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The Long-Term Challenges of Digital Archives — *What You Really Need to Know*

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Management Summary

The affordability of digital storage, regulatory requirements for corporate documentation, and the familiarity of search and classification have fostered a new interest in longer-term digital archiving. Archives are unique aggregations of records with long-term value. Presidential archives are a familiar example. **All archives contain raw information (called primary sources), not just interpretations from a retrospective point of view. Their virtue is a completeness of related information that tells you the *why* behind the *what* that most people are looking for.** Academic archives consist of many disparate kinds of collections that are deemed to have enduring value. For businesses, an archival repository is the single source of static business information for all use, avoiding the concern of versioning – for, to be authentic, archival information *must not change and must not be diminished by data loss*. Business archives also serve to document the organization and hold intellectual property and other information that has persistent value. They support a strategy for reuse that can leverage corporate experience. They have often been organized following the business structure, because context is often a critical factor for use. At an operational level, an archive is a destination for information offload from production systems, whose performance then can improve.

Unlike a book on a shelf, digital data is accessed by a process – via application software on a server. In the short term, archiving can be treated as an extension of information lifecycle management (ILM) – another tier of storage to be accessed traditional application-based means. However, for the longer term, the relatively short life-span of technology and the many dimensions of use to which information can be put combine to present some interesting physical, logical, and cultural challenges in digital archive organization. To avoid the archive becoming a collection of multiple generations of aging hardware and software technology – which is uncomfortable in the short term and unsupportable in the long run – information access and information interpretation must be made more easily portable. The surrounding environment that archive assets must be made independent from includes the physical media and the logical constructs (file systems, databases, repositories), in which they have been persisted. This can best be done by harvesting information documenting the context and assumptions as metadata as soon and completely as possible, and by creating a self-sustainable entity or object. To retain its integrity and completeness, this entity must be read-only. It must be protected from the degradation that careless reproduction can induce. In short, long term archiving demands a *declaration of independence*. It might go something like this:

> *We, the assets, in order to sustain our enduring value, extend access to all of those to whom we are relevant, and persist over time into an unforeseeable future, and do it in a way that is economically supportable, must be autonomous, self-sustaining, and independent of the systems that spawn, access, and persist us.*

In its own way, supporting a long-term archive is a form of extreme computing – with lessons for us all. For more details, please read on.

IN THIS ISSUE

The Long-Term Challenges of Digital Archives

Keeping archives of digital material for the long term is, in many ways, a frustrating undertaking. Most media on which the information is stored has a shelf life of just a few years, so careful, loss-free iterations of data migrations are a part of standard operating procedures. For IT administrators these repeated painstaking migrations may seem like Lewis Carroll's Red Queen's running hard to stay in one place – a great deal of effort for an inconspicuous result.

From the many-decade, long-term archival perspective, applications, and proprietary formats are short-lived. Over that kind of long term, each application, database, file system, and format becomes a boat anchor to be dragged through each migration of data, with the risk that on new hardware the application will run differently – or will not run at all. Somewhat feasible alternatives are to emulate or even modernize the applications and data structures (each of which carries a degree of risk). A better option is to make the data independent of the applications that spawn and use them by metadata tagging for security and access rights, as well as for attributes like file paths and table definitions. Another approach is to standardize data access or include a "reader" capability with the archival entity. (See *The Challenge of Readability*, which follows.)

Of course, any of these approaches greatly increases the bulk of data that must be migrated, which leads to more *gotchas*. High-availability schemes like RAID, space-saving devices like deduplication, and optimization vehicles like storage virtualization set up dependencies on algorithms and other processes that must be carried forward as well. Special hardware features, in the long run, create as many or more problems as they solve, for their effects must be somehow emulated on new hardware with different features.

Thus, any dependency becomes a potential addiction, for it must be persisted, either physically or as data (accurately across multiple data migrations) as information to be retrieved in its full, unaltered, original form. If multiple tools from multiple sources must be supported – which will probably be the situation over the long term – long-term preservation of information becomes more complex and thus system administration becomes more expensive than can be economically supported, in many cases. Utilization of archival material is long-tail low, as contrasted with transaction-system high. Therefore, the technology supporting archives must be reliable yet inexpensive – two qualities that do not often coincide – both to procure and to run.

Technology challenges aside, one must remember that, over the long term, a digital archive must be more than just a class of storage capacity. There is a great difference between having a parking space – or even having a guaranteed parking space – and having a well-designed parking facility. The archive is a segregated resource, and, to keep the assets optimized for *use*, its operations must be managed as a facility. This is more than a matter of technology. Without a certain amount of conscious effort, any trove of fixed information can become contaminated by re-interpretation, obscured by vocabulary obsolescence, eviscerated by peremptory discards or accidental data loss, and so debased as to be not worth the cost of maintaining it.

The Challenge of Fixity

The integrity of information is insured by *fixity*, a concept that encompasses *full*, *original*, and *unaltered*. *Provenance*, the curriculum vitae of information, proves the integrity and adds context. The use of *WORM* (write once read many) technology and watermarks, fingerprints, or notary stamps, together with a remote copy, are part of the discipline that supports sustainable persistence. An all-encompassing discipline, in the case of very long-term retention of digital data, has not yet been fully developed.

The Challenge of Findability

Still, the challenge of fixity is straightforward compared to *findability*. **Findability depends, not just on search, indexing strategies, Semantic Web capabilities, and other tools, but also on the knowledge base of the people using the material.** This changes over time. Last year's information is easy to use. In a few years, it takes a moment to remember how things were done, and to translate into an expanded vocabulary or new modes of use. A decade later, users may need some explanatory material to make that transition.[1] In a few more decades, effective use of historic information will require a preparatory tutorial, or, even worse, an archivist or archaeologist.

The Challenge of Readability

***Readability* is also an issue. This is separate**

[1] Descriptions developed for *ease of use* are often prescriptive, and may omit "unnecessary" characteristics. This may limit innovative reuse over time.

from *information access*, which is a matter of control. Open Standards, like *ODF*, Adobe's *PDF-A* and Microsoft's *OODF*, as well as Industry-specific standards, like *DICOM* for health care, have proliferated. This is a good first step, but you need the capability at the client to interpret the information coming in. The success of the downloadable *Adobe Reader* in providing a capability with widespread readability offers one route to circumventing the need to maintain obsolete client-side hardware and software. In theory, a reader could be packaged with the archival assets.

XAM, the Storage Networking Industry Association's *eXtensible Access Method* specification, provides an industry standard information access method for network-attached storage (NAS), Content addressed storage (CAS) and storage area networks (SAN). SNIA's standardization of application information access and basic storage management policy metadata will simplify the challenges of anybody dealing with information generated from many sources and used by many applications. Recently, SNIAs Long Term Digital Information Retentions & Preservation Technology Working Group (LT-DIRP TWG) has proposed to develop a self-describing, self-contained data format (SD-SCDF) – a container format that will also work with the XAM standard.

The Challenge of Changing Use

Addressing all the challenges described above assures that archival assets have currency – that is both the integrity and the accessibility to be used within usual processes. But, the challenge of use over time brings some new factors into play.

One is confidentiality. In the short term, access to business information may be limited to need to know. Archives of politicians are also closed completely for a period of time until the dust settles or they are safely dead. Even over time, some kinds of information will never be broadly available – a situation that has been referred to as a *dark archive*. Other kinds of information flourish in new uses, as many of use have seen with Internet-based content.

There are other ways that use of information morphs in ways that could not have been anticipated at the time that the information is collected into an archive. Past business campaigns may be unfamiliar enough to be brought back as retro (with modern tweaks to process) – or they may seem incredibly naïve – or even deceptive. Music becomes social history. Old medical treatments become tutorials in what not to do anymore.[2]

Over time, the way information can be analyzed changes due to new analysis tools. Information is enhanced by relationships to other, potentially newer, information sources. It often becomes of interest to new audiences. What seemed like a detailed description may prove to be inadequate for these new audiences. Therefore, *usage aids* will need to be enhanced over time, often for specific audiences – as is the case today in traditional, paper-based archives. Over time, the history of the information and how it has been used (the provenance) came to be and how it was used will continue to grow.

These multiple layers of description are part of the heritage of archives – but are foreign to people used to using information only within the context of a process. The three descriptive focuses of *heritage*, *usage*, and *audience* need to be independent so that each can be evolved at its own pace, and that evolution tracked (for archival justification).

It is no wonder that the version of archiving that vendors address at present is largely focused on shorter-term email and eDiscovery, where the offload of information solves IT operational and performance issues, and advanced features such as search and enforced retention have business value[3]. However, even in email and e-discovery, after the first or second generation of hardware, and certainly after the adoption of new applications, all long-term retention of digital information faces the challenges outlined above.

Digital Archive Operations

The development of a digital archive, like the development of a data warehouse, establishes a quasi-independent operation that must be explicitly managed. Even departmental archive, while clearly a local asset, must be proactively managed to optimize its benefit to users as well as to keep it whole and usable.

The *OAIS (Open Archive Information System)*[4] framework, established as an international standard in 2002, most fully documents classic

[2] The problem with purging information that is no longer *state of the art* is that someone will recreate it, uninformed of its shortcomings. Archives exist to prevent this.

[3] Medical archives are another focus, but a more limited market.

[4] The OAIS standard gives a technical blueprint for establishing an evolvable digital archive. Developed in 2002 by an international group of experts, it is a negotiated settlement whose broad outlines have an imperative validity. The group does not expect that full implementation of the details (which run to over 150 pages) will be the norm.

archival practices, including workflows, finding aid generation, and the full panoply of administrative functions needed to create and maintain the bureaucratic side of an archival organization. **The OAIS model, in concert with SNIA's Long Term Archives efforts, are a path toward a mode of digital archives operations that will both support the preservation of the assets and support wider use of them.** While archives of a more limited range may not wish to establish the full panoply of functions OAIS describes, they would well to follow the basics of the OAIS model when setting up operations. Among other consideration, while physical archives have tended to be insular, with digital archives, the nature of the assets and downloadability may change this paradigm, as it has changed commerce.

Archival operations allow latitude of granularity and description. This begs a clear statement of the scope and intent. A clearly articulated mission will help the management of an archive define what granularities and descriptors users may expect. This will not limit innovative use, but will be a statement to revisit in order to determine where re-examination and re-indexing may be needed.

Archival Ingestion

Archival ingestion is most cleanly handled as a gateway[5] event. Materials may be transferred to an archive once or episodically. Generally, the ingesting becomes a gateway event, by which responsibility for the information is transferred from the donor to the archive.[6] At that point, harvesting and retaining all available information about the provenance of the material is at the highest priority. A detailed description of the content (exactly what it is), a unique identifier, and a guarantor of authenticity (watermark, fingerprint, or something similar) are core elements. This is just the first kind of description that is needed. OAIS suggests that an interpretive description, a description for users and a marketing description are also appropriate.

This is a situation where a *collection policy*, a more localized version of a mission statement,[7] can be of great help. By articulating for *what use* the information is being preserved, a collection policies can give guidelines for what ancillary information should also be collected, *without requiring any specific actions*. **A collection policy allows an archive to be a component of a larger universe, not just a destination.**

The specifying the *what* but not the *how* is important because, especially over time, archival operations will change. If the archive is held by an oil and gas company, users will probably be able to use archival information – even old archival information – with very little assistance. As the information held becomes more diverse, and the audience for that information less well defined, more explanatory information will be needed.

Operational Trade-Offs

Granularity

To a certain extent, the *granularity* in an archive depends on the focus of the collection (organization, subject, and collector). The original order of the materials can be an important characteristic, just as the file naming and structures a person uses can tell you a lot about his or her personality. Traditional archives come in collections. Astronomical observations might be a collection. How they are organized provides another layer of granularity. If appropriate, it can be the basis of finer grained objects that can be accessed as separate services. The records of a business unit for a year (or a decade) might be retrievable as an archival object. In the entertainment industry, an animation project, or even a particular part of it, might be designated as an object – because that is the granularity at which the information would be reused.

Thus, use is a second driver of granularity. **Digital assets tend to be accessed via download.** Downloads must be manageable. Particularly with the size of the digital archives being

[5] Anything less will leave lingering dependencies. For shorter-term operational archives, or those of a limited scope in a field where standards are plentiful, maintaining a closer relationship with applications may be feasible and attractive.

[6] The relationship with the producer or donor should be a contractual one. The contract may be simple, and it may be one time or chronic. It should specify IP considerations – whether residual digital rights still pertain to the object, whether the archive inherits these rights, and whether the archive may charge for access to this material or otherwise make commercial use of it are other topics best specified upon acquisition. Much of this information will not be of interest to those who use the information, of course. But, as in any long term endeavor, useful is a term that should never be determined by the view of any one stakeholder, but should be an aggregate of the requirements of them all.

[7] Many archives are set up for operational reasons – to offload infrequently used information, to create a repository for broader sharing of information. Even in these pragmatic circumstances, there is great value in setting up a formal mission – of what the archives proposes to do for whom. A mission statement gives a context in which to build the structures that will support fullest use. It properly identifies the archives as a resource and gives the definition needed to enter into relationships with other archival organizations. Like a business plan, it gives a focus and parameters that can control the growth that would otherwise make the archive more and more difficult to support.

assembled, accessing the whole of a collection may be impractical. Therefore, like large databases, collections probably will be segmented.

When segmenting, fewer large records are easier to manage, but more granular collections of objects may suit users better, in terms of both the ability to be downloaded and the granularity of their focus. One must consider homogeneity of the segment of an archival entity that must be retained, and protected, and replicated as it is moved over time. One must consider what kinds of descriptive accessories are specific to a particular record, and which become assets of the archive – a separate tier from the archival material – that then take on their own life (with documentation and preservation requirements) perhaps retained under the aegis of what OAIS calls *common services*.

One must also realize that multiple views of archival objects often will be desirable. This is a front-side aspect of granularity that should not be overlooked.

Vocabulary Control and Evolution

There is a trade-off between the contextual richness of larger collections versus the specific findability that more granular entities afford. Because findability is often a matter of description, the option of front-loading a digital archival entity with a separate tier – not just of descriptions, but also of situational applications – becomes attractive. With them, use of digital archive materials could be greatly enhanced. These applications could be drawn from the well-established disciplines of *Records and Content Management*.[8]

Business rules in computer systems can identify information that has persistent value. Records Management has a heritage of many decades of standardization. It sees information as flows. The publishing industry's structures for proper data reuse, sees information as characterizable components. It is typified by the *DITA (Darwin Information Typing Architecture)* open standard. The strategies of all these heritages are germane use of archival material.

Content Management wants more granularity, because its components are built on composability and reuse. The granularity and classification of content management allows the system to evolve what they deliver (web pages are an extreme example of this). **Records management works with flows of information in their purview – a much coarser granularity.** Storage managers' granularity comes is blocks – or in the more human-facing concept of files – which may be tiny or huge.

In order to foster ongoing findability and the kinds of ancillary information (dictionaries, etc.) needed to use archival information well, elements of social software offer a way to do so without building overhead into archival operations. Since these accessories would be part of a common services domain, they would not affect the data retrieval process. Wikis, tag clouds, and even ratings, recommendations, and tag links to archives at a collections level could enhance the use and value of digital archives.

What control and description elements are relevant to any archival initiative depends on the nature of the environment, the information, the intent of those setting up the archive, and even such details as whether, as with some film archives, there is a commercial element to be supported. Two things make this challenge doable. First is the *inherent flexibility and support for complexity built into IT-based information systems.* General rules, like rhymes, are strategies of oral traditions and human memories. The re\conciliation engines supported by IT can handle more rules and more variables. With information systems, the ability to retain masses of information in a highly-accurate and relatively-permanent form lets *models* be used to address all of the related parts.[9] Formulas and business logic then leverage the models to build operational structures.

Second, the ideal of *federations of declarative components* – that underlies service-oriented architectures – is also helpful. Federation can be the model for interactions between institutions. The model is a generalization; the particulars may change. With properly granular definition (and this is one reason there are so many pieces in the OAIS model), digital archives can both evolve and cooperate as needed.

Consider the more complex archival use case of land records. Land use, land development, and land ownership records typically reside in separate jurisdictions, and evolve at different rates. Their

[8] These tools are, strictly speaking, not part of the archive tradition – but neither are digital archives. With physical archives, the materials are at risk and degrade every time they are used. Therefore, their use involves security, surveillance, mandating the use of pencils and paper with holes in the middle so that ink stains and theft can be prevented. With digital archives, use is of a copy. Controls may still be needed for some collections – but the ease of downloads, together with registries like the US NUCMC (National Union Catalog of Manuscript Collections, pronounced "nuk-muk"), the accessibility of multiple collections begs a front end to prioritize and expand the possibilities of use.

[9] OAIS has many parts, for archiving is a complex operation.

assets often reside in separate digital archives. Yet when a fire, natural disaster happens, access to the aggregate of all sources, is important and excellent search and role-based filters are all needed for an information strategy that supports an effective response. This kind of scenario, not just rarefied research, is where the completeness of archival collections and descriptions has compelling value, and where support for real-time use cases should be developed.

Design Considerations

Inevitability of Growth

The primary tendency of any archive is to grow large. This will be particularly true of digital archives. The explosion of information has created a situation not unlike that seen in college admissions. Just as more students are applying to more colleges, so more people are seeking to use more sources of information. More business processes now span multiple companies. Findings spawned by the release of the human genome have increased the variety of factors that must be considered in the study of any particular disease. And so, as storage is only getting cheaper, repositories of all kinds will grow.

This inevitability of growth matters in two domains: control systems such as security, and operating expenses (particularly energy). In security, the broadening of identity management to include not just applications and end users but also archival objects, as a paradigm for management of fixity, is imperative, because directory-based permissions age badly and will not scale.

The energy challenge over time can never be permanently "solved," but must be a matter of periodic assessment, taking into consideration all new options that become available.

Scope of the Archive

The narrower the audience, the more familiar they may be with the information they are using and the way it was gathered, even decades ago – and the less interpretation is needed. Repositories of oil and gas data, or astronomical data, used by experts, need documentation of place, time, and collecting strategy but at least in the short term, less descriptive analysis of what the lines on the graphs mean. The same is true in other particular fields.

If the archive is of an organization, it is inevitable that new kinds of information will be added. The descriptions of the information will change as more kinds of things about the information become interesting.[10] The preservation information will surely change, as information is migrated from one generation of media to the next. The system that manages the archive will change as security and capabilities evolve. The audience – the user of the archive will probably change in ways one cannot easily predict. Certainly, the way they analyze the information, and the associations of information they find relevant will change – one need only look at biotech research to realize how rapidly this kind of change can occur.

Finding and Retrieval

The basic architecture of digital archives is often an aggregation of intelligent bricks containing both processing capability and storage capacity. While this is most evident in the processing found in high-end storage arrays, even tape cartridges have indexes that allow them to be more expeditiously accessed.

Cellular federation allows the archive to scale. Central management is important, but its scope is minimal. Use of directories and registries is traditional, but must be constrained to ways that do not impede search. This favors self-describing containers over more traditional hierarchies, unless the hierarchies are well disciplined.[11]

Incongruity of Archival Need and Vendor Marketing

In order to make the information value independent of the environments and media on which it is stored, generic technology is preferable. None of the bells and whistles, file systems, or indexing schemes that vendors hype to sell their product are useful in the long term. What is required is something that will perform well over its expected lifecycle, and then surrender its assets cleanly and without fuss. The more assets are moved to this style of technology (and it makes performance sense to move seldom-used assets off of performance systems, as long as you can remount it when performance is needed), the less call there will be for high-performance technology. This is not congruent with how storage has been sold in the past. But, there is a saving grace for vendors that comes in the way that fixed information will be used in the future.

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[10] For more about this topic, see the issue of Clipper Notes entitled *How to Derive Value Effectively from All Your Business Information*, dated April 17, 2007, and available at http://www.clipper.com/research/TCG2007090.pdf.

[11] This discipline would involve prescriptive parameters of contextual inheritance, as is found in lab data organized by date and machine. It would not tolerate haphazard naming conventions.

Looking Toward the Future

The archival paradigm of information use described in this bulletin is useful in any situation where petabytes of information support initiatives, activities, and decisions. As we, as businesses, institutions, or individuals, learn how to use the glut of information now available, we will be faced with masses of heterogeneous sorts of information, with no time, energy costs for space, or money to reconcile it all to a norm. Information access will be a service, probably often held as archival-style collections, if it does not merit parsing into databases, or content or records management repositories. The peculiarities, caveats, and limitations of information can then be described as metadata, and, in use, by something like mouse-over XBRL tags.

21st Century Requirements for Archives Use

High-performance and availability will be required by the use of massive information, particularly in certain time-sensitive situations. These situational uses of archived information *will* require all the hardware and software tools vendors have to offer – just as part of retrieval (on the way to the user) instead of as part of the storage process. We are already seeing some of this kind of optimization in network optimization efforts like the P4P effort of Internet service providers and P2P software to minimize the network impact of large file transfers.

Digital Archive Take-Aways

- **Archiving is not a start-from-scratch initiative**; it invariably is an offload, which comes with a legacy of requirements.
- **Open standards should be used wherever possible.** By their nature, they have a longer life than proprietary formats, which are succeeded by the next great idea.
- **Generic structures should be used.** Hierarchies, if they exist, should be as flat as possible (for easier searching). Save the peculiarities for your objects
- **The loose coupling and late binding** that are fostered and required by that declaration of independence are strategies that complement and do not compromise asset integrity.
- **Frameworks and tools, like registries and search, are used to arrange asset**s, rather than structured hierarchies or rigid taxonomies, both of which are great as tools, but not as organizing principles.
- **Governance must be intentional and explicit.** Processes must be defined and security baked in. Though "use" will be of a copy of the archives material, integrity must still be assured.
- **Documenting use and patterns of use of the archive is a good practice.** It is mandatory in medical records. It is also necessary in situations like film archives, where you want to be able to trace reuse. Often, it is seen as inappropriate in academic situations, but, as usage grows, remember that you cannot model what you do not measure. Even if you have no overt mandate to document use, funding requests go better with the good story that usage patterns can portray.
- **In archives, the efficiency of operations is not measured in response times, but in the effectiveness of the service**. This is a matter of presenting the user with the right information in a timely fashion. The new academic field of Service Science will have teachings of relevance to archival operations.

Conclusion

Long-term digital archives require a new IT paradigm. The requirements are not primarily based on workflows[12], like traditional batch processing and multiprocessing. What is needed is not like the reconciliation engines of telecommunications systems[13], which meter usage and bill a set number of services, all of which must be used with a reasonable frequency to make things work economically. The economics of keeping data for a low frequency of use demand a set of different design points.

The frantic pace of operations of all kinds today does not mean that we can ignore the lessons of the past. **It does mean that to leverage them, relevant information must be accessible on modern terms.** The best way to keep information findable and usable is to put it in something built for that purpose. ***Consider, then, the benefits of an archive.***

[12] Of course, workflows are needed for properly migrating data as media come to the end of their lifespan.

[13] If the archives is part of a revenue-generating operation (most are not), some reconciliation capabilities will, of course, be needed.

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