Editor's Note

In the summer of 2024, Clifford Lynch announced his retirement as executive director of the Coalition for Networked Information (CNI) after 28 years at its helm. CNI quietly launched a project to create this Festschrift to document and honor his legacy. Authors began contributing articles in early 2025, with a planned publication date of July 2025. Since the final membership meeting of Cliff's tenure was April 7–8 in Milwaukee, the plan was to surprise him, surrounded by colleagues and friends, with a presentation of the table of contents of this special issue. However, just two weeks prior to the meeting, Cliff's health worsened; he was told about the Festschrift and received project details and articles. Though unable to attend in person, he participated in the CNI membership meeting via Zoom and also virtually joined his retirement reception, which included readings of excerpts from each article in this volume. Sadly, on April 10, 2025, Clifford Lynch passed away. Festschrift contributors wrote their articles prior to his passing, and we have chosen not to alter their original language.

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The Invisible Influencer in Information Infrastructure

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abstract: The UPS Prototype was a proof-of-concept web portal built in preparation for the Universal Preprint Service Meeting held in October 1999 in Santa Fe, New Mexico. The portal provided search functionality for a set of metadata records that had been aggregated from a range of repositories that hosted preprints, working papers, and technical reports. Every search result was overlaid with a dynamically generated menu, called an SFX-menu, that provided a selection of value-adding links for the described scholarly work. The meeting eventually led to the Open Archives Initiative and its Protocol for Metadata Harvesting (OAI-PMH), which remains widely used in scholarly communication, cultural heritage, and elsewhere. The SFX-menu approach became standardized as the National Information Standards Organization (NISO) OpenURL Framework for Context-Sensitive Services (NISO OpenURL), and compliant linking servers remain operational in academic and research libraries worldwide. Both OAI-PMH and NISO OpenURL, as well as associated systems and services, have been so widely deployed that they can be considered an integral part of the scholarly information infrastructure. The authors, who were deeply involved in devising the UPS Prototype and played core roles in the OAI-PMH and NISO OpenURL specification efforts, take the reader behind the scenes of the development of these technologies. They reveal Clifford Lynch as an invisible influencer in the establishment of scholarly information infrastructure.

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Introduction

We should have known better than to impulsively choose the Universal Preprint Service (UPS) project, which we jointly initiated and executed in 1999, as the topic of this 2025 article. It intends to illustrate Clifford Lynch's impact on the development of infrastructure for research and education. Some memories have remained strong, others have faded and become uncertain, and undoubtedly much has just evaporated into the fabric of time. Fortunately, there are external memories that can serve as fallbacks when ours fail. Many aspects of the project and its context were documented in research papers. These papers reference documents with details about underlying discussions that are long gone from the organizational websites on which they

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were published but fortunately were saved for posterity by the indispensable Internet Archive. Despite the fog of time, we are confident that our story is an accurate reflection of events that were crucial to the eventual broad adoption of metadata harvesting using the Open Archives Initiative protocol (OAI-PMH) and open linking using OpenURL and, especially, of the crucial role Cliff played in making that happen.

Two PhD Candidates, in for a Surprise

The middle to late 1990s were exciting times for people into computers, networks, and information. The times seemed to hold an unlimited potential, rather abruptly brought about by the combination of the http/HTML web, the mainstreaming of the Internet, affordable personal computing, and increased digitization capabilities. Like many others, we were excited about how these technologies could bring about a better world and consequently devoured *Wired*, a magazine that abounds with "techno-utopianism and hippie-idealism."[1] We had jobs that presented challenges in which this powerful combination of technologies could be leveraged to imagine and implement innovative solutions.

Herbert became systems librarian at the Ghent University Library in Ghent, Belgium, in 1981, after completing an administrative automation project there to obtain a degree in informatics. He did not exactly hit the ground running as he was trying to figure out what automation in academic libraries was all about. Most libraries were focusing their efforts on the catalog, but, given his science education, that did not seem to tick all the boxes. Eventually, the science librarian turned on the light by putting the automation challenge in terms of the "consultation chain": first searching secondary sources to find journal articles, then searching catalogs to determine where the journals were, and finally obtaining the articles.

As soon as CD-ROMs became available, Herbert started providing public access to abstract and indexing (A&I) databases, initially on stand-alone PCs, later on PCs in local area networks (LANs), and eventually on PCs across the university's wide area network. He also initiated an effort to create a Belgian Union Catalogue on CD-ROM and hooked it up to the network. Access dramatically improved, but constraints remained: consultation was restricted to Windows PCs, the LANs had to run the Banyan VINES operating system, and networking a large collection of CD-ROMs published by a variety of vendors was a dark art. It all amounted to access being restricted to dedicated library PCs operated in departmental libraries, which was better than what most other European academic libraries offered but not good enough for Herbert. That is why he experienced the interoperability fabric introduced by the web as the chains coming off regarding ways to deliver scholarly information to researchers and students.

Herbert's enthusiasm resulted in the 1997 release of the Ghent University Library's Executive Lounge, a menu-driven environment that provided web-based access to all information that had previously only been available on library PCs. It also included some electronic journal collections for good measure. But something was still missing: the web had links, and the Executive Lounge did not. Herbert put it as follows: "When using a library solution, the expectations of a net-traveler are inspired by his hyperlinked Web experiences. To such a user, it is not comprehensible that secondary sources, catalogues, and primary sources, that are logically related, are not functionally linked."[2] The frustra-

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tion expressed in this quotation led to a collaboration with SilverPlatter and Ex Libris to implement dynamic links from journal article descriptions in A&I databases to journal descriptions in the library catalog. It also provided fertile ground for PhD research on how to empower libraries to create links across their electronic collections by means of an open linking framework.

Michael began his professional career at the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) in 1991, originally working in the Analysis and Computation Division of the supercomputer center. Early experiences with Usenet and anonymous file transfer protocol (FTP) began to divert his attention from supercomputing and cluster computing (now known as *cloud computing*) to information networks and libraries. In 1993, he set up an anonymous FTP server, the Langley Technical Report Server (LTRS), for technical memorandums and technical papers published by LaRC. It effectively brought to NASA the culture to share and access technical reports via FTP, which already existed in computer science. Later in 1993, he added a web interface to LTRS, providing a much-needed boost in usability. Browsing functionality improved, abstracts were indexed, and they became searchable using the Z39.50-based wide area information server (WAIS). WAIS was almost the only free search software at the time (for example, MySQL was not released until 1995). Around the same time, the Center for AeroSpace Information (CASI) brought their own WAIS server online; it provided abstracts for all publicly available, NASA-authored reports and articles. Other centers and projects were inspired by this activity and wanted to set up their own "report server." It became clear that a website—the term *digital library* was not yet widely adopted—was needed that would allow simultaneous WAIS search of all the NASA and NASA-affiliated report servers. A bit of Perl hacking later, by Michael and his colleagues, and the NASA Technical Report Server (NTRS) was released in 1994.

The development of LTRS and NTRS assumed a one-to-one relationship between a metadata record and the URL of the associated full-text document. But with the progression from ".ps.Z" to ".pdf" files, the usefulness of that assumption started to break down. It became unworkable by 1998, when Michael created a separate digital library for the scanned documents of the National Advisory Committee for Aeronautics (NACA), the 1915–1958 predecessor of NASA. Obviously, none of these documents were born digital. A single NACA report presented on the web was composed of TIFF images, large and thumbnail JPEGs, and a PDF of the entire report. Based on the experience of managing and presenting these collections of files as a single web object, Michael's dissertation evolved in the direction of creating *buckets*.[3] Buckets are the smart objects in the Smart Objects, Dumb Archives (SODA) model.[4] The basic premises of SODA were that individual reports are more important than the repositories that hold them and that it should be possible for multiple digital libraries to simultaneously make them discoverable. This 1997 insight is now commonplace, but it went against the conventional wisdom of the time. It precedes, yet aligns with, the perspective of the W3C architecture of the World Wide Web that individual resources are more important than the web servers that host them.[5] As a matter of fact, the architecture of the World Wide Web mentions only resources, not web servers.

As Herbert and Michael embarked on their respective PhD explorations on different sides of the Atlantic, they did not realize they were about to meet to collaborate on the

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UPS project and to present their results at a meeting that would be moderated by Cliff Lynch, a man they both admired but had never met in person.

The UPS Prototype

By early 1999, Herbert's ideas to give libraries a say regarding links across their electronic collections had taken shape.[6] He had also conducted an experiment illustrating the components of the open linking framework he envisioned. A linking server operated by the library would feature a knowledge base detailing its collection as well as a rule engine that would dynamically decide which links to provide for which type of collection item. A user interested in links for a specific item would click the associated SFX (special effects) link, which allowed the server to collect sufficient metadata about the item to evaluate the rules and return item-specific links.[7] But inserting SFX links required control of the systems that provided access to the collection. As a result, the experiment only used sources operated locally by the Ghent University Library. Demonstrating the general feasibility of the approach required an experiment without such constraints.

When Rick Luce, director of the Los Alamos National Laboratory Research Library, visited the Ghent library to check out the linking approach, it became clear that his groundbreaking Library without Walls project would provide the ideal setting. Its collection combined locally and remotely controlled sources, including locally operated full-text resources. It also maintained close relationships with various parties in the scholarly information industry.[8] So, Herbert packed up in February 1999 for a six-month stint in Los Alamos and successfully conducted an elaborate experiment that demonstrated the feasibility of the approach with sources under both local and remote control, including full-text collections from Wiley, the American Physical Society, and the International Digital Electronic Access Library (IDEAL), and linking servers at Los Alamos and Ghent.[9]

But Los Alamos was also where the famous physics preprint server then known as xxx.lanl.gov and now called arXiv ran under Paul Ginsparg's desk. Having witnessed many years of fierce discussions at Ghent University about subscriptions to journals and their ever-increasing prices, Herbert understood the appeal of the new communication paradigm arXiv entailed. He had brought his video camera to Los Alamos, hoping to interview the much-revered Ginsparg. He need not have bothered. Rick and Paul were already exploring whether the Library without Walls, which ran a mirror of the preprint server, could become an institutional host for it. Herbert started taking part in those conversations.

One brainstorm led to another, and by the time Herbert got ready to return to Ghent, the trio published a call to action for "the further promotion of author self-archived solutions" in which they announced a meeting with 25 invited experts to be held in Santa Fe, New Mexico, in October 1999, to kick things off.[10] The stated goals were "to reach an agreement regarding an approach to build a promotional prototype multidisciplinary digital library service for the main existing e-print archives" and "to create a forum that will continue to address the interoperability of self-archiving solutions, as a means to promote their global adoption."[11]

Over time, Herbert had come to understand and embrace the "seeing is believing" power of prototypes. He had decided that a concrete strawman to illustrate services

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across e-print repositories would be needed to fuel discussions, but he would need collaborators to pull that off. When he reached out to e-print repositories to obtain metadata dumps, Thomas Krichel, a major force behind the Research Papers in Economics (RePEc) effort, enthusiastically came on board.[12] Rick Luce identified just the other person who was needed. Via the New Mexico Library Alliance, he knew Michael's supervisor Mike Little. Together, they engineered a meeting in Washington, DC, anticipating that their Young Turks would resonate. During a four-day meeting in April 1999, they drew up technical plans for a prototype and even managed to meet with Deanna Marcum at the Council on Library Information and Resources (CLIR) and Donald (Don) Waters at the associated Digital Library Federation (DLF), securing support and funding for the meeting and the prototype.

Together, Herbert, Michael, and Thomas started working on the UPS Prototype to be presented at the very outset of the planned Santa Fe meeting. Although the prototype was intended "not to make statements about the architectural directions that UPS should take, but rather to facilitate discussions,"[13] its design did entail some significant technical choices. Metadata would be collected from various e-print repositories using static dumps. The metadata would be normalized to the ReDIF format, the Research Documents Information Format used in the RePEc initiative.[14] The SODA model would be used to manage and present individual e-prints as buckets. Searching across the aggregated metadata would be done using the NCSTRL+ extension of Dienst that supported buckets. Each e-print-specific bucket would provide SFX linking capabilities. To realize all this in a six-month period, the prototype trio brought more help on board.

The Santa Fe Meeting for ...?

To increase the chance of success for the meeting, the collaboration of Cliff Lynch and Don Waters had been secured as moderators of the meeting, and their collaboration turned out to be fundamentally important. In the acknowledgments section of his PhD dissertation, Herbert put Cliff's impact on the direction of the meeting and on his own thinking as follows:

> When starting to work on this thesis, I went back reading several of his early papers and could not feel other than intimidated by the far forward-looking vision expressed therein. At several occasions, I heard Cliff address large audiences, discussing complicated digital library matters with an amazing clarity. Cliff's work has always been a great inspiration to me. I met Cliff for the first time in person at the Open Archives meeting in Santa Fe, for which he had enthusiastically accepted my invitation to serve as a moderator. His involvement was crucial to the successful conclusion of the meeting.[15]

The meeting started off in a very concrete manner, with the presentation of the UPS Prototype, some presentations on repository interoperability, and reflections about institutional versus discipline-oriented archives. As the first day progressed, however, the discussions became increasingly distracted by back-and-forth arguments about the necessity of peer review. The Stevan Harnad "self-archiving" camp (archiving the peer-reviewed version of a contribution on a personal or institutional server) insisted that peer review is essential to keep scholarly communication trustworthy. The Paul Ginsparg

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"preprint" camp advocated publishing unreviewed contributions on a discipline-oriented or institutional server, arguing that knowledgeable readers can assess quality without external review and that novice readers should wait until a peer-reviewed version becomes available. The peer-review tension had existed prior to the meeting and is even reflected in the evolution of the title of its announcement: an unpublished version dated April 1999 was titled "Call for Participation Aimed at the Further Promotion of the Preprint Concept," but the version published in July 1999 was titled "Call for Your Participation in the UPS Initiative Aimed at the Further Promotion of Author Self-Archived Solutions." After the meeting, the title was modified to become "The Open Archives Initiative Aimed at the Further Promotion of Author Self-Archived Solutions."

Cliff was the moderator for the first session of the second day. In a manner that exemplified one of his many unparalleled capabilities, Cliff opened by providing two discussion topics regarding interoperability that he had synthesized from the first day's wide-ranging discussions. One topic was whether archive functions, such as data collection and maintenance, should be decoupled from user functions, such as search. The other was about the choice between distributed searching across repositories and harvesting from them to build cross-repository search engines. The meeting report says this about the outcome of discussion regarding the first topic:

In a manner that exemplified one of his many unparalleled capabilities, Cliff opened by providing two discussion topics regarding interoperability that he had synthesized from the first day's wide-ranging discussions.

> Although archive initiatives can implement their own end-user services, it is essential that the archives remain "open" in order to allow others to equally create such services. This concept was formalized by the distinction between providers of data (the archive initiatives) and implementers of data services (the initiatives that want to create end-user services for archive initiatives).[16]

The outcome of the second topic discussions in favor of a harvesting solution is remarkable because distributed search using WAIS/Z39.50, an international protocol for searching and retrieving information, was in vogue in libraries and digital libraries in those days. Cliff himself had a significant track record in Z39.50 and its standardization,[17] but he had also identified harvesting approaches as a topic for further research.[18] Motivated by complexity and scalability concerns, he gently nudged discussions in favor of harvesting. In a paper in which he clarifies the complementary nature of Z39.50 and OAI-PMH, Cliff credits the meeting participants for the decision that was considered controversial by some in the community:

> The Santa Fe group wanted a very simple, low-barrier-to-entry interface, and to shift implementation complexity and operational processing load away from the repositories and to the developers of federated search services, repository redistribution services, and the like. They also wanted to minimize the interdependency between the quality of applications services as viewed by the user and the behavior of repositories that supplied data to the applications services.[19]

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By the end of the meeting, there was a general sense that the UPS Prototype had been helpful to illustrate the potential of cross-repository services and, hence, to emphasize the need for cross-repository interoperability. A paper that provides a rich summary of the Santa Fe meeting describes it as follows: "There was general agreement among the participants at the meeting that the prototype was an extremely useful demonstration of potential. There was also agreement, however, that trying to reach consensus on the full functionality of the prototype was 'aiming too high' and that a more modest first step was in order."[20]

Toward OAI-PMH and OpenURL

By turning the focus of the meeting on these two topics, Cliff fundamentally changed its course. Guiding the discussions toward these concrete outcomes, he set the stage for work on what would become the Open Archives Initiative Protocol for Metadata Harvesting. Both Herbert and Michael became editors of the protocol.[21] Undoubtedly, Cliff had technical skills that would have allowed him to make significant contributions to the actual specification effort. But in a manner that characterizes Cliff, he silently took a step back and let the community decide its direction while expressing continued support for the work on many occasions and at venues around the world. His endorsement played a crucial role in the global adoption of OAI-PMH, which has been an integral part of the scholarly and cultural heritage infrastructure for over two decades.

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The focus on interoperability, to realize just a single aspect demonstrated by the prototype cross-repository discovery, also meant that discussions about its other technical elements, including SFX linking, would have to be postponed. But both Cliff and Don were aware of the problem it addressed and the nature of the solution. They were both part of the NISO Reference Linking Working Group that investigated how to tackle the so-called appropriate copy problem. Simplifying the charge to the group, the appropriate copy problem can be summarized as follows: "How to resolve a reference link to a paper in such a manner that it ends up at one of potentially many distributed copies of that paper to which a user, covered by an institutional subscription, has access."[22]

The working group resulted from a meeting in February 1999,[23] in which various models for a link localization solution had been explored.[24] Don Waters invited Herbert to present his linking work at a second meeting in June 1999.[25] The meeting report praises SFX linking for its ability to address link localization challenges beyond the appropriate copy problem.[26]

Cliff extended an invitation for a presentation at the spring 2000 meeting of the Coalition for Networked Information.[27] The room was packed with representatives from libraries, the scholarly publishing industry, and library system vendors, and the

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talk became a breakthrough for SFX linking. But significant tasks remained, including standardizing the SFX link and demonstrating the ability of the approach to integrate with the emerging DOI-based reference linking approach pursued by journal publishers and instantiated by CrossRef.[28]

The standardization's history is well documented.[29] It started in December 2000 when the original SFX URL specification—by then renamed OpenURL—was submitted to NISO.[30] It concluded five years later with the release of the OpenURL Framework for Context-Sensitive Services.[31] The DOI integration was explored by means of a limited prototype that was demonstrated and discussed at the July 2000 NISO/DLF/CrossRef meeting.[32] The meeting seemed to reach a consensus in favor of the proposed model with an institutional localization component powered by OpenURL—essentially the SFX open linking approach. A question was raised, however, as to whether the model with a centralized localization component that had been identified in the first meeting of the working group should also be further discussed. At that point, Cliff firmly stepped in, stating, "No. We have a solution!" In doing so, he paved the way for the endorsement of the OpenURL linking framework by the working group, the rigorous testing of its feasibility in an extended prototype,[33] and its eventual acceptance in the scholarly communication community in the United States and beyond. Afterward, Cliff continued to express support for the approach at numerous venues and gave it his strongest possible endorsement by becoming a member of Herbert's PhD jury.

Thank you, Cliff

By means of the UPS Prototype effort, this article has illustrated Cliff's fundamental impact on the direction taken by the infrastructure for research, education, and cultural heritage in the past decades. An extended version that includes petites-histoires featuring the protagonists of the effort is available as a blog post.[34] Two technologies, OpenURL, which was used in the Prototype, and OAI-PMH, which resulted from the UPS Prototype, became an integral part of that infrastructure. Cliff had a significant part in the outcome, not as an author of specifications, a writer of code, or a builder of tools, but rather as an identifier of problems to come and as a perceptive influencer. He gently nudged forward the solutions he believed in and strongly supported the community efforts that realized them. We have witnessed the same impact in other efforts since the UPS Prototype and can safely assume that others have experienced it in projects aimed at improving the status quo of scholarly information infrastructure.

Cliff had a significant part in the outcome, not as an author of specifications, a writer of code, or a builder of tools, but rather as an identifier of problems to come and as a perceptive influencer.

When we dreamt up the outlines of the UPS Prototype, we were early career researchers with a modest track record. Cliff (CNI), along with Paul Ginsparg (LANL), Rick Luce (LANL), Deanna Marcum (CLIR), and Don Waters (DLF), strongly and publicly endorsed our effort. They shone the spotlight on us and had a major impact on our career

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trajectories. We vividly remember receiving that support and the experience has led us to similarly support the young researchers we have mentored since.

As we were selected to write a contribution for this Festschrift, on behalf of all infrastructure plumbers, we want to profoundly thank Cliff. We do not envy the person who will step into his shoes once he has retired. The work ahead is enormous, with needs for new infrastructure and the existing infrastructure crumbling. Indeed, OAI-PMH is being supplanted due to its reliance on XML, a technology that has been increasingly replaced by JSON. The OpenURL Framework is also under attack by the centralized Get Full Text Research effort, launched by the major commercial publishers.[35] It mutes the capabilities of libraries to influence the nature of links across their electronic collections. The 25 years of OAI-PMH and OpenURL seem a substantial period considering that the lifetime of many digital library phenomena can be measured in months or years. Cliff's influence is directly visible in the global penetration and longevity of these two technologies, which can be traced back to the 1999 UPS Prototype.

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