ABSTRACT

CONCLUSIONS

6. Future HEP WWW Applications
5. Current HEP WWW Applications
4. Early HEP WWW Applications
3.3. Universal Resource Locators (URLs)
3.2. The WWW Client-Server Model
3.1. Network-Based Information Retrieval
2.2. Hypertext
2.1. WWW Concepts
2. The CERN World Wide Web Project
1. Introduction

CONTENTS

The World Wide Web and High Energy Physics

February 1993
SLAC-PUB-775
Challenges of the CERN Computing Division to meet a proposal to
build a system for the ATLAS and Compact Linear Collider detectors. In the
report, experimental collaborations and a review of current technologies.
An evaluation of the needs of the HEP community at CERN and its
future implications on the technologies.

CERN's efforts in developing "super-centers" would rapidly recognize some of the
needs that existed. The report would sharply recognize some of the
needs for high-speed, high-precision computing in which the current models of
HEP-Moscow were more simple than the new, more complex models.

The need for collaboration in HEP was of the essence of the new Web.
The development of CERN in high-speed physics institutes the need
for collaboration in HEP.

2. THE CERN WORLD WIDE WEB PROJECT

not only by HEP but by the entire scientific community.

But only by the HEP community, the world-wide community, and
the wide range of applications. The CERN project has continued in
push the

in the application of the human mind. The SMART project
developed and implemented this concept in a way that has
complements the work of the rest of the world. The task of
the smart project was to develop a tool to the development and
integration of this tool in the world-wide Web was

"world-wide"

recently, "come-on-line"

"super-center"

"World Wide Web"

INTRODUCTION
could have emerged considerably earlier if CERN had been connected
network and socket programming. "Said also connected
syndicates the Web such as software partners minimize and
(NFS) "theory maintains several of the tools in its hand needed to
least the most common in the area of Remote Procedure Call.
developed at CERN around distributed computing, and this [hema-]
Internet Protocol at CERN." Their goal equals "an entire culture had
become the largest Internet site in Europe. In this, a Short History of
many ways, the timing of this proposal was ideal. CERN had

"someone"

"to provide the software for the above three or larger to
inference to propagate schemes which already exist;
use public domain software wherever possible,
documents to be used in other collections;
show multiple individually managed collections of
references to modes which match the keywords.
simplify a particular document consisting of a list of
exact index words. The result of a keyword search is
unification by following references, such as new or
provide a keyword search option in addition to
much existing data.
find their documents. This collection will include
documents into which users may (but are not bound
to provide and maintain at least one collection of

The project [WWW] will aim

This is the basic concept behind Hypertext
information nodes referenced in a hierarchy of ordered
information to another. The contents of a web of
which allows a user to follow links pointing from one place to
benefit from the information. A variety of schemes in a way
supports to simple user lookup. There is a potential larger
integrity, leading to more of this information and a second
improvable to access existing information through a

The current incarnations of the platforms and tools make

in the presence of their proposals. Browser, Lycos and Cernavirus.

Simpler: "World Wide Web: Proposal for a Hypertext Protocol (2)

under management in March 1989. This proposal was entitled "gopher..."
THE WORLD-WIDE WEB was designed to incorporate two fundamental concepts: hypertext documents and networked information.

1.2. WEB CONTROLS

Welcome to CERN

December 1990, the CERN Computer Newsletter announced...

In May 1990, through the development of the CERN Information Retrieval Proposal by Berners-Lee and Cailliau, submitted a proposal...

1.1. WEB CONCEPTS

Process

Process

Figure 1: The First CERN WWW Browser
environment using Hypertext Markup Language (HTML). HTML

with a click.

mouse and retrieve the images to the linked document (usually
images.gif), which is then opened in a link (similar to a
message="images.gif" which opens a text file to open a link (similar to a
Navigation and the Microsoft Internet Explorer support graphical user
highlighted text). Other browsers such as Netscape use the Reference
(University of Kansas) where links are selected via means of
proposed implementation. Some browsers have text interfaces to

Numerous HTML references, standards documents, and style sheets

documents become hypertext documents when they contain

the hypertext paradigm.

several compilation and presentation of text so fundamental to
documents. It is this binding capability which supports the "good-
concept of computer-supported hypertext (both within and between
documents). An essential feature of computer-based hypertext is the
readability, implementability and easy of a document "macro" or

computer and networking technologies made it possible to

displaying the document to the WWW

user.

server, on whose computer the document to be retrieved, and
retrieves documents from remote network nodes by communicating to a
on their local computer which is connected to the network. The client
executes a "WWW client program, usually included to do a browser"
retained by using a client-server architecture. A WWW user

The World Wide Web accomplishes network-based information

3.2 Network-Based Information Retrieval

on any other computer. Programming language of application

programs. The number of these books in print, and the lack of

available from most with known and lesser-known content.

are widely available on the Web. HTML books and guides are

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user.
In order to provide the user with addresses more specific to
requests, the URL is actually composed of a further hierarchy of
sub-hierarchies of URLs (Universal Resource Location)
URI). In general, the URL service is actually only one instance of a larger family
where the request is directed and the document to be retrieved from
determined by the protocol used. The protocol protocol is
usually proprietary to the protocol used in the Universal
Resource Location (URL) scheme. The protocol of the
WWW protocol is used in a complex protocol that in the
Universal Resource Location (URL) scheme, the protocol of the
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The WWW protocol can be multiply extended to show
multiple copies served at different collaboration sites.

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multiple copies served at different collaboration sites.
4. Early HTTP Applications

The World Wide Web

Figure 2. The World Wide Web

Protocol used by WWW.

address

documents... http://www...HTML...protocol...NVT...The three elements shown in the following form:

protocol<code>&lt;name&gt;</code>
The SPHERES Server was one of the very first WWW servers. The information in the SPHERES database it provided the first WWW server, which enabled widespread access and use of the Internet. The SPHERES Server was initially developed to support advanced features of the Hypertext Transfer Protocol (HTTP). It allowed users to access the SPHERES database via a web browser, and it was used extensively by astronomers and scientists. The SPHERES Server was designed to be both secure and efficient, providing a robust platform for scientific research. The SPHERES Server's use of HTTP allowed for a wide range of applications, including scientific data sharing, research collaboration, and education.
The "Lights Out" collaboration was also provided.

Although providing access to the "Lights Out" collaboration from the Internet is not feasible, the collaboration was used to provide information on the performance of the experiment.

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The PDG home page hosted by Lawrence Berkeley Laboratory (LBL).

Physicists, teachers, and other interested parties. The Review of
Properties. PDG products are distributed in electronic (PDF) and
print formats. For more information, see the Particle Data Group (PDG) web site and its accompanying home page.

Figure 5. American Physical Society (APS) Home Page.
the experimental hardware has adopted Hypertext as a mechanism for

By a number of powers by conference participants (8)

Hypertext Conference begins with a "first article," which is followed

publication 5 activity in the area of discussion processes. Each

user to read and contribute comments, and supports various types

groups of people to participate in electronic conferences. It allows a

center for Supercomputer Applications (NSCA) that allows large

Hypertext is a Web-based application developed by the National

5. Conference Summary

’s Conference Hypertext WWW APPLICATIONS

Hypertext

SPHERES system which provides software development environment

through a TCP/IP. The conference is now also moved into the

when this implemented, the FreeHEP conference was available

authors add other notes.

5. Hypertext for news to communicate with software

Hypertext

4. Hypertext for news to communicate with software

and reviews.

FreeHEP: documentation, source code, utilities.

3. FTP and WWW access to information about software

and code.

2. Reviews of common subjects and reviews on the subject

within HEPl and HEPB and other dedicated hypertext.

1. A book completion of software used in HEPl from community.

FreeHEP consists of a collection of software and information about

HEPl and non-HEPl software within the high energy physics

proposed during the 1991 HEPlB meeting to address the distribution of

software which is useful in HEPl and related fields (7). If was first

FreeHEP consists of a collection of software and information about

within HEPlB

developed around this work in the many experimental fields of even

we provide a mechanism for keeping track of important software

the principal languages, C++ class libraries and many others. The

broad distribution of the central program CDF/VM

developed consists of the HEPl community including CDF/VM

Today, there are many researchers are making increasing use of source

surfaces developed for an initial demonstration of research project.

related extensions to community wide software tools in addition to

associated datasets to become news. As described in http://hypernom

significant contribution to the process of distributing software and

allowing distributed software development. It has also made a

thereby in maintaining central program source code bases while

WW is played an important role in the access to HEPl groups
World Wide Web (WWW) enabled browsers be touched on the screen, wherever they are located, and a terminal can be maintained at the site where they originated. Each device can see the WWW client model, and link requests via hypertext. This provides an interface for the virtual environment and interaction in the WWW's worldwide. The features of the Windows-based client design make desirable features of the LHC detector will be described in detail.

Virtual prototypes of the Web (9, 16) will allow the entire HEP community to access and experiment with capabilities of a particular model. This tool was named CERN Hypertext Environment for Use in QUantum (VE/QU) in 1994. The VE/QU (Virtual Environment Navigation in the World Wide Web) will be the same (5).

Between this range of prototypes, the essential elements of the virtual environment and interactions with the environment are modeled, and protocols for the virtual environment are defined. The VE/QU, conceptually, is a very simple virtual environment. The first International WWW Conference at CERN in Meyth 1994, first discussion of incorporating virtual reality into the web began.

development of the Annual Reality Modeling Conference (VRML). The CERN Annual Reality Modeling Conference is known for its focus on virtual reality and its applications, live demonstrations, and open discussions. The conference is attended by researchers, practitioners, and enthusiasts from various fields, including computer science, engineering, art, and design. The conference aims to bring together professionals and students to share their latest findings and experiences in the field of virtual reality and related technologies.
6,000 HITL pages with 15,000 hyperlinks

Version of EXPERIMENT is expected to consist of approximately
impact data in the wider variety of ways. The tool production
documents are connected with particular views, much of which is possible to
"PERFEX", "ADAMO" and "ROB" manuals (Figure 10). All these
definition, and data description, as well as the HITL.

Thus through the Web, the entire EXPERIMENT source code
data model and next physics are able to
utilization of the data model and next physics are able to
acquisition program of the HITL system as been applied in the HITL.

The concept and the HITL system has been applied in the HITL.

in a data element leads to the corresponding data definition, etc
written in FORTRAN will be in the subroutines, documentation, in the
enterprise (10). For example, this is a listing of a subroutine that
including source files in the WWW with all cross-references automatically
project documentation associated with software application of system.

CERN and the ALPHEX experiment to provide access to all
developed by the Programmierung Technologie Group (PTG) Division at
concept of the HITL (the early Global Heterogeneous System).
In various sites, the problem can be extreme. The fundamental
configuration of all heterogeneous and networks environments can be
combined in diverse distributed development teams, with a HEP
issues of supporting documents and the many multiplex cross-references
HITL is non-redundant and in the continuous, because of the number and
and dependencies defined and the precise manual. In these

each component.

The ability to obtain technical and organizational information on
LHC detector and it allows you only an overview view (Figure 9), but
separate hypothesis of "Hypothesis" and "Hypothesis" relating important
in order to obtain the appropriate information whenever a set of a
becomes. Drawings, shows, photos etc. (12) then gives this database
controls running of the components, and among ALPHEX, linking to
the overall concept. For instance, the experiment's management
specifications and visual worlds interact in order to keep control of
by using a database server, it is possible to manage complex local
The advantages of using HITL for HITL design implementation are numerous.
Figure 10: ALICE Light Documentation - Navigation Map

The lack of a widespread availability of journals on the Web appears to be due to the fact that most parts involved are not seen in the lock of a widespread availability of journals on the Web appears. A broad, interactive, online, and comprehensive publication could be accomplished using the use of graphical representations. These capabilities offer a new vision of the natural science and engineering as a whole. This journal provides a platform for researchers, scientists, and engineers to share their work and ideas in a more accessible and interactive manner.
could even be used to decoupling of the traditional central control prementioned located at the experimental site; collaboration systems.

Because it is important to have all the critical personas scheduled meetings and conferences are no longer scheduled in a collaborative session involving their contributions and members' drawings, sketches, updates, and such reports can be.


discussions improve communication and help reinforce the conversations of secure data, analyses, instructions, and interaction spaces.

To facilitate scientific work, collaboration systems must support the scientific simulation of behavior, thereby being developed online and accessible while others. The definition - the immense interaction. Some of these tools are already in wide use, such as for participatory and interactive research to work. Analyzing components in a new scientific environment in which group members can perform collaborative research on scientific interaction within a group.
Chapter 4: The Collaborative Working Environment

The chapter focuses on the implementation of collaborative working environments. It explores how the Web can be utilized to support the development of applications that foster collaboration and knowledge sharing. The implementation of Web technologies has been crucial in shaping the Web as a platform for collaborative work. The Web has enabled the development of new applications that support collaboration, making it a powerful tool for enhancing productivity and efficiency in the modern workplace.

CONCLUSIONS

In conclusion, the chapter highlights the importance of Web technologies in the implementation of collaborative working environments. The Web has evolved into a platform that supports the sharing of information and knowledge, fostering collaboration among teams and organizations. The implementation of Web technologies has been pivotal in driving the development of applications that support collaborative working environments. The chapter concludes with the assertion that the Web is poised to continue its growth and development, further enhancing its role in the implementation of collaborative working environments.
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THE WORLD WIDE WEB AND HIGH-ENERGY PHYSICS

The Web—what you may now be using to buy an airline ticket or look up Miles Davis's discography—began life as a tool for improving the flow of information at CERN.

Bebo White

In his 1998 State of the Union address, President Bill Clinton told Congress:

We should enable all the world's people to explore the far reaches of cyberspace. Think of this: The first time I made a State of the Union speech to you, only a handful of physicists used the World Wide Web—literally, just a handful of people. Now, in schools, in libraries, homes and businesses, millions and millions of Americans surf the Net every day.

Who were the physicists that Clinton was referring to, and why did the physics community provide the fertile ground from which the Web first sprouted? Although the Web has come to mean many things to many people—electronic commerce, digital libraries, mass advertising, for instance—its roots lie in the simple need for scientists living and working far apart to collaborate with one another on common interests and purposes.

The nursery

CERN, located on the Franco-Swiss border near Geneva, is one of the most successful high-energy laboratories in the world. Its success can be measured in terms of both the number of Nobel prizes its staff have garnered and its proven record of carrying out huge projects. Experiments at CERN and other high-energy physics laboratories use complex particle detectors, which cost millions of dollars and typically involve hundreds of physicists from institutions spread around the world.

Two major elements of successful collaboration are communication and documentation. Researchers working together in different countries must have easy access not only to experimental data, computer program code and drafts of scientific papers, but also to more mundane administrative information, such as meeting minutes and agendas and telephone and e-mail lists. In general, computing and networking technologies provide useful tools for collaborations, but the implementation of specific technologies can also create roadblocks, since collaborating institutions tend to use different computer operating systems and document preparation systems. It was in this environment and to address these kinds of problems that the Web was conceived at CERN.

The early years

The development of the Web at CERN was actually the convergence and synthesis of three separate technologies—computer networking, document/information management and software user interface design. Applying these technologies to the needs of the experimental collaborations led to the solution that became the Web. However, as described below, the Web was not immediately recognized as the solution. CERN’s Ben Segal remembers:

In the beginning was—chaos. In the same way that the theory of high-energy physics interactions was itself in a chaotic state up until the early 1970s, so was the so-called area of Data Communications at CERN. The variety of different techniques, media and protocols used was staggering; open warfare existed between many manufacturers’ proprietary systems, various home-made systems, and the then rudimentary efforts at defining open or international standards. There were no general purpose Local Area Networks (LANs); each application used its own approach.1

Network experimentation at CERN continued through the late 1970s and the 1980s. CERNET, which was started in 1976, linked a number of mainframes and minicomputers. From 1981 to 1983, the STELLA Satellite Communication Project used a satellite channel to link CERNET, the Istituto Nazionale di Fisica Nucleare in Pisa, Italy, and the Rutherford-Appleton Laboratory in Didcot, England. Despite the introduction of Ethernet to the CERN community in 1983, most mainframe and minicomputers still used proprietary networking systems. And although the chaos noted by Segal had been somewhat alleviated, an overall networking strategy was still missing.

While CERN was busy seeking solutions to its networking problems, the global phenomenon known as the Internet was maturing in the US. At the time, no one foresaw that these two efforts would collide and revolutionize the world of communications.

The birth of the Internet

Work on the Internet was initiated in the late 1960s by the US Department of Defense, which wanted to develop a communications network that could survive a nuclear war. In particular, messages had to be able to reach their destinations, even if significant communication routes were destroyed. The solution, the “packet switching”
network, was designed so that the particular route a message takes to reach its destination is unimportant. This ability of a message to travel by other routes assures the sender that it will eventually be received. The original Internet was named Arpanet, after its sponsor, the Advanced Research Projects Agency.

Arpanet led to the development of numerous important networking technologies. Among them was TCP/IP (Transmission Control Protocol/Internet Protocol), which is a method for converting messages to data streams, directing them to a particular address on the network and reassembling the message at the destination. Arpanet (and later the Internet) was designed to be a network of networks that contain different types of computers and different networking technologies. To be able to communicate, all the computers and networks simply had to “speak” TCP/IP.

Arpanet’s first “killer application”/a software program whose popularity surpasses its competitors to the point of all but killing them off/ was e-mail, thanks to which Arpanet’s potential was quickly realized by many people outside the US Defense agencies.

Formally decommissioned in 1989, Arpanet became, more generically, the Internet. Its users scarcely noticed, for Arpanet’s functions not only continued, but also steadily improved. The use of TCP/IP standards for computer networking is now global.

Between 1985 and 1988, CERN local networks converged on TCP/IP. In 1989, CERN opened its first external connections to the Internet, and, by 1990, it was the largest Internet site in Europe. CERN quickly became a major force in the development and support of the Internet both in Europe and worldwide. In his account entitled “A Short History of Internet Protocols at CERN,” Segal writes:

A key result of all these happenings was that by 1989 CERN’s Internet facility was ready to become the medium within which Tim Berners-Lee would create the World-Wide Web with a truly visionary idea. In fact an entire culture had developed at CERN around ‘distributed computing’. It is my belief that the Web could have emerged considerably earlier if CERN had been connected earlier to the Internet.

The networking experience of CERN provided a foundation for the development of the Web. Missing, however, was a way to describe information that could easily be delivered to the user community over the nascent Internet.

Hyperdocumentation

Back in 1983–84, a working group was set up to design an electronic document handling system that would facilitate the storage and retrieval of CERN’s engineering and computing documents. At that time, document preparation at CERN was centered on the use of Waterbox Script on the IBM central mainframe computer. In 1985, some groups began experimenting with SGML (the Standard Generalized Markup Language). The first prototype of this documentation system was introduced on the IBM mainframe and named CERNDOC. It was one of the first electronic documentation systems to use a client-server model. As Eric van Hooijjen (one of the architects of CERNDOC) told me:

Tim [Berners-Lee] was very interested in CERN-
Information Management: A Proposal

On Berners-Lee, CERN
March 1989, May 1989

This proposal concerns the management of general information on a computer network, an analogous of CERN. It includes the notion of hypertext, information about documents, and links to notations and other information sources.

Proposing the Web

The Berners-Lee perspective is a programmer working on networking at CERN's computer division. In a 1980 paper entitled “Information Management: A Proposal,” he described:

In 1980, I wrote a program for keeping track of software with which I was involved. Called Enquire, it allowed one to store snippets of information, and to link related pieces together in any way. To find information, one proceeded

DOC and spent quite some time talking about possible extensions to CERNDOC. The way that images were handled was particularly unsatisfactory: Postscript was just becoming popular at that time, and the system couldn't automatically translate from IBM's EPIDOC to ASCII for VAX clients. I believe that Tim got the client-server vision from CERNDOC as well as the idea of formal negotiation through a special purpose protocol that relied on something looking like SGML as the document format.

With the Internet providing the transfer mechanism and CERNDOC providing a profile like concept, the Web, based only on a user interface, FTP, ETP, Transfer Protocol, and Gopher were treated as an information retrieval service, but neither provided a uniform, platform-independent user interface. And perhaps worst of all from the user's point of view, both systems required knowledge of a specific set of commands. The solution to this interface problem was found in the concept of linking entities of information.

The new proposal was called “World Wide Web,” later renamed.

In October 1989, the two programmers submitted the revised proposal, whose key goals were stated as being:

- To provide a uniform, simple protocol for requesting and returning information stored at a remote site across local networks;
- To provide a model within which information can be logically or physically organized in different contexts and the consumer;
- To provide some method of validating it (at least) in the user's environment by a large proportion of the computing systems in use at CERN.
- To provide an embodiment of a single collection of documents, site which users may, but are not bound to, put their documents. This collection will include many existing data;
- To provide a keyword search option, in addition to a mechanism for following references, using any new or existing indices. The result of a keyword
search is simply a hypertext document consisting of a list of references to nodes which match the keywords.

- to allow private individually managed collections of documents to be linked to those in other collections;

- to use public domain software where possible, or interface to proprietary systems which already exist;

- to provide the software for the above free of charge to anyone.

With the Berners-Lee-Cailliau proposal, which got the go-ahead in September 1990, all the pieces contributing to the development of the Web at CERN were complete. However, implementing the described model was not simple. It required the development of server software to provide content and client software to receive and interpret content. In addition, the method that allows the client and server to communicate with one another—that is, the Hypertext Transport Protocol (HTTP)—had to be invented, as did the Hypertext Markup Language (HTML), which enables content to be displayed effectively on a client or browser. HTML is based on SGML, revealing again the Web's CERNDOC roots.

By November 1990, the initial implementation of a Web client for the NeXT computer (see figure 3) had been developed. This client was able to display documents using multiple fonts and styles and could even be used to edit documents (capabilities only now becoming widespread in many browsers), but access was limited to NeXT users.

March 1991 brought the development of the CERN "linemode" browser, which is shown in figure 4. It could run on numerous platforms, but displayed output only on character-based terminals, such as the VT100. Soon afterward, the Web server software was successfully installed on the CERN VAX/VMS platform and the central IBM mainframe.

In December 1991, the CERN Computer for newsletter first introduced the Web to the high-energy physics community. At that point, Cailliau estimates, there were 10 Web servers worldwide.

Contrary to popular belief, the Web did not initially take the CERN and high-energy physics community by storm. Hanssorg Klein of the Delphi collaboration recalls that a Hypertext colloquium given by Berners-Lee at CERN in November 1990 before the Web's formal announcement was over-whelming to many physicists, who viewed it as an esoteric computer science exercise and did not immediately recognize it as an improvement over existing methods for helping physicists to do physics. Early efforts to get the Delphi experiment on the Web were not successful. Van Herwijnen remembers:

As for initial user reactions, I remember that no one believed in the Web at CERN in the beginning. Many people thought that Tim [Berners-Lee] was not right in inventing yet another protocol (HTTP)—now they take part of the claim of having invented it. The Web was only taken seriously here after Mosaic came along.

And Paul Kunz, a mainstay of the high-energy physics computing community, who was instrumental in establishing the first US Web site, at the Stanford Linear
The first world wide web t-shirt. Dating from 1992, it bears the names of the five high-energy physics laboratories on the Web at the time—the Stanford Linear Accelerator Center (SLAC), the National Institute for Nuclear Physics and High-Energy Physics (NIKHEF) in Amsterdam, the German Electron Synchrotron Laboratory (DESY) in Hamburg, Fermilab (FNAL) and CERN. The designers of the shirt joked: “Maybe some day we’ll have enough sites to go around the wearer’s chest.”

Accelerator Center (SLAC), recalls:

The first I heard about the WWW was an article in a comp.sys.next newsgroup. Tim announced to NeXTStep (the NeXT operating system) users the availability of his application. My thoughts were something like: “what are these CERN people up to now?” I had absolutely no interest as the application was pushed as a way to distribute documentation, and what developer finds documentation fun?

Others, however, were quick to see the Web’s potential. In early 1992, Ruth Pordes and Jonathan Streets of the Fermilab computing division’s on-line systems department (OLS) were considering the problem of providing high-energy physics experimenters with information about on-line data acquisition systems. Seeing the Web presentation to the Artificial Intelligence in High Energy Physics conference (AIHEP 92) at La Londe, France, in February 1992, Streets recommended the Web as being “the best thing around,” and OLS decided to adopt it. Kunz attended the same presentation and recalls that the Web demonstration included a connection to the SLAC server, which was already in production at that time.

At the wrap-up session of the Computing in High Energy Physics conference (CHEP92) held at Annecy, France, in September 1992, Terry Schalk of the Santa Cruz Institute for Particle Physics told the attendees that the conference highlight for him had been the short presentation about the Web. (The commemorative t-shirt is shown in figure 5.) Ever since then, Web applications have played a major role at the CHEP conferences. CHEP97 in Berlin held joint sessions via videoconferencing with the Sixth International WWW Conference in Santa Clara, California.

According to Caillau, the number of Web servers worldwide at the end of 1992 was approximately 50.

CERN’s Bjorn Nilsson recalls that in June 1993, the ALEPH experiment at CERN was able for the first time to provide information previously limited to users of ALWS (the Aleph offline system). A Web version of ALWHO provided an accurate phone list and e-mail data. ALWS HELP and detector status were also provided.

The first browsers

The Web is often described as the killer application of the Internet. However, in those early days, it needed its own killer app to catch on within the high-energy physics community. That application may well have been the Web’s readily accessible, easy-to-use interface to the SPIRES databases at SLAC. SPIRES (the Stanford Public Information Retrieval System) is used to support a set of databases covering a wide range of topics of relevance to high-energy physics, including experiments, institutes, publications and particle data.

Since 1974, the SLAC library has participated in providing SPIRES-HEP, a 300,000-record bibliographic da-
The Future Impact of the Web on the Physics Community

The usefulness of the World Wide Web to the high-energy physics community is no longer questioned, and the operation of a major experiment or laboratory without the Web is almost unimaginable. Not just a tool, the Web has also made research in high-energy physics more accessible to the general public through offering pages written for the educational community and the press. And the Web provides institutions with an excellent mechanism for making exceptional public announcements about such critical events as Nobel Prizes and important discoveries.

Although, for many, the Web has become an advertising and commercial medium whose credibility should not be taken for granted, the high-energy physics and other scientific communities continue to use it in many of the same ways that prompted its conception. There are, however, at least three major areas in the scientific community that could be dramatically changed by some of the new Web technologies—namely, advanced forms of software management, collaborative tools, and electronic publishing.

Software management

High-energy physics experiments depend on computer software that is written, maintained, and run by large numbers of people. The Web has played an important role, helping experimental groups to manage central databases of program code while allowing programmers at different locations to develop the source code. It has also significantly eased the process of distributing software, documentation, and associated databases to remote sites. Good examples of current applications in this area are the Web interface to the FreeHEP collection and the CERN LIGHT (Life cycle Global HyperText) system.

But in the near future, Web-based software systems will be quite different and exciting. For example, think of a physician writing platform-independent analysis software in Java on a local personal computer. The software would be compiled, tested, and debugged locally, but then uploaded to a remote server. Software users would run the application in their Web browsers after downloading the program code from the server. The server could also provide data sets of the most current experimental data. Such a system could potentially eliminate the need for local program libraries and guarantee access to the latest data. Where local program and data libraries are still necessary, Web "push" technology could provide version control by installing the latest software fixes. Current, or especially significant data sets could also be pushed to experiment collaborators for analysis.

Collaborative tools

Physicists must collaborate. The first Web-based conferencing system, WIT, was developed at CERN in 1994 as a quick hack. The BaBar experiment makes extensive use of HyperNews, a conferencing system developed by the National Center for Supercomputing Applications. Various other commercial and homegrown tools are also being used in other high-energy physics collaborations.

But the current text-based conferencing systems—and even videconferencing—provide only tantalizing pieces of the collaborative systems of the near future. DOE2000 is a new initiative that will fundamentally change the way in which scientists work together and how they will address the major challenges of scientific computation. Web technology plays an important role in the implementation of the initiative, concept of the "collaboratory," which promotes itself as a "center without walls, in which researchers can perform their research with regard to geographical location—interacting with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information in digital libraries."

Electronic publishing

In a PHYSICS TODAY article (January 1996, page 42), Peter Boyce and Heather Dahlerup analyzed the electronic publishing of scientific journals and concluded that, ultimately, "it creates new capabilities that extend far beyond what paper journals can provide. It is precisely these new capabilities that will make electronic publishing such a powerful tool for scientists." However, their enthusiasm was tempered by their concern that Web-based electronic publishing suffered from at least three major shortcomings: (1) Hypertext Markup Language (HTML) is not sufficiently structured or versatile for scientific literature; (2) papers are useless unless they can be promptly found; (3) electronic journals must collect enough revenue to support the infrastructure, but not in a way that inhibits the use of electronic tools.

Recent advances in Web technology have addressed these three issues head on. The Extensible Markup Language (XML) is presently being defined by the World Wide Web Consortium (W3C) promises to combine the power of SGML with the compactness of HTML. With XML, Web authors will be able to create sets of data element tags and structures that define and describe the information contained in a document. XML emphasizes the separation of document structure and content. In conjunction with supplementary style sheets (for mathematics, say), XML will provide high-energy physics authors with the tools and functionality previously available only with TeX/LaTeX or SGML.

Continuing advances in search engine technology will make finding material on the Web easier, but will only partly address the frustrating resemblance Web searching bears to indiscriminate drift-net fishing. Document metadata will be used to ensure document applicability, quality and stability. Efforts such as the Dublin Core initiative seek to identify a core set of metadata elements—that is, indexing key words—for finding things more effectively on the Web. Originally conceived for author-generated descriptions, this initiative has also attracted the attention of archivists at museums and libraries.

Document subscriptions work well in the paper world, but are unlikely to work on the Web. Micropayment technology[1] addresses the revenue generation issues of electronic publishing. Under a micropayment, readers of Web documents will pay cents (or fractions of cents) for access. According to Jakob Nielsen, "Micropayments lower the threshold and do not require a big decision before users get their initial benefits."

[1] [Footnote: "Micropayments lower the threshold and do not require a big decision before users get their initial benefits."]

[Figure: New Astronomy web interface]

Now three years old, the journal "New Astronomy" was launched simultaneously in Web and print versions.
tabase, to the world’s high-energy physics community. Before its implemention on the Web, the only way to access SPIRES-HEP was to log in to the IBM system at SLAC, where the database resides, or to use the QSPIRES interface, which operated only from remote nodes using BITNET. With either method, a rudimentary knowledge of the somewhat esoteric SPIRES query language was required. According to Berners-Lee, the mounting of SPIRES-HEP on the Web was a vitally important factor in the rapid acceptance and utilization of the Web by the international high-energy physics community.1

Although ready access to SPIRES may have facilitated the acceptance of the Web, “It wasn’t until NCSA (the National Center for Supercomputing Applications) made Mosaic that the average person could see why this was really a good thing,” recalls David Ritchie, who chaired the working group that designed the first home page for Fermilab.5 Mosaic brought forth the Web from physics and computer science laboratories and set the path for the role it plays today. The first version of Mosaic emerged in February 1993, but before its release, several other significant Web browsers had already been developed.

The early browsers developed at CERN in 1991–92 had been quickly followed by the first browsers designed for the X Windows computer environment—namely, the Viola browser developed by Pei Wei of the University of California, Berkeley (and later O’Reilly and Associates) and the Midas browser developed by Tony Johnson at SLAC. (See figure 6.)

Like the Midas and Viola browsers before it, Mosaic was freely available on the Internet. Features provided by Midas and Viola undoubtedly influenced the course of Mosaic’s development. Fermilab’s Pordes remembers:

In 1993 I invited Tim [Berners-Lee] to Fermilab. I contacted NCSA and suggested that we go down and meet them. It was clear they were really going to make Mosaic. That was the first time we realized that he [Berners-Lee] was really going to have a big success.6

Through 1993 and 1994, CERN and NCSA continued to lead the browsers in Web development. NCSA provided a rapid succession of improvements (and new features) for Mosaic and developed the NCSA server. Meanwhile, the small but dedicated Web group at CERN continued its efforts on the CERN server. More important, however, the CERN group developed and supported Libwww, the general software library—the nuts and bolts—for building Web browsers and servers. Pioneering work on critical Web features, such as access authorization, resulted from the Libwww effort.

In May 1994, the First International WWW Conference was held, at CERN. Described by one press pundit as the Woodstock of the Web, it was rapidly oversubscribed. Caillaud estimates that the number of Web servers worldwide went from 2500 at the end of 1994 to 30,000 at the end of 1995. This growth was due largely to the availability of server software developed by CERN and NCSA.

Berners-Lee had long argued that the standardization of the Web be open and nonproprietary. His model was that of the X Consortium, which had been formed in 1988 to further the development of the X Window system and whose major goal was the promotion of cooperation within the computer industry in the creation of standard software interfaces at all layers in the X Window system environment. MIT had for many years provided the vendor-neutral architectural and administrative leadership required to make that organization work. In December 1994, after much negotiation, Berners-Lee left CERN for the MIT Laboratory for Computer Science (LCS) to become director of the newly formed World Wide Web Consortium (W3C).

Ultimate irony

Ironically, it was high-energy physics that brought the end to Web development at CERN and effectively at any other high-energy physics laboratories. In late December 1994 and early January 1995, the CERN Council unanimously approved the construction of the Large Hadron Collider, the world’s most ambitious high-energy physics accelerator to date. Because the LHC would cost so much, the council decided not to fund further Web development, and, in negotiations with the European Commission and INRIA (the Institut National pour la Recherche en Informatique et Automatique in France), transferred the CERN Web project to INRIA. It was also agreed that INRIA, along with MIT/LCS, would host the W3C. (Keio University in Japan became the third host of the W3C in 1996.)

By the end of 1997, Caillaud estimates the number of Web sites worldwide had reached 650,000—on every continent and, possibly, in every country. The number of Web users is now estimated in the millions. Web addresses have become almost as widespread as telephone numbers, while Web sites provide every conceivable form of content or service. And, as described in the box on page 35, the Web promises to dramatically change how scientists work and interact.

In reflecting on the current size and scope of the Web, it is important to remember that this revolutionary technology grew from the needs and imagination of the high-energy physics community and that scientific research—even on the ultimate constituents of matter—often leads to significant technical spin-offs.

I wish to thank Tim Berners-Lee, Robert Caillaud, Tony Johnson, Hanspeter Klein, Paul Kauf, Jennifer Masek, Bjorn Nilsen and Eric van Herwijnen for their help and recollections. Work for this article was supported by the US Department of Energy Contract No. DE-AC03-76SF00515.

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The World-Wide Web and High-Energy Physics

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The World-Wide Web and High Energy Physics

(Submitted to Physics Today)

In his State of the Union address in January 1998, President Bill Clinton told the U.S. Congress - "We should enable all the world's people to explore the far reaches of cyberspace. Think of this -- the first time I made a State of the Union speech to you, only a handful of physicists used the World-Wide Web. Literally, just a handful of people. Now, in schools, in libraries, homes and businesses, millions and millions of Americans surf the Net every day." [1]

Who were these physicists that President Clinton was referring to, and why did the physics community provide the fertile ground from which the Web was born? While the Web has come to mean many things to many people - electronic commerce, digital libraries, mass advertising, and many others - its roots lie in the simple need for scientists living and working far apart to collaborate with one another on common interests and purposes.

CERN, located on the Franco-Swiss border near Geneva, is probably the most successful high-energy laboratory in the world. Its success can be measured both in terms of the number of Nobel prizes research there has garnered, and in terms of how it has proven that international collaborations can work together conducting sophisticated experiments. Experiments at CERN (and other high-energy physics laboratories) use complex particle detectors which cost millions of dollars. It is not unusual for an experimental collaboration to involve hundreds of physicists from institutions spread throughout the world.

Two major elements of successful collaboration are communication and documentation. International collaborators must be able to quickly share not only experimental data, computer program code, and drafts of scientific papers, but also more mundane administrative information, such as meeting minutes and agendas and telephone and e-mail lists. Computing and networking technologies provide useful tools for collaborations, but can also create roadblocks - collaborating institutions use different computer operating systems and document preparation systems. It was out of this environment and to address these problems that the Web was born at CERN.

The development of the Web at CERN was actually the convergence and syntheses of three separate technologies - networking, document/information management, and interface design. Application of these technologies to the needs of the experimental collaborations led to the solution that became the Web. However, as will be described later in this article, recognition of the Web as the solution was not immediately realized.

"In the beginning was - chaos. In the same way that the theory of high-energy physics interactions was itself in a chaotic state up until the early 1970's, so was the so-called area of 'Data Communications' at CERN. The variety of different techniques, media and protocols used was staggering; open warfare existed between many manufacturer's proprietary systems, various home-made systems, and the then rudimentary efforts at
defining open or international standards. There were no general purpose Local Area Networks (LANs); each application used its own approach.” [2]

Network development at CERN continued through the late 1970’s and the 1980’s. CERNET, beginning in 1976, linked a number of mainframes and minicomputers. The STELLA Satellite Communication Project, from 1981-83, used a satellite channel to link CERNET running between CERN and INFN-Pisa and a Cambridge Ring network between CERN and the Rutherford-Appleton Laboratory (RAL) in the United Kingdom. In 1983, Ethernet was first introduced at CERN. DECnet and BITNET provided networking capability for VAX VMS and IBM VM/CMS platforms, respectively. An overall networking strategy was still lacking.

Between 1985 and 1988, CERN local networks moved methodically to TCP/IP. In 1989, CERN opened its first external connections to the Internet and by 1990 it was the largest Internet site in Europe. CERN quickly became a major force in the development and support of the Internet both in Europe and worldwide.

In his “A Short History of Internet Protocols at CERN” Ben Segal writes, “A key result of all these happenings was that by 1989 CERN’s Internet facility was ready to become the medium within which Tim Berners-Lee would create the World-Wide Web with a truly visionary idea. In fact an entire culture had developed at CERN around ‘distributed computing’…It is my belief that the Web could have emerged considerably earlier if CERN had been connected earlier to the Internet.” [2]

Network developments at CERN provided the networking infrastructure needed for the development of the Web. Missing, however, was an information infrastructure that could be easily delivered to the user community over these networks using a technology such as the Web.

In 1983-84, a working group was set up to design an electronic document handling system that would facilitate the storage and retrieval of CERN’s engineering/computing documents. At that time, document preparation at CERN made heavy use of Waterloo Script (on IBM VM/CMS). In 1985, some groups began experimenting with SGML (the Standard Generalized Markup Language). The first prototype of this documentation system was implemented as a virtual machine on VM/CMS and named CERNDOC. It was one of the first electronic documentation systems to use a client/server model. It used SGML, though it wasn’t dependent on a particular DTD (Data Type Definition) - the Web’s HTML is an SGML DTD.

Eric van Herwijnen (one of the architects of CERNDOC) recollects, “Tim [Berners-Lee] (and Mike Sendall, who later became something like the ‘adopted godfather of the Web’) was very interested in CERNDOC and spent quite some time talking about possible extensions to CERNDOC. The way that images were handled was particularly unsatisfactory. PostScript was just becoming popular at that time, and the system couldn’t automatically translate from IBM’s EBCDIC to ASCII for VAX clients. I believe that Tim got the client/server idea from CERNDOC as well as the idea of format negotiation through a special purpose protocol that relied on something looking like SGML as the document format.” [15]
With the Internet providing the transfer mechanism, and CERNDOC providing a prototype for content, the only piece of the Web missing was the user interface. FTP (File Transfer Protocol) and Gopher were accepted Internet information retrieval systems, but neither provided a uniform, platform-independent user interface. And perhaps worst of all, both systems required user knowledge of a specific set of commands. The solution to the interface problem was found in pointing and linking features of hypertext!

In his 1989 proposal “Information Management: A Proposal” [3], Tim Berners-Lee wrote, “In 1980, I wrote a program for keeping track of software with which I was involved. Called Enquire, it allowed one to store snippets of information, and to link related pieces together in any way. To find information, one progressed via the links from one sheet to another, rather like in the old computer game ‘adventure.’ I used this for my personal record of people and modules. It was similar to the application HyperCard produced more recently by Apple for the Macintosh. A difference was that Enquire, although lacking the fancy graphics, ran on a multi-user system, and allowed many people to access the same data.”

In his proposal, Berners-Lee offered a solution for the management of general information about accelerators and experiments at CERN and the problems of loss of information as “the integration of a hypertext system with existing data, so as to provide a universal system, and to achieve critical usefulness at an early stage.” Figure 1 shows a diagram from the proposal illustrating how the proposed system would integrate such diverse information sources such as VAXNOTES, USENET, IBM GroupTalk (which the author implemented at CERN), and CERNDOC. This proposal never used the term “World-Wide Web.”
 Independently of Berners-Lee, Robert Cailliau was also interested in use of hypertext as a solution to CERN's information retrieval problems. He was especially interested in platform-dependent hypertext systems such as HyperCard and hypertext scripting languages such as HyperTalk. In 1990, Berners-Lee and Cailliau decided collaborate on a revision of the 1989 proposal to CERN management. The new proposal was entitled "World-Wide Web: Proposal for a Hypertext Project" [4].

Cailliau recalls the discussion with Berners-Lee (held at the CERN cafeteria) over what to name the proposed project: "We agreed that Greek names were out - too old-fashioned. Then one of us had the idea: 'What about the World-Wide Web?' 'That'll do,' said the other. 'Let's put that down, and think of something better later.' " [15] Later never came.

In October of 1990, Berners-Lee and Cailliau submitted the revised proposal. It defined the key goals of the project as,
• "to provide a common (simple) protocol for requesting human readable information stored at a remote system, using networks;
• to provide a protocol within which information can automatically be exchanged in a format common to the supplier and the consumer;
• to provide some method of reading at least text (if not graphics) using a large proportion of the computer screens in use at CERN;
• to provide and maintain at least one collection of documents, into which users may (but are not bound to) put their documents. This collection will include much existing data;
• to provide a keyword search option, in addition to navigation by following references, using any new or existing indexes. The result of a keyword search is simply a hypertext document consisting of a list of references to nodes which match the keywords;
• to allow private individually managed collections of documents to be linked to those in other collections;
• to use public domain software wherever possible, or interface to proprietary systems which already exist;
• to provide the software for the above free of charge to anyone." [4]

With the Berners-Lee/Cailliau proposal, all the pieces contributing to the development of the Web at CERN were complete. By November 1990, the initial implementation of a Web client for the NeXT platform had been developed. This first browser was able to display documents using multiple fonts and styles and was even able to edit documents (capabilities only now becoming widespread in many browsers), but access was limited to NeXT users.

Tim Berners-Lee
The NeXT "Cube" Which Ran the Original WWW Server and Browser

March 1991 brought the development of the CERN "linemode" browser (Figure 2.), which could run on numerous platforms but displayed output only on character-based (e.g., VT100) terminals. The Web server code was subsequently ported to the CERN VAX/VMS platform and the IBM VM/CMS mainframe. In December 1991, the CERN Computer Newsletter announced and described the Web to the high-energy physics community.
Contrary to popular belief, the Web did not initially take the CERN and high-energy physics community by storm. Hansjorg Klein of the Delphi collaboration recalls that a Hypertext Colloquium given by Berners-Lee at CERN in November of 1990 was "overwhelming to many physicists." [15] Early efforts to get the Delphi experiment "on the Web" were not extremely successful.

Eric van Herwijnen remembers, "As for initial user reactions, I remember that no one believed in the Web at CERN in the beginning. Many people thought that Tim was not right in inventing yet another protocol (HTTP) - now they take part of the claim of having inventing it. The Web was only taken seriously here after Mosaic came along." [15]

Paul Kunz, a mainstay of the high-energy physics computing community who was instrumental in establishing the first U.S. Website at the Stanford Linear Accelerator Center (SLAC), recalls "The first I heard about the WWW was an article in a comp.sys.next newsgroup. Tim announced to NeXTStep users the availability of his application. My thoughts were something like: 'what are these CERN people up to now?' I had absolutely no interest as the application was pushed as a way to distribute documentation, and what developer finds documentation fun?" [15]

Others were quick to see the Web's potential: In early 1992, Ruth Pordes and Jonathan Streets of the FermiLab Computing Division's Online Systems Department (OLS) were considering the problem of providing information about online data acquisition systems to high-energy physics experimenters. Seeing the Web presentation to Artificial Intelligence in High Energy Physics (AIHEP'92) at La Londe, France in February 1992, Streets recommended the Web as being "the best thing around," and OLS decided to
adopt it. [5] Paul Kunz attended the same presentation and recalls that the Web demonstration included a connection to the SLAC server, which was already in production at that time.

At the wrap-up session of the Computing in High Energy Physics Conference (CHEP) held at Annecy, France in September, 1992, Terry Schalk of the Santa Cruz Institute for Particle Physics (SCIPP) announced to attendees that the conference highlight for him had been the short presentation on the Web. Since then, Web applications have played a major role at the CHEP conferences. (CHEP97 in Berlin held joint sessions via videoconferencing with the Sixth International WWW Conference in Santa Clara, CA.)

Figure 3. is a photograph of a T-shirt made for CHEP92. The shirt bears the names of the 5 high-energy physics laboratories on the Web at the time - CERN, SLAC, DESY, NIKHEF, and FNAL. The joke amongst the designers of the shirt was that “maybe some day we’ll have enough sites such that the names will go around the shirt wearer’s chest.”

![Figure 3. The First WWW T-shirt](image)

Bjorn Nilsson recalls that in June 1993, the ALEPH experiment at CERN was able for the first time to generally provide information previously limited to ALWS (the Aleph offline system) users. A Web version of ALWHO provided accurate phone list and e-mail data. ALWS HELP and detector status were also provided. [15]
The Web is often described as the “killer application” of the Internet. However, in these early days of its implementation, it needed its own “killer app” in order to “catch on” within the high-energy physics community. That application may well have been the Web’s readily accessible, easy to use interface to the SPIRES databases at the Stanford Linear Accelerator Center (SLAC). SPIRES (the Stanford Public Information RETrieval System) is used to support a set of databases covering a wide range of topics of relevance to high-energy physics including experiments, institutes, publications, and particle data.

Since 1974, the SLAC library has participated in providing SPIRES-HEP, a 300,000 record bibliographic database, to the world’s high-energy physics community. Prior to its implementation on the Web, the only way to access SPIRES-HEP was to log in to the IBM VM/CMS system at SLAC where the database resides, or to use the QSPIRES interface which operated only from remote BITNET nodes. With either method, a rudimentary knowledge of the somewhat esoteric SPIRES query language was required. According to Tim Berners-Lee, the mounting of SPIRES-HEP on the Web was a vitally important factor in the rapid acceptance and utilization of the Web in the international high-energy physics community. [6]

While ready access to SPIRES may have aided in the acceptance of the Web in the high-energy physics community, “It wasn’t until NCSA (the National Center for Supercomputing Applications) made Mosaic that the average person could see why this was really a good thing,” recalls David Ritchie, who chaired the working group that designed the first home page for Fermi National Laboratory. [7] Mosaic brought the Web from physics and computer science laboratories and set the path for the role it plays today. The first version of Mosaic came in February 1993, but prior to its release, Web browser development had hardly been stagnant.

The early browsers developed at CERN were quickly followed by the first browsers designed for X Windows - the Viola browser developed by Pei Wei at the University of California, Berkeley (and later O’Reilly and Associates), and the Midas browser developed by Tony Johnson at the Stanford Linear Accelerator Center (SLAC).
Tony Johnson and the Midas browser

Like Mosaic, both the Midas and Viola browsers were freely available on the Internet. The features they provided undoubtedly had an impact on Mosaic’s development. Ruth Pordes of FermiLab remembers, “In 1993 I invited Tim [Berners-Lee] to FermiLab. I contacted NCSA and suggested that we go down and meet them. It was clear they were really going to market Mosaic. That was the first time we realized that he [Berners-Lee] was really going to have a big success.” [7]

Through 1993 and 1994, CERN and NCSA continued to be the leaders in Web development. NCSA provided a rapid succession of improvements (and new features) to Mosaic and developed the NCSA server. The small but dedicated Web group at CERN continued their efforts on the CERN server, but more importantly, developed and supported Libwww, the general software library for building Web browsers and servers. Pioneering work on critical Web features such as access authorization resulted from the Libwww effort. In May 1994, the First International WWW Conference was held at CERN. Described by one press pundit as “the Woodstock of the Web,” it was rapidly oversubscribed.

Tim Berners-Lee had long argued that standardization of the Web be open and non-
proprietary. His model was that of the X Consortium, formed in 1988 to further the
development of the X Window System and having as its major goal the promotion of
cooperation within the computer industry in the creation of standard software interfaces at
all layers in the X Window System environment. MIT had for many years provided the
vendor-neutral architectural and administrative leadership required to make that
organization work. In December 1994, after much negotiation, Berners-Lee left CERN
for the MIT Laboratory for Computer Science (LCS) to become director of the newly-formed World-Wide Web Consortium (W3C) (http://www.w3.org/).

Perhaps it is the ultimate irony that it was high-energy physics that brought the end to Web development at CERN (and effectively at any other high-energy physics laboratories). In late December 1994 and early January 1995, the CERN Council approved unanimously the construction of the Large Hadron Collider (LHC), the world’s most ambitious high-energy physics accelerator to date. Due to stringent budget conditions resulting from the LHC decision, the Council decided not to continue Web development and, in negotiations with the European Commission and INRIA (the Institut National pour la Recherche en Informatique et Automatique, France), transferred the CERN Web Project to INRIA. It was further agreed that INRIA along with MIT/LCS would host the W3C.

There is no longer any question regarding the acceptance or usefulness of the Web to the high-energy physics community. It would be difficult to imagine the operation of a major experiment or laboratory without the Web as an essential tool. Institutional and experimental resources on the Web have made research in high-energy physics more accessible to the general public. Many laboratory Websites now contain information and resources specifically targeted to general audiences, such as the educational community and the press. Web pages have also provided institutions with an excellent mechanism for exceptional public announcements such as Nobel Prizes (e.g., http://www.slac.stanford.edu/slac/hottopic/mperl95/mperl95.html) and important discoveries (e.g., http://www.fnal.gov/pub/top95/top_news_release.html).

While the Web is viewed by many as having evolved into an advertising and commercial medium where the credibility of much of its content should be in question, the high-energy physics community (and perhaps most scientific communities) continues to use it in many of the same ways which prompted its conception. There are, however, at least three major areas in the scientific community that are likely to be dramatically changed by some of the new Web technologies - software development, management, and distribution; collaborative tools; and Web/Electronic publishing.

Software Development, Management, and Distribution

High-energy physics experiments depend on computer software. The Web has played an important role in the success that experimental groups have had in maintaining central program source code bases while allowing distributed software development. It has also made a significant contribution to the process of distributing software, documentation and associated databases to remote sites. Good examples of current applications in this area are the Web interface to the FreeHEP collection (http://slacvm.slac.stanford.edu:5080/FIND/FHMAIN.html) and the CERN LIGHT (Life cycle Global HyperText) system (http://alephwww.cern.ch/LIGHT/).

A Web-based software system (development, management, and distribution) for high-energy physicists in the near future will be quite different and exciting. A physicist might write platform-independent analysis software in Java on a local PC or workstation. This software could be compiled, tested, and debugged locally and then uploaded to a remote
server. Software users would run the application in their Web browsers after downloading the program code from the server. The server could also provide datasets of the most current experimental data. Such a system could potentially eliminate the need for local program libraries and guarantee access to the latest data. In those instances where local program and data libraries are necessary, Web push technology could provide version control by installing the latest software fixes and patches. Current or especially significant datasets could also be pushed to experiment collaborators for analysis.

Collaborative Tools

Physicists must collaborate. The first Web-based conferencing system, WIT, was developed at CERN in 1994 as “a quick hack.” [8]. The BaBar experiment makes extensive use of HyperNews, a conferencing system developed by NCSA. (http://babar-hn.slac.stanford.edu:5090/HyperNews/index). Various other commercial and “home-grown” tools are also being used in other high-energy physics collaborations.

Text-based conferencing systems and even videoconferencing only provide tantalizing pieces of the collaborative systems of the near future. DOE2000 is a new initiative [9] that will fundamentally change the way that scientists work together and how they will address the major challenges of scientific computation. Web technology plays an important role in the implementation of the initiative’s concept of the collaboratory, a “...center without walls, in which researchers can perform their research without regard to geographical location - interacting with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information in digital libraries.” [10]

Web/Electronic Publishing

Peter Boyce and Heather Dalterio [11] in their analysis of electronic publishing of scientific journals reach the conclusion “In the end it [electronic publishing] creates new capabilities that extend far beyond what paper journals can provide. It is precisely these new capabilities that will make electronic publishing such a powerful tool for scientists.” This enthusiastic vision was, however, tempered by their concern that at the time of their work (1996), Web-based electronic publishing suffered from at least three major shortcomings: 1) “HTML is not sufficiently structured or versatile;” 2) “Even the best papers are of no use if they cannot be found when you need them. The research literature is of most value when you can search and recover articles of interest from a large fraction of the entire collection;” 3) “Who will pay...how to charge the users. They must collect enough revenue to support the infrastructure...revenue collection should not inhibit the use of electronic tools.”

Recent advancements in Web technology have addressed these three issues raised by Boyce and Dalterio “head-on.” The limitations of HTML for scientific papers are well known. The eXtensible Markup Language (XML) presently being defined by the W3C promises to change this situation. XML has the power of SGML but with the compactness of HTML [12]. With XML, Web authors can create sets of data element tags and structures that define and describe the information contained in a document. XML emphasizes the separation of document structure and content. In conjunction with technologies supporting style sheets (CSS, XSL, and DSSSL) and mathematical markup
(MathML). XML will provide high-energy physics authors with the tools and functionality previously available only with tools such as TeX/LaTeX or SGML.

Continuing advancements in search engine technology will make finding material on the Web easier, but only address a part of the problem faced by researchers. Document metadata will be used to assure document applicability, quality, and stability. Efforts such as the Dublin Core initiative (http://purl.org/metadata/dublin_core) are seeking to identify a core set of metadata elements for Web/Internet resource discovery. Originally conceived for author-generated descriptions, it has also attracted the attention of formal resource description communities such as museums and libraries. The metadata elements of the Dublin Core fall into three groups which roughly indicate the class or scope of the information stored in them: 1) elements related mainly to the content of the resource (e.g., subject or source); 2) elements related mainly to the resource when viewed as intellectual property (e.g., creator or rights); 3) elements related mainly to the instantiation of the resource (e.g., date or format).

Micropayment technology [13] addresses the revenue generation issues of electronic publishing. Document subscriptions work well in “the paper world,” but are unlikely to work on the Web. Under a micropayment scheme, readers of Web documents will pay cents (or fractions of cents) for access. “Micropayments lower the threshold and do not require a big decision before users get their initial benefits.” [14]

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