Implications for Electronic Records Encapsulation Strategies: A Comparative Analysis of METS and VEO

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Abstract: This research examines the packaging methodology for electronic records, with particular emphasis on the component-based design of the US METS 2.0 specification and its benefits in metadata consolidation and resource linkage. The investigation further analyzes the characteristics of Australia's VEO 3.0 standard, highlighting its distinctive approaches to separating logical and physical components while maintaining data integrity. In response to practical challenges faced by China's Electronic records Encapsulation Package (EEP)—such as difficulties in traceability and utilization, data package invalidation due to directory structure changes, and performance bottlenecks in file access—this study proposes recommendations based on a comparative analysis of mainstream international encapsulation strategies. These recommendations include decoupling the logical structure from physical storage, constructing an open metadata framework, and adopting a hierarchical encapsulation approach. The article aims to provide references for improving electronic records encapsulation standards and to promote the establishment of encapsulation specifications that align with China's practical needs while incorporating advanced and operable features.

Keywords: Electronic Records; Records Encapsulation; Long-Term Preservation

1. Introduction

Amidst the comprehensive digital transformation of society, electronic records have become the primary medium for information documentation. Challenges such as susceptibility to tampering, complex composition prone to loss, and dependency on specific technological environments continue to pose significant difficulties in managing the authenticity, integrity, and usability of electronic records. Electronic records encapsulation, which binds records and their metadata into a self-contained, self-describing, and self-verifying information package, constitutes a fundamental unit for achieving long-term preservation. China's National Archives Administration introduced the XML-based Digital Document Encapsulation Standard (hereinafter referred to as the "Specification") in December 2009, which proposed the concept of Electronic File Encapsulation Package (EEP).The core design philosophy and technical framework of EEP drew upon two mainstream international encapsulation technologies at the time—Australia's VEO and America's METS—forming a localized solution based on mature international experience and practical archival management needs. Nevertheless, the prolonged interval since the initial publication of the "Specification" and its subsequent lack of revisions have resulted in certain limitations regarding implementation methodologies for packaging procedures. Meanwhile, in 2025, the United States released the METS 2.0 schema, and Australia's PROV updated its standards based on VEO 3.0. Therefore, a systematic study of mainstream international encapsulation strategies is of great significance for establishing electronic records encapsulation specifications that are tailored to China's context and embody both advancement and operability.

At present, scholars have conducted relevant research on electronic records encapsulation strategies. In terms of international mainstream encapsulation strategies, Wang et al.[1], through a comparative study of VEO 3.0 and EEP technologies focusing on package structure, long-term preservation formats, metadata, and digital signatures, proposed implications of Australia's new VERS standard for China's electronic records metadata encapsulation strategy. Liu [2] analyzed changes in the VERS standard regarding encapsulation methods, XML syntax structure, electronic signature mechanisms, and supported software tools, and reflected on the positioning and application of electronic records metadata encapsulation strategies. Cheng [3], via a comparative study of VEO's "onion-style" and METS's "modular" encapsulation models, suggested adopting METS either as a replacement for or a supplement to VEO to improve encapsulation strategies. Luo [4], by dissecting the similarities and differences among typical encapsulation strategies and proposing an evaluation index system, concluded that METS, with its improved safeguarding mechanisms, better aligns with the requirements for electronic records encapsulation.

In terms of China's local electronic document encapsulation strategies, Du and Yuan [5], in their research on technical strategies for long-term preservation of electronic archives, mentioned the strategy of long-term preservation information package encapsulation. Their study emphasizes the importance of establishing uniform standards for package structures and making these specifications openly available, while also recommending that XML Schemas be both publicly accessible and archived alongside the digital materials. Huang et al. [6] proposed the RASM model, a standardized management model for electronic records and archives centered on "Three Packages, Two Structures, and One Integration." The "Three Packages" refer to the Archival Information Package, Discovery Information Package, and Management Information Package, with detailed explanations of the model's management objects—information packages, metadata, and data management processes. Xia and Chen [7] interpreted the content, structure, and naming rules of the archival information package as stipulated in the Archiving Specification for Electronic Records of Government Service Matters, which specifies that electronic records be archived per case unit, typically stored in ZIP format. Fang and Zhu [8] provided specific construction suggestions regarding standard specifications, module design, and transmission paths for archival information packages in the "electronic archiving" module of government service systems within digital archives. Li [9], in his exploration of a universal archiving interface scheme for enterprise digital archives, proposed an archival information package encapsulation strategy based on the archival industry standard Specification—the package is a compressed file with the SIP extension, composed of multiple electronic files such as XML, XSD, and FILE.

2. Purpose and Information Package Structure of Electronic Records Encapsulation

The concept of electronic records preservation through encapsulation encompasses much more than basic file compression and aggregation. It constitutes a methodical, standardized approach comprising a set of guidelines and techniques aimed at preserving the long-term reliability, completeness, and operational accessibility of electronic records. This methodology entails the organized consolidation and arrangement of all critical elements that constitute a fully functional electronic records, implemented via carefully designed technical frameworks and data representation models. Consequently, electronic records encapsulation fundamentally constructs a self-contained, self-describing, and self-verifying "information package," ensuring that the record and the context essential for its comprehension are never separated. This enables the record to be accurately identified, understood, and utilized independently of its original creation system, even after traversing time and technological changes.

Specifically, an information package is a logical container composed of two types of information objects: Content Information (CI) and Preservation Description Information (PDI). CI and PDI are encapsulated and identified through Packaging Information. To enable the information package to be defined, identified, and searched, Package Description may optionally be included. The CI consists of a Content Data Object and its Representation Information (Figure 1. Information Package Concepts and Relationships).

3. In-Depth Analysis of Mainstream Electronic Records Encapsulation Strategies

3.1 Metadata Encoding and Transmission Standard (METS)

3.1.1 Background

The Metadata Encoding and Transmission Standard (METS) represents a collaborative initiative spearheaded by the U.S. Library of Congress in partnership with the Digital Library Federation. This international effort involves numerous research library organizations and higher education establishments worldwide. Initially introduced in 1999, the framework reached a significant milestone with the launch of METS 2.0 specifications in 2025. It focuses on the standardized processing of metadata for complex digital objects (encompassing various types such as text, video, and images). Its core positioning is to provide a unified XML document format for the integrated encoding of descriptive, administrative, and structural metadata for digital objects. This standard aims to address two core needs: first, to support the efficient management of digital objects within repositories; second, to facilitate the interoperable exchange of digital objects between different repositories or between repositories and users. As noted by Owens D et al. [10], the richness provided by cataloging metadata for different described objects is limited, whereas METS can offer this richness.

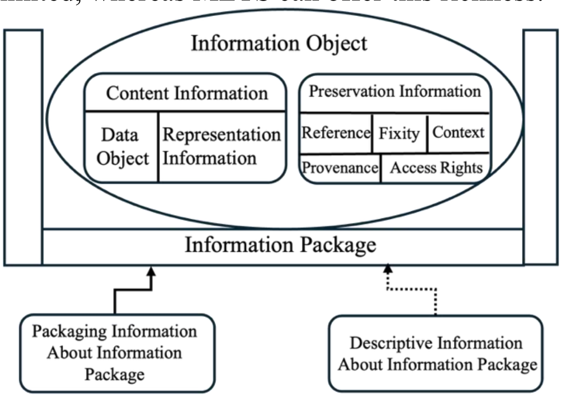

Figure 1. Information Package Concepts and Relationships

3.1.2 Content

METS document employs a modular structural design, consisting of four interrelated core sections. These sections are linked through unique identifiers (ID attributes) to form a comprehensive metadata and resource description system for digital objects. The components include METS Header, Metadata Section, File Section, and Structural Section (Figure 2. METS Structure).

Part 1: METS Header. The header records metadata about the METS document itself, not the digital object it encodes. Its core function is to ensure the document's traceability and manageability, containing three key dimensions of information. "Basic Attribute Information" records the document's creation date/time and processing status, identifying its generation time and current management phase. "Participant Information" records the individuals or institutions involved in the document's creation and management, clearly specifying their roles and types, preferably using controlled vocabularies to ensure consistency. "Identifier Supplement Information" can record multiple alternative identifiers, supplementing the primary identifier in the document's root element, thereby enhancing the uniqueness and management flexibility of document identification.

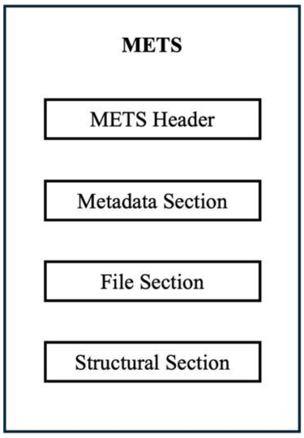

Figure 2. METS Structure

Part 2: Metadata Section. This section records metadata about the METS object as a whole or its components. This portion documents comprehensive information pertaining to the METS entity and its constituent elements. It consolidates digital assets featuring varied metadata categories while supporting two distinct storage approaches: external linkage and internal incorporation of metadata. Association with the File Section and Structural Section is established via ID attributes. Metadata is organized hierarchically, with basic units as the core, which can be grouped as needed. All metadata-related modules, groups, and basic units require unique identifiers, providing the foundation for cross-module association. METS supports five primary types of metadata: descriptive metadata, technical metadata, intellectual property rights metadata, source metadata, and digital provenance metadata regarding the digital object. Storage methods include external referencing, which points to metadata resources stored externally via a Uniform Resource Identifier, requiring clear specification of the external metadata's MIME type, format type, reference type, and specific location to ensure precise location and invocation; and internal embedding, which encapsulates metadata directly within METS, supporting two forms: XML format metadata under non-METS namespaces, and binary or text format metadata encoded in Base64, with the metadata's MIME type and format type annotated to clarify parsing rules.

Part 3: File Section. This segment oversees the digital asset's constituent content files, systematically cataloging and identifying their positions within the METS framework. It methodically arranges all files forming the digital entity, creating structured inventories while linking files to their corresponding metadata records. The system enables logical file categorization based on various parameters including file format or functional purpose, with each category usually representing either an alternative rendition or a logically connected portion of the digital asset's file repository. Detailed file profiles are maintained, encompassing fundamental characteristics like exclusive identification codes, media formats, storage requirements, and temporal creation data. Distinctive markers may differentiate between variant editions of files sharing identical content, thereby elucidating inter-file content relationships. Two principal approaches govern file storage: external linkage and internal incorporation. The external method connects to resources housed in separate systems through reference indicators, while the internal approach embeds content directly within the document structure. The former approach establishes connections through references and identifiers, allowing for associations without content replication. In contrast, the latter method incorporates file data directly within the METS document, either in XML format or as Base64-encoded information, effectively containing the complete digital entity. This internal integration proves particularly advantageous for scenarios involving inter-repository digital asset transfers or remote preservation of archival materials.

Part 4: Structural Section. This module describes the logical and physical organization of the digital object. It defines the arrangement of the digital object's components through a hierarchical structure, establishes associations between structural units and content files/metadata, and supports user navigation and resource localization within the digital object. Multiple structural views (e.g., logical content structure, physical storage structure) are constructed for the digital object. Each view builds a hierarchical structure through nested hierarchical units, clearly presenting the organization of the digital object. Each hierarchical unit, as a basic component of the structure, requires information such as a unique identifier, display label, unit type, and sequence number to specify its identification, meaning, and position within the overall structure. The resource association mechanism includes three types: file association, fragment location, and external document association. File association links to specific files in the File Section via file identifiers, binding structural units to actual content files and clarifying the corresponding content. Fragment location allows precise positioning to specific segments (e.g., a specific time segment in an audio file, a specific content range in a text file) for associated files, defining the segment scope via start position, end position, and location type. The external document association feature facilitates connections between structural elements and separate METS documents, serving as an effective solution for managing extensive collections (like complete journal series or archival groupings) by avoiding the operational inefficiencies that arise from handling excessively large single METS files.

3.1.3 Characteristics

First, Metadata Integration and Standardization. While METS itself does not provide the vocabulary or syntax for encoding the metadata it contains or references—content guidelines are supplied by the specific standards used—it offers a means to link this metadata with the entity's digital content and other types of metadata related to the object. It is compatible with various mainstream metadata standards (e.g., MARC, PREMIS, Dublin Core), supports both external referencing and internal embedding, addresses issues of scattered sources and heterogeneous formats of digital object metadata, and provides a unified framework for metadata management.

Second, Precise Association of Resources and Structure. Through attributes such as ID and FILEID, cross-module binding of metadata, files, and structure is achieved, even allowing localization to specific file fragments. This provides technical support for the refined management of digital objects and user navigation.

Third, High Flexibility and Modular Structure. METS does not mandate fixed metadata schemes or file organization methods; instead, it provides a modular "container." Implementers can select and configure these modules according to specific needs, like building blocks, without necessarily including all parts. This design enables adaptation to various scenarios, ranging from simple single-file documents to complex, multimedia digital objects.

3.2 Victorian Encapsulated Object (VEO)

3.2.1 Background

The Victorian Electronic Records Strategy (VERS) represents a pioneering initiative developed and disseminated by Public Record Office Victoria (PROV), an Australian governmental institution. This framework primarily aims to facilitate Victorian public sector organizations in generating, acquiring, and maintaining digital records that are genuine, comprehensive, and contextually significant. The mandated transfer format involves Victorian Encapsulated Objects (VEOs), with PROV regulations stipulating that electronic records of enduring value and their associated metadata from state agencies must adopt this XML-based, VERS-compatible encapsulation structure. The PROV introduced successive iterations of VERS standards, with Version 1 launched in 1999, followed by Version 2 in 2003, and Version 3 in 2015. Subsequent developments included the 2018 release of "VERS Digitising Forever 2018-2021" alongside a comprehensive standard. The year 2019 witnessed substantial revisions to the VERS Version 3 specifications, while 2025 saw additional enhancements to both the principal standard and two supporting technical documents.

3.2.2 Content

At present, the VERS Version 3 framework consists of seven distinct documents: a primary standard document, five detailed technical specifications, and one set of operational guidelines. The principal standard establishes the foundational principles and mandatory criteria governing all processes related to digital record generation, acquisition, and management. Specification 1 (PROS 25/02 S1: DIGITISATION) stipulates the requirements that Victorian public sector bodies must meet when planning to digitize records and use the digital copies as official records. This specification functions within the regulatory framework established by the Conversion or Digitisation of Records Retention and Disposal Authority (RDA), which legally permits the destruction of certain original physical records after digitization, provided specific conditions are satisfied. Additionally, this document mandates that digital reproductions intended for permanent preservation must be submitted to PROV using the VEO file format. Specification 2 (PROS 19/05 S2: MINIMUM METADATA REQUIREMENTS) defines the minimum set of metadata that must be captured when creating or receiving a record (document, information, data). According to Specification 3 (PROS 19/05 S3: LONG TERM SUSTAINABLE FORMATS), it establishes the approved digital file types for transmitting records of enduring significance to PROV, while also serving as a suggested approach for maintaining non-permanent records over extended periods. Specification 4 (PROS 19/05 S4: CONSTRUCTING VEOs) defines the encapsulation structure and generation mechanism for VEOs. Specification 5 (PROS 25/02 S5: ADDING METADATA PACKAGES TO VEOs) is intended for technical developers building systems and tools to construct VEOs, specifying requirements for adding metadata packages to VEOs. The guideline describes how to construct a VEO and outlines the criteria PROV uses during record appraisal.

A VEO is a ZIP file containing specific files and subdirectories, employing a "separated" encapsulation strategy (Figure 3.VEO Structure). The encapsulation package uses the extension .veo.zip and includes six subdirectories: Content subdirectories store the specific information files encapsulated in the VEO; VEOContent.xml logically organizes the information in the content subdirectories and associates metadata with the components; VEOHistory.xml contains an event log recording the history of the VEO; VEOContentSignature?.xml and VEOHistorySignature?.xml can be used to detect any tampering with the VEOContent.xml and VEOHistory.xml files, respectively; VEOReadMe.txt is a textual description of the VEO and its components.

3.2.3 Characteristics

First, Standardized Structural Composition. The VEO package maintains a consistent ZIP-based architecture with six mandatory internal directories that follow established specifications.

Second, the separation between conceptual and actual data arrangement is achieved. The VEO framework distinguishes content representation from its storage mechanism. At the conceptual level, specified in the VEOContent.xml file, materials are systematically categorized into discrete elements (such as data entities) and linked with descriptive attributes, facilitating both linear and nested perspectives through document pointers. Meanwhile, the storage layer located in content subfolders maintains absolute freedom regarding file nomenclature and organization, allowing unrestricted implementation of storage solutions. Significantly, the conceptual ordering remains autonomous from physical storage configurations, thus permitting ideal content display determined by operational and administrative requirements rather than being limited by storage considerations.

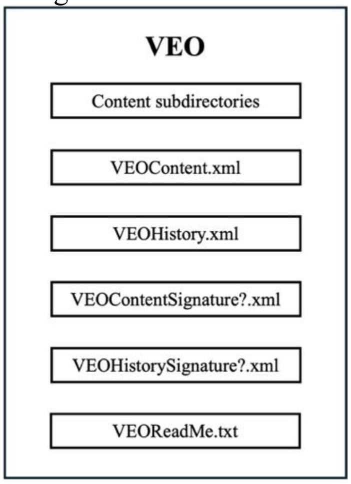

Figure 3. VEO Structure

Third, Emphasis on Data Authenticity and Integrity Assurance. VEO incorporates multiple safeguards: (1) Hash Value Verification, where VEOContent.xml stores cryptographic hash values for each content file (with the hash function identified) to detect tampering; (2) Digital Signature, applied to both VEOContent.xml and VEOHistory.xml, with all signature details (algorithm, timestamp, signatory, value, and certificate chain) stored in dedicated files for verification; and (3) Certificate Chain Mechanism that uses layered verification—the first certificate holds the matching public key, subsequent certificates validate the prior one, and the final certificate is self-signed—to ensure signature reliability.

Fourth, Rigorous Compression Standards and Security Protocols. The concluding packaging phase mandates adherence to precise technical requirements for ZIP files: all internal file paths must conform to the VEO naming convention; data compression is exclusively limited to the conventional Deflate method; and advanced ZIP functionalities including encryption, digital authentication, and update mechanisms are strictly forbidden to guarantee interoperability and archival durability. This ensures correct directory structure upon extraction, avoids compatibility issues, effectively controls post-encapsulation file size inflation, and balances long-term preservation usability needs.

4. Problems in the Practical Application of EEP

4.1 Difficulties in Traceability and Utilization

EEP adopts an "integrated" encapsulation strategy, encapsulating electronic records and their metadata in a nested, layered manner. Although EEP contains the files themselves and their metadata, this metadata is often "locked" inside the encapsulation package, lacking open interfaces to external systems. When massive numbers of EEPs are stored in a system, each one resembles a "black box" to the archival management system or retrieval platform. For the system to understand its internal content, it must first parse the entire encapsulation package's structure to extract metadata information. This process is computationally intensive and time-consuming, preventing immediate, efficient retrieval akin to querying database fields. Consequently, rapid cross-file, cross-fonds retrieval and big data analysis become exceptionally difficult.

4.2 Data Package and Media Obsolescence Triggered by Changes in Directory Data

The EEP typically encodes the directory structure of its internal files within the package itself. Consequently, any changes to the top-level directory structure or naming conventions of the file management system—due to system upgrades, management optimization, or other reasons—pose a risk of complete obsolescence for EEPs generated based on the old directory paths. This rigid dependency on a fixed directory structure renders EEPs highly fragile. For instance, during system migration or data consolidation in an archival repository, any modification to storage paths may result in all archived EEPs becoming unreadable or unparsable by the new system, leading to the disintegration of internal file linkages. To mitigate this, managing institutions are forced to incur substantial costs to maintain the stability of legacy directory systems. Alternatively, they must perform extensive "surgical" operations with each system change: batch-unpacking all affected EEPs, remapping file paths, and repackaging the data. This process is not only labor-intensive but also prone to introducing errors during repeated handling, thereby compromising the authenticity of the records.

4.3 Performance Degradation in Access and Processing Due to Excessive File Size

While the multi-layered encapsulation approach of EEP appears robust, it effectively imposes a significant performance burden on electronic records. When encapsulating composite files containing numerous images, attachments, or complex version histories, the resulting EEP can grow to gigabytes or even terabytes in size. If a user or system needs to access only a single sub-component within such a large file, the entire EEP must be downloaded and parsed—an operation analogous to "moving an entire filing cabinet to retrieve a single sheet of paper." This results in severe wastage of network bandwidth and computational resources, leading to prolonged response times and a poor user experience. Furthermore, during batch operations such as format migration, virus scanning, or integrity verification, processing these oversized encapsulation packages places immense strain on servers, creating a systemic performance bottleneck and significantly increasing operational costs and time overhead.

5. Implications and Recommendations for Electronic Records Encapsulation Strategies

5.1 Promoting Decoupling between Logical Structure and Physical Storage

On one hand, it is advisable to adopt a "logical mapping" mechanism. New encapsulation standards or practical guidelines should utilize an independent, XML-based manifest file to define the logical relationships among files. On the other hand, unique identifiers should be employed for associations. The manifest file should reference specific file content via a unique file ID rather than relative paths. This architecture establishes a crucial preservation feature: modifications to storage arrangements necessitate revisions solely to the conceptual mapping document, preserving all original data files intact. Through separating conceptual structuring from physical storage locations, this technique effectively prevents package degradation caused by folder reorganization, guaranteeing enhanced durability and sustained usability for packaged digital materials.

5.2 Constructing an Open and Integrated Metadata Framework

Establishing a standardized metadata framework is crucial, with a focus on developing both mandatory and optional components. Priority should be given to metadata elements that verify document authenticity, maintain data integrity, and preserve contextual connections. Additionally, implementing external metadata linking mechanisms is vital, enabling synchronization of critical descriptive information with external metadata repositories during the packaging phase.

Furthermore, the system should facilitate streamlined data access and large-scale analytical processing. Through the integration of external metadata links and accessible application programming interfaces, archival systems gain the ability to conduct rapid searches and comprehensive analyses on extensive collections of packaged files without requiring decompression. This approach enhances operational efficiency while maintaining data security.

The direct-access approach converts archival information into a readily searchable and analyzable asset. This methodology reconfigures the EEP from an opaque system into a clearly identifiable, interconnected, and comprehensible component within a knowledge network, significantly improving electronic document traceability and their utility for information exploration.

5.3 Advocating for a Layered and Extensible Encapsulation Design

On one hand, a "divide and conquer" encapsulation strategy should be introduced. For large, composite electronic records—such as major engineering project archives or official documents containing numerous attachments—a hierarchical encapsulation approach is recommended. A master encapsulation package should be created for the top-level file or project, which internally links, via a logical mapping file, to multiple sub-packages, each corresponding to a specific topic or an independent document. On the other hand, this design aims to improve system performance and user experience. When a user needs to access only a specific sub-component, the system need only locate and decompress the relevant sub-package, without processing the entire massive data entity. This "on-demand loading" mechanism can dramatically reduce the consumption of network and computational resources, alleviate performance bottlenecks caused by oversized files, provide users with a seamless access experience, and facilitate routine system maintenance, backup, and migration operations.

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References

[1] Wang Bo, Qu Jian, Huang Yan. Enlightenment of Australia's New VERS Standard on China's Electronic Records Metadata Encapsulation Strategy: A Comparative Study Based on VEO 3.0 and EEP. China Archives, 2025, (3):70-72.
[2] Liu Yuenan. Rethinking the Metadata Encapsulation Strategy for Electronic Records: A Study Triggered by Changes in the VERS Standard. Archives Science Study, 2019, (4):116-123.
[3] Cheng Yanyan. A Comparative Study of International Electronic Records Metadata Encapsulation Methods VEO and METS. New Technology of Library and Information Service, 2011, (10):7-11.
[4] Luo Wenwu. A Comparative Study of Electronic Records Encapsulation Strategies. Master's Thesis, Zhejiang University, 2013.
[5] Du Linlin, Yuan Jiaxin. Research on Technical Strategies for Long-term Preservation of Electronic Archives. China Archives, 2021, (12):67-69.
[6] Huang Jianfeng, Yuan Ping, Dai Min, et al. Setting and Analysis of Management Objects in RASM Mode. Archives Science Communication, 2024, (6):39-45.
[7] Xia Zhenhua, Chen Lin. Interpretation of "Specifications for Archiving Electronic Records of Government Service Matters". China Archives, 2023, (11):26-27.
[8] Fang Xia, Zhu Zhenhui. Discussion on the Technical Path of "Electronic Archiving" in Digital Archives Room. Zhejiang Archives, 2023, (10):13-15.
[9] Li Chunwei. Exploration of a Universal Archiving Interface Scheme for Enterprise Digital Archives (Rooms). Beijing Archives, 2023, (4):36-39.
[10]Dwight Owens, Dilumie Abeysirigunawardena, Ben Biffard,et al. "The oceans 2.0/3.0 data management and archival system." Frontiers in Marine Science 9 (2022): 806452.