50 years after “as we may think”: The Brown/MIT Vannevar Bush Symposium

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50 Years After "As We May Think": The Brown/MIT Vannevar Bush Symposium

This paper gives a thematic view of the Vannevar Bush Symposium held at MIT on October 12-13, 1995 to honor the 50th anniversary of Bush's seminal paper, "As We May Think". It is not intended to be an exhaustive review of the speeches and panels, but rather to convey the intense intellectual and emotional quality of what was a most extraordinary event, one that was self-referential in ways unanticipated by the planners. To capture this event further, we are planning a Web site that will contain extensive hypertextual written, audio, and video records.

Introduction

In honor of the 50th anniversary of Vannevar Bush's seminal paper, "As We May Think", Brown University and MIT cosponsored The Vannevar Bush Symposium on October 12-13, 1995, at MIT. The featured speakers — Douglas Engelbart, Ted Nelson, Robert Kahn, Tim Berners-Lee, Michael Lesk, Nicholas Negroponte, Raj Reddy, Lee Sproull, and Alan Kay — are all pioneers who have shaped the legacy of Bush we are immersed in today. They also represent the major topics of "As We May Think": augmentation of human sensory and mental capabilities; information structuring, retrieval, and transmission; and the synergistic interplay of technology and human enterprise. The invited audience included people from many diverse areas, literary computing to sociology to computer engineering; many of them were as well known or influential as the speakers themselves. Together the speakers and participants represented the multidisciplinary community that reflects the many lines of research and thought emanating from Bush's paper.

In addition, Andy van Dam and Paul Kahn presented background and supporting information about Vannevar Bush's life and the history of attempts to transcend the linearity enforced by a paper medium. Paul Kahn, co-author of *From Memex to Hypertext*, presented an animated simulation of the memex created for the symposium that provided a valuable context for the speeches that followed.

The symposium was designed as a "posthumous Festschrift" — a research symposium in honor of Bush's vision. Andy van Dam, the symposium organizer and moderator, charged the speakers to ground their talks in the intersection between their work and Bush's vision and then to look at the still unsolved problems — to, in effect, set the research agenda for the next 50 years, as the prescient Bush had for the previous 50. But these two days became — perhaps inevitably, given the speakers, the audience, and the occasion — rather more than either a Festschrift or a repositioning of a research agenda. The talks, plenary discussions, and coffee-break conversations taken together turned into a celebration of Bush's vision and its powerful influence in creating the world in which we now live and an extension of that vision into today's physical, social, and cyberspace realities.

The event was in fact an exhibition of Bush's legacy, a self-referential, interweaving (intertwingling, Ted Nelson would say) of all the themes — social, technological, and psychological — from Bush's paper. In the course of the two days it became very clear how deep and ambitious — socially and culturally — Bush's most central ideas were. At every turn we were reminded that Bush was writing about how fundamentally new intellectual practices could change the entire landscape of human social life. Bush's vision was not just about hypertext, or data management, or information retrieval, let alone about microfilm or calculating machines; rather, it was about extending the power of human beings by giving them radically new ways of working together.

The goal of fundamentally changing how we work in order to address pressing human problems continued to be central throughout the development of Bush's legacy in the '60s and '70s, most obviously in the work of Engelbart, Nelson, and Kay. Its continued evidence throughout the symposium — even (perhaps most notably) in the presentation of Tim Berners-Lee, the youngest speaker — and the warm response of the audience made it clear that this optimistic social agenda still resonates. It seems that we are not too jaded, skeptical, or post-modern to believe, 50 years later, that technology can bring us "a new relationship between thinking man and the sum of our knowledge", one that will promote "the application of science to the needs and desires of man" ("As We May Think").

"As We May Think"

In 1945 Vannevar Bush (1894-1974) published "As We May Think" in *The Atlantic Monthly*. A condensed, illustrated version was published in *Life* later the same year. In these articles Bush reflected on how technology could help solve the problems of post-war society. He was particularly concerned about the explosion of scientific information and describes, among other things, a device, or rather system of devices, that could be used to help researchers search, record, analyze, and communicate information. These descriptions, and Bush's accompanying account of how new tools could radically change the nature of intellectual work, were rich and compelling. Today almost every litany of the pioneers of hypertext, computer-supported-cooperative work or interface theory begins with Bush and his extraordinarily influential "As We May Think".

Bush was well situated to reflect on the course and promise of technology, the explosion of knowledge, and the emergence of large-scale collaboration in scientific endeavors. An accomplished engineer and research manager (see sidebar), he had served as the Director of the Office of Scientific Research and Development, coordinating the war efforts of 6,000 scientists against the dramatic backdrop of the end of a great war and the beginning of the atomic age. The opening paragraph of "As We May Think" captures this context, as well as the pragmatism and optimism about the usefulness of technology that was characteristic of both Bush and the symposium.

> This has not been a scientist's war; it has been a war in which all have had a part. The scientists, burying their old professional competition in the demand of a common cause, have shared greatly and learned much. It has been exhilarating to work in effective partnership. Now, for many, this appears to be approaching an end. What are the scientists to do next?

Bush goes on to describe a system that would allow scientists and others (he also mentions lawyers, physicians, businessmen, and historians) not only to cope with the massive increase in scientific production and the need for managing large amounts of data in all walks of life, but to do so in ways more suited to human thought.

> The human mind does not work that way [i.e. linearly]. It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of throughts, in accordance with some intricate web of trails carried by the cells of the brain. It has other characteristics, of course; trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory. Yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature.

At the center of his vision is an imagined device he calls a "memex", what we see now as a workstation, based on a variety of analog technologies such as microfilm storage and readers.

> The owner of the memex, let us say, is interested in the origin and properties of the bow and arrow… He has dozens of possibly pertinent books and articles in his memex. First he runs through an encyclopedia, finds an interesting but sketchy article, leaves it projected. Next, in a history, he finds another pertinent item, and ties the two together. Thus he goes, building a trail of many items. Occasionally he inserts a comment of his own, either linking it into the main trail or joining it by a side trail to a particular item. When it becomes evident that the elastic properties of available materials had a great deal to do with the bow, he branches off on a side trail which takes him through textbooks on elasticity and tables of physical constants. He inserts a page of longhand analysis on his own. Thus he builds a trail of his interest through the maze of materials available to him.

Sections of text highlighted in blue, are linked to "As We May Think" which precedes this article

[Later the owner finds a friend who is interested in this topic.]

> A touch brings up the code book. Tapping a few keys projects the head of the trail. A lever runs through it at will, stopping at intersecting items, going off on side excursions…. he sets a reproducer in action, photographs the whole trail out, and passes it to a friend for insertion into his own memex, there to be linked into the more general trail.

Imagining a world in which such technology was deployed, Bush sees new products:

> Wholly new forms of encyclopedias will appear ready-made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified,

and new professionals:

…there is a new profession of trail blazers, those who find delight establishing useful trails through the enormous mass of the common record.

This is an surprisingly accurate description of the sort of information environment we are today on the verge of realizing. Bush's achievement here is, of course, his functional description of such an environment. That his environment was analog and based on microfilm, telephony, and mechanical technologies, where ours is digital and relies on electronics, doesn't matter. Even when **Paul Kahn's** 53 memex simulation made vivid the now quaint analog technology that Bush's version was based on, it was still clear that functionally the memex was almost exactly what we are still trying to perfect.

The prescience of Bush's vision is astonishing. He defined a goal, a strategy, and a research agenda that are still alive today. But, as **Andy van Dam** 53 made clear in his opening remarks and the subsequent symposium speakers confirmed in their testimony, Bush turned out to be not so much predicting the future as creating it through the influence, both direct and indirect, of his compelling vision on major figures like Engelbart, Nelson, and the other symposium speakers.

Van Dam introduced the symposium by describing his own "trail to Bush", which ran first through Nelson, with whom he collaborated on the hypertext system HES (Hypertext Editing System) in 1967 and 1968. Van Dam and his students then went on to build FRESS, the first hypertext system on commercial hardware, in 1969. They founded Brown's Institute for Research in Information and Scholarship (which developed Intermedia) in 1983 and in 1990 helped found Electronic Book Technologies (a maker of software for developing and viewing SGML-based hypermedia books and document management environments). He has assigned "As We May Think" to generations of students now teaching, researching, and working in industry.

Van Dam described each of the speakers' backgrounds and roles in helping create the technological state of the art in collaboration technologies, networks, hypertext, graphics, and personal computing, emphasizing the tangled web of influence and interaction (of his own: "I had the privilege of spending nearly a week in Engelbart's lab, and stole many great NLS ideas for FRESS") that always seemed to lead back to Bush.

Van Dam pointed out that Bush's memex was not the first imagined device for assisting intellectual work; speculations about various mechanical devices and techniques for extending reading and writing technologies can be found in history back at least to the Middle Ages. Language itself is a technology for organizing and transmitting information, as are symbolic systems for writing, numeration, and calculation, organizational devices such as alphabetization, tables, and catalogues, and conventions for page layout and numbering, and annotation. The intricate systems of commentary and cross-referencing used in the Talmud and the Bible, for instance, make it clear that hypertextual complexity comes naturally to the human mind.

Van Dam also noted that recent researchers such as Michael Buckland and W. Boyd Raymond have been recovering for our attention neglected 19th- and 20th-century thinkers in the history of information systems, such as Paul Otlet and Emmanuel Goldberg. Otlet, for instance, implemented hypertext-like systems with analog means and also imagined document management systems that would work with linked microfilm and telecommunications. Goldberg, the first Managing Director of Zeiss Ikon AG, demonstrated and later patented a prototype of a microfilm selector using a photoelectric cell, the first functioning electronic document retrieval system in 1932 — his patent blocked Bush's attempt to patent his "rapid selector".

Van Dam commended these investigations, but noted

Symposium Program

Thursday, October 12

Opening Remarks
Andries van Dam, Program Chair
Paul Penfield, Jr., MIT Host
Paul Kahn, "Memex Historian"
Douglas Engelbart—The Strategic Pursuit of Collective IQ
Theodor Holm Nelson—Where the Trail Leads
Robert Kahn—Augmenting Bush's Vision with Digital Technology
Tim Berners-Lee—Hypertext and Our Collective Destiny
Michael Lesk—The Seven Ages of Information Retrieval
Douglas Adams, Banquet Speaker

Friday, October 13

Nicholas Negroponte—Being Digital
Raj Reddy—Bush's Intelligent Systems Revisited
Lee Sproull—Information Is Not Enough: Computer Support for Productive Work
Alan Kay—Simex: the Neglected Part of Bush's Vision
Closing Remarks

that in the time available this symposium could not address the definitive history of information systems and hypermedia in general, or the genesis or priority of Bush's vision, but would limit itself in particular to first-hand accounts by pioneers of the influence of "As We May Think" — and its significance for the future.

Bush's Legacy in 1995

While many components of Bush's vision were addressed by the speakers and many new themes were apparent, one overarching theme was evident in both "As We May Think" and almost every talk in the symposium: the potential of intellectual technology to alter the very foundations of the society in which we live and to provide solutions for the problems that may threaten our well-being, if not our very existence.

Bush's paper begins with a reference to the historic and unprecedented team contributions of scientists to winning World War II and ends with a somber yet optimistic call to science to save the human race:

> **The applications of science have built man a well-supplied house, and are teaching him to live healthily therein. They have enabled him to throw masses of people against another with cruel weapons. They may yet allow him truly to encompass the great record and to grow in the wisdom of race experience. He may perish in conflict before he learns to wield that record for his true good.**

Nearly every speaker echoed Bush's focus on the social effects of technology and exhibited the same combination of pragmatism and optimism. **Tim Berners-Lee 52,** the speaker whose work, the World Wide Web, is most in evidence at the moment, ended his talk with a quote from that paragraph: "They may yet allow him truly to encompass the great record and to grow in the wisdom of race experience."

Most references to Vannevar Bush in recent literature call him the inventor of the modern concept of hypertext and stop there. What was intriguing and important at this symposium is that hypertext was not much in evidence. Other themes just as prominent in "As We May Think" were at the forefront, and it was clear from the speakers who had been directly influenced by the *Atlantic* article that hypertext was not the most important legacy, but rather a byproduct or a means to achieve other goals such as human augmentation and collaboration. However, the WWW and the ubiquity of the Internet both in academic life and, increasingly, in commercial and personal spheres highlight the Web as the most widespread instantiation of Bush's vision.

Of the many specific themes that wove through the symposium, three stand out, each reflecting the master theme of technology and society:

- That technology has enormous potential to augment human power, increasing our ability to achieve our goals or shape new ones.
- That by far the most significant augmentation is achieved via technology's ability profoundly to reshape the structures and dynamics of human collaboration.
- That the co-evolution of technology and human practice is producing fundamentally new ways of human/machine interaction.

These are easily recognized as reflecting Bush's fundamental vision of new powers, new tools for collaboration, and new relationships to our tools, and they are each closely connected to his dominant concern with the societal impact of technology. These themes, which seem to have guided so much of recent development since Bush and are now being taken to new levels of insight and refinement by contemporary researchers such as our symposium speakers, are a convenient matrix for conveying some of the thoughts and ideas of those two intense days at MIT.

Douglas Engelbart 52, who was the keynote speaker and the numinous soul of the symposium, has interwoven these themes throughout his life's work from the very beginning when, shortly after WWII, he decided to devote his life to a vision of using computers to help individuals and groups augment their capabilities to deal with 'complexity and urgency'.

He has had one of the most significant records of technical contributions to computing in the period since Bush, so it was entirely appropriate that he was the most commanding presence for the entire community at the symposium. The extent of his influence over several generations could be gauged by comments ranging from those by **Alan Kay 52** and **Ted Nelson 52** to those of the student volunteers. Kay commented that

> *This was the visit that changed my life. What Doug Engelbart offered was not just a vision of interacting with the system, but also a philosophical underpinning that is even more important today than it was then.*

while Nelson variously referred to him as "my wonderful and very great stepfather Douglas Engelbart" and as "one of the two men I admire most in the world" (the other is Tim Berners-Lee). The graduate student volunteers, in a discussion after the symposium, agreed that the opportunity to hear and meet with him was the most important part of the symposium to them, something they would remember for the rest of their lives.

Paul Penfield is Professor of Electrical Engineering and Head of the Department of Electrical Engineering and Computer Science at MIT, and is affiliated with the Microsystems Technology Laboratories.

Tim Berners-Lee is the creator of the World Wide Web. He currently is with the Laboratory for Computer Science (LCS) at the Massachusetts Institute of Technology (MIT) and directs the W3 Consortium that coordinates WWW development.

Alan Kay is best known for the idea of personal computing and the intimate laptop computer, and the invention of the now ubiquitous overlapping-window interface and modern object-oriented programming. He is a Fellow at Apple Computer and a Fellow of the American Academy of Arts and Sciences, the Royal Society of Arts, and The World Economic Forum.

Dr.Raj Reddy is Dean of the School of Computer Science at Carnegie Mellon University and the Herbert A. Simon University Professor of Computer Science and Robotics. His research interests include the study of human-computer interaction and artificial intelligence. His current research projects include speech recognition and understanding systems; collaborative writing, design and planning; JIT Learning Technologies; and the Automated Machine Shop project.

Douglas Carl Engelbart is the inventor or the mouse, interactive real-time telecollaboration, outline processing, and hypertext creation and navigation tools. Throughout the `60s and `70s his lab pioneered an elaborate hypermedia-groupware system called NLS (for oNLine System), most of whose now-common features were conceived of, fully integrated, and in everyday operational use by the early 1970's. In 1989 Engelbart founded the Bootstrap Institute, feeling the time was ripe to pursue in earnest his comprehensive strategy for bootstrapping organizations into the 21st century.

Ted Nelson was always media-intensive. In 1960 he took a computer course and saw a chance to create a new world of interactive media — a new fusion of literature and movies, based on arbitrary constructs, interconnection and correspondence. Since then he has worked on digital media designs outside the prevailing paradigms.

Andries van Dam is Professor of Computer Science at Brown University. Since 1965, his research has concerned computer graphics, text processing and hypermedia systems, and workstations. He has been working for 30 years on systems for creating and reading "electronic books" with interactive illustrations, based on high-resolution graphcs for use in teaching and research.

Nicholas Negroponte is a founder and the director of the Massachusetts Institute of Technology's uniquely innovative Media Laboratory. He founded MIT's pioneering Architecture Machine Group, a combination lab and think tank responsible for many radically new approaches to the human-computer interface.

Lee Sproull is Professor of Management at Boston University. Prior to joining Boston University, she was Professor of Social Sciences at Carnegie Mellon University for 13 years. Professor Sproull's research centers on the social, managerial, and organizational implications of computer-based technologies that augment human communication such as electronic mail, computer conferences, and interactive video.

Robert E. Kahn is President of the Corporation for National Research Initiatives (CNRI), which he founded in 1986 after a 13-year term at the Advanced Research Projects Agency (ARPA). He was responsible for the design and development of the Arpanet, the first packet-switched network, and for originating the Internet Program, and is a co-inventor of the TCP/IP protocols .

Michael Lesk manages the computer science research group at Bellcore. He is best known for work in electronic libraries, including the CORE project for chemical information, and for writing some Unix system utilities including those for table printing (tbl), lexical analyzers (lex), and inter-system mail (uucp).

Not photographed

Douglas N. Adams was educated at Brentwood School, Essex and St. John's College, Cambridge, where he read English. He originally created "The Hitch-Hiker's Guide to the Galaxy" as a radio series for the BBC, and then wrote it again as a novel. Adams has also written two Dirk Gently books, and with John Lloyd he co-wrote "The Meaning of Liff" and "The Deeper Meaning of Liff", and with zoologist Mark Carwardine he has written the wildlife travelogue "Last Chance to See."

Paul Kahn has training in literature and typography and has worked with a variety of electronic publishing systems since 1977. He worked at Brown University's Institute for Research in Information and Scholarship (IRIS) from 1985-1994 where he served as project manager and director, developing educational hypertext applications in Intermedia. In 1990 he formed the information design firm of Dynamic Diagrams, Inc. with Krzysztof Lenk.

Elli Mylonas provides consulting and project management at the Scholarly Technology Group at Brown University. Her areas of specialty are hypertext, SGML and structured text problems and electronic publishing. Before coming to STG she was Managing Editor of the Perseus Project at Harvard University, a multimedia database on classical Greek civilization.

Allen Renear directs the activities of the Scholarly Technology Group at Brown University, as well as participating in STG consulting. His current research interests are in theoretical issues in text encoding and document abstractions, epistemology and technology, large systems for collaborative work and publishing, and the use of interactive networked hypermedia to support education reform.

Rosemary Simpson is an information structures artist, the designer of Gateway, an interactive object-oriented hypermedia system developed at LMI (Lisp Machines, Inc.) in 1985, and President of Information Programming (formerly Indexing Unlimited).

The Two Days at MIT

The two days of the Bush symposium were full and fully engaging, both because of the busy program and because of the many informal opportunities to meet with speakers and other participants and discuss the issues that had been raised in paper session, at coffee breaks and meals.

Another such moment was provided by the highly entertaining and compelling banquet speech by, Douglas Adams. This speech, by a writer who has invented one of the best known computer augmentation systems in fiction, the Hitchhiker's Guide to the Galaxy, gave a different perspective on the influence of "As We May Think" that was nevertheless congruent with those presented by the other speakers. One of Adams' main points was the contrast of the historical development and deployment of computers with the views of the future held by computer "experts" and science fiction writers. His conclusion was that they were both wrong, because they overvalued the importance of the computers and discounted the societal contribution. Another vivid image that has stayed with all who heard the speech was of two Amazon tributaries, one white and the other black, that join but do not merge. Each stream travels in parallel for many miles before finally blending into one. The lesson for those attempting to introduce new ideas was clear and the analogy provided yet another metaphor from nature in a symposium dominated by biological images.

Finally, the closing panels on both days provided moments of synthesis that brought together many ideas expressed during the individual presentations. The questions for the panel on the first day ranged from the ethics of malleable content, which sparked an interesting debate between Ted Nelson and Tim Berners-Lee about the best methods of protecting author rights, and concerns about McCarthy-style witch hunts, through queries on handling 'spaghetti-web' information structure problems, to projections about all-electronic libraries and digitally alive paper and clothing.

The final panel was extraordinary in that Douglas Englebart, Tim Berners-Lee, and Alan Kay gave mini-presentations that elaborated and extended the themes addressed in their speeches, and the entire panel participated vigorously in debates that centered around two questions: 1) what would our world be like if Microsoft had never existed? and 2) how can we improve our educational system? In response to the final question asking the panelists to comment on what they had in common, Berners-Lee gave a striking analysis:

...one thing everybody had in common was persistence, having ideas and, then though people told you not to do it, hanging on to it, being really stubborn and doing it, even though nobody's giving you money to do it. That seems to be something which everybody has in common. I don't know if it's something that's intrinsic to us or whether it's the ideas – once they've got you, they don't let go.

Augmentation

■ Bush's Vision

Human and social augmentation was the keynote theme of "As We May Think". It permeates the entire article, from the opening paragraph with its description of the extraordinary team efforts engendered by WWII, through the descriptions of technological advances needed to aid investigators overwhelmed by an information glut and isolated by specialization, to the final call to use technology in the service of society. Augmentation, in Bush's view, involves both sensory enhancement and mental enhancement. He proposed tools that would supplement and extend the visual, vocal, and memory capabilities of the human being, as well as tools that would reflect and supplement the nature of the human mind—both the cognitive and associative aspects.

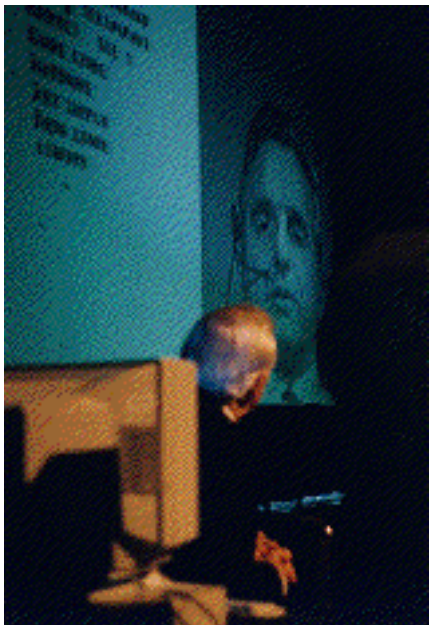
■ View from the Symposium

Human augmentation by means of technology appeared in macro- and micro-contexts at the symposium. The WWW provides the first glimmer of the global network within which people will work, which will become an extension of their own information banks, and within which they will need increasingly sophisticated help to function creatively. As several speakers pointed out, personal augmentation through symbiosis with specialized hardware that is part of

our clothing and other mundane objects, as well as integrated physical and virtual reality studios, used to be the stuff of science fiction but is now rapidly becoming feasible.

The first speaker, **Doug Engelbart**, told how he first encountered Bush's article in a hut in the South Pacific and after the war decided to develop methods and tools to help humans augment their intelligence, both individually and collectively.

During the first part of his career Engelbart created tools for augmenting human intelligence, such as the mouse, interactive real-time telecollaboration, outline processing, and hypertext creation and navigation tools, as well as software engineering methods that enhanced the productivity and effectiveness of the tool-builders. One of the highlights of the symposium was a set of clips from the "mother of all demos" (as van Dam described it) that he gave at the 1968 FJCC (Fall Joint Computer Conference), a demo of NLS (oNLine System)—a multiuser hypermedia system that included the advances described above.



At the same time, he was developing concepts and methods to help organizations deal with complexity and change management—what he calls group IQ augmentation. These strategies for guiding organizations through paradigm shifts (which are at the heart of the Bootstrap Institute, his current effort to disseminate his theories on group augmentation) include concepts of bootstrapping, scaling, hypertext, and the co-evolution of tools and humans in a systematic and effective way.

In Engelbart's view, augmentation of human powers makes possible better handling of complexity, greater ability to shift paradigms, and enhanced capacity to see farther and deeper into any issue. Engelbart's theories on the nature of the human mind are a logical extension and expansion of Bush's dual vision of cognitive and associative processing. **Kay** describes one aspect of Engelbartian thought:

> *One of the phrases that he [Engelbart] used that I particularly liked was "thought vectors in concept space". I'm not sure I understand what he meant, but what I think is that you are creating an extension of the kinds of spaces that you think in terms of inside of your head. So, you are creating an augmentation of the ways of thinking, the ways of representing, the ways of associating that was now going to be extended in a way somewhat analogous to the way writing has extended us but somewhat more like the way we actually think.*

Engelbart describes it as a method

> *…to externalize your thoughts in the concept structures that are meaningful outside; moving around flexibly, manipulating them and viewing them. It's a new way to operate on a new kind of externalized medium.*

Like Engelbart, **Ted Nelson** had a vision from a very early age that has molded his life and world, a vision of a 'docuverse' shaped by the tripartite concept structure of transclusion, transparallelism, and transcopyright. To him they are so fundamental to any viable approach to electronic information that he declared in response to a question from the audience: "Transclusion and transparallelism are the answer. It doesn't matter what the question is."

In the film in which he demonstrated a prototype of his work in Japan, Nelson described transparallelism and transclusion:

> *…putting it into today's terms, we're talking about transparallel media, meaning things which are side-by-side and explicitly connected. So, for example, transparallel media includes captions for a picture which point directly to the picture, transparallel media includes anything where you have explicit connections. Parallel media is where you just see things side by side, like an article and an illustration. So, what I'm showing you here is transparallel media with transclusion only. We're leaving out links because I want to stress the notion of transclusion as the counterpart of links – transclusion and link are like left and right hand. Links are connections between things which are different. Transclusions are system-maintained connections between instances which are the same in different contexts. So, to me transclusion has always been the heart of electronic media, and I think eventually people will understand this.*

Raj Reddy 52, the Dean of the School of Computer Science at CMU and a pioneer in speech processing and AI, presented essentially the same augmentation thesis as Engelbart, i.e. augmentation of human powers makes possible better handling of complexity and change.

Reddy spoke about current work under way at CMU in intelligent multimedia database retrieval systems, mixed virtual and physical reality research, and speaker-independent

Human History

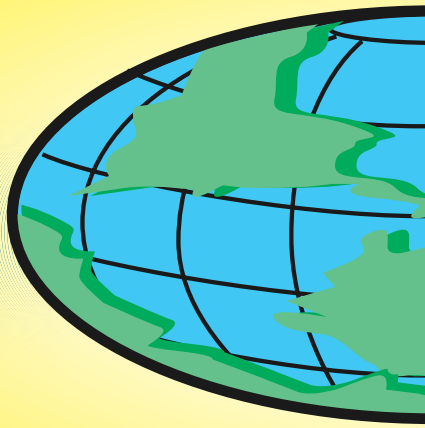
World War II and the Post War

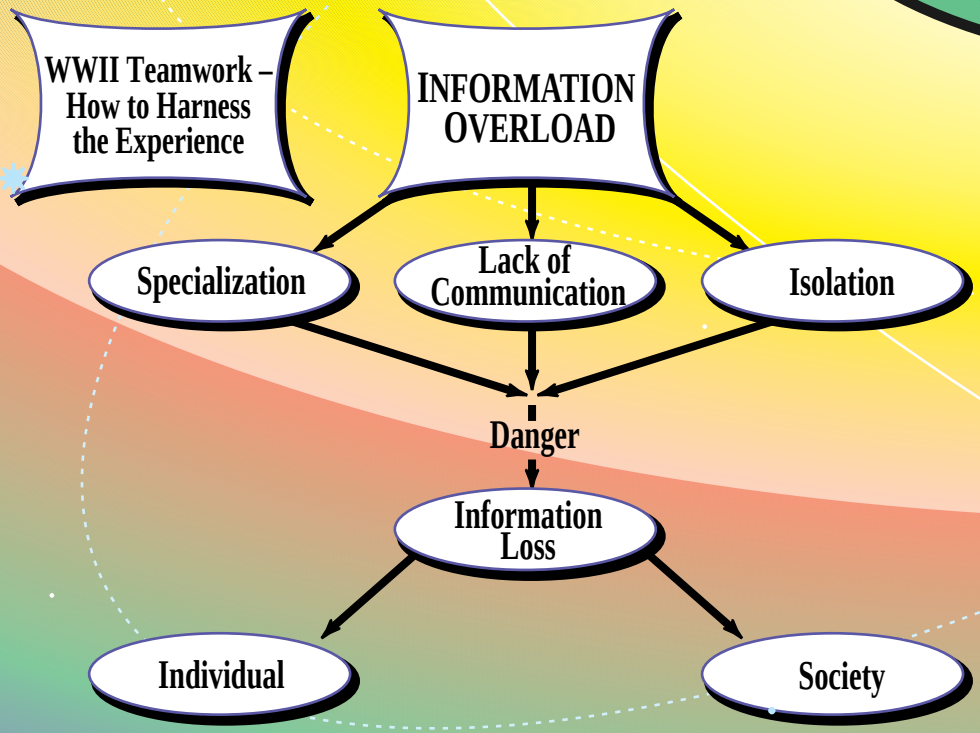
p r o b l e m s

Bush wrote AWMT within an interwoven context consisting of his own career as scientist and manager, the end of World War II, and the experience of human history and civilization.

The problems delineated in his paper reflect his focus on the nature of *information overload* and the dangers that information loss resulting from that overload presents to both the individual and to society.

The solutions he proposed for *information management* comprised four activities: 1) more effective *capture* of infor-



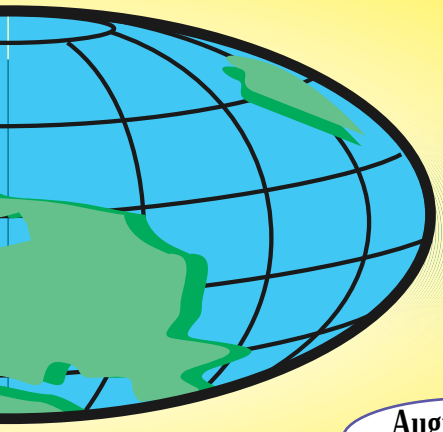


by Brad Black

and Civilization

Period including Digital Electronics

mation through augmentation of the mind and the senses, 2) better *organization* of that information both through technical advances such as logic machines (what we call AI) and through new information structures that he called associative trails (what we call hypertext), 3) new methods of *retrieval* to be implemented through the memex, and 4) *sharing* that information with colleagues. The first and last paragraphs of AWMT only allude to the related issues of collaboration and what Doug Engelbart calls co-evolution.



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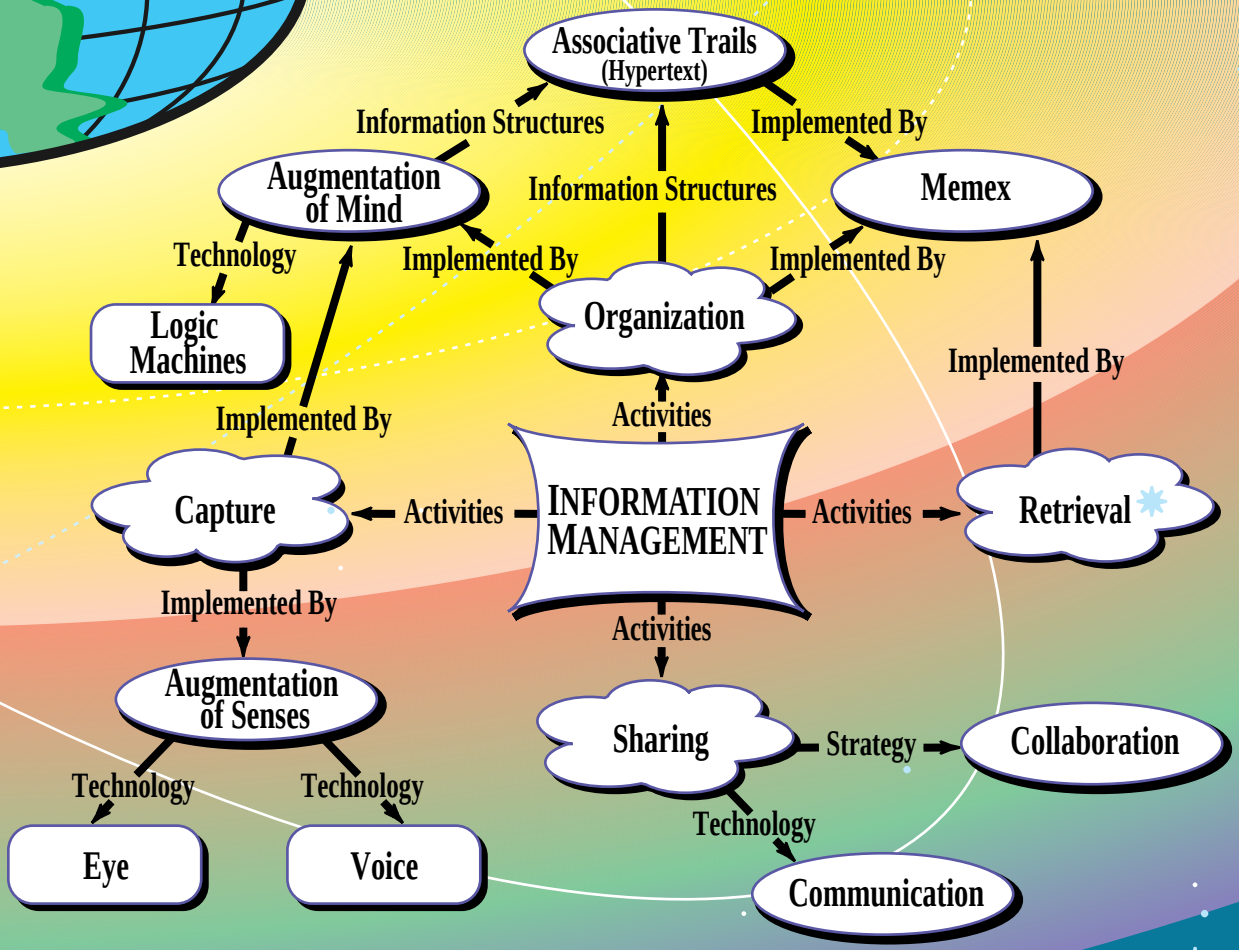
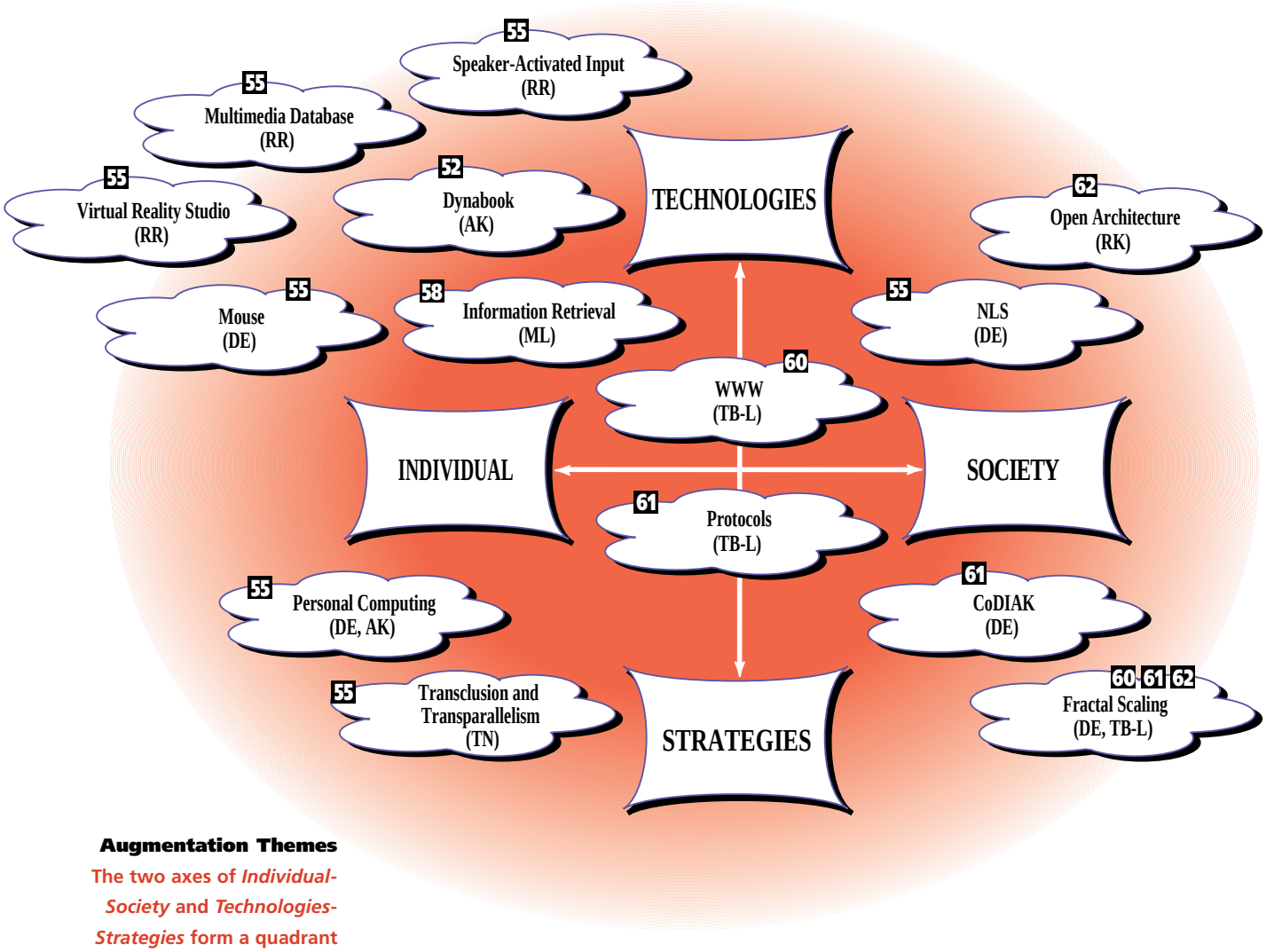




Augmentation Themes

The two axes of *Individual-Society* and *Technologies-Strategies* form a quadrant within which the augmentation approaches of the various speakers can be placed. These theme range from technological aids for the individual, such as *speaker-activated input*, to strategies for transforming society, such as the *CoDIAK* proposals of Doug Engelbart.

unlimited vocabulary dictation. He showed three demos illustrating this work. The first showed the email application of the speaker-independent unlimited vocabulary dictation system, an application of more than casual interest to those who suffer from carpal tunnel syndrome. The second demo showed Infomedia, the intelligent multimedia database retrieval system that combines research in natural language processing with image processing and retrieval. The third demo showed Takeo Kanade's mixed virtual and physical reality research studio at CMU's Robotics Lab.

He said that the motivation for this work comes from the desire to enhance human productivity by orders of magnitude over what is possible now. This goal, in turn, is motivated by the desire to help humans handle ever-increasing amounts of information and thereby more effectively deal with a rapidly changing environment. He spoke of the importance of obtaining relevant information on demand and of the need for information structures that both work the way the mind works and effectively locate what is needed.

Reddy was a pioneer of the early days of AI in the 1960s, so it was interesting to hear his current characterization of AI as a practical common-sense effort to amplify human intelligence:

> *Almost all the areas we are looking at, that Vannevar Bush wanted – speech, image, language, information retrieval – all kinds of things, these are what I call imprecise technologies. They are never going to be perfect. Nevertheless, we are at a stage where useful systems doing useful things for average people are possible.*

Reddy's view was that it is the nature of humans to create and think — and to take advantage of all the augmentation tools that the research labs can imagine and develop.

Michael Lesk 53 of Bellcore also focused on the aug-

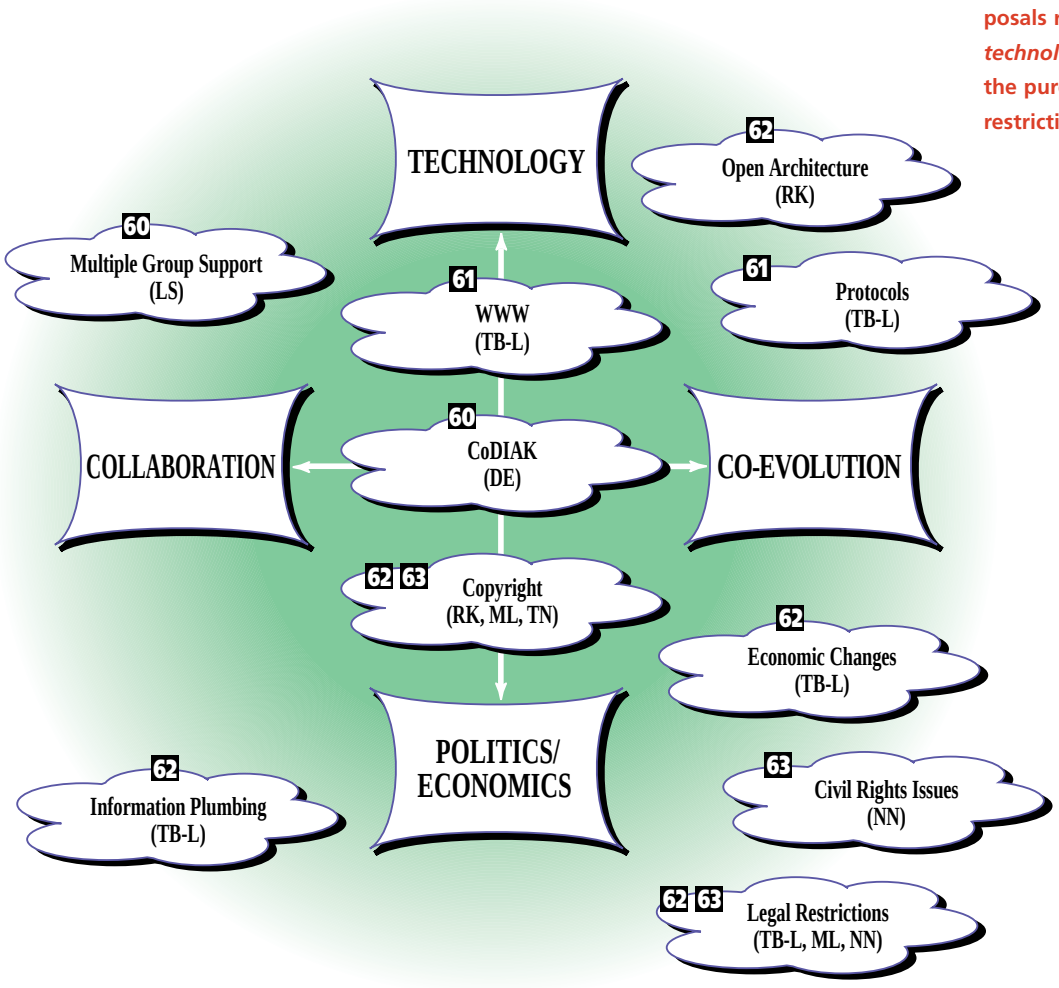
mentation of human capabilities in the area of information retrieval. He took a historical approach, however, beginning by evaluating Bush's predictions and comparing them with what has already been achieved. His own prediction is that the capabilities described in "As We May Think" will have been achieved by 2010, that is within one lifespan from the writing of the article. As he traced the development of information retrieval and, by necessity, of online information from the 1940s into the third millennium, Lesk described the alternating cycles of machine and human categorization as a solution to the information retrieval problem. He concludes that we will arrive at a mixed solution, driven by manual data entry and linking, as in the WWW, which he considers a kind of embodiment of the memex but augmented by algorithmic retrieval methods. The new area of research that Lesk pinpointed as most interesting is the introduction of nontextual media into online databases, which should trigger much of the whole cycle of information retrieval research all over again.

Many of the speakers discussed the WWW and the growing use of the Internet; the consensus was that it is a suggestive example, despite its limitations, of what a working memex might actually do. The shared and collaborative aspects of the WWW are not highlighted in the description of the memex, but embody scholarly practice that Bush would have taken for granted and might have included had he been familiar with technology that allowed it. **Robert Kahn** 53, President of the Corporation for National Research Initiatives and a creator of the ARPANET (forerunner of the Internet), for example, located human augmentation in the network itself, specifically in the intersection of the evolving communications infrastructure with new technology and new uses of information.

In this light, **Tim Berners-Lee**, director of the WWW Consortium and creator of the WWW, seemed the most likely heir of Bush's vision. His description of the beginnings of the WWW, however, and of its subsequent development highlights the problems that can occur when commercialization of a design creates a de-facto

Collaboration/Co-Evolution Interaction

The two axes *collaboration-co-evolution* and *technology-politics/economics* provided a framework around which the symposium discussions of the human/technical interaction interwove. Concerns and proposals ranged from the purely *technological* (protocols) to the purely *political* (legal restrictions).



standard that may be difficult to update or replace: the WWW was originally designed as an interactive means for collaboration and augmentation, but has instead become a static medium for hypertextual publication. These issues were further discussed in the panel on the second day when **Alan Kay** told how the PARC windows interface, which was intended to be a naive set of training wheels for children, a stepping stone to be replaced by more powerful interfaces, became frozen into an inflexible, difficult-to-change form.

Berners-Lee's original vision of the WWW was of a sea of interactive shared knowledge, in which our computers are memexes whose knowledge base exists in cyberspace rather than microfilm. He presented a vision of the "great brain", as he calls it, as a living organism, a vision that conveyed an oscillating analog/digital sense of the dynamic, interactive information continuum that is the Net and its users.

At the same time as the WWW provides a form of augmentation on the global level, the incorporation of computers into everyday objects is a form of augmentation on the personal level. **Nicholas Negroponte** 53 of the Media Lab described the blending of the digital and analog into ordinary objects such as paper, clothing, and doorknobs. This vision is a striking enough enhancement of the personal information space that several other speakers, including **Raj Reddy** and **Robert Kahn**, also alluded to it.

Collaboration

■ Bush's Vision

It has sometimes been suggested that Bush neglected the importance of collaboration and work groups, since he did not make these issues as explicit as later writers have. It is true that this theme is only latent in Bush. Nevertheless, supporting collaboration and managing teams is an essential aspect of Bush's vision. "As We May Think" actually opens with a comment on the teamwork of scientists during the war, and one of its most compelling scenarios incorporates the sharing of trails among investigators using the memex. Bush clearly imagined researchers working together and using the shared results of trail building as part of a strategy for managing information overload. That the theme of collaboration is understated in Bush isn't surprising. At the time of "As We May Think" and throughout much of his life, Bush was an organizer and administrator of large research and development projects in the university, the military, and in industr; he would take for granted the importance of the world of collaborative scientific interaction.

■ View from the Symposium

Lee Sproull 53 of Boston University gave a thorough historical and theoretical summary of collaborative work in the sciences as it is actually practiced and of the process of discovery as it is thought to occur by the scientists themselves. In her opinion, Bush, like **Kay** and Licklider among others saw the process of discovery as a fairly solitary one. Information sharing, in this view, is not part of a collaborative process, but rather something that takes place after the fact, as a record or for validation. She went on to describe research suggesting that science is a social enterprise and to pinpoint the areas and relationships in which collaboration occurs and information is transmitted among members of a team. Computers and networks, ever since the early Arpanet, have supported collaborative work among scientists. In her view, technology has to improve in order to foster better communication among scientists and other researchers. It can do this by modeling the multiple social contexts in which collaboration works effectively and by customizing the information environment to the type of social interaction that is occurring. As her title, "Information is Not Enough: Computer Support for Productive Work," shows, information alone, however well structured and linked, is not enough to engender productive work. The single early researcher Sproull cited as realizing the importance of collaborative work was Doug Engelbart.

From the beginning, **Engelbart's** work focused on collaboration through both software tools that support cooperative work and strategies for helping organizations deal effectively with the issues surrounding complexity management and paradigm shifts. At the symposium Engelbart reported on his current thinking, which centers around a comprehensive strategy he calls CoDIAK—Concurrent Development, Integration and Application of Knowledge. The key insight behind CoDIAK is the need to apply effective tools to an organization's process for improving productivity, not just to the elements of the organization or to specific problems it faces. In this he is using the same principles of good software engineering that he applied to the development of his own inventions. In effect, he is proposing meta-management change tools, where previously he had designed and used meta-assemblers and meta-compilers:

> *I mentioned the other day that you've got to have a strategy to lift organizations – you can't just lift them all at once. The strategy I finally worked out is that in the improvement infrastructure there are roles in the improvement process for high-performance teams. They would really be helping the improvement process come about since there would be ways for them to be plugged into an organization in a very supportive function… they are an elite team.*

As in the past, he is still creating tools to improve the creation of tools, thereby leveraging many-fold the efforts of

everyone involved in the process.

Ted Nelson described his approach to collaboration (or its absence) and its relationship to Doug Englebart's approach in this way:

> *The fundamental difference between my wonderful and very great stepfather Douglas Engelbart and myself is that he wanted to empower working groups and I just wanted to be left alone and given the equipment and basically to empower smart individuals and keep them from being dragged down by group stupidity. The amazing thing is that our designs have converged to some degree, showing, I think, the fundamental validity of this whole approach.*

Tim Berners-Lee talked about how the WWW was created as a collaborative tool for underfunded, geographically dispersed teams. The original implementation, although not as visual as some of today's browsers, actually had interactive editing capabilities, so that creating a link was as easy as following one. For Berners-Lee, another important part of the collaborative scenario inherent in the WWW is its distributed, decentralized form. However, in order that there be apparent decentralization, a less visible, underlying shared set of rules and a centralized, common protocol typically exist. The development of the collaborative universe that is now in its infancy will be affected by the evolution of these shared rules and protocols. The collaborative and decentralized aspects of the WWW are in the hands of the bodies who are evolving the protocols, on the technical level, and the rules of behavior, on the social level.

Sounding a less optimistic note, **Nicholas Negroponte** detailed exactly how legal developments and social tendencies towards centralization and control are working against the open and collaborative nature of the Internet. He cited several examples of censorship that were possible because of the ambiguous legal nature of the Internet. These are significant because the Internet and the information available over the WWW have no fixed legal status—they are too new. Negroponte's cautionary message is that the collaborative nature of the Net depends on social, legal and constitutional events that still happen outside of it.

Co-Evolution

■ Bush's Vision

Bush viewed technology as a partner in the evolution of society towards a future in which human beings use technology to solve their political and social problems. Human practices and technological tools develop in concert. At one point he even imagines a bionic melding of humans and electronics that would avoid "the present cumbersomeness of first transforming electrical vibrations into mechanical ones, which the human mechanism promptly transforms back to the electrical form". But the critical partnership is not about physical connections but about the co-evolution of practices and capabilities. This is a deep theme that has continued to develop and was prominent and explicit at the conference.

■ View from the Symposium

The co-evolution of humans and their technology threaded through most of the talks in a variety of different ways. **Engelbart** introduced the term itself when he described the collaboration processes involved in the CoDIAK strategy. He feels that a mix of humans and tools is crucial to successfully effecting a paradigm shift. In fact, that perspective provides the criterion by which we should evaluate new tools—we should look at not how they fit today but what changes would occur as the system evolves with the use of that tool. Thus, just as in biology, the evolution of mammals is constrained by their environment, "nanotechnology is exactly right" as a correctly scaled successor to current silicon technology.

Vannevar Bush's memex was a tool that was never built, couched in terms of technology that did not develop in the ways Bush thought it would. However, it provided the seed for describing a revolutionary way of thinking and working that would take place because of, and by means of, emerging technology. The memex illustrated a way for a researcher to collect and navigate information, leaving his or her own personal narrative marks on it. As already remarked, the best-known example of this revolutionary way of working and thinking can be found in the Internet, specifically on the WWW. Bush may never have imagined the shared, network component of the WWW, but otherwise, the vast database of information that is organized by authored, narrativized collections of links is very close to the memex and the style of work it was intended to support. As users of the WWW become more sophisticated and begin to evolve new methods of working, their innovations are influenced by what is happening in the technology they are using, while at the same time the technology evolves to their needs. At the symposium, the theme of co-evolution of human and technology was prominent, encompassing the parallel development of the network and the societies that use it.

Co-evolution, on the technological side, takes the form of advances that reflect, amplify and support the social structures that are unfolding on the Net. There was a great deal of discussion at the symposium of what some of these developments might be. It was the proposed and predicted evolution in the human realm, however, that was the most interesting. Most of the speakers alluded to the paradigm

shift that our minds must accomplish in order to be able to function productively in this new, global collaborative space. However, they also discussed the changes likely to happen in many of the social institutions that influence our lives. These changes, for which there are no real models, are the most intriguing, and perhaps the most formidable.

Robert Kahn, in describing the open architecture requirements of the National Information Infrastructure (aka Information Superhighway), talked about the need to give our increasingly complex networks the ability to tell us about their state. He foresees the certainty that humans will not be able to understand the behavior of these systems and must therefore build in adaptive and intelligent reporting capabilities. Ultimately, the systems and humans will co-evolve in partnership.

Kahn also described the difficulties in communicating new concepts and helping people to make the cognitive shifts that new technologies mandate. Solving this problem becomes increasingly urgent as we move into a world in which the virtual reality of cyberspace is the only locus for certain experiences; when an event is experienced only in cyberspace, as distinct from being experienced in physical space and reported in cyberspace, there will be no "objective" external referent to which participants can point. There will be only the sum of each individual experience, which Kahn compared to Kurosawa's movie Rashomon taken to the ultimate degree of subjectivity. In such a world, the need for effective structures to help people be flexible and adaptive is more than just important, it is essential. **Ted Nelson**, in describing his motivations for creating his hypertext theories, also referred to Rashomon. He, however, used it as a metaphor for the many paths that can be made through any given set of information. He described linear writing as a destructive process in its selection of one path among many and affirmed his desire to make all the information accessible.

Kahn's solution to these issues is to emphasize creating open architectures, allowing the network to evolve within that open architecture. This gives everyone a chance to make a contribution. He also points out that the challenge in development is not in technology itself but in the applications to which it is put. The interesting developments are at the intersection of technology and the people using it. **Reddy**, in reporting on the work his labs are doing in blending virtual and physical reality, echoed Kahn's concerns. He feels that part of the answer lies in giving people tools that enormously enhance their ability to deal with change and information overload.

Kahn, **Lesk**, and **Nelson** commented on the need for re-evaluation of copyright law, the whole paradigm of financial transactions on the network. Nelson described his transcopyright concept:

> *What I am trying to do is build a new literature in which you have automatic copyright handling by electronic means. Here anyone is free to quote anybody else but they're only referencing the original object which is taken out and the royalty is paid on a prorated basis to the copyright holder on each frame, audio sample, or piece of text.*

and elaborated on its use in response to questions from the audience. **Tim Berners-Lee** discussed how the technology in the form of the link and human economic behavior as represented by the dollar have become intertwined in the evolution of the Web.

Berners-Lee suggested that the acute political and social issues currently swirling around the debates about the Internet can best be handled through the creation of protocols that allow people to behave reasonably. People need to have links at many levels, and when a society provides these links it becomes stable and able to successfully walk the path between the "mountain of despotic dictatorship and the swamps of terrorism". He described these protocols as fractal topologies that can occur both in network and social structures. Fractal topologies are those that scale so as to be present at all levels. In the Web, these result from creating effective protocols. In society, they result from setting up interpersonal linkage structures, which he calls "information plumbing". When the right information plumbing exists for a team, it can work together effectively and feel comfortable. Like Bush, Berners-Lee feels that our goal as a community and a society must be to learn to work together lest we perish as a species. His essentially optimistic view of this partnership was revealed again when, in response to a question from Michael Lesk about the political dangers threatening to destroy the Internet, he reiterated his confidence that protocol changes can stave off that threat.

In the final presentation of the symposium, **Alan Kay** gave a retrospective of a period that he felt embodied a great paradigm shift in the way people thought about and wanted to use computers. He described the figures who influenced him in the '60s and helped shape his own vision of a computing society and its technology. Prominent among these influential figures and events were Ivan Sutherland with Sketchpad, Doug Engelbart and the FJCC demo, the Simula language, and the Grail system at Rand. The people and systems populating Kay's talk were all examples of successful efforts to do something completely new. His explanation for their success was that at this point in the evolution of research in computer science, the players were all people whose main interests and training came from outside the field. They didn't know what the technology couldn't do, and so weren't bound by such restrictions.

Technology at the Conference

Technology itself was a participant in the symposium in the form of a combined Mbone, video/cable, and audio real-time transmission of the proceedings. The control center that guided the multiple forms of recording and interactive transmission across the Internet was next to the stage and the activities of the crew were apparent as they interacted with the speakers. Their presence reinforced and underscored the meaning of the entire celebration.

The Mbone production for the symposium involved three components – real-time audio, video, and a whiteboard, plus a fourth application that displayed the speakers' transparencies. Each component of the multicast was in a separate window so participants could arrange their screens to suit their preferences. The audio window simply showed volume controls, while the video displayed the video feed that was simultaneously being broadcast over cable to the MIT community. The transparencies were made available through a facility created by Paul Penfield and Ed Moriarity called the Companion. The whiteboard was an interactive text window that enabled participants from all over the world to communicate with each other by typing messages into the window.

Producing the varied transmissions was another self-referential example of the themes the gathering was addressing. In this case, it involved getting people from very different disciplines, with very different working needs and processes, to work together in real time to create a coherent and useful production. In this process, content and form were intimately interconnected in what were not only cutting edge technologies but also cutting edge collaboration methods of handling the interaction of the different teams. This involved linking together different forms of communication – local audience, video (cable – MIT community) and Web, and different production dynamics, blending the technologies and the disparate processes involved with producing those processes. As Ed Moriarity, who coordinated the different teams, said, "This was a proof-of-concept experience involving the coming together of cutting-edge technology, content, and collaboration methods. The process is not polished yet, but it worked. In a sense it was like the Wright brothers' flight."

Kay's talk, which looked back at a period of great innovation and co-evolution, was a fitting conclusion to the paper sessions, which had begun with a look at an innovative vision of 50 years ago, hoping to be able to understand how innovation, creativity, and technology will continue to work together.

The Future

What future vision and research agenda emerged from this symposium? Clearly there was great concern as well as great optimism for the impact on society and the Internet of the increasing involvement of the political process in the Internet's management and direction. **Negroponte** sounded the alarm most emphatically when he described the civil rights violations involved in the Michigan student pornography arrest and the extradition of a California resident for trial under Tennessee laws. But, he also reflected an optimism that the Internet would survive intact when he described the persistence of a migrating flock of birds in which there is always a new leader at the point of the formation, no matter how many times hunters may shoot the previous leader. **Nelson** addressed the issues of intellectual property rights and their erosion through copyright problems with networked media, reiterating his confidence that the correct solution lay in the implementation of the transcopyright concept.

Both **Lesk** and **Reddy** addressed the future of information retrieval. Lesk sees the completion of an all-electronic information system, including video and audio as well as images and text, by 2010. Reddy further elaborated this vision by describing the need for information on demand, information that is in "decision-ready form." In describing what would be required to implement this vision—really intelligent image processing, semantically-based information retrieval, and natural language processing—he described the components of a research agenda for the next 50 years.

Engelbart, **Berners-Lee**, and **Sproull** all outlined ways in which the coevolution of technology and society could facilitate the process of collaboration among groups ranging

Future of Hypertext

What of the future of hypertext, the information structure represented by the memex, beyond the Web? This issue was not addressed by the speakers, but we can speculate based on current developments in the field.

One direction can be seen in the work being done by groups such as Brown's graphics laboratory in the intersection of virtual reality research and the Web. Waxweb, which the New York Times calls "sophisticated work... deeply surreal" ("Art in Cyberspace: Can It Live Without a Body?" Sunday, January 21, 1996), provides an interesting illustration of some of the potentials of this medium.

Another direction of active research is in the use of more expressive markup and knowledge representation, facilitating richer retrieval, inference, and link discovery. Tim Berners-Lee alluded to some of the work related to this when he talked about typed links.

A third possibility lies in spatial hypertext and information farming. Information farming provides an extremely large plane, called a farm, on which units of information may be laid out in groups that reflect their meaning and use. When combined with computational agents that can link together pieces of information located in different areas of the plane, the result is a fluid medium in which information is internally associated spatially and logically as well as being linked into the Web and other Internet applications.

Most current commercial hypertext and hypermedia systems are based on work initially reported in the ACM Hypertext conferences, the first of which was held in Chapel Hill, NC in 1987. The proceedings of these annual conferences are available from the ACM and are an excellent resource for tracking the future of this information structure and its domain. Hypertext '96 will be held in Washington, DC on March 16-20.

in size from small project groups to nations. Engelbart, in addressing the urgent need to help groups to flexibly and rapidly handle complex issues and accelerating change, has developed a comprehensive strategy to boost the capabilities of those portions of organizations whose mission is improved productivity. Berners-Lee spoke of the need to evolve the Web into an interactive environment for people to work together and described the social tools, information plumbing, that can facilitate collaboration and paradigm change. Sproull described some of the technical developments needed to support more effectively the kind of collaborative work that is rapidly evolving within a highly interlinked society.

Kahn and **Kay** pointed towards the types of environments that would be needed to support the social and technical innovation necessary to handle a rapidly changing world. Kahn spoke about the urgent need for open architectures to allow new components to be created and integrated within existing frameworks. Kay, by stressing the reasons why so very much was accomplished during the '60s, helped set the requirements for a research environment that would facilitate that kind of creative ferment in the future. He described a world in which the funding agencies funded people, not projects; a world in which the people came from different backgrounds and had diverse sets of knowledge and experience on which to draw when thinking about problems and their solutions; a world in which optimism and confidence in one's own ability were the norm. He warned about the dangers of engineering suboptimization as an inhibitor of genuinely new thinking.

In the panel that ended the second day, **Engelbart**, **Berners-Lee**, **Nelson**, and **Kay** engaged in a spirited discussion of the role and deficiencies of education in shaping the future. Engelbart closed the discussion with a powerful plea that we cannot wait for future generations to reshape our world:

> *We can't wait for the 20 years or so until those children are out and integrated into society with the roles with which they could start making changes. The change-driving things in both world events and the technology are moving too fast, so we are faced with the fact that we must learn a better way to shift organizations with the people that are in them now. That's really why you need a strategy for it.*
>
> *It's exciting to think of what children can become and how they can flourish, but the daunting problem I think we really have to face is how you deal with the change of the adult world.*

In the end, a group of extraordinary visionary thinkers interacting amongst themselves and with a stimulating

audience still did not come up with as gripping a research agenda as the solitary visionary, Bush. What we do have is a collection of ideas and points of view that can lead to the formulation of a new agenda. To facilitate this, the authors plan to create a Web site that will function as a core resource for the development of this agenda. Initial plans include converting the videotapes into a digitized database at Carnegie Mellon and making that searchable database available at the site. In addition, the lead author has abstracted the videotapes and will, subject to author permission, create a hypertext from these abstracts in conjunction with the text of this paper and extensive links into the Web and make it available on the Web. From these and other resources we hope that a clear vision will emerge that will carry our legacy from Bush well into the next century.

Acknowledgements

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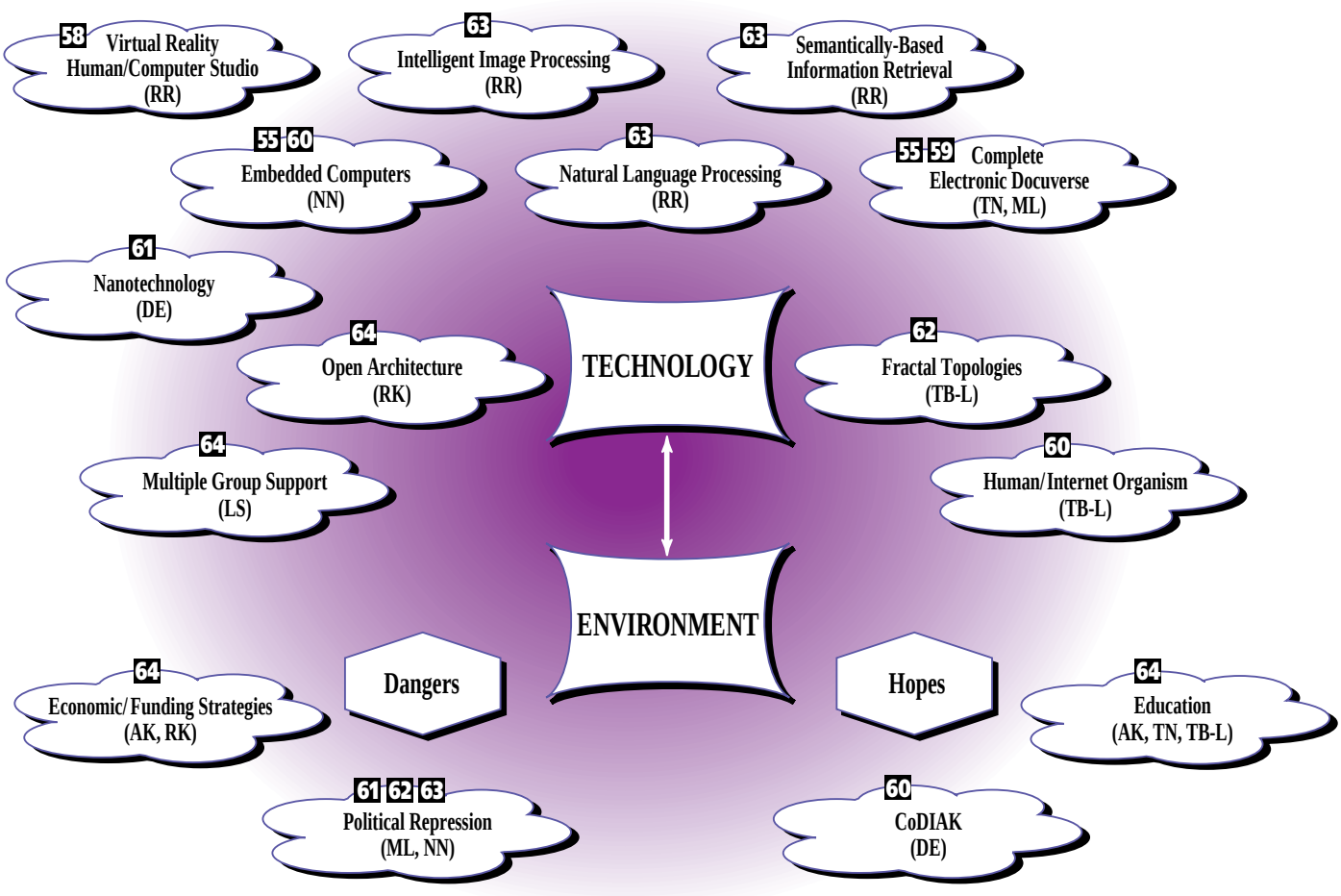
Future Visions

While no single vision emerged from the symposium, the set that did clustered along the axis form by the *augmentation technologies* at one pole and the impact of the *environment* at the other pole.

The technological visions ranged from clear extensions, such as *intelligent image processing,* of what we are currently developing to radically new approaches incorporating new approaches such as *nanotechnology* and *virtual reality.*

When speaking of the *dangers* presented by the current environment, speakers described economic and political realities that impact the human/technical internet organism. When speaking of the *hopes* presented by the current environment, speakers described both social and technological structures that can influence the future.

Thus we see both an extension of Bush's information management vision and a flowering of the social implications to which he only alluded.



WWW Pointers

Bush Symposium Web Site: The web site that was set up in anticipation of the symposium:

http://www.cs.brown.edu/research/graphics/html/info/vannevar_bush.html

Bush Symposium Information Farm: The concept maps in this article, with additional information and pointers into related Web resources, are available as an information farm named 'Bush Symposium'. It may be accessed through Eastgate Systems' Web Squirrel™ web site:

http://www.eastgate.com/squirrel

Electronic Labyrinth — Hypertext History and Technology: "The Electronic Labyrinth is a study of hypertext technology, providing a guide to this rapidly growing field. We are most concerned with the implications of this medium for creative writers looking to move beyond traditional notions of linearity and univocity." This site provides an excellent timeline and series of articles on major hypertext projects, concepts, and people:

http://www.ualberta.ca/~ckeep/hfl0276.html

Hypertext '96 Conference Site (Seventh ACM Conference on Hypertext, March 16-20, 1996, in Washington, DC.)**:** "Docuverse Takes Form…" In the '70s Ted Nelson coined the term "docuverse" to describe a global network of interlinked and personalizable information. Now, two decades later, the docuverse is taking form. Graphics and computing technology now brings inexpensive hypermedia technology to everyone, and the World Wide Web is linking all those everyones together." The web site is:

http://www.acm.org/siglink/ht96/

SGML Markup and Hypermedia: The Brown University Scholarly Technology Group (STG) supports the development and use of advanced information technology in academic research, teaching, and scholarly communication. STG pursues this mission by exploring new technologies and practices, developing specialized tools and techniques, and providing consulting and project management services to academic projects. STG focuses on three related areas:

- hypertext and hypermedia
- SGML textbase development
- networked electronic publishing and scholarly communication

Taken together these three areas of focus constitute the enabling technology for the electronic book or, more accurately, what the electronic book is evolving into: a networked, interactive, high-function hypermedia vehicle for the development and communication of knowledge. While the technologies of the electronic book provide its material focus, STG also has a particular approach to the development of these technologies. All STG consulting and projects are governed by this principle:

The effective creation and deployment of academic information technology requires a thorough-going critical engagement with the theory and practice of the disciplines that the technology is serving.

Only with this sort of substantive involvement in disciplinary practice can technology and methodology evolve in concert and genuine methodological innovation be achieved. This approach to the development of new technology we call scholarly systems analysis. The web site is:

http://www.stg.brown.edu/stg/brochure.html

WAXweb: WAXweb is the hypermedia version of David Blair's feature-length independent film, "WAX or the discovery of television among the bees" (85:00, 1991). Developed by David Blair and Tom Meyer, it combines one of the largest hypermedia narrative databases on the Internet with an authoring interface that lets users collaboratively add to the story. The web site is:

http://bug.village.virginia.edu/guest/viewer=tav/lang=EN/html=1675

Lloyd, and Steve De Rose of EBT who first had the idea of holding a commemorative event and helped in its production; Allen Renear of Brown University; Marilyn Jaye and Maria Clara Valenzuela of MIT's Industrial **Liason Program:** Audio/Visual Staff; Jim Rose and Robert McDermott of the University of Utah; Ed Moriarity, Scott Dynes, and Larry Gallagher of MIT; Dave Klaphaak and Andy Forsberg of Brown University; student volunteers from Brown and MIT; **Paper Support and Reviewers:** Thanks to Steve De Rose, Dave Klaphaak, and Peter Wegner for review comments on the paper as a whole, Mark Bernstein for help with the Future of Hypertext section, Trina Avery for world-class copyediting, Dave Klaphaak for heroic efforts in obtaining necessary resources, and the Scholarly Technology Group (STG) and the graphics lab at Brown for resources and moral support.

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