition of a new heading, Overview, in 14 sections and subsections. This functions as a scope note, except in sections 5 (Preservation Perspectives) and 6 (Archive Interoperability), where a comprehensive overview of the content is provided in full.

Subsection 1.5, Road Map for Development of Related Standards, in the 2012 version - whose purpose was "to identify areas suitable for the development of OAIS-related standards" and which offered a list of regulatory developments - has been removed. Because the regulatory environment is constantly evolving, that list of standards has been replaced by Annex B, which provides three links to the CCSDS Digital Archiving and Interoperability Working Group website, where the information is kept up to date.

Subsection 1.5 (2024), formerly 1.6 (2012), of the introductory section, incorporates three new explanatory subsections:

1.5.3 Diagram Conventions, with illustrative examples.

1.5.4 Typographical Conventions, explaining the typographical features used to distinguish terms requiring well-defined meanings, together with certain exceptions.

1.5.5 Nomenclature, presenting the conventions that apply to normative specifications, as noted above.

Section 2. OAIS Concepts incorporates two new subsections:

2.4 Preservation Objectives, which "are intended to allow the repository to make it possible to test whether the information actually is Independently Understandable by members of the Designated Community now and into the future, in particular having adequate Representation Information." (CCSDS 2024, s 2.4) To fulfil this function, every Preservation Objective should be specific, actionable, and measurable.

2.5 Supplementary Information Held by the Archive, consisting of items presented as a list of information that the archive needs to preserve.

Both developments affect the very concept of Designated Community, now defined as: "An identified group of potential Consumers who should be able to understand a particular set of information in ways exemplified by the Preservation Objectives." These ways are primarily concerned with understanding the information independently, regardless of changes in the Designated Community and in its knowledge base over time.

Section 5, Preservation Perspectives, has also been revised. Subsection 5.2, Preservation of Access and Use Services (2012), has been removed, and two new subsections have been added:

5.3 Adding Representation Information, "to the Representation Information Network associated with a Content Data Object in order to ensure that the Content Information will continue to be understandable and usable by the Designated Community" (CCSDS 2024, s 5.3.1). The text provides examples of Structural Representation Information, Semantic Representation Information, and Other Representation Information.

5.4 Handing over to Another OAIS, a brief subsection of only six lines prescribing how the transfer should be conducted when an OAIS ceases its activity and another OAIS assumes responsibility for preservation.

4.2.2 Functional Changes

These are subsections that have changed or transformed their function by becoming normative:

2.3 OAIS Information, the text of which remains unchanged, but its function changes.

3.2 Mandatory Responsibilities, which identifies the minimum responsibilities that shall be discharged by an OAIS. These responsibilities remain the same as in the 2012 version. Annex F discusses security considerations that may apply to them.

4.3 Information Model, which provides concrete Unified Modeling Language (UML) class diagrams for the conceptual information objects introduced in 2.3.

In other cases, change arises from the addition of new functions. Thus, 4.2.3.7, Preservation Planning Functional Entity, incorporates a new function: Preservation Watch, defined as "the role of collating preservation related information from a variety of internal and external entities. The Preservation Watch function also brings in reports, requirement alerts and emerging standards from the Monitor Designated Community function and technology alerts, external data standards, results and reports from the Monitor Technology function. Changes in the environment of the Archive (financial, political, and environmental) can be part of the Preservation Watch function" (CCSDS 2024, s 4.2.3.7).

4.2.3 Conceptual Changes

Seven new acronyms and abbreviations have been added (CPU, HTTP, ID, IETF, RFC, TCP/IP, and USB), while one (UNICODE) has been removed. Terminology is the area in which the greatest number of changes has been made, affecting 26 of the 88 terms used (29.5%), although most of these changes may be regarded as relatively minor: more precise definitions adapted to the revisions noted above, such as Context Information and Preservation Description Information; shorter definitions, such as that of Data Management Functional Entity; or the addition of new elements that clarify established terms, for example the change from Representation Network to Representation Information Network. In addition, one genuinely new term has been introduced: Preservation Objective, reflecting the greater importance accorded in this version to Preservation Perspectives.

The concept of OAIS itself represents the principal change, as shown above, and deserves closer attention. The subject of OAIS shifts from the Archive (an organization) to the Archive system (put in place and operated by an organization and its staff), thereby altering the sequence and articulation of the concepts involved: an Archive system, integrated into an organization, which bears responsibility for preservation and which may belong to, or form part of, a larger organization. These responsibilities, detailed in 3.2 as mandatory, are what characterize an OAIS Archive and distinguish it from other uses of the term Archive.

Similarly, the text reinforces the value of the concept of Provenance. Although the glossary entry (Provenance Information) remains unchanged, its importance is strengthened in section 1.3, Rationale, which states that "information is more and more easily altered or faked. Ways to be more sure of the authenticity of information, by knowing its provenance and being sure that it has not been altered, will help to counter these threats" (CCSDS 2024, s 1.3).

The definition of Information Package changes substantially, as does the figure representing it. "An Information Package is a logical container composed of optional Information Object(s). Associated with this Information Package is Packaging Information that describes how the components of an Information Package are logically or physically bound together and how to identify and extract the components" (CCSDS 2024, s 2.3.3). It is now described as a logical rather than a conceptual container (2012), which is more precise, less abstract, and better aligned

with the meaning of Information Package in the ICT environment. The revision also clarifies the nature of the packaged object, namely Information Object(s), which replaces Content Information plus Preservation Description Information (2012). The Information Object is defined as a Data Object plus the associated Representation Information required to make it understandable.

Within the high-level external interactions of OAIS between Producers and Consumers, the concept of Producer Interaction changes significantly with regard to the contents of a Submission Agreement: "The Submission Agreement should make it clear whether the Content Information contains links to other information. If there are such links, then the Submission Agreement should make it clear whether that referenced information is included in the SIP (Submission Information Package). For example, a document submitted may contain hyperlinks to web pages or documents, and a decision should be taken as to how these are to be treated by the Archive" (CCSDS 2024, s 2.6.3).

The concept of Consumer Interactions is also revised by introducing limits on access to information through a DIP (Dissemination Information Package) for various reasons: "The Consumers must also be informed of restrictions, if any, arising from the Access Rights Information associated with the Information and must agree to abide by those restrictions. Such restrictions could include, for example, limitations on commercial use by the Consumer or attributions which must accompany results derived from the Information" (CCSDS 2024, s 2.6.4). The concept of the Order Agreement, which mediates relationships between Consumers and the Archive, is likewise refined so as to encompass scenarios in which the request is not clearly described or in which the request is informal and no written Order Agreement exists.

Another central aspect connected to Provenance is Evidence of Authenticity, which may take many forms and is intended to support the assertion that the object is what it purports to be. Initial evidence is provided by the Producer during the submission process, "and this evidence is maintained, updated, and/or incremented by the Archive over time" (CCSDS 2024, s 4.2.3.3). Since the object may need to change over time, those changes are documented as part of its Provenance Information, so that the object remains traceable in the long term and understandable to the Designated Community. In order to preserve authenticity, the object must retain its Content Information unaltered and provide evidence of authenticity through Information Property Descriptions.

In addition to the structural implications already discussed, Section 5, Preservation Perspectives, undergoes a conceptual shift. Whereas version 2 (2012) focused on migration as a preservation technique, version 3 (2024) adopts a more forward-looking perspective. It begins from a set of observations that condition preservation prospects:

1) The time horizon for the accessibility of standardized formats is unknown.
2) Storage media are incompatible with the concept of long-term preservation, which incorporates the idea of permanence.
3) Technological systems evolve rapidly, making many of them less cost-effective even in the short term.
4) As operating systems evolve, it becomes increasingly difficult to maintain operational software as part of the Representation Information essential to the preservation of Content Information.
5) In addition, changes will occur in the knowledge base of the Designated Community, which will affect the Representation Information required (CCSDS 2024, s 5.1).

From this starting point, the content being preserved may be retained by the archive in one of three states: changed, unchanged, or transferred to another archive. In the first case, the archive may transform the Content Data Object; in the second, it may add Representation Information to ensure that the content remains independently understandable; and in the third, it may hand over the AIP containing the content. "For each of these approaches there will be the need to ensure that an Information Object being preserved continues to be Independently Understandable by the Designated Community, the components of its AIP are not lost and are updated appropriately" (CCSDS 2024, s 5.1).

The concept of Digital Migration is itself expanded through the addition of a new motivation: "Avoid Information Loss: The rapid pace of technology evolution means that the software used to process the Content Data Object, the hardware used to run the software, and the media used to store the Content Data Object will become obsolete over the short to medium term

while the Content Information may need to be preserved over the Long Term. An OAIS may choose to migrate their AIPs so that they can be used with incumbent hardware, software, and media" (CCSDS 2024, s 5.2.2).

Finally, Archive Interoperability also undergoes significant development, leading to a more mature and comprehensive concept. Interactions between archives and other organizations must be based on agreements that include:

- the protocol(s) to be used in the transfer, for example, TCP/IP, HTTP, USB memory stick, etc.;
- the interfaces to be used;
- the definition of the packages (SIP/AIP/DIP) transferred;
- the processes that the sending and receiving organizations should follow. (CCSDS 2024, s 6.2.1)

These interactions lose their exclusively technical character; indeed, the adjective technical disappears from version 2 (2012). At the same time, the model acquires greater breadth through the addition of new categories alongside the pre-existing Distributed category (2012):

- All in-house: Archives that perform all archival functions in-house.
- Shared resources: Archives that have entered into agreements with other organizations to share resources, perhaps in order to reduce costs. This requires various standards internal to the Archive (such as ingest-storage and access-storage interface standards) but does not alter the user community's view of the Archive. (CCSDS 2024, s 6.2.1)

These categories are organized into two groups.

Those with the highest levels of organizational interaction:

- Independent.
- Cooperating.
- Federated.

Those that are orthogonal to the previous set:

- All in-house archives.
- Archives with shared resources.
- Archives with distributed functionality.

"Since these are two somewhat separate sets of categories, a single Archive would be categorized in each category separately. For example, an Archive could be categorized as an Independent, with regard to auditing and certification processes, the third version of OAIS adopts a clearer and more pragmatic approach. Without losing its nature as a conceptual model, which does not prescribe any particular architecture or technological solution, the text is now more precise in identifying its normative parts and mandatory responsibilities. This helps to establish clearer guidelines for interpreting the model and resolving doubts when implementing it in practice, in response to the demands of the preservation community. This is confirmed by the fact that the key standards for certification have been revised or, in some cases, drafted for the first time in a coordinated manner. This is the case with the second version of ISO 16363:2025 (Audit and certification of trustworthy digital repositories), the third version of ISO 16919:2025 (Requirements for bodies providing audit and certification of candidate trustworthy digital repositories), and the new standard ISO 23507:2025, Information preparation to enable long-term use (IPELTU), published in July 2025. All-in-house or an Independent, Distributed Archive and other Archives could be a Federated Archive with Shared Resources or a Federated and Distributed Archive." (CCSDS 2024, s 6.2.1).

These, in essence, are the main changes introduced in the latest version of OAIS. Their implications are discussed in the following section.

5. *Discussion and Conclusions*

The first striking feature of the OAIS landscape is that the process of reception and acceptance of the standard as a theoretical foundation, conceptual framework, and lingua franca in the field of preservation, as characterized by Brian Lavoie (2014), can now be considered complete. Although a qualitative review of the literature was not among the objectives of this study, our thematic analysis of the 53 selected core papers indicates that criticisms of, and expressions of incomprehension towards, the reference model have disappeared in comparison with the literature published between 2003 and 2015 (Bettivia 2016; Eschenfelder et al. 2019; Cruz and Díez 2014; Cruz and Díez 2016; Corujo, Revez and Silva 2020).

In this respect, more recent publications have focused instead on doubts and practical difficulties faced by researchers and practitioners in developing preservation projects based on the reference model. On the basis of a selected sample

of references, the most significant topics are the design of architectures (Celesti et al., 2018; Faiza, Suhardi, & Ramdhani, 2022; Sadirmekova et al., 2021), the importance of integrity, authenticity, and provenance in forensic and health environments (Hyun, Shon, & Park, 2020; Löbe et al., 2023; Molina & Rodriguez, 2017), and, above all, the difficulties that arise in audit and certification processes (Frank, 2022; Le Meur & Taroco, 2019; Wilson, 2017). Other studies have addressed specific terminological and conceptual issues (Bettivia, 2015; Hilgengerg & Faria, 2018; Kärberg & Saarevet, 2016).

With regard to auditing and certification processes, the third version of the OAIS adopts a clearer and more pragmatic approach. Without losing its nature as a conceptual model, which does not prescribe any architecture or technological solutions, the text is more precise in pointing out the normative parts and mandatory responsibilities. This helps to establish clearer guidelines for interpreting the model and resolving doubts when implementing it in practice, in response to the demands of the preservation community. This is confirmed by the fact that the essential standards for certification have been revised or even drafted for the first time in a coordinated manner. Such is the case with the second version of ISO 16363:2025 (Audit and certification of trustworthy digital repositories), the third version of ISO 16919:2025 (Requirements for bodies providing audit and certification of candidate trustworthy digital repositories), or the new standard ISO 23507:2025 Information preparation to enable long-term use (IPELTU) published in July of 2025.

We have also observed that the revision process has taken into account the demands expressed in the literature, especially those most frequently repeated, such as the issues mentioned in the previous paragraph. There is only one respect in which the standard has not changed substantially: the term and concept of Designated Community, even though some authors have raised doubts about it (Donaldson, Zegler-Poleska, & Yarmey, 2020; Frank & Rothfritz, 2023; Moles, 2022). This is a concept that has become deeply rooted in the preservation community and functions as an umbrella term for all types of consumers or users of information; in that sense, it has demonstrated its validity across very different environments.

Finally, it should be noted that, on the basis of the reference model, progress is being made in new projects such as the Open Archival Information System Interoperability Framework (OAIS-IF), which was "developed by the Data Archives Interoperability (DAI) Working Group (WG) of the Consultative Committee for Spatial Data Systems (CCSDS), [and aims] to provide interoperability between archives users (producers and consumers of archival data) and archives, as well as interoperability between archives" (Kearney et al., 2018, 2025, p. 173).

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