

# From Experience: Linking Available Resources and Technologies to Create a Solution for Document Sharing - The Early Years of the WWW

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## *Abstract*

This article studies the circumstances and events that finally led to the world's first way to browse the Internet, called the World Wide Web (WWW) at the European Laboratory of Particle Physics (CERN). It is shown that few bright and adventurous persons created the innovative technology from an unique combination of existing technologies and actions spirited by the demanding environment of high energy physics with its global need to share documents. This technology is now reforming and changing the existing mode of work, trade and communication, simply affecting the whole society. Partly the non-mission oriented management approach accompanied with individualistic ideals and unique surroundings were the driving forces behind this innovation. Direct communication with the end-user community prevented the developers from producing something with no relevance and application, as even the first prototype tools were immediately used and exploited. The story goes back to the beginning of 1980's world of physics with multiple word processors and document formats, network pioneering and the multimedia hypes along with hypertext philosophies. The article limits its scope to activities prior to the rapid and global diffusion of the WWW on the Internet, i.e. on what happened at CERN between 1980 and 1992. Surprisingly, the WWW story shows that the original key technologies in networks, document formats and desktops were all somehow present when the innovation was made. They had laid dormant for decades before one desktop computer integrated them into one functional unit enabling the innovator to materialise his vision.

Keywords: World Wide Web, innovation, technology transfer, product development, diffusion, Internet, document management, hyper text, CERN



### **About the authors**

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## Preamble

In terms of diffusion speed the use of World Wide Web (WWW) and Internet is without any equivalent phenomenon in the business world, even fashion cannot match with it. Similar rates of replication and expansion can only be found in biological and chemical processes. Since its global introduction in 1993 the number of services and applications available through the WWW have been exponentially increasing [14]. This trend is about to continue as the number of Internet nodes keep increasing, partly because of limited access networks called Intranets for industrial use are being implemented and integrated to the overall networks. It is not an exaggeration to say that networking, both in terms of information sharing and mode of collaboration is changing our cultural premises [8]. The third technological revolution since mass production and electricity has been dated to the birth of transistor, yet, perhaps the real outburst of this revolution is taking place now.

Most of the WWW literature fail to tell the true origin of the new networking technology. Majority of them start from the activity taken place at the National Centre for Supercomputing Applications (NCSA) and the avalanche of developments from the end of year 1993 onwards. Only obscure hints indicate that there was something before this and that it was somehow associated with the European Laboratory for Particle Physics (CERN\*). It is the aim of this article to document the innovative process that led to the first Internet browser and related server software at CERN in 1990. By exploiting as much as possible original documents, including project proposals, even copies of electronic mail exchange and minutes etc., and by interviewing several people involved directly or indirectly in the development process, the article documents the process and environmental constraints that produced the first operational WWW-prototype.

It has become clear that the original and profound reason triggering the activities towards the WWW was simply the need to share documents and information across multiple platforms and sites. Design, construction and operation of particle accelerators is a global effort requiring multinational collaboration and contribution. Technology-wise the particle physics instruments comprise all aspects of human engineering resulting in non-conventional and one-off solutions to tackle front-end technical challenges. It was this environment where the idea, technical solution and first prototype of the WWW browser and the related server application were created. Managing the ever more complicated research systems, and their continuous up-grading, had in mid-1980's reached a level where electronic document sharing was the only way out. Thus, the fundamental driving theme for understanding the early days of the WWW is the document sharing cross global and technologically heterogeneous platforms.



Methodologically the article follows several innovation studies [1,2,7,9,12,21,22] in documenting the key events in chronological order and by viewing situational constraints from social and technological point of view, also financial and managerial aspects are considered. The time horizon is limited between the beginning of the 1980's and the year 1992, just before the technology started its very rapid and global diffusion. The notes of the interviews [11] were verified by the subject people, also major contradictions between statements were corrected. The final decomposition of the events as presented in the article is within the sole responsibility of the authors.

The article first sets the scene for the innovative process by describing the unique and apparently the most fertile environment in which the WWW could have been created, i.e. the high energy physics research and their global need to share documents and information cross scattered and diversified collaboration. This chapter emphasises the benefit dimension of the product concept' foundation. Then the technological constraints, solutions and finally the triggering coincidences influencing and assisting the innovative process are described. This is followed by a description on how the innovators themselves experienced the process, i.e. how the product concept's for was established. Management issues and the general spirit of running research work at CERN is then reflected to provide some managerial insight for other product and system development projects, be they industrial or not. Then the lesson learned is summarised and, finally, conclusions are drawn together with a tentative outline of the implications of the present case to the innovation studies in general.

### The HEP community - setting the scene

The high energy physics (HEP) community is a global family of researchers performing the forefront scientific research aiming at revealing the deeper structures and properties of matter. In doing this the research and its results projects mankind's role in the whole panorama of scientific and universal evolution. The key feature of scientific research is to test hypotheses, and thereafter to reject or improve them objectively [18]. Following this strict criteria of scientific conduct all theories are tested and their results verified up to the extend it is possible to discard or provide them with inductive support. In this process Galileo's telescope has evolved into large-scale satellite observatories and huge particle accelerators, which require design, construction and operational activities in global scale across all political, religious and racial barriers. The advancement in the field of HEP has been enormous and its impact on our world-view even more profound.

During the 1980's the HEP community associated with CERN was constructing LEP (Large Electron-Positron collider), the largest ever built accelerator at that time. With four experimental





facilities to study the colliding particle beams and to verify the results, it today operates at even higher energy levels than before. One such experiment has more than hundred participating institutes from 30 different countries and the particle detector itself is constructed through collaborative contributions. In this respect the whole effort resembles that of a well planned global “bring-a-dish-party”, where the complete menu is built up from individual contributions. The annual outcome of this scientific interaction is more than 1.000 scientific articles with round 12.000 bibliographic cross-references. Technologically the present instruments are the manifestations of the state-of-the-art technologies of 1980’s. The new instruments under design will require so far unknown solutions with presumably far reaching impact on the technological development in the next year thousand.

The HEP community works in distributed manner through globally spread institutes, which all share their own political and computational habits, but still striving towards common scientific goal. Design and engineering activities take place in parallel and the quality constraints for the systems are almost as strict as for the space research. Technologies involved in the systems cover a very broad spectrum, practically all activities within the scope of human engineering. The dimensions of collaboration comprise hard scientific discipline with technologically challenging tasks, which cannot be accomplished without major joint effort between academics and industry. In addition the operation and continuous up-grading of the instrumentation is a major task and requires multiple skills and global participation. This globally distributed multi- and high-technology environment is at the very core of the HEP community and it is exactly this environment which triggered, or directed the development towards the global networking concept called the World Wide Web.

From the WWW point view it is vital to understand that the main objective of fundamental research - to produce scientific results - breaks into following detailed and crucial facts from document and information system point of view:

1. Thousands of documents, notes, works, designs, software applications etc. are being produced, which must be accessible, retrievable and even modifiable to the whole global community or for selective parts of it.
2. Due to HEP community’s heterogeneous and distributed nature, practically all existing computer platforms, formats and network protocols are being used in the daily operations by the community.
3. Information itself that is being interchanged tends to require an increasing number of different document formats.



This was the situation in the beginning 1980's and it still is, except that the volume of information has increased exponentially. Managing documents, resources and objectives for distributed and global environment in a process aiming to produce both documents and high-tech scientific instruments was the fertile soil needed for the birth of the WWW. This heritage is being further exploited during the 1990's when the main design effort for the new, ever larger accelerator is being designed by CERN and the global HEP community.

## Technology perspective

Three parallel and strongly intertwined technological trajectories [6], were prevailing in the 1980's computing environment at CERN. Here, a technological trajectory encloses all engineering activities with state-of-the-art solutions or approaches to tackle certain well defined set of similar practical and technical problems. First, there was the network itself, i.e. the medium with the necessary hardware and protocols to exchange information. Second, the formats in which documents were stored and disseminated. Third, the desktop and software tools available to develop applications to manipulate documents and access them through the network. All of these trajectories are studied here within a general CERN time window starting from the beginning of 1980's, ending until the year 1992.

### *Networking*

In the beginning of 1980's all major computer manufacturers provided their own proprietary systems with vertical integration from top to bottom. This meant that networks, i.e. interconnected computers, would use only specific CPU's and operating systems. Industry in general was pursued towards one vendor solutions and multi-vendor computer and network platforms were regarded as destructive and inefficient solutions for the business. Due to its unique nature at CERN the situation was by default a multi-vendor solution. The International Standards Organisation (ISO) had started to pay serious attention to the heterogeneity in networking already in mid 1970's. This work was to last several decades as the national telecommunication providers started to pursue their own solutions. In U.S the Department of Defence (DoD) had initiated their own significant development with the ARPANET using the special protocol called IP (Internet Protocol). This approach which eventually had grown to a world wide standard, used non-point to point connections for military reasons. This was opposite to the approaches taken by national telecommunication providers and supported by most computer vendors.



In this messy situation the HEP community around CERN started to discuss their future computing needs, especially in the light of building the LEP (Large Electron Positron) collider (completed in 1989), the first truly global effort. The large collaborations responsible for the experiments were clearly facing the most severe problems related to networking. Their user requirements already in the beginning of the 1980's enclosed remote terminal access to computers, file transfer, electronic mail and teleconferencing. Yet, the level of networking related services was far from being able to satisfy their needs for collaborating between more than 20 countries and hundred institutes. The conclusion was to promote a vendor independent solution called the Academic Network basing on common standards. There was no other solution available than the ARPANET, which, however, was ignored by the European HEP community in the first place but gained momentum in mid 1980's. Yet, CERN was not starting from scratch, as it had already in late 1970's tested packet switching based networking, and the expertise generated at CERN was later used by several standardising and expert bodies in Europe.

ISO started to promote Open System Interconnection (OSI), a supplier independent protocol already during 1970's. This activity was very theoretical right from the beginning and few operational systems existed not until the end of 1980's. The clash between rudimentary, operational and reliable TCP/IP (Transmission Control Protocol / Internet Protocol) based ARPANET and OSI was evident. Despite the low level of TCP/IP services it worked and managed the basic tasks, also its free distribution along UNIX-operating systems made it available faster, especially in the U.S. It was the reluctance and safeguarding of the powerful European national telecommunication providers that almost blocked the acceptance of the TCP/IP based network services. Due to TCP/IP's functionality it was no wonder that the academic world, including the HEP community, adopted the U.S. protocol first in the Europe. One may see it also as a battle between connection and connectionless oriented worlds, as direct point-to-point connections are more easier to charge from and to establish solid business.

The decision to move on with TCP/IP was not a clear one, although UNIX machines were used already since 1979. In 1985 a special group was appointed to co-ordinate TCP/IP activities within CERN. Somehow the general feeling was that the TCP/IP was a temporary solution and it was only to be used internally before OSI would take it over. Other options were also studied and tested like the Decnet from Digital Corporation, but it was not until 1989 when IBM went officially behind TCP/IP and offered the basic networking services to CERN free of charge. Later the same year external TCP/IP connections were opened. In 1990 the official decision for TCP/IP was made and



the “war of protocols” was over, and the implementation and adaptation phase to enter global communication phase started at CERN. In 1995 CERN was the biggest single node in the Internet.

### *Document formats*

Entering electronic document handling was a nightmarish process at CERN. In the beginning of 1980's the number of available word processors was significant. It seemed that each and every manufacturer of computers, typewriters, printers, including the printing houses, some academic institutions and even big companies themselves were to develop their own word processing applications. The heterogeneous hardware platform accompanied with huge variety of document producing tools generated a situation of total non-compatibility. At CERN with it is main outcome being a document in the form of article, specification, manual, program code etc., the situation was very complicated, even absurd. The need for some kind of unifying document format was evident, in order to assure fluent interaction among geographically distributed collaborators.

The problem had existed already earlier even in environments using single vendor systems. People maintaining multiple development work around mainframe based system were used to document their work with various “write-up's”. For this purpose IBM had developed already in 1970's the SGML (Standard Generalised Mark-up Language) format. For some reason this was not used by the HEP community, as they chose LaTeX for writing their scientific articles with mathematical formulae. Perhaps, one reason for avoiding SGML was the fear to get hooked with single vendor invention. However, SGML was picked up by other people at CERN, who wanted use its application independent features and the possibility to link format with structured database storage. Controlling other than scientific documents with a unified document format was tested and CERN even contributed on the standardisation process of the SGML.

Other ‘unifying’ formats were also introduced and tested, notably the PostScript, which gained momentum through the increased use of PC's and, especially, through the need to print electronic documents around the world. Simple ASCII-format was also used to distribute information. Yet, SGML had already delivered the necessary seed for further development towards the WWW, namely the idea that a document consists of a structure and format which are to be separated. Later SGML was ‘lightened’ to be HTML (HyperText Mark-up Language), which fit better for the purposes of the WWW developers. Another important thing was that structure must be separated from the presentation, i.e. from the black and white on the paper when documents are printed or displayed. This simple division between structure, content and the final presentation was profound for further development towards global hypertext based document and information exchange.





### *Desktop applications and tools*

To get documents in some sort of order several initiatives were set up to tackle the problem of heterogeneity in formats and tools used at CERN. In 1984 a dedicated group started to develop an interactive document handling system based on a prototype developed at one fellow HEP institute. This CERNDOC system was using SGML and the starting point was ambitious; to manage tens of thousands of documents through a hierarchical tree structure. In 1986 first production prototype went into use and it started to host a modest amount of documents. Due to its rather clumsy programming platform the system remained prototype-like for a while and never gained the desired momentum. The effort was halted in 1990, and during 1991 the HEP community adopted rapidly the “e-print archives” as the medium to distribute scientific pre-print articles (see <http://xxx.lanl.gov/>). Since its start this source has managed tens of thousands of documents.

Meanwhile, from 1984 onwards Apple MacIntoshes were entering the laboratory, and in 1988 the user community of this new desktop was gaining enough momentum to cable them to each other with AppleTalk. The new protocol proved to be very operational and easy to install. It was the only commercial medium that really worked and made document sharing reality. At the same time HyperCard was distributed freely, which made it easy to integrate desktop functions, like buttons, fields and links to documents to form simple hypertext featured applications. The new network enabled to develop further the ideas of having a workspace, where documents were stored where they were created in the first place. Only links were to be managed and maintained to distribute the information. In small scale the thing worked, yet the system was closed for other platforms, which hindered larger exploitation and testing of the great idea of universal document and information sharing.

HyperCard refreshed the long line of hypertext research right from 1940's and Bush's [5] ideas of private document management, through the 1960's universal document handling ideas of Nelson [15]. Suddenly, the Apple network and desktop enabled to test various ideas of document sharing. Multiple small scale pilots were made, yet interactive linking of texts was still difficult. Hotwords embedded in the text were difficult to manage and catching the mouse clicks with their intended reference to the document link was an awkward task. HyperCard was not directly supporting the development of hypertext applications, it merely made it possible to create data links between desktop objects and simple presentations of data. However, in doing this it had broken the barriers of traditional linear text.



At those times, various computer brands were continuously emerging and the computer division at CERN had an access-free room for testing the latest hard- and software tools on the market. In 1990 a completely new product called NeXT was spotted and the newcomer was bought to the non-mission oriented test ground at CERN. Especially, its special operating system with open and reliable connections with TCP/IP based network made it very attractive. The enthusiasm was high, as finally there was a machine with high-class desktop, display Post Script, UNIX compatibility, micro-kernel and programming environment called Application Builder, together with a full capability to exploit the ruling network protocol. This was the machine, that first integrated the main technological development paths within various network protocols, formats and desktops. And it was to be *the* platform where the first World Wide Web browser was to run.

### *Summary*

The information technology (IT) environment was under continuous change during the 1980's. It was truly an evolutionary combat of survival and being *ex post* wise one may conclude that those solutions survived which were robust and most adaptable for the diverse circumstances and needs that existed. Too fancy solutions never made it and those with no functionality were immediately discarded by the users. It was also a commercial struggle of volume and momentum, which finally dictated the outcome. The three parallel development trends of network, formats and desktop were strongly intertwined, and they pushed each other towards the creation of the WWW (see Figure 1).

In 1990 the technological stage was finally set for the WWW, yet the battle of technological superiority has not ceased. What is striking in the above described technological evolution is that in all cases the original and first innovations have pull it through in the end. In networks the IP-protocol survived and forms the basis of Internet, in formats the SGML with its lightened version of HTML has formed the state-of-the-art in networked document presentation, and in desktop UNIX has survived as a strong player through the tough competition. All of these technologies have their roots in the 1960's, when the IT industry started its continuous growth path. To put it bluntly, only object based approaches, some database solutions and graphical user interfaces have been introduced since these basic ideas, the rest being idle enterprising.

### The innovation

Meantime Tim Berners-Lee had been working on various software projects at CERN. His multiple skills contributed to several software projects helping the HEP community to better exploit their



infrastructure. In 1980 he was working for the people at the PS-division, which runs and controls an accelerator system. At that time he had written a simple hypertext program called *Enquire* in order to help the machine operators to easily access important documents from a number of different sources. The operators needed constantly to adjust the system parameters such as magnet current, radio frequency voltage, vacuum etc. The information was scattered and the tool helped their, or at least the Innovator's work a lot, as previously they had to fetch the person concerned where ever the specialist might have been. The platform was Norsk Data computer under Sintran III, and the code itself was written in Pascal. Despite the apparent advantage of the software, the development work was not continued after Mr. Berners-Lee left the project.

Later in 1984 Berners-Lee was working for the main four LEP experiments. The situation was very much like the one with accelerator operators. But this time he needed the software for himself to keep track on his own work. It should be emphasised here that he was used to contribute on several parallel software developments at the moment. His multiple contributions generated problems, as he had to control his files, sources and programs. So the program was rewritten for the VAX/VMS environment, yet with one major limitation, the new platform did not allow creating external links beyond one database enclosure. In 1987 first concise plan was written on making *An interactive project management tool* [4], which allowed to structure and link information, be it files, local data units or external databases.

Along with his proposal, which he advertised around CERN, he contributed to collaborative standardisation work, which may have reshaped his attitude towards more democratic and compromising way of doing things. An other thing, which may have been crucial for the later development, was his contribution to retrieve information from network. The Remote Procedure Call-protocol was extremely important, not only because it enabled remote reading e.g. the settings of gas distribution system, but because it could be used to link practically any application or document to each other over the network without being constrained to one physical system or database. One could jump from software documentation to a list of people to a phone book to an organisational chart and so on. This protocol, which was mainly used for control system purposes, was turned into a hypertext tool in the hands of the innovator. As he sighs: "The technologies were there to do it (that is the application specified in his proposal), already in 1988."

In Autumn 1990 Berners-Lee and Robert Cailliau, who had been working on hypertext and document management related issues at CERN, worked out a joint proposal for a CERN-wide document management system. The system defined was called the World Wide Web. This proposal,



which was very much based on Berners-Lee's original proposal introduced the key concepts like the 'web', 'browser', 'nodes' and 'navigation'. Also the far reaching, and since then globally dispersed acronyms such as HTML (HyperText Mark-up Language), URL (Uniform Resource Locator) and HTTP (HyperText Transfer Protocol) were defined in the proposal. The HTML was a kind of lightened versions of the old SGML format from the late 1970's. The new format fit better for the needs at hand when the prototype phase started.

In middle 1990 the technologies, needs and skills met. The introduction of NeXT computers made it possible to test the ideas set in the proposal. Due to the high-level and ready-to-use text manipulation libraries of the new programming environment it took only a couple of months for Berners-Lee to build the very first WWW browser and the needed server software. The whole system was practically ready by Christmas 1990. The year 1991 one was used to expand its usage. Right from the beginning it was used to do something useful, like links to CERN telephone directory, file indexes, printing service, and quickly the server started to host general information concerning the laboratory.

This was only a prelude, as by middle of 1992 some dozen HEP servers around the world had been established. Communication was becoming very vivid and the rate of new servers entering the network was very rapid. At the same time the idea, source code and the applications itself were freely given away. This was not only because of Berners-Lee's sincere conviction that nature of WWW required it, but also because the resources to maintain the increasing interest were running out. It was considered that putting it in the public domain would boost the development, which was eventually the case in 1993, when the idea was picked up by others. Also it followed the very nature of HEP community's way of doing things, where free sharing of ideas and documents (e-mail, gopher and news groups) has always been the working mode.

An other interesting feature of the WWW development was its continuous evolution. Once it was on-line the pages and documents started to evolve, which actually has made it practically impossible for history researchers to find the original HTML-documents. Yet, the original browser on NeXT still exists, also the line-mode browser written by Nicola Pellow can be accessed. The latter was freely distributed from Spring 1991 on. These interfaces introduce the original and rudimentary idea of linking documents with each other through hot-words. Since then graphics, sound and other features have been added to original concept. Once the application was available, the original hypertext ideas dating back to the 1940's got their real boost towards the ideal of global document sharing.





## Management insight

Due to the scientific nature of CERN the management part of the story is difficult to track, yet several decisions were made, or should it be said discussions leading to some sort of conclusion were carried out, during the process. These activities did have direct impact on the technologies used and resources signed for the effort. The aim here is to further study the managerial issues behind the pivotal steps during the process. Here the term CERN management refers to the level of division and group leaders and above, i.e. those with authority to sign. In chronological order these steps are:

1. *Test use of the TCP/IP.* Already in 1981 a committee for future accelerators (European Committee for Future Accelerators) was concerned with the communication and information sharing problems of the HEP community. Especially, the building of the LEP accelerator was seen to generate significant communication problems. The committee was strongly reluctant to adapt the solutions offered or planned by the national telecommunication providers. They were aware of the ISO work and hoped that this would provide them with the necessary protocols and technologies. Surprisingly in 1981 the committee was ignorant of the ARPANET development, which would have met their initial requirements. The result of these endless discussions was to keep an open mind and to follow closely the standardisation work, which was using also CERN resources. However, the UNIX machines had the in-built TCP/IP capability, and these were tested in a small scale by a handful of pioneers at CERN. The effort was not supported beyond small scale and local use. Due to its reliability the activity gained momentum and in 1985 a TCP/IP co-ordinator was nominated at CERN. Once the major information technology vendors went behind the protocol it was made an official policy.
2. *Document has a structure, context and presentation.* Although this idea dates back to 1970's its use in practice took a long time. CERN needed to manage its documents and a special group was called together to set up a CERN-wide system to do the job. It became clear that a typical physics document enclosed several challenging desk top functions, i.e. multitude of graphs, equations, technical drawings and plain text associated to them. Yet, the most severe criteria was to have an application and platform independent representation of the documents. One way out was to use the SGML. Although the centralised document management system never made it, the benefits of three fold content of a document was understood. Perhaps one reason for this was that the real end-users and developers never really met.



3. *Documents should be stored where they are created.* Testing novelties was supported by the computer and network responsible division at CERN. Apple MacIntoshes were part of this philosophy of not hooking up into one solution. AppleTalk was naturally tested, and because of its easy installation also other people than fully computer literate ones could exploit networking and document sharing in small scale. The new infrastructure made it possible to access documents from other computers where they were originally created. This idea was also supported by increased use of the remote procedural call-protocol for running and controlling the accelerator system. These events triggered the idea, that documents should be stored where they are originally created, and it was incorporated in the WWW-proposal.
4. *The action of making the WWW a public domain software.* There is no doubt that the innovator itself made this decision. It was his conviction that the tool should be exploited globally and not only by the HEP community. This follows also the non-profit status of CERN with its main goal being the study of fundamental physics. Also the nature of the product required free exploitation. However, there were requests to increase resources to maintain and further develop the product, but the CERN management did not support these requests, as they were considered to be outside the mandate of the organisation.
5. *The consequence of rapid creation of complementary products.* Once freely released the number of users increased rapidly, which in turn, attracted complementary development and better products. This, and the use of the Internet as the low-cost distribution channel, finally secured the rapid market penetration for the initial product concept.

It is striking that the first three pivotal development efforts on the above list took place within different development groups, only very loosely connected with each other. Also none of these isolated and small-scale activities had a clear customer orientation, i.e. the connection with the to-be-users was more than vague. The efforts were far from being concerted and planned, yet they generated knowledge and experience which diffused within the laboratory. It is difficult to pinpoint the sponsors or champions of this product development project. At best these roles together with the development know-how can be found in the innovator itself, who in the first place was developing the tool for himself.

What could an industrial company learn from CERN and the early days of WWW in respect to product management? The first and third steps of the above list translate into a modern product management dogma in emphasising the importance of continuous research and alertness on emerging and other existing technologies. The benefits may not be direct, yet the indirect ones may latter prove to be crucial when forming new product concepts. The second step stresses the difficult



task of turning company or organisation specific peculiarities into new sources of innovation and challenge. Tackling the document management problem with mid-1980's technologies in CERN's heterogeneous environment was clearly an impossible task, but generated a multitude of new ideas and technical competencies. The fourth step tells somewhat the old wisdom that an organisation should stick with its core business and diversification should be planned carefully. The last step touches the competitive advantage [19] hype, as it clearly shows that entering markets with severe competence tests the product concept most severely. WWW entered the Internet with a new approach, which was immediately diffused, used, tested and further developed. Surviving in this evolutionary environment guaranteed the product concept's success.

In more practical terms, the low threshold to initiate new projects and studies is among the most vital management lesson here. At CERN one simply calls people together, makes a proposal, and the amount of support received determines the size of the effort. Yet, this does not guarantee that the effort is financially supported, thus, in the end the whole thing depends on the individual enthusiasm and evolutionary contingencies. Probably this is not the most efficient management style, but gives employees possibility to present their ideas and to further develop them with others. One should remember that the 1990 WWW-proposal was never formally approved, but it was supported in terms of infrastructure. The project was never formally evaluated or reviewed except by a handful of users testing the prototype. Thus, the present study may not be contributing much to the body of product management knowledge, but it does give some insight on how creative processes and talented individuals could be managed. From the management perspective the lesson in this respect is not very flattering, i.e. provide the researchers with tools but do not spoil them, give them space and control from distance, once something comes out, then formalise the process.

## Lesson learned

Being a radical innovation with a major impact on the way how society works, the WWW story still shares the same features as any other innovation. Looking from today's perspective the actions, development paths, passions and drawbacks all form some sort of logical sequence of causally interrelated coincidences. This fits well with the tendency that technological development is in many ways random, but not an illogical process [9]. The lesson learned from the WWW is synthesised under six main topics [7] which characterise the various facets of the innovation process.



*Technologically* the WWW was a task to incorporate existing tools in a novel way to communicate over the network. Even the idea for the global pool of interacting actors and documents had been there for a while, yet, it was the unique environment within the HEP community that triggered the whole process. Introduced in 1960's the file transfer protocol based on TCP/IP and the Telnet network terminal were the first concrete steps towards global communication via network. In formats the SGML-format from the 1970's mainframe era already had the idea of separating between document's structure and content. UNIX operating system with its huge evolution from 1960's till today's workstations is fine example of its adaptability and solid structure. These key technological elements were incorporated with an advanced computer platform and object oriented programming to form the first WWW-browser. Thus, the technological novelty of the innovation is in the integration of existing technological solutions that tackled the existing problem, i.e. how to share documents and information among dispersed collaboration.

The *gestation time*, i.e. the time between the original idea was expressed and had its commercialisation, is difficult to determine for the WWW. The hypertext idea dates back to 1960's [15] and to even earlier days of automating and interconnecting human knowledge [5], not to mention Charles Babbage's original idea of computers in late 18<sup>th</sup> century. WWW has brought most of these fantasies into a reality with a tremendous power. This indicates that the incubation time for major innovations reforming societies closes to several decades. Transistors together with visions for global networking through multiple media were to meet each other through networking before the era of integrated information and communication society could commence. On the other hand, from innovator's point of view the refined idea was expressed in 1988, it was first running in 1990 and was given freely away during 1991. Commercially the idea was picked up in 1993, which gives an average gestation time of 5 years. This seems to fit well with other innovation studies [22], which document gestation times round 5 to 7 years.

It would appear that, the interventionist *technology policy* such as the one pushed by several European national telecommunication companies may temporally be successful, but not in the long run. Internet shows that the hands-off approach adopted by the U.S. authorities is much more successful and profitable. In the end, it is the technical, operational and available solutions, not political decisions that generate the markets. TCP/IP worked right from the beginning, while ISO/OSI was being formed by celebrated committees, with no applicable results to real problems. It could even be argued that the top to bottom enforcement of ISO/OSI might have triggered counter activity, i.e. radical search other alternatives, which in the end favoured the Internet penetration into European markets. This was also the case with CERN, where Internet was eventually picked up and





used for internal purposes. The case also shows that the technology policy at CERN has always favoured, or has always been forced towards open solutions and acceptance of technological diversity.

The *expertise* of the individuals behind the innovation show a long and profound understanding of the needs for global document sharing in a demanding environment such as high energy physics. Prior to the year 1990 each of them had been associated around ten or more years with the laboratory. During this time period all of their professional activities have somehow been related to the same problem area, i.e. distributed information sharing and access. Tackling continuously the emerging problem of information sharing and control clearly has had its crucial impact on the innovation. This becomes evident from the maturity of the technical proposal defining the WWW. This proposal already specified almost down to a smallest detail the system, its functions, key terms and how to implement it. This was not a coincidence but rather a result of deliberate and through understanding of the kind system, that would best serve the HEP community. Some features of the research material hint that the initial proposal was intended to serve global purposes and not only CERN's needs. The free distribution of the software supports that this was the case.

*Financial* constraints wreck many prominent ideas prior to their market entry. The present case is somewhat an exception as the infrastructure and development costs were covered by the laboratory. The individuals concerned were doing what they were supposed to do, that is to generate tools to ease the document and information integration of the distributed HEP community. However, the situation was unchanged even when the original idea was turned into operational prototype system. Practically no extra support was given for further development or exploitation. This clearly shows the policy of CERN, which allows certain individual freedom, yet does not support activities that are not directly linked to particle physics research. This attitude may be criticised or thanked for, yet it is a fair play and lets the field of technology transfer [10,20] for those who are willing to do it on their own capital. CERN is open for technological collaboration with industry and possesses unique expertise and technological problems with challenging possibilities to upgrade technological competencies [3,13,16,17].

The *management* culture of scientific research centre such as CERN is far from being an industrial one, yet it is not fully an academic one either. Especially in projects, which require design and engineering effort, the work descriptions allow a certain amount of self education and up-grading of personal skills. These non-mission oriented parts of the work time and the in general spacious work descriptions were also present when WWW was being invented. Also, the management encouraged



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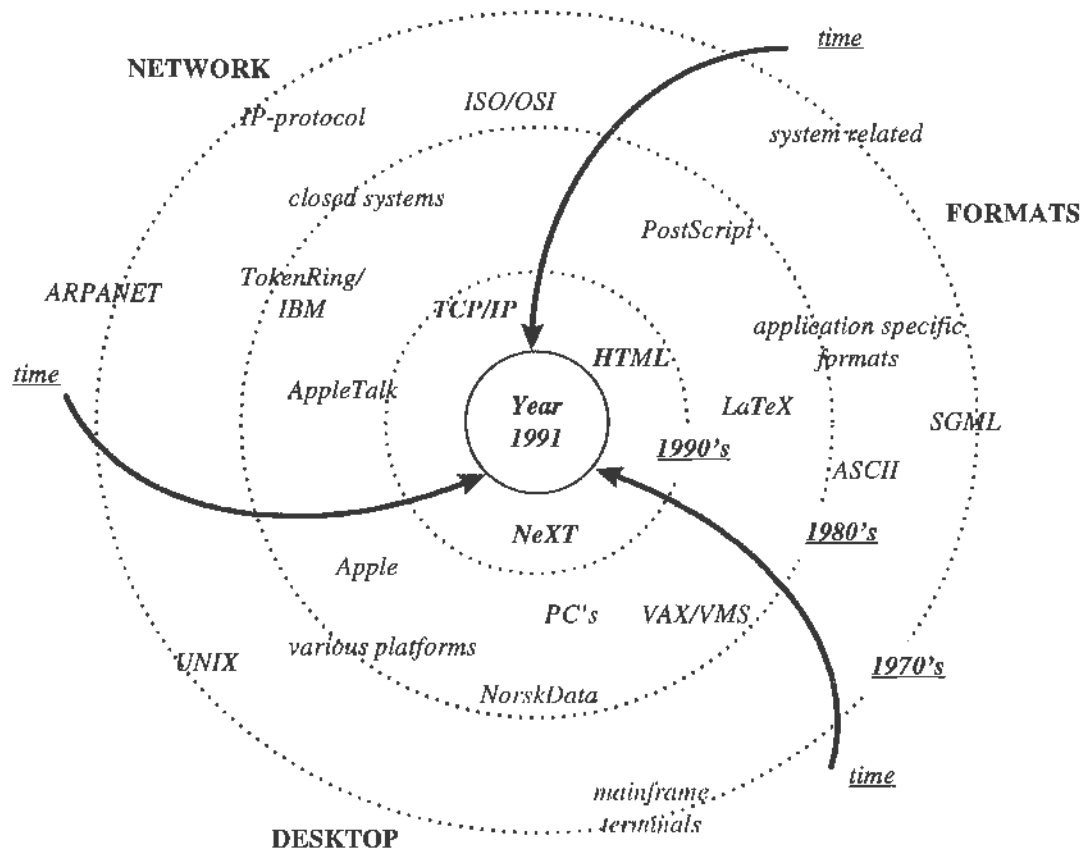


Figure 1. The necessary technological evolution preceding the birth of the WWW at CERN in the year 1991.



	<i>Network</i>	<i>Formats</i>	<i>Desktop</i>
<b>Technology</b>	⇒ original rudimentary and operational technologies survive (TCP/IP)	⇒ satisfying each and every option is an impossible task (CERNDOC), special solution with wide applicability made it finally (HTML)	⇒ even the one that integrated the best available solutions did not survive in the end, yet it produced WWW (NeXT)
<b>Gestation time*</b>	⇒ around 30 years	⇒ around 25 years	⇒ around 30 years
<b>Policy</b>	⇒ hands-off policy rather than top-to-bottom enforcement (European national operators)	⇒ solution may be a new and simple, yet relies on accepted standard (HTML)	⇒ exploit available ideas, and study systematically the markets (the room for testing latest models)
<b>Expertise</b>	⇒ rely on operational solutions, when making prototypes, do not wait (ISO/OSI)	⇒ use existing know-how, modify it if needed (SGML)	⇒ allow individuals an easy access to new ideas and make it an educational routine (NeXT)
<b>Finance</b>	⇒ exploit the non-mission oriented research marginal (AppleTalk)	⇒ heterogeneity of used solutions is costly and complicated to tackle (CERNDOC)	⇒ invest for the study of the latest state-of-the-art solutions (the testing room)
<b>Management</b>	⇒ closed and one-sided solutions seldom last long, study also general and other existing solutions	⇒ exploit organisational and internal peculiarities to generate new challenges and competencies	⇒ certain part of the total work effort must be directed towards activities with loose objectives

\* Has only an informative role here; calculated from the first introduction up to the birth of WWW.

Table 1. Summarising the lesson learned from the innovative process that led to the world's first WWW browser, in parenthesis the particular case referred.

