Information Architectures and Infrastructures[1]

Value Creation and Transfer

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Abstract

In this paper we address the issues of information as a means to value creation for a business enterprise or for an individual. To that end, we develop the concept of information and provide several definitive definitions that are of use for strategic and policy purposes. We then select a definition based upon the need to create and measure value in an economic context. The value based definition of information then provides a base to determine the structure of information systems and their architectural framework. The world view element of an architecture is developed and discussed for many existing systems. This then leads to the definition of an infrastructure and the use of this definition to analyze several recent proposals for information infrastructures. The authors present deconstructionist methodology for the analysis and synthesis of future information infrastructures.

1.0 Introduction

Information has been defined in various ways over the past fifty years. In 1948, Shannon attempted to provide a quantitative definition of information based on a set of symbols and their relative probabilities of occurrence. At the other extreme is the definition of information by Walter Wrist on, the former Chairman of Citicorp, who said the information would be the currency of the twenty first century and that it would be a defined and imputed value by its ability to effect transactions. Specifically, Wrist on indicated that information created value on the part of its owner by empowering the owner to act.

In this paper we shall consider six main concepts. They can be considered to be several of the key questions that may be asked about information infrastructure and the information industry. These concepts are as follows:

o What is the meaning of information. Can this meaning be developed without a context and, if not, what is the context dependent definition that most suits that of an infrastructure.

o What is the value of information. How is value defined and in what context should the value be measured, namely through its effective use or through the actual use that is made of it.

o What is an information architecture. What constitutes the key elements of information systems and how do these elements relate to the overall system functioning.

o What is an infrastructure, and specifically what is communications infrastructure. Based on this construct, what cane said of the efficacy of an infrastructure in terms of information usage and the value created in an information system.

o What types of information systems are there today and where are these systems going. This is an issue of taxonomy and evolution within the context of an already evolved taxonomy. It begs the question of, does ontogeny recapitulate phylogeny. Namely can we tell where things are going by having a clear understanding of how we have arrived at where we are in the information industry.

[1] September 29, 1991, The Nineteenth Annual, Telecommunications Policy Research Conference

o What are the distribution channels for information systems, services and products. Specifically, how should the elements be interconnected and what are the roles of the operators of the elements in order to best provide for the creation of value offal players in the chain of distribution of information. This question also relates to the issue of the food chain concept for information systems. What relationships are essential for survival.

The overlying theme of this paper is the development of structure and the elements of information systems and the means to render value to these systems and through these systems to the users of them. It is critical to remember that value creation is the primary concern for an information system. They do not existing and for their own use. They are economic entities that must be justified in terms of their ability to contribute directly or otherwise to the creation of value for the user.

1.1 Past Information Systems

Information systems have evolved from complex and cumbersome manual systems into what we know today as complex information storage, processing and retrieval systems. The successful information systems in current operation fall into four major categories. The first are those systems that are for internal corporate use that permit the business user to meet the needs of the business by accessing and disseminating information in various ways in an closed corporate environment. The second type of system is that typified by a financial data base that provides for the access to and updating of financial information and transactions. Tolerate and TRW are typical of this variety. The third type of system is one that provides access to specialized information available on stored data such as provided by Dialog and other such companies. A fourth type of information network that has developed is the current Internet that evolved from teethe AREA Net of the early 1970 s. This network allowed for these and sharing of data elements and was the first distributed environment that was not centrally controlled in a hierarchical fashion.

All of these existing systems, except the AREA net and its descendants, are based upon past paradigms of centralized data storage, limited processing at the user location and hierarchical control and management. They also reflect the limitations of text only and have expanded only slightly into the areas of full text.

1.2 Current Trends in Information Systems

There are several current trends in information systems that provide a window on the future directions of the business. These trends reflect both the changing base of technology as well as significant change in the perception of the end user. Some of these changes are as follows:

o Multi Media Communications Systems: Multimedia Communications systems combine the human user in a seamless fashion with the data and information that is required to perform their tasks. These systems have arisen from the development of user friendly desk top machines such as the Apple Mac that allow for simple desk top publishing. This publishing allows for the integration of text, images, voice annotations and text annotations into single finished product. This type of system also allows for these and annotation by several people at the same time in displaced environment.

o Distributed Networking Environments: Distributed systems have developed in the context of sharing resources from many users. and in turn allowing multiple users to communicate with others in time and space displaced fashion. The distributed systems have evolved into those that distribute not only processing but also database and database management.

o High Density Local Storage Devices: These storage devices aroused for the storage and retrieval of multiple forms of data. This may include text, image, voice, video and other types of sensory data. Each of these has a different set of access technologies. In the medical area one can see the ARC NEMA standards whereas in the data area for general purpose systems one sees PICS and other similar standards.

o Broadband Communications Links: Broadband communications accounts for the data rates in excess of 45 Mbps. Rates at this level and below are provided by the local telephone companies. The higher rates are now available on dark fiber using proprietary hardware and software. Rates in excess of 100 Busier currently available and have been used in various systems for trial and operational purposes (McGarty 1990, [1], [2], 1991[3]). The advantage of such systems and data rates is the availability of non voice based communications links. The links can be tuned for the specific application desired.

o End User Interface Software: Empowerment of the end user is key factor in the development of effective information systems. The end user empowerment is based upon a shifting from complex user interfaces to simpler end user interface software. The Apple Mac is an example of such an initial transition. The menu driven Dialog Business Connection is a second example and the Citibank Direct Access interface is a third. Dow Jones interface is counterexample of a user friendly interface. User interfaces cane used to hide or mask the complexities of the system interface. In fact, end user interfaces are just a part of an overall layered software architecture construct.

o Open Systems: An open system is one that allows not only transportability of software but the migration of hardware from one point to another. UNIX (TM AT&T), X Windows, C and C++ are examples of open interface environments as is TCP/IP for internetting. As we see the developments in multimedia communications we see similar first attempts to provide similar open interfaces for shared multimedia conversational environments.

These trends in technology show that there is significant potential for reducing the barrier to entry for the end user in accessing meaningful information sources. The goal for access is one that requires no training or even better no manual at all.

1.3 Future Directions

There are many possible trajectories that can be speculated forth evolution of information systems In this paper we argue that the most likely trajectories are those that both empower the maximum users and at the same time permit the maximum creation of value. As we have already discussed, such systems as the videotex system of the 1980 s have had little if any success. They did not empower the user and more importantly created no value. Indeed these systems are archetypical examples of how not to proceed with the development of information systems.

In contrast, however, such systems as Mead's system and the Dialog system have clearly define value created and directly empower the user of the data. The value can be directly recognized and factored into the overall utility as perceived byte consumer.

In contrast to many others who are studying and creating policy in the area of information infrastructures, the authors of this paper take a significantly different stand that is in contrast topmost of the other proponents. Specifically, in this paper, we develop the thesis that an infrastructure, specifically physical infrastructure, in a technologically active environments strongly counterproductive to all economic interests and that the focus on infrastructure in the area of information systems will retard the development rather than foster it.

The authors build the arguments to this thesis in this paper in the following fashion.

(i) The nature of information is not well known. The ability to define it has still led to much confusion amongst policy makers and users of information.

(ii) The value created by the use of information, in the context of any of its current definitions, is also not well defined. Value of information is at best defined in its ability to create economic value for its users. In this paper we focus on the economic value measure of information and extend it to cover aide variety of information systems.

(iii) Information systems are composed of a set of common elements, arranged in the context of a specific world view, and embodied in the physical realization of available technology. The architectures all to often reflect the world view of the designers and this world view is based upon a set of paradigms, examples, experiments, that have been both successfully carried out in the past and are accepted by the collective set of users. However, information uses, users, and in turn paradigms of use are changing at a rapid pace. Thus it is anticipated that thievery architectures of information systems are subject to radical change in the near future.

(iv) Infrastructures are sharable, common, enabling capabilities, having scale in their design, sustainable by an existing economic market, being the physical embodiment of an underlying architecture. The architecture is the driver of the infrastructure and it in turn is driven by the world view. Stability of this view is essential for there to be a sustainable infrastructure. That clearly is not the case in current information systems. Secondly, the issue of sustainability by existing economic markets is also essential. Clearly, the information industry is in its economic infancy. Suffice it today that there is not eve a stable definition of value.

(v) Economic structure that is viable assumes several factor sexist. First there must be a defined product, then there must bean determinable and addressable customer base or market, and third there must be both a viable pricing mechanism and efficient distribution channel for product dissemination to the erstwhile customers. This distribution channel is the food chain of the information industry. Taken in a holistic sense, all of the elements must be in place not only for existence but for survival. In none of the current proposals does there exist the slightest interest in this critical factor.

Therefore, an information infrastructure is not only premature from the architecture point of view but it is not economically survivable from an economic perspective. In the following sections we shall address each of these factors in detail, proving the assertions above and explaining how an information industry may evolve.

The future directions of technology are currently changing essentially what is information and to paraphrase McLean, what's knowledge. Multimedia communications systems, currently in their earliest stages of development, are now capable of allowing multiple users to session together in a conversational fashion and dialog using multiple forms of expression including video, image, text, voice, and interactive tactile movements (See McGarty 1991 [1], 1990 [1], 1989). However, these communications systems are best implemented using dark fiber with complex interface and interconnect capabilities resident in the end user terminals. Thus if we were to enable the users to maximize their benefits in this area, we would be best suited by providing minimalist approach. This is in sharp contrast to the visions of centralist and hierarchical architects such as George Heilmeier, President of Bellcore, who envisions a future dominated by his own limited world view. This paper looks to the maximum enabling of the end user in an economically efficient fashion.

2.0 Information Definitions

Information is, at one level, a well understood concept. However, when asked to specify exactly what information is and how it is measured there is a great deal of confusion as well as many differing opinions as to how best to define it. In this section we shall review some of the current definitions and then we shall demonstrate that in an economics context the concept of information is best understood only in the context of its impacting creating new value for an enterprise.

One of the earliest attempts to define information was made by Wiener and Shannon in the 1930 s and 1940 s. This definition was based upon the constructs of coded data and the fact that such data streams had content only if they contained bit streams that are not known to the receiving party at a prior time. Thus the more uncertain the received bit stream the more information it was assumed to contain. This measure of information was given in terms of the construct of entropy, taken from the field of statistical thermodynamics. It was this construct that led to the development of the idea of a bit, or binary information unit, that is common in communications and computers today.

2.1 Definition of Information

An attempt has been made by Barman to provide a set of definitions to the word information in the context useful for policy makers. Her paper presents four different definitions that have been in use in various ways. Before summarizing her definitions we should first indicate what elements are necessary for the development of a definition of information.

A definition for information must have the following characteristics:

o Characterizable: The definition must be capable of pointing toad characterizing the information. It must allow the user, the policy maker, the buyer and seller to see what information is. This may be done in a direct fashion by counting bits or pages of data or in an indirect fashion by measuring the impact that the information has on a system. In the latter case the impact must be Characterizable directly. If the information is directly Characterizable, we call it First Order Characterizable. If it is Characterizable through a first order effect then we call it Second Order Characterizable. Higher orders are possible but its clear that such higher order effects are more difficult to justify.

o Measurable: The definition must have a means of measuring the amount of information available in the element being discussed. The measurement must be comparable and consistent when comparing this information measurement to any other.

o Relatable: We must be able to relate information from one source to another. Information must have an additive property, in that taking one set of Characterizable and measurable piece of information and adding to it another, the result is more information. Thus we can relate bits of information. More complex relations can also be performed on information such as deletion and negation.

o Actionable: The information must also have the capacity of producing a result. The use of information must create a change in the state of a system that would not have taken place had not the information been available.

We can now take these characteristics of a definition and use them in the context of evaluating the definitions of information that have been proposed. The following are four different definitions of information that have been proposed by Barman.

(i) Resource (Existence):

Information is anything that can be stored, processed or manipulated. It is a discrete and isolatable entity and can be measured like any other economic resource. It measure is independent of the content or the use to which it is put. It isn't differentiated in any way from any other cluster of information and is measured only in terms of the resources ictuses in its storage, processing, or transfer.

o Characterizable: To characterize information in this definition, we merely point to the amount of storagethat is consumed or the amount of disk space used. Onemay also merely measure the number of bits occupied in-memory. The characterization is quite primitive,involving the basic measure of information as quantity.

o Measurable: The measure of information is based uponthe measure of physical storage measure. Specifically,let M RES be the measure of information I, then wehave;

M RES (I) = No. Bits

The measure is independent of the information form, useor impact.

o Relateable: Information in this context can be added or deleted in a simple fashion. If we define I_j and I_k as two types of information, then if we let I_n be the sum of these two;

$$I_n = I_j + I_k$$

Then this new information is defined merely as thephysical collection of the underlying two elements.

o Actionable: The actions that can be effected by this information are merely those that account for the-storage and movement of them from one location toanother.

(ii) Commodity (Content):

Information is an entity that grants economic power that is measured by its content independent of the use that content is put to. Unlike a true commodity, however, it lacks materiality inthat an image exists due to relationship of its bits and not in anondivisible entity. Namely, multiple versions of the materialimage can be made for various purposes. The owner of the digitalimage, if such can be defined, has been granted the economicpower to exchange that image in a monetary transaction. Thetransaction is viewed as a transaction of content and notprocess.

o Characterizable: We characterize this information byits underlying meaning. Namely, if we have a picture ofa specific event, then the information is the abstractconcept or construct of the picture. If we store this - picture as ten bits or two million, as long as thepicture is identically reconstructable, then this is the characterization of the information. Thus thecharacterization is termed in the context of itsmeaning to the user as object vis a vis its content.

o Measurable: The measure of this information is quite complex. Consider the information, I_k ,as a picture of a certain event. We define a measure of this in terms of its economic value, that is the free market value - that can be ascribed to the sole possession of this information. It is a value that may be defined in the-context of selling a special picture of a news event to a newspaper, or the value of a certain software package that has been developed and copyrighted. Thus the measure of the information, M_{COMM} , is given by;

$$M_{COMM} = \text{Economic Value } (I_k)$$

o Relatable: This definition allows for only a loosely relatable definition of information. One picture may or may not relate to another. A picture stands by itself. A software program may be added to another to create anew program in the commodity context, but it inarguable whether this is a proper relation.

o Actionable: This is an actionable definition. In the simplest sense any book is information in this context and the publishing industry is business based on the movement and partitioning of this information, controllable under the copyright.

(iii) Pattern (Change):

Information is the ability of a data element to reduce uncertainty. It allows for value and measurement in an analytical framework. It is a semiotic definition that interprets information as a sign, a display of definition or description, permitting or enabling the dissolution of uncertainty.

o Characterizable: This definition of information is based upon the work of Shannon, Weaver and Wiener. Its a definition that is in one sense abstract but in another quite simplistic. In the view of these researchers, information is characterized by a series of bits, ones and zeros. These bits are further characterized by a randomness of appearance in sequence of the bits. Not every bit is a one or zero and the chance or probability of any bit taking on specific value is given by a probability, p. The information is defined as a sequence of bits;

X = {x1 , ..., xn }

where the probability of xk being a 1 is pk,1 and that of zero is pk,0 .

o Measurable: The measure of information in sequence Has been defined by Shannon as;

$$M\left(I_X\right) = -\sum_{k=1}^{N} p_k \log\left(p_k\right)$$

o Relatable: Since this is a highly mathematical definition, considerable effort in analysis has shown that both weak and strong relationships exist(Gallagher).

o Actionable: In the case of this definition, actionable is an immediate consequence since this information reduces uncertainty. The information may be the reduction of uncertainty in a weather forecast or some other uncertain event.

(iv) Force (Impact or Process):

This definition of information is that of an ability to interact. It is a definition that measures information by a result or effect on a process or creates a process of economic value. It sin a sense a teleological definition. As we shall see, in this case information is defined as the ability to act differently with it than without it, and that the ability to act with it increases the value or wealth of the set of actions taken as awhile.

o Characterizable: In this definition, the information's defined a posteriori, namely in terms of its result. The information as a storable, processable, communicatable data resource, when received and acted upon, produces a change in the state of an economic entity. That change results in a difference in the perceived marketable value of that entity. It is the change in that marketable value that characterizes the information.

o Measurable: The measure of the information, Ik , is defined as the change in value. Let V(0) be the value of the economic entity in the absence of the information and let V(I k) be the value after. Let the value be defined in terms of such measures as net present value or similar well defined economic measures. Specifically, let;

$$V(*) = \sum_{n=1}^{(1+M)n} CF(n) = \sum_{n=1}^{(1+m)n} R(n) - E(n) - C(n)$$

where CF is the cash flow, and R is revenue, E expenses and C the capital, and m the cost of money. Thus wehave;

M(Ik) = V(Ik) - V(0)

o Relatable: This is highly relatable since with two such collections of information, when can combine both,- measured in terms of their joint economic impact.

o Actionable: By definition, this is actionable, pari passu.

2.2 Applications of Definitions

Having spent a great deal of effort on these four definitions, weshall briefly describe the best contexts in which thesedefinitions are to be used. It should be clear that from a policyor regulatory viewpoint, that each of these definitions hassignificant import. For example, in the breakup of the BellSystem, one of the restrictions is on information provisioning.Which of the definitions that we have developed applies. It is - arguable that the definition of prohibition was never consideredab initio but followed from the tort process. Thus Judge Greene considers each case on its "merits" and responds accordingly.

Resource: In the sense of stored bits as information, JudgeGreene has delimited the Regional Telephone Companies from evenstoring bits, despite what happens to them. This is the extremeexample of "bits are bits are bits".

Commodity: The basis of much of the current body of intellectualproperty law and rights is surrounded by the concept of value tobits as an embodiment of connected relations and unique value. Apicture, a song, a book or a software program.

Pattern: This definition is at best the basis for mathematicaland analytical studies. First conceived in 1944, it has evolvedinto a theory of coding and data compression. Despite its valueas an analytical tool. it cannot be used in some simple andanalytical appearing cases. For example, an X ray image is merelya collection of bits. Using this definition of information it is possible to compress the image and retain the underlying-information content. However, a radiologist would not allow thatfor fear of litigation, a misdiagnosis based on a distorted image. In this case the Radiologist deals with the Commodity definition and not the Pattern.

Force: This is a transaction definition. The stock market andcommodity markets trade on scraps of this information. This formof information is one contingent upon use. However, it has aproblem. The same information may not be used as effectively byone user as compared to another. Thus if I know the market forcellular telephones is now moving to the retail consumer base andmy competition knows the same information, the value depends uponmy ability to act effectively on this information. Thus withforce information, we measure not only the information itself butthe effectiveness of the holder of the information.

3.0 Value Measures of Information

Information has value only in its ability to effect change in some set of subsequent actions, and its value is definable in terms of the costs or profit of those acts as compared to thesame acts in the absence of such information. Consider a simple example of the case of the Rothschilds in the Battle of Waterloo.The Rothschild bank in London had access to the outcome in thebattle prior to any other bankers and as a result was able to take positions in commodities, knowing the outcome, that providedit with dramatic returns. In this case, the value of the information was readily calculable.

Thus, in this paper, we will focus on information as Force, as anability to create change and to effect a transaction. It is withthis definition that we have the ability to efficiently measurevalue.

3.1 Value Measures

As we discussed in the last section, if we define value in itseconomic fashion then we can have a direct measure of informationas a business. Let us begin by considering that information, I,exists and is available to a single business. Consider four casesof that information.

Case 1: A company has knowledge of a competitor's bid in acompetitive bid process. The process gives the contract to thelowest bidder. We shall assume that there are no ethical problems involved. Assume that this company can beat the competitors priceby a small amount.

Case 2: A physician performs a MRI scan on a patient on an annualbasis. On the scan for this year, the physician notes a growth inthe sinuvial sinus. An excision is performed; it is found to bean early malignancy, but is totally excised.

Case 3: An investor hears of the upheavals in the Soviet Union on August 18, 1991. However, he has inside intelligence information that the coup will be overthrown. His competitor has a license to build a large communications system in Moscow. He offers to buy the license for one cent on the dollar. The deal is complete August 19, 1991.

Case 4: A biologist has developed a strain of bacteria that generates a specific set of proteins. A chemist has developed a process for binding these proteins together into a long stranded polymer that is a plastic. A botanist has found a virus that can reverse transcribe the gene from the bacteria and create the chemist's process in a cell and thus have a plant that grows plastic. A venture capitalist exchanges electronic mail on the network with all three of the scientists.

The question we ask in each of these cases is two fold. First, what is the information in each; second, what is the value of the information. The conclusions we can reach are as follows:

o First, we can use any of the definitions that we have developedto describe the information.

o Second, The information has an economic value as long assomeone acts on the information as well as the actions are efficient. That is that the bid is lower, that the patient agreesto the surgery, or that the venture capitalist knows what he is seeing as a potential for organically grown plastic.

Cover has analyzed the process of stock market investments, withand without information. Specifically, he assumes that an investor has access to general information, X, as does all otherinvestors, and side information, Y, known only to himself. Forexample, let us assume he knows that a company is to be acquiredfrom his brother who works in Mergers and Acquisitions in theinvestment bank. Then, if we define $S_n{}^*$ as the best he can do with his investments at time n having just X, and $S_n{}^{**}$ as the best he can do with the side information, Cover has shown that;

$$S_n{}^{**} / S_n{}^{*} = [2^{(W(X|Y)-W(X))}]^n$$

Where W() is the doubling rate. Cover then goes on to prove that;

$$W(X|Y)-W(X) = I(X;Y)$$

the Shannon information measure of mutual information. Thus if wedefine the value as;

$$V(Y) = V(X+Y)-V(X)$$

and V( ) is a net present value valuation (Fruhan), then we obtain;

$$V(Y) = V(X) [(2^{I(X;Y)})^n -1]$$

This simple case shows how we can readily relate value toinformation. Specifically, we can relate the economic transactionmeasure to the information theoretic measure.

In the work by Tirole on the theory of industrial organizations,there is developed the quantitative value of a businessenterprise, in the context of a duopoly, where the parties haveunequal amounts of information. Tirole shows that information is a key elements in decision making and the analysis is done in thecontext of game theoretic analyses. We show this structure indetail in Figure 1.

3.2 Value Processes

Value processes are those industrial processes that makeinformation have value in the context of the business. Porter hasintroduced the concept of the Value chain and McGarty (1989) hasused this concept in the detailed evaluation of businesses interms of implementing the value chain. Value processes aredefined as those actions that an economic entity takes withinformation to convert it into economic value for the firm.

If the firm makes optimal use of the information, we call that a fully efficient firm. That means that if I is the information increment, the value from I is;

$$V(I) = V(I:X)-V(X)$$

where X is the existing information set. Let F* be the firm that reaches:

$$V^* = \max_{\text{all } F} (V(I))$$

That firm is the maximum user. Any other firm is less efficient. The question to be asked is what is V * and does F* exist. We defer these questions to later.

However, if we further look at value as Fruhan has in terms of the net present value of an economic entity, then we have:

$$NPV = \sum_{n=1}^{(1+m)n} CF(n)$$

where CF, the cash flow, is;

$$CF(n) = R(n) - E(n) - C(n)$$

Thus information must increase revenue, or decrease expenses orcapital requirements. Let us take the case of the MRI scan inCase 2. What does that information do. Clearly it increasesrevenue of the individual since he is allowed to live and beproductive longer. Secondly it reduces expenses of complexsurgery, hospital care and medications. Third it reduces capitalexpenditures for new hospital beds. This the information of theMRI, not just the MRI, that creates economic value. This assumesefficiency of use. If the patient ignored the information, wecould readily calculate the lost revenue, added expenses, andneeded capital. Thus, in this case the value of efficiently usedinformation is quite evident.

The value processes are thus clearly defined:

o Efficient Use: Information must be obtained, disseminated,interpreted and acted upon. It is implicit that the processor ofthe information, or the human, is a capable agent. The patientwho ignores the diagnosis is inefficient and will suffer theconsequences.

o Economic Impact: The economic impact must be definable,measurable and implementable. Revenue, expenses, and capital mustbe interpreted in terms of the use of the information. Forexample, we may consider a home banking system. By using thesystem, the user saves time, time is travel, travel is anexpense, and thus there is an economic value.

We can now present value measures of information in several keyareas. Each of these areas have direct economic and policyimpacts. We take six specific cases and show first the nature ofthe information and second the nature of the value of theinformation. We do not address the architecture of the systems that provide the information nor do we address the efficiency ofthe use of the information by the user. We assume in all casesthat the user is a rational user and takes maximum advantage ofthe information. Inefficiency in user information utilization areaddressed elsewhere (McGarty 1989).

o Investment Value: Investment value is the value of informationas relates to the investment of funds in open markets, assumingthat all players in the trading of investment instruments performin an ethical fashion. We shall take the case of options tradingand show the various levels of information and its value. Intrading options, a buyer or seller purchases or sells rights tobuy or sell at a later time a stock at a certain price. The-option has a value that can be determined by the Black Scholesmodel (Brealey and Meyers).

The Black Scholes model shows that the value of the optiondepends on the volatility of the stock, that is its current andprojected price variations. However this piece of information is not available. What is available is the history record of thestock's performance for a period of time and exogenousinformation about the performance of the company and theindustry. Let IS be the stock price history. We desire tocalculate VS , the volatility of the stock. Let us assume that allplayers, using IS can calculate and estimate, V* S , of the-volatility. Let us further assume that we can, using our otherfactors of information, called IE , calculate a better estimate,V** S .

Using this latter value, we can attain better accuracy in thevolatility and thus a marginal improvement in our investmentportfolio. This example raises several issues of information.First, the general information is available to all, namely thestock history. The effectiveness of that information in theoptions analysis is based upon the analytical model forestimating the volatility. That model is also developed usinganother level of information that the model builder has. Thus, tofirst order, the endogenous information processing of informationavailable to all players can be different, independent uponwhether the users efficiently use it. Second, the exogenousinformation is more tightly held. Its acquisition and itsintegration make for significant value creation. The details ofthis value can be determined using standard measures of optionpricing and the Black Scholes approach.

o Consumer Value: The value of information to the consumer is inmany ways analogous to the values imputed by the commercialsegments. Consumers may get better pieces, thus a transactionvalue, consumers may find better investments, thus an investmentvalue, or consumers may find ways to reduce their expenses andthus a cost value. However, if we view information as havingvalue only in its ability to cause an action, then all activitiesthat a consumer acts in that is the consumption of informationfor the purpose of action are activities that are informationvalued.

o Competitive Value: If we assume that there are two or morecompetitors, then we can assume that there is certain informationthat one competitor may have about another that leads to acompetitive advantage. Porter has discussed these issuesextensively. He indicates that understating the competition'sproduct development or market development strategy may help afirm in focusing its own development efforts. Consider a case ofcurrent interest in the cellular communications world. Currentcellular systems are all analog systems. There are two digitaltransition strategies that can be formulated with potentiallyavailable technology. The need to transition to digital waspredicated upon a need for new capacity but capacity has beenhandled by more cell sites and not by more capacity per site.Thus the introduction of digital technology is driven by purelymarket factors to attract new customers and not solve anoperational problem.

Consider the current situation with two competitors. If both stayanalog, then they compete on service quality and price, since ineffect the service is fundamentally a commodity. If however, oneof the firms changes to digital, perception by the customer maylead to a differentiator in the market equation. The competitormay then do one of three things. First, if they know for certainof the conversion, they may pre-emptively convert and if themarket accepts the new technology, they may capture market shareand thus a competitive advantage. Second, they may lag, let thecompetition establish the market viability and then convert,suffering lowered market share yet reduced risk. The third optionis to stay analog, reduce the price, capture share, assuming thatthe customers will choose on the basis of price and not digital.

There are two types of competitive information in this scenario.The first is competitive action information as to what thecompetition will do. The second is competitive market informationas to what the customer will do in response to actions of thecompetitor. It is possible to perform a detailed analysis ofthese three scenarios and determine the value of the informationin each case.

o Market Value: The market value is the impact on the net presentvalue of information on the revenue side of the equation. We havealready discussed some of these issues but they relate to pricinginformation, market elasticity information and market demandinformation.

o Cost Value: The cost side is comparable to the market side butit relates to all negative cash flow elements such as expenses,cost of goods, and capital.

o Transaction Value: Transaction value relates to the use ofinformation in transacting any purchase. It relates to suchsimple factors as the reservation price of the buyer or sell inany transaction. For example, in any negotiation, if I, as thebuyer, know the reservation price of the seller, and the sellermakes a certain value, then if I counter with value that averagedwith the first asked price equals the reservation price, then I-will in most negotiations reach the sellers reservation price,defined as the lowest price at which a transaction will occur.Therefore, knowledge of the information of the reservation pricewill be worth the upside excess if I bid too high to buy it andthe value of the loss to me as the potential buyer if the sellerwalks from the deal.

4.0 Information System Morphologies

Information systems have evolved over the past forty years andhave taken on many shapes and forms. It will be argued in this section that there appears to be a stable set of elements thatare common to all information systems and that these elements canbe further classified to distinguish one system from another. Theapproach taken in this section follows the approach taken byLinneaeus in the eighteenth century in the classification ofplants and animals. Linneaus used the information gathered onthousands of different species of plants and from this generatedthe structure of kingdom, division, family, genus, and species.Each subdivision, or taxa, was based on some morphological, ofform difference. In order to do this it was first necessary totalk about a set of higher level forms. In plants, these were theroots, shots or stems, leaves and flowers. In this section wedevelop a set of basis-set of forms for information networks andthen use these in a morphological base.We then, in the next section, expand these to a taxonomy that leads to an-architecture. The advantage of this approach is that it leads tomeasurable differences and similarities between informationnetwork species and also allows for evolutionary analyses; frompast, through present and into the future.

4.1 System Elements

There are five system elements in information systems. Theseelements are the control functions, the transport function, theinterconnect function, the database function, and the interfacefunction (See Figure 2 where these are generically depicted). Wenow provide further detail on these functions. It should be noted-that these functions have evolved over the years in content andcomplexity. We view these elements in the context of aninformation and communications network that must support the mostadvanced current concepts in information and communicationsapplications. Specifically, the world view adopted in this paper-that lead to an interpretation of this architecture is:

(i) End users desire to have interactions in a real time fashionwith images and other high resolution information that must beprovided in a fashion that meet both time and resolutionrequirements (See Barlow).

(ii) The end user devices are extremely intelligent and complexand can operate in a stand alone environment.

(iii) The users desire to operate in a totally distributedfashion. Data bases will be at different locations, users are atdifferent locations and input output devices are also atdifferent locations (See Dertouzos and Moses, and de Sola Pool pp 57-59 for details on these directions).

(iv) The network may provide different levels of service todifferent users. There is no need to provide universal service offull capability to all end users.

This view of the network will significantly influence howextensively we defined the elements and in turn will impact thecombination of those elements in an overall architecture. All ofthese assumptions on the world view are different than before, inan all voice world. In this paper, we define a network as an embodiment of an architecture, in all of its elements .

The architectural elements are control, transport, interconnectand interface. In Figure 3, we depict the overall architecture ofthe element interrelationship and the elements of the functionsof the separate elements. The details on each are describedbelow:

o Control: Control elements in an architecture provide for suchfunctions as management, error detection, restoral, billing,inventory management, and diagnostics. Currently, the voicenetwork provides these functions on a centralized basis, althoughin the last five years there have evolved network management andcontrol schemas and products that allow for the custom controland management of their own network. Companies such as IBM, AT&Tand NYNEX have developed network management systems that move the-control from the network to the customer (McGarty and Ball,1987). On the sub-network side, companies such as NET, Timeplex,Novell, 3-COM and others have done similar implementations forlocal area networks, data multiplexers and other elements.Centralized network control is no longer necessary and in fact itmay not be the most efficient way to control the network.

What is important, however, is that network control providing theabove functions is an essential element for either a public orprivate network. Thus as we consider network evolution, this element or set of functions must be included.

Control has now been made to be flexible and movable. The controlfunction is probably the most critical in the changes that havebeen viewed in the context of an architecture. All buildings needwindows, for example, but where one places the windows and whatone makes them of can yield a mud adobe or the cathedral atChartres. The same is true of the control element. In existingnetworks, the control is centralized, but in newer networks, thecontrol is distributed and empowered to the end users. The users can now reconfigure, add, move, and change their networkconfiguration and capacity

Let us briefly describe how the control function can now bedistributed. Consider a large corporate network consisting ofcomputers, LANs, PBXs and smart multiplexers, as well as abackbone fiber transport function. Each of these elements has itsown control facility for management and restoral. Each has thecapability to reroute traffic from one location to another, andthe routing systems are programmed into the system as a whole. Ontop of these sub element control functions is built another layerof control that views the network as a holistic entity. This formof control has been termed a manager of managers. It monitors allof the sub net elements and takes control if necessary. It is embodied in several independent controllers, each having the-capability of taking control from a remote network. This form oforganic network control has evolved in recent years and is nowcommon in many corporate networks. In addition, this concept ofthe organic network was described in detail by Huber in the DOJreport to the U.S. Justice Department during the first TriennialReview of the MFJ (Huber).

o Transport: The transport element is provided by the underlyingtransport fabric, whether that be twisted pair of copper, fiberoptic cable, radio or other means. Transport should not be mixedor confused with other elements of the network. Transport is merely the provision of physical means to move information, insome form such as digital, from one point to another. At most itis expressed in bits per second and at best it is expressed inbandwidth only. Bandwidth as a transport construct is the mostenabling. Transport does not encompass the need to change theinformation or to make any other enhancement to the information.

In the early regulatory cases such as the Above 890 Decisions inthe microwave systems that were the precursors to MCI (See Kahn(II p12)), the Bell System argued that the technology oftransmission limited the transport to only those companies thathad the transport, interconnect and control. MCI on the other-hand recognized that the customer was able and willing todifferentiate these elements of the architecture and wouldsegment them in a more economically efficient fashion.Specifically, in the early days of MCI, customers in the midwestwould select multiple transport paths and would do the controlfunction on their own premises. In addition, the customers werewilling to accept lower quality of service for a lower cost of-service. The lower quality was reflected by possibly a higheroutage time.

It could then be recognized that the horizontal scale economiesof all of the network elements, including but not limited totransport, were actually diseconomies of scale in the market.(See Fulhaber for a discussion of a more detailed view of scalediseconomies in terms of the new architectural elements)Fragmentation and segmentation along architecture elementsallowed for the growth and efficiency of MCI. The emphasis shouldalso be made on the statement of the FCC Examiner in the MCI casewho stated (Kahn II p 134), "MCI is a shoestring operation ...the sites are small and the architecture of the huts is lateSears Roebuck toolshed." It is prescient to note that theexaminer used the term architecture for the microwave repeatersites when indeed MCI was changing the architecture of thenetwork. This remark is more than just an embodiment of ametaphor.

In the current network environment, the issue of transport andits enabling capacity has again arisen. This has been the casewith the introduction of fiber. Fiber may be segmented for theuser in terms of data rates or in terms of bandwidth. In theNREN, the three steps are all focused along the lines ofincreasing data rates, from 1.5 Mbps to 45 Mbps to Gbps. As wehave discussed, bandwidth is the more enabling dimension, leavingthe choice of data rate and data structure to the end user. This capability is best deployed by using a dark fiber network.Consider the two networks shown in Figure 7. The top network is astandard fiber network with repeater at periodic intervals. Incurrent technology limitations these are necessary because of the-losses in fiber transport. However, with the current state of theart technology, fiber can be strung for many tens of mileswithout such repeaters and still maintain adequate transmissioncapacity.

Thus the repeaters are not there solely as a result of fiberconstraints on transport. They are also there because theyenforce the voice regime of the voice based world view. Namely,the repeaters do not repeat data rates, they also repeat framingsequences based on 64 Kbps voice frames. Thus any work stationmust use 64 Kbps as the underlying data fabric. As an extremeexample, NREN in its Phase 2 will provide 45 Mbps to the users.Regrettably, there is no 45 Mbps modem. That is, direct access to45 Mbps is not achievable. It must be sub multiplexed to theequivalent of voice grade digital circuits. Thus the world viewis pervasive in this design. The same is true as SONET protocols are used in upgrades to broadband ISDN, especially over an ATMswitch (See Fleming for a discussion of broadband switching andthe voice paradigm).

In contrast, dark fiber is the provisioning of an optical fiberto be used as the end user sees fit. It is the world view analogof the LAN. The LAN provides co-axial bandwidth of severalhundred MHz whereas the fiber provides the bandwidth of GHz toTeraHz.

o Interconnect: The interconnect element of the architecturedescribes how the different users are connected to one another orto any of the resources connected to the network and is synonymous with switching. Interconnection assumes that there is an addressing scheme, a management scheme for the addresses, anda scheme to allow one user to address, locate and connect to anyother user.

Interconnection has in the past been provided by the CentralOffice switches. As we shall discuss latter, this implementationof an architectural element was based on certain limitations ofthe transport element. With the change in the transport elementof structures allowing greater bandwidth, the switching needshave changed. Specifically, distributed systems and scaleeconomies of the distributed architectures allow for-interconnectivity controlled by the CPE and not the CentralOffice. As we shall show later, the advent of Local Area Networksand CATV voice communications are those using distributedinterconnectivity elements.

This argument for interconnection, combined with transport andcontrol (namely horizontal integration) was valid in 1970. Ithowever is not valid today. They are separable functions andscale economies are in the hands of the CPE manufacturers not thenetwork providers. In effect, there exists no monopoly in-interconnect as a result of these technology changes. This is adramatic change from 1971 and Kahn's analysis.

There are three general views of interconnection that are validtoday; the Telcom, the Computer Scientist, and the User. TheTelcom view is based on the assumption of voice based transportwith universal service and the assumption of the inseparabilityof interconnect and control. The Computer Scientist view is based-upon the assumption that the network, as transport, is totallyunreliable, and that computer hardware and software must be usedin extremis to handle each data packet. Furthermore the ComputerScientist's view of the network is one where timeliness is secondary to control.

The Computer Scientists view has been epitomized in the quote,"Every Packet is an Adventure". This is said with glee, in thateach data packet is sent out across the network and it is throughthe best of hacking that the Computer Scientist saves the packetfrom the perils of Scylla and Charybdis.

The third view is that of the user, who is interested indeveloping an interconnect capability that meets the needs andminimizes cost. This third view is one in which minimization ofboth obsolescence and cost is the strategy. Figure 8 depicts thechallenge to the User view of interconnect. Processing cost orcapacity is declining every year. Thus an investment must try tofollow the curve. In a hierarchical view of interconnect, such asa large centrally switched network, the changes occur once everyfew years. Thus the lost cost or performance efficiency canbecome significant. In contrast, in an end user controlledenvironment, with a fully distributed architecture, the lostefficiency is minimized as technology advances.

o Interface: The interfaces are the end user's connection to thetransport element. The interface element provides for theconversion from the end user information stream and theinformation streams that are used in the transport form of thenetwork. For example, the telephone interface for voice is theanalog conversion device.

o Databases: The interfaces of the system elements are for themost part interfacing to end users. In the case of an informationsystem the interfaces are connected to a set of users anddatabases.

We have divided the network elements into these four categoriesto demonstrate that there are clearly four distinct and separableareas for growth and policy formation. Issues of regulation, dueto potential monopolist control are always a concern, but it willbe demonstrated that in all four there are economies in marketdisaggregation.

5.0 Architecture

The concept of a telecommunications architecture has been acornerstone in the development of new telecommunications systems.However, the structural elements of these architectures have notplayed a role in the development of policies. In this section wewill develop the concept of an architecture as a means to-understand the network as both a market and regulatory entity,and will provide a new set of perspectives for viewing thenetwork in terms of new paradigms and world views.

5.1 World Views

An architecture, first, requires that the underlying system betreated in terms of a set of commonly understood elements andthat these elements have a clearly demarcated set of functionsand interfaces that allow for the combining of the basic set ofelements. The way the elements then can be combined, reflected-against the ultimate types of services provided, determine thearchitecture. Such a construct is depicted in Figure 4.

An architecture, secondly, is driven by two factors; technologyand world view. Technology places bounds on what is achievable,however those bounds are typically well beyond the limits thatare self-imposed by the designer or architect in their view ofthe user in their world. This concept of architecture and the useof design elements is critical in understanding the paradigms used in the structure of information systems (See Winograd andFlores, pp 34-50, especially their discussion of Heidegger andThrowness in terms of design). World view is the more powerful driver in architecture (See Kuhn, pp 72-85) . We argue in this - paper that it is essential to develop a philosophical perspectiveand understanding of how to view networks. We argue with Winograd and Flores, and in turn with Heidegger, that we must be thrown into the network, to understand the needs of the users, and to understand the structure of the paradigms that are used to- construct the world view.

The concept of a paradigm is in essence the collection of current technologies that we have at hand for the network and the ways weput these elements together. However, the true meaning of aparadigm is in the context of the examples or experiments that weall relate to with that technology. Paradigms are not technologyin and of itself, but technology as example. New paradigms resultfrom new technologies. New technologies allow for the placing ofthe elements together in new ways. Kuhn, then goes on todemonstrate that the world view, that is how we view ourselvesand our environment is based upon the our acceptance of theseparadigms, as either collections of techniques and technologiesor as collections of embodiments of these techniques andtechnologies in "examples". We then tend to accept this as theway things are and should be. Then Kuhn argues, as thetechnologies change, changes in the paradigms do not occur in a- continuous fashion but almost in quantum leaps. The new paradigms build and congeal until they burst forth with new world views. Itis this model that we ague applies to the evolution of broadband.

Thus, architecture is the combination of three parts: the commonelements, the underlying technology and the world view. In Figure 4, we depict the conceptualization of architecture as the amalgamof these three elements. We shall develop this construct morefully as we proceed.

The concept of a world view is an overlying concept that goes tothe heart of the arguments made in this paper. To betterunderstand what it implies, we further examine several commonviews and analyze the implications of each. If we view our worldas hierarchical, then the network may very well reflect thatview. If we further add to that view a bias towards voicecommunications, these two elements will be reflected in all thatwe do. The very observations that we make about our environmentand the needs of the users will be reflected against that view.As an external observer, we at best can deconstruct the view andusing the abilities of the hermenutic observer, determine theintent of the builder of the networks.

Take, for example, the use of twisted pair, pairs of copper wire,to transport telephone traffic. For years it was implicitlyassumed that this transport medium was limited to 4,000 Hz ofbandwidth, that necessary for an adequate quality voice signal.Specifically the world view was that of a voice network that wasto be used for voice traffic only. Ten years ago, this was a truelimitation, since the transmission was forcefully limited to- 4,000 Hz by inductive loads or coils on the telephone lines,assuring that you could do no more than the 4,000 Hz ofbandwidth. Then, there was a short period in the mid 1980s, whenLocal Area Network manufacturers found that you could transmit1.544 Mbps over the common twisted pair, and that data was viablein what was assumed to be a voice only medium. What had beenalmost religiously believed to be a limit was found to be untrue.Then with the introduction of digital switches, the old"inductive loads" were returned with the switch now limiting thedata to 4 KHz or 64 K samples per second. The world view of a- voice only network took hold again, but this time in the context of a data rate limitation, rather than a bandwidth limitation. Inthe early 90's there is another attempted break out of the worldview and to put 100 Mbps on twisted pair, so called FDDIcircuits. Again, due to the limitations on the part of thenetwork as a voice dominated system, the world view keeps this high data rate capability on the customer's premise only, and notthe network.

The designer of the transport facility may limit the data rate byselection of signaling format or delimit bandwidth by filtering.Twisted pair actually has a bandwidth-datarate profile thatstresses voice paradigms. It encompasses a large capability ofeither providing bandwidth or data rates to the user. The twolimiting world views are indicated as two solid lines, one at4,000 Hz and one at 64 Kbps. Both are voice only world views. Wecan readily see, that with optical fiber superimposed the sameissue of architecture dominated by world view may result. In thefiber case, the result may be a segmenting of the architecturealong selected data rate lines, again formed by the voice worldview.

Thus, architecture can be defined as the conceptual embodiment of a world view, using the commonly understood set of constructuralelements, based upon the available set of technologies .

For example, Gothic architecture was a reflection of the ultimatesalvation in God in the afterlife, in a building having a roof,walls, floors, and windows, and made of stone and glass. Romanticarchitecture was, in contrast, a celebration of man, using thesame elements, but some employing a few more building materials.- The impact of the differences in world view are self evident inthe embodiments of the architecture. (See the discussions on theimpact of world view on architecture in Wolfe. In addition seethe cultural or world view impact on the Go thic architectures inJantzen and in Toy.)

Let us consider a second example of the impact of world view onarchitecture, specifically the difference between the ISDNarchitecture and the architecture embodied in Local AreaNetworks, LANs. ISDN is an architecture consistent with a voicedominated, hierarchical world view of single points of control.LANs are architectures of world views that reflect both end userself empowerment and the environment of a data driven utility.

This evolution in thought is critical to understand the impact ofworld view. The LAN is an embodiment of empowerment of theindividual view, developed in the context of the 1960's and1970's. The LAN concept, originating at such locations as XEROXPARC, was driven by the developers' needs to enable and empower- the end user with computing capabilities heretofore unavailable.

Out of this view came the LAN architecture of a fully distributedsystem, using a coaxial transport mechanism to do nothing morethan provide bandwidth. The transport mechanism is a broadenabler. The actual implementation of the details is done at theusers terminal in hardware and software. This is in sharp- contrast to ISDN, where the ISDN central switch does theenabling. In ISDN, bandwidth is not provided, rather it is avoice based data rate, 64 Kbps or multiple thereof. Considerthis contrast in terms of how cable TV companies provided voicecommunications in the early 1980's. Both Cox and Warner, usingvariations on LAN technology, delivered a voice, video, and dataservice over the coaxial transport medium, by empowering the endusers terminal, not by regimenting the transport network.

5.2 Architectural Alternatives

Is there a natural taxonomy for the set of network architecturealternatives? Do these present limitations on what can be done orare they extensive? Is there a natural limitation in the existingarchitectures that prevents the new technologies from introducingthe new paradigms to the communications world? We address these- issues in the context of several existing network hierarchies.

o Hierarchical: The current network architectures are structuredin a hierarchical fashion. As we have already indicated, thereare historical and technical reasons for this architecture. Weshow in Figure 9 a sample design of such a network. Specifically,we see the set of transmission schemes connecting from a lowerlevel to higher ones. A path may or may not go horizontally. Itmay go vertically, all controlled by a single control at thehighest level.

o Centralized: A centralized architecture is similar to ahierarchical system in that the control function is centralized.However, the transport elements are not in a hierarchical format.This is shown in Figure 10. The hierarchical structure is nolonger present, but there is a single point of control. Thecontrol element covers all other elements in the system. Atypical example of this type of network is that of a large bankin a metropolitan area. Part of the network is the local ATM(Automated Teller Machine) network and the voice network for thebank. Each are separate but the bank controls both from a singlepoint of control.

o Distributed: The distributed system has distributed control,distributed interconnection and flat transport alternatives. This is shown in Figure 11. Here we first note the reduction inconcatenated switch and transmission elements. The network is much less dense and the switch is actually co-located with the-interface. The LAN networks are typical example of distributeddesigns.

o Segmented: A segmented network is really a hybrid. Each segmentuses a subarchitectures that meets the requirements of theexisting system but the networks are interconnected throughstandard interfaces. This is shown in Figure 12. In this case weshow that this network architecture is an amalgam of the firstthree. What is still common, however, is the partitioning intolocal and long distance nets. A typical example of this networkis that of a large corporate network. Part of the network can befor the voice circuits, controlled at a single point and basedupon use of both local and inter-exchange carrier circuits. Thesecond part of the network is the data network, again using bothlocal and long distance carriers, and control from a separate-location.

o Partitioned (Local and Long Distance combined in a community ofinterest): In all of the above, we have assumed that local andlong distance transport are separate. This is a world viewdominated by the regulatory environment. We can see thesegmentation along community of interest lines rather than alongthese more traditional lines. Thus one community of interest is anetwork for financial service companies and a second for anetwork providing service to the residential user. These eachhave all of the local and long distance services, but are nowsegmented by the user market or the community of interest. Thesub architecture may be any of the above. This is shown in Figure13. The major difference in this system is that we have segmentedseveral overlay networks, each containing elements of the abovefour. This architecture allows for local and long distance inseparate partitions. It says that you can segment the network byusers not just by function. Had the MFJ understood users ratherthan functions, the results could have been dramatically-different. An example of a Partitioned network would be that forAmerican Express or Sears. It contains the set of local and longdistance networks as well as subnets for specific distributedapplications. However, each of these companies may have access toa separate public switched environment.

We show these alternatives in Figure 5 through 9.

Understanding that there are several varying architecturaldesigns allows one to better understand that each reflects notonly connectivity but also the world view. We have applied thesetechniques to three different networks; the NREN, Prodigyconsumer network and the Dialog information service. In Figures10, 11 and 12, we depict these networks and one can readily seethe difference and the similarities.

5.3 Impact of Technology on Architecture

We have just discussed the elements of the architecture and theembodiments of design that these elements may lead to. We shalllater discuss the details of the technology evolution but it isappropriate at this stage to make several observations about thecurrent impact of technology on architecture.

In the current telephone system, the interconnect element of thearchitecture is provided by the Central Office Switch and thephysical interconnection of the wires from the street to thatswitch. The point at which the many wires from the street meetthe switch are at a device called the Main Distribution Frame(MDF). The Frame must be able to connect any incoming wire to anyoutgoing wire. The MDF, as it is called, has been the same forover fifty years. It is a manually connected system , where thecraft person must connect each incoming telephone wire to acorresponding location on the switch, each time a customer movesor changes their phone number. In computer systems, this is alldone in an electronic fashion.

In contrast, the central processing unit in computers goesthrough changes once every two years. The standard processingcapacity curves show a doubling of processing capability in thesame two year period. Computer users have a more rapid turnoverof technology because they generally work in an environment withno regulation, shorter depreciation schedules and a focus onmeeting specific business needs.

In contrast, the centrally based network must meet a collectionof common needs and serve them in a least common denominatorbasis. The conclusions from these observations is clear. Ifchange is at the heart of the services and technology is drivingthem, then migrating the elements to the customer of control,interconnect and interface maximize the change and innovativenessof the network.

In terms of a national network, this then begs the question,should not the network, as infrastructure, be nothing more than abroadband transport of open single mode fiber and let all otherfunctional elements be provided by the end user.

6.0 Infrastructures

Let us extend the concept of infrastructure. In our context, aninfrastructure is a shareable, common, enabling, enduring,resource, that has scale in its design, and is sustainable by anexisting market, and is the physical embodiment of and underlyingarchitecture. Specifically;

o Shareable: The resource must be able to be used by any set ofusers in any context consistent with its overall goals.

o Common: The resource must present a common and consistentinterface to all users, accessible by a standard set of means.Thus common may be synonymous with the term standard.

o Enabling: The resource must provide the basis for any user orsets of users to create, develop and implement any and allapplications, utilities or services consistent with theunderlying set of goals.

o Enduring: This factor means that for an infrastructure to besuch, it must have the capabilities of lasting for an extensiveperiod of time. It must have the capability of changingincrementally and in an economically feasible fashion to meet theslight changes in the environment, but must meet the consistencyof the world view. In addition is must change in a fashion thatis transparent to the users.

o Scale: The resource can add any number of users or uses and canby its very nature expand in a structured form to ensuresconsistent levels of service.

o Economically Sustainable: The resource must have economicviability. It must meet the needs of the customers and theproviders of the information product. It must provide for all ofthe elements of a distribution channel, bringing the product fromthe point of creation to the point of consumption. It must haveall of the economic elements of a food chain.

o Physical Embodiment of an Architecture: The infrastructure isthe physical expression of an underlying architecture. Itexpresses a world view. This world view must be balanced with allof the other elements of the infrastructure.

An infrastructure is built around the underlying architecture. Aninfrastructure is in essence the statement of the architecturewhich in turn is the conceptual embodiment of the world view.

Infrastructures as physical embodiments of architectures must, tohave economic lives that are meaningful, be developed when theworld view, technology and user needs are stable. If any of thesethree are in states of significant flux, the infrastructure maysoon not meet the change in the world view and then become-obsolete.

6.1 Types of Infrastructure

It is important to distinguish between architecture andinfrastructure. We have extensively defined architecture in terms of its three parts: elements, world view and technology.Infrastructure unfortunately has been reified in terms of somephysical embodiment. The discussion of NREN being aninfrastructure is viewed by many as being a determinate thing.Kahin has, however, de-reified the concept in terms of its beingan embodiment of a concept or set of common goals. We expand that and state that an infrastructure is an enabling capability builtaround a common construct.

There are four types of infrastructure views that are pertinentto the current discussions of networks. These are of particularimport to such networks as NREN since they will lead to thepolicy directions that it will take. These four infrastructuretypes are as follows:

o Physical: This is the most simplistic view of aninfrastructure. It requires a single investment in a single-physical embodiment. The old Bell System was such aninfrastructure. The National Highway system is such aninfrastructure.

o Logical: This network may have separate physical embodiments,but all users share a common set of standards, protocols andother shared commonalities. All users have access through anaccepted standard interface and common higher level transportfacility. IBM had attempted in their development of SNA in the-mid 1970's to develop a logical infrastructure in datacommunications. This was expanded upon by the ISO OSI seven layerarchitecture, selecting a specific set of protocols in eachlayer.

o Virtual: This type of infrastructure is built on intermediariesand agreements. It provides shared common access and supportinterfaces that allow underlying physical networks tointerconnect to one another. Separately, the individual networksmay use differing protocols and there are no common standards.The standards are at best reflected in the gateways to theinterconnection of the network. Thus this infrastructure is aloose binding through gateways. It is in many ways what is theINTERNet today, if we include all of the subnets.

o Relational: This type is built on relationships between thenetwork parties and the establishment on higher level accessingand admission. Specifically, a relation infrastructure is basedon agreements on sharing addresses, not necessarily commonaddressing, and on the willingness to share data formats andtypes. It is an infrastructure based on shared common interestsbut not shared common access. This type of infrastructure is whatin essence exists in most cases today. Users can move fromnetwork to network through various gateways. The difficulty isthe fact that the interfaces are cumbersome and may require-sophistication on the part of the users. However, moreintelligent end user terminals and interfaces will reduce this cumbersome interface problem.

We show the relationship of these four infrastructures in adiagrammatic fashion in Figures 13 through 16. Our conclusion isthat understanding the type of infrastructure that the coalitionof users want, will also impact the architecture, based upon animputed world view. Arguably, a physical infrastructure leads to-maximum hierarchical control and the resulting impacts that suchcontrol leads to. This is a critical issue for networks such asNREN, since by choosing infrastructure and architecture may notbe as uncoupled as desired. In particular, the selection of Gbpscapability may really be GHz capability and is best suited to a-Virtual or Relational infrastructure.

6.2 Current Infrastructure Options

There is a considerable amount of effort to define and implementan information infrastructure. In this section we describe someof these current proposals, many of which are still quiteformative and lack substance. In some case we shall try to placethem in the context of the constructs that we have developed inthe preceding sections. In order to fully describe theseinfrastructures, it is also necessary to deconstruct the work ofthe authors, understanding their meanings in the contexts of whatthey are saying and taking an approach that blends thehermenutics of Gadamer with the semiotics of Levi-Strauss. We nowaddress several of the more current views of infrastructures. Ineach case, we describe as best can be done the concepts of eachof the individuals, and then attempt a deconstruction in terms oftheir underlying architectural assumptions, their view ofinfrastructure and more importantly their world view ofinformation and information networks.

(i) Dertouzos Infrastructure

This is the most widely discussed of the informationinfrastructures having been proposed by Professor Dertouzos whois a Computer Scientist and the Head of the Laboratory forComputer Science at MIT. Simply put, he defines the informationinfrastructure as:

" Common resource of computer-communications services,as easy to use and as important as the telephone.."

Dertouzos states that there are three elements to his vision ofan information infrastructure. These are:

o Flexible Transport: This includes bandwidth on demand, flexiblepricing and security and reliability.

o Common Conventions: This includes his concepts of E Forms andKnowbots. The former is a set of standard for formats and thelatter are intelligent agents for the movement and processing ofdata.

o Common Servers: This is a set of common file servers orgeneralized servers to provide directories, text/imagetranslation, data base access and active knowledge.

In Figure 17 we depict all of these elements.

In the paper, Dertouzos discusses this architecture and he usesas an example a system conceived of and designed by the seniorauthor (McGarty 1990 [1],[2], 1991 [1],[3]). In the author'ssystem, the assump tion was to both empower the end user and to doso in an incrementalist fashion. The architecture shown in this - second system was based upon:

o Available Transport: Take what is present and build in aneconomically viable fashion. Build communications on anincremental and economically effective basis.

o Open Interfaces: Use standards as appropriate, and allow theusers the freedom to meet their economic needs. Recognize thechanging needs of the user and buyer and incrementally change tomeet the evolving needs.

o Client Server Architecture: Maximize use of end user terminals and empower end user applications development. Provide tools andnot strictures.

The system designed and operated by the author actually connectsthe MIT campus with hospitals, publishers, and other economicentities in a build-a-little, test-a-little, use-a-littleapproach that allows for use acceptance and economicjustification. The Dertouzos Infrastructure assumes directionsthat are significantly different and diverge from the end userdriven approach of the author but take a more centralistapproach. This latter approach has been advocated by Moses in his discusssions on the subject, yet are somewhat counter to Moses'layered organizations that maximize flexibility and minimizecomplexity.

(ii) Kahn Infrastructure: The vision of Bob Kahn, of CNRI is oneof a broad band research backbone, loosely coupled, with darkfiber and as high a bandwidth as possible, read data rate. This proposal, frequently confused with the Gore infrastructure, is generally more open and flexible. However, it too lacks any- economic underpinings.

(iii) Gore Infrastructure: Gore, the Senator from Tennessee, sonof the initiator of the Federal Highway system, and presidentialcontender, has argued for a single network, government directedand funded, hierarchical in fashion, that allows everyone to haveaccess to every bit. Consider his comparison of data bits to cornkernels;

" Our current national information policy resembles theworst aspects of our old agricultural policy, whichleft grain rotting in storage silos while people werestarving. We have warehouses of unused information- "rotting" while critical questions are left unansweredand critical problems are left unresolved."

He believes that every bit is a good bit. He further has no valueconcept of information. His definition is clearly the one ofquantity and not value. Researchers are not necessarily starvingfor lack of bits. Quite the contrary, there is a need forcoherent data reduction. He further states;

"Without further funding for this national network, wewould end up with a Balkanized system, consisting ofdozens of incompatible parts. The strength of thenational network is that it will not be controlled orrun by a single entity. Hundreds of different playerswill be able to connect their networks to this one"

He is somewhat contradictory. On one hand he states that thereshould be one network and not many, on the other hand he has allthe separate networks connecting to this one. In this case, his world view comes through cleary. He wants a hierarchical or atmost centralized architecture as well as a physical architecture.- The proposal lacks the flexibility of a economic entity.

(iv) Heilmeier Infrastructure: Heilmeier, the new President ofBellcore, the R&D arm for the Bell Operating companies on theregulated side, advocated a hierarchical, BOC controlled, networkintensive, monolithic network. This is not surprising consideringhis extensive stay in Washington as a government bureacrat. He- further argues for control of both wire based and wirelessnetworks. He is quoted as saying;

"I'd like to see a bona fide information infrastructurerather than a fragmented world of different systems for- everything."

Networks are currently fragmented and as a result of thisfragmentation local economic optimization has occurred. Incontrast to the hierarchical, centrally controlled view ofHeilmeier, also formerly head of DARPA, wherein he views the needfor a single point of control and direction, the world ofcommunications networks and information networks have grownthrough the increased power of the end user interfaces and- interconnected distributed throughout the network. In additiongrowth has resulted from less control in the network and lesscentralization. The work of the author (McGarty 1990 [1], [2],1991 [1],[3]) has shown an architecture for a distributedmultimedia environment that has been built and is still inoperation that uses a mix of communications channels and thriveson those channels that have the least functionality.Specifically, dark fiber transport is the most enabling andempowering of any communications channel.

6.3 Proposed Infrastructure

Infrastructures are enabling entities. As we have discussed, aninfrastructure does not have to be a single centrally controlled,managed, and funded entity to be effective. In fact aninfrastructure on the loosely constructed basis of a relationalinfrastructure is just as effective as the extreme of a physicalinfrastructure. We make the following observations, and based onthe prior developments in the paper propose an alternativedirection for infrastructure development.

(i) Technology is rapidly changing and will continue to do so.The directions in technology are towards increased processingcapability per unit workstation and increased capacity inperforming both complex processing tasks while at the same timehandling sophisticated protocol procedures. We depict this change- in Figure 18.

(ii) User terminals are expanding in a network multimediaenvironment that is empowering the end users to both use many newmedia types as well as dialog in a conversational basis withother users in the same network. The extremes in this environmentare depicted in Figure 19

(iii) End users are becoming more pervasive and training of usersbased upon strict confines of computer languages aredisappearing. The end user is empowered to act and to useinformation system with no training or education. Citibank, in its development of the ATM network has ensured that the systems have minimal need for human intervention or training. In addition, the Citibank home banking product, the most widely used of any home banking products on PCs, is almost instruction free. The Apple MAC computer is also another example of enduser empowerment through intimidation free end user interfaces. The relationships between these are depicted in Figure 20.

(iv) Successful technology development in a productive fashion has best been effected within the constructs of entrepreneurial small companies that allow for the creation of new ideas judged by the dynamics of a free market. Large centralized technology development organizations have time scales that are much longer than the time scales of the underlying technologies. The developments in the computer industry of today are prime examples.

(v) Users are not only empowered to use systems in a variety of ways but they are also able to select from a wide variety of systems, interfaces and data sources. To quote A.G. Fraser of Bell Laboratories:

"Every standards body seems to be churning out protocols left, right and center. We may already have-passed the point where we can all come together." (Coy,1991)

Thus, distributed networks, interfacing with disparate other networks, through gateways is already a reality.

These observations then indicate that with a changing base of customers, a changing set of needs and an already progressing infrastructure that is relational at best, that to continue to maximize our technical creativity it is best to match the information infrastructure to our cultural paradigms. Thus it is argued that the proper evolution of an information infrastructure should be along the relational model. That, in fact, the physical extreme is counter to the trends of user empowerment and economic efficiency. It further could provide a roadblock to technical creativity.

7.0 Distribution Channels

In consumer marketing, one is continually reminded of the old adage that the dogs must eat the dog food. This is a very telling statement. Dog food is packaged for sale in stores to humans. The humans are the buyers. The manufacturers of dog food must meets the needs of two constituents: the decision maker and buyer as well as the user. The decision maker or buyer is the human who is attracted to the package, the price or the method of storage and packaging. The user however is the dog. The dog generally, as far as the authors know, does not differentiate dog foods on the basis of the labels or the packages. The dog does not look at the television commercials or read the newspapers. The dog smells and tastes. The first can of dog food can be sold to the buyer or decision maker but if the user does not consume it, the second and ensuing cans will not be sold. A trivial thought but of extreme importance to the information economy.

Videotex was a significant example of the preceding adage. A great deal of effort was made to sell the owners of the dogs, in this case the mass market consumer, on a new food. The food was interactive home shopping, banking, travel, ticketing and many other factors. The success of this is best exemplified by the graveyard of videotex companies: Viewtron, Indax, Qube, Prestel, and many others. Compuserve and Prodigy still survive but for other reasons. Compuserve meets the E-mail needs of a well defined niche market and has progressed to sustain its ability to meet the changing needs. Prodigy is sustained by the deep but emptying pockets of IBM and Sears. If one went back to 1981, and read the literature describing videotex, it was obvious to those-at that time that in ten years the use of this type of service in the home would be pervasive. Clearly history has told a different story.

Information is a product. It has a buyer and seller and it has a value. It is viable in the context of a business if and only if the buyer and seller can be connected in an economically efficient fashion. In addition the product must meet the needs of the buyer, and in the simplest terms it must create value for the buyer. In this section we shall focus on the three major factors; the user, the product and the distribution channel.

7.1 Users

The users are those entities who will both use the services provided as well as pay for them. Again, we are driven by thesales adage, money is neither created or destroyed, it just moves from the left pocket to the right. By this is meant that a userhas a set of utility curves and a fixed amount of discretionary funds. The choice of one service over another or of one productover another is based on the maximization of that benefit to theconsumer. Thus an information service must have value in order todisplace expenditures from other areas that already have intuitedvalue by their very existence.

In Dertouzos (1991, [1]), he discusses the need for aninformation infrastructure, as we have already presented, intotal absence of any economic rationale. In Dertouzos (1991,[3]), he states:

"Until a better explanation is devised, let me suggestthat information has economic value to people if it can-lead them to the acquisition of tangible goods.Similarly, information has intangible value if it canenable them to satisfy less tangible human desires."

This quote is both the recognition of and justification for aneconomic basis of an information infrastructure. The authors contend however, that to understand the user it is necessary tofirst understand the product and its value to the user. Currentmarketing tactics (Kottler, Porter [2]) clearly demonstrate thatan understanding of the value chain to the user is essential.That value chain is the basis for product competition and-displacement. It will be necessary for the Dertouzos model toinclude an explicit recognition of this market dynamic.

Users have a progressive interaction with information, as they dowith any new product or service. In this paper, we argue thatthere is a need and benefit cycle that leads to the introductionof any new product or service. Figure 21 depicts a cycle betweenthe provider of the information services and the user who willpay for these services that are offered. The cycle has fourelements:

o In this cycle, the supplier may have a need to distribute thenew service. They then offer this service to users.

o The users then perceive the benefits of this service. Thebenefit is a transient effect for the user. Through education andpromotion and persistence the benefit becomes a need.

o The consumer need establishes the basis of a market for this information service. Once established it delivers a set ofbenefits to the provider.

It should be noted that in information services as in all productintroductions, the time to go through this cycle may beextensive. We depict this cycle in Figure 21. Videotex is anexample. The need is there, yet the benefit proof has yet to beestablished.

7.2 Uses, Products, Goods or Services

The use to which a user puts the information gathered is acritical factor. Consider the analogy in Gore's infrastructureconcept to that of corn or wheat silos. Take specifically thesimilarity to corn. Each bit of information is a kernel of corn.As consumers, one is hard pressed to find any grocery store thatsells corn by the kernel. One may find processed, pre cooked,packaged frozen kernel corn, suitable for rapid heating,-preferably in a microwave oven. Sometimes, in season, one mayfind ears of corn. Rarely does one find kernels of wheat.Possibly in a health food store, and then only in California.

What one does find is a processed and usable form of the originalcommodity. More importantly one finds the commodity in a brandname package. "Birds Eye" frozen corn is the package that theconsumer buys. "Pepperidge Farm" bread is the form of wheatpurchased. The commodity has been not only transformed butrepackaged to get effectively to the consumer. The transformationcreates a product. The product can be a good or service.

We must then ask the question, what information is at the kernelof wheat stage and how does the information move from that pointto that of a consumable product such as a croissant. Clearlythere are many things that have to be done and many hands in theprocess. We argue that we must deal with information as aproduct, and that it is a product when and only when it is in acondition to be consumed by the user or consumer. Thatconsumption implies the ability to create or transfer value.

Let us return again to the Gore concept of every bit being animportant bit. Information is the ability to change state. If welook at an X-ray, we have typically 20 billion bits ofinformation in a typical chest X-ray. The information is in thesmall area that indicates a hilar mass from lymphodenapathy. This in turn is caused by a primary mass in the lumbar lobar lobe.Simply put, the information to change state is fifty to onehundred bits worth out of 20 billion. The productization ofinformation is the task of performing that processing and-developing the packaging.

7.3 Distribution Channel

Getting the product from a raw material form to a usable productin the hands of the user is the function of the distributionchannel. The distribution channel is the food chain of theeconomic entity. Having a link in the chain missing leads toattrition in the chain, starvation and death.

The distribution channel for information must take theinformation from it raw form, process and package it, distributeit to the users and support it during its useful lifetime. Let usfirst consider an example of information distribution consideredin the professional market, specifically the academic andresearch areas. Such companies as STN, Dialog and Nexus (MeadData Corp) operate data base systems and networks for access byend users. They acquire the rights to distribute such informationas whole text documents from professional journals and patentdatabases. The information is provided to these companies by thejournal perparers who act as the initial suppliers of the data.The database companies then mount or package the data on theircomputer systems, and then through their own networks or thepublic switched telephone system, they allow end users to accessthe information.

A specific example is the Dialog Medical Connection. A physicianmay turn on their computer and log into Dialog directly from amenu driven system. The logon then allows for the selection ofkeywords for searching. After some delimiting of the items available, the search is performed and the references, inabstract or whole text are delivered to the searcher. The systemnow allows a practicing physician to access the data directly.

In this specific example there are several roles. These roles areas follows (see Figure 22):

o Supplier: This is the primary data supplier. It may be the NewEngland Journal of Medicine that provides a full text data file,addressable and searchable by a Dialog data base system.

o Packager: This entity takes a set of disparate data sources andpackages them together for a specific user niche or verticalmarket. In this case the Medical Connection software andinterface selects sets of databases adequate for addressing theinterests of the practicing physician.

o Distributor: The entity creates a dynamic market for thepackaged set of information. The distributor deals directly withthe end user and does the sales, support, training and billingfunctions in this business.

o Network: This entity must provide a data communicationsinfrastructure for the information sources. Currently, whole text means only words. There are few data bases which provide thewhole article as image, including the figures. If the networkallowed for low cost ease of access and transport, then the wholearticle would be accessible.

All of these elements are part of the network. We show theseplayers in the distribution channel in Figure 22.

8.0 Conclusions

The vision of an information infrastructure should and must bebuilt upon a firm and well understood foundation of meaning ofinformation, its value in an economic context to a set of users,the world view of the designers, implementers and users, and theeconomic infrastructure that is needed to build and maintain it.- An information infrastructure as political rhetoric is speciousat best and serves the worst interests of all its stakeholders.In this paper we have provided answers to the questions that wehave posed as being essential in the examination and developmentof an information infrastructure.

Many of the current proposals call for the development of aphysical infrastructure. This physical infrastructure is beingconceived in a hierarchical and centralized fashion, by designerswhose world view is embedded in times past. The designers alsoreflect a belief in the efficacy of Governmental control and-management of resources and the need to have centralcoordination. They use as current paradigms the nationalinfrastructures used in other centralized nations wherein theinformation networks are perceived as national resources.

Comparisons are made to highway systems. However, feet, horses,donkeys, carriages and cars, existed for years before systems such as the national highway infrastructure was developed. As asystem of roads it met all of the requirements of aninfrastructure. However, information systems have been around forless than thirty years, and have been evolving at a very rapid pace. Innovation in these systems has been as a direct result ofunfettered entreprenurialism.

The authors argue that all of the elements of an informationinfrastructure are in place today. They are evolving at a rapid pace and at a pace that is economically effective and efficient.Ideas are evolving and the free market tests these ideas outagainst the economic realities and accepts those that pass thetest. Videotex did not pass this test in the United States. Itwas never given the change in France where it was mandated by thecollaborative efforts of the telephone company and thenewspapers. The matrix of computer networks, as described byQuarterman, has evolved with limited Government intervention. Infact, the most rapid evolution occurred during periods ofgovernment disinterest, rather than government focus

9.0 Glossary of Terms

Architecture: The conceptual embodiment of a world viewconstructed of the system elements utilizing the availabletechnology.

Benefit: An unexpected positive influence, of a monetary or nonmonetary nature, that is attained by a user of a service.

Centralized: A system philosophy that ensures the overalloperations of a system based upon a single and centrally locatedpoint of control and influence.

Control: The means of monitoring, managing, adapting, andreconfiguring all information network elements to ensure aconsistent level of service delivery.

Data Base: A device or set of devices that stores and retrieves data elements on one or many types.

Distributed: A system that has a fully disconnected andindependent set of elements that separately or together providefor all of the elements necessary for the support of the fullservice.

Distribution Channel: The complete and uninterrupted set of tasks and functions necessary to ensure the economic viable flow ofinformation goods and services from the source to the consumer ofthose services.

Hierarchical: A system with a single point of definition,development, management and control, with reporting relationshipsof all elements that flow ultimately upward to a dominant controlpoint.

Infrastructure: A sharable, common, enabling means to an end,enduring in a stable fashion, having scale of design, sustainableby an existing market, being the physical embodiment of anunderlying architecture.

Interconnect: The ability to and the systems necessary to effectthat ability to provide the connection between any viable set ofentities in a network.

Interface: The layers of protocols, tools, development mechanisms that enable an end user to achieve the maximum use of allresource available to them on the network to which it is attached.

Logical Infrastructure: An infrastructure wherein the commonalityis based upon the agreements on a single set of protocols thatoperate on different physical elements that may be underdisparate control and management.

Market: The collection of users who create an economicallyefficient and effective set of transactions for information.

Multimedia: The use of multiple sensory data and inputs by humanend users that allows for the interaction of the sensory datawith the user.

Multimedia Communications: A multimedia environment consisting ofmultiple human users in a conversational format in a temporallyor spatially based environment.

Need: The creation of a sustaining economic imperative based onconsistent benefits to a user.

Network: A transport mechanism combined with the interconnect andcontrol functions.

Paradigm: A specific example, experiment, or physical test casethat is used by a large group to explain a broad set of phenomenathat are directly or indirectly related to the underlyingphysical example. A typical set of examples are the use of theApple MAC icon screen to redefine human interface, the Watson andCrick view of DNA as the coding mechanism for life or waves usedby Maxwell to describe light.

Physical Infrastructure: A fully integrated, centrally controlledand defined and regulated physical embodiment of an architecture.

Process: An embodiment of a set of procedures in a softwareprogram to effect a set of well defined changes to input.

Processor: A physical device that is used to run a process.

Relational Infrastructure: An infrastructure that is the loosecoupling of totally independent sub infrastructures. Theinterfacing is built upon agreements to interface and the sharingof internal standards in each sub infrastructure.

Segmented: A structured partition between two tightly controlledsubnetworks.

Transport: The movement of physical information from a set ofpoints to another set of points.

User: Any entity or agent that uses resources on the network.

Value: An economic measure of the effectiveness of the use ofinformation.

Virtual Infrastructure: An infrastructure that is based uponcommon but disparate sets of protocols that are agreed to on thebasis of group decisions.

World View: A philosophy, either explicitly or implicitly,adopted by the system designer, owners, or managers, thatreflects the accepted limitations of the prevailing paradigm.

10.0 Acknowledgments

The authors would like to thank several individuals whosecomments and thoughts have led to a clearer focus in this paper.Specifically, Brian Kahin of The Kennedy School at HarvardUniversity has provided continuing intellectual support andcritiques of the ideas in this paper. Discussions with Drs.Vincent Chan and Al McLaughlin of MIT Lincoln Laboratory havealso provided significant input in several areas. Gustave Hauser,for whom both authors worked for several years, laid the groundwork of many of the economic realities of the business concepts.Discussions with Nicholas Negroponte, and years of joint-collaboration with his team at MIT have provided visions of userempowerment. Specifically, the senior author, beginning with highresolution displays and a vision of a conversational userempowerment worked closely with Professor Negroponte and his students in attaining its realization in an economically viable-environment. Professor Joel Moses of MIT has also providedseveral critiques that have been used in the preparation of this work. Lastly, the seminal work of Winograd and Flores has notonly been an inspiration of what information systems should bebut has also been a road map and bible of intellectualexploration.

The author was an employee of NYNEX at the time of the writing ofthis paper. The views expressed are those of the author only anddo not reflect those of NYNEX or any of its subsidiaries. Thepaper is based upon earlier work of the author while a Lecturerat MIT in the academic year 1989-1990.

11.0 References

1. Alpar, P., Kim, M., A Microeconomic Approach to the Measurementof Information Technology Value, Journal of ManagementInformation Systems, Vol 7, No 2, pp 55-69, Fall 1990.

2. Antonovitz, F. and Roe, T., A Theoretical and Empirical Approachto the Value of Information in Risky Markets: A Reply, TheReview of Economics and Statistics, Vol 70, No 3, pp 545-547,1988.

3. Arms, C., Campus Networking Strategies, DIGITAL Press (Maynard,MA), 1988.

4. Artamonov, G.T., The Laws and the Models of Pragmatic InformationScience, Automatic Documentation and Mathematical Linguistics,Vol 20, No 4, pp 70-75, 1986.

5. Avery, J.E., VAN, The Regulated Regime, Telecom and Posts Div,Dept of Trade and Industry, UK, Conf on Communications, IEE, pp78-81, May 1986.

6. Barlow, W. The Broadband Revolution, Info Tech and Pub Policy, Vl8, No 1, pp 6-8, 1989.

7. Barron, A.R., Cover, T.M., A Bound on the Financial Value ofInformation, IEEE Transactions on Information Theory, Vol 34, No5, Part 1, pp 1097-1100, September 1988.

8. Bell, D., The Coming of the Industrial Society, Basic Books (NewYork), 1973.

9. Bell, T., Technical Challenges to a Decentralized Phone System,IEEE Spectrum, pp 32-37, Sept., 1990.

10. Berkman, R., Information Quality: An Emerging Issue, NationalOnline Meeting Proceedings, pp 43-50, 1990.

11. Bernstein, J., Three Degrees Above Zero, Scribner's(New York),1984.

12. Blackwood, M.A., A. Girschick, Theory of Games and StatisticalDecisions, Wiley (New York), 1954.

13. Bostwick, W.E., Program Plan for the National Research andEducation Network, Dept. Of Energy, May, 1989.

14. Bowers, R.A., Getting Serious About the Information Age, OpticalInformation Systems, Vol 9, No 3, pp 131-134, May-June, 1989.

15. Barman, S., Defining Information: An Approach for Policymakers,Telecommunications Policy, Vol 13, No 3, pp 233-242, September1989.

16. Brealey, R., S. Myers, Principles of Corporate Finance, McGrawHill (New York), 1990.

17. Carnevale,M.L., "Untangling the Debate over Cable Television",Wall Street Journal, p. B1, March, 19, 1990.

18. Cole, S., The Global Impact of Information Technology, WorldDevelopment, Vol 14, No 10/11, pp 1277-1292, 1986.

19. Coll, S. The Deal of the Century, Atheneum (New York), 1986.

20. Copeland, T.E., J.F. Weston, Financial Theory and CorporatePolicy, Addison Wesley (Reading, MA) 1983.

21. Cordell, A.J., The Uneasy Eighties: The Transition To AnInformation Society, Computers & Society, Vol 16, No 4, pp 12-18,Winter-Spring 1987.

22. Couch, S., T.P. McGarty, H. Kahan, QUBE: The Medium ofInteractive Response, A Compendium for Direct Marketeers, DirectMktg Assn., pp 162-165, 1982.

23. Coy, P., How Do You Build an Information Highway, Business Week,pp 108-112, September 16, 1991.

24. Davis, S., B. Davidson, 2020 Vision, Simon and Schuster (NewYork), 1991.

25. de Sola Pool, I., Technologies Without Barriers, HarvardUniversity Press (Cambridge, MA), 1990.

26. de Sola Pool, I., The Social Impact of the Telephone, MIT Press(Cambridge, MA), 1977.

27. Depew, D.J., B.H. Weber, Evolution at a Crossroads, MIT Press(Cambridge, MA), 1985.

28. Dertouzos, M.L., Building the Information Marketplace, TechnologyReview, pp 29-40, January, 1991.

29. Dertouzos, M.L., Communications, Computers, and Networks,Scientific American, pp 62-69, September, 1991.

30. Dertouzos, M.L., et al, Made in America, MIT Press (Cambridge,MA), 1989.

31. Dertouzos, M.L., J. Moses, The Computer Age, MIT Press(Cambridge, MA), 1979.

32. Dertouzos, M.L., Personal Correspondence, March, 1991.

33. Dorfman, R.A., P.A. Samuelson, R.M. Solow, Linear Programming and Economic Analysis, Dover (New York), 1986.

34. Drucker, P., Adventures of a Bystander, Harper Row (New York), 1979.

35. Dugan, D.J., R. Stannard, Barriers to Marginal Cost Pricing in Regulated Telecommunications, Public Utilities Fortn., vol 116, No 11, pp 43-50, Nov 1985.

36. Eaton, J., Grossman, G.M., The Provision of Information as Marketing Strategy, Oxford Economic Papers, Vol 38, pp 166-183, Nov Suppl 1986.

37. Egan, B.L., Costing and Pricing of the Network of the Future, Proc of International Switching Symposium, pp 483-490, 1987.

38. Egan, B.L., T.C. Halpin, The Welfare Economics of Alternative Access Carriage Rate Structures in the United States, Telecom Journal, Vol 54, No 1, pp 46-56, Jan 1987.

39. Fleming, S., What Users Can Expect From New Virtual Wideband Services, Telecommunications, pp 29-44, October, 1990.

40. Fox, C., Future Generation Information Systems, Journal of the American Society for Information Science, Vol 37, No 4, pp 215-219, 1986.

41. Fruhan, W.E., Financial Strategy, Irwin (Homewood, IL), 1979.

42. Fulhaber, G.R., Pricing Internet: Efficient Subsidy, Information Infrastructures for the 1990's, J.F. Kennedy School of Government, Harvard University, Nov. 1990.

43. Gallagher, R.S., Information Theory, John Wiley (New York), 1967.

44. Gawdun, M., Private-Public Network Internetworking, Telecommunications, Vol 21, No 11, pp 49-58, Nov 1987.

45. Geller, H., US Domestic Telecommunications Policy in the Next Five Years, IEEE Comm Mag, Vol 27, No 8, pp 19-23, Aug 1989.

46. Ginman, M., Information Culture and Business Performance, International Association of Technological University Libraries Quarterly, Vol 2, No 2, pp 93-106, 1987.

47. Gore, A., Infrastructure for the Global Village, Scientific American, pp 150-153, September, 1991.

48. Graham-Tomasi, T., A Theoretical and Empirical Approach to the Value of Information in Risky Markets: A Comment, The Review of Economics and Statistics, Vol 70, No 3, pp 543-545, 1988.

49. Henderson, J.M., R.E. Quandt, Microeconomic Theory, McGraw Hill (New York), 1980.

50. Hills, J., Issues in Telecommunications Policy- A Review, Oxford Surveys in Information Technology, Vol 4, pp 57-96, 1987.

51. Hoffman, E., Defining Information - II: A Quantitative Evaluation of the Information Content of Documents, Information Processing & Management, Vol 18, No 3, pp 133-139, 1982.

52. Huber, P.W., The Geodesic Network, U.S. Department of Justice, Washington, DC, January, 1987.

53. Hudson, H.E., Proliferation and Convergence of Electronic Media, First World Electronic Media Symposium, pp 335-339, 1989.

54. Ingwersen, P., Pejtersen, A.M., User Requirements - Empirical Research and Information Systems Design, Information Technology and Information Use: Towards a Unified View of Information and-Information Technology Conference, pp 111-124, 1986.

55. Irwin, M.R., M.J. Merenda, Corporate Networks, Privatization ans State Sovereignty, Telecommunications policy, Vol 13, No 4, pp329-335, Dec 1989.

56. Jantzen, H., High Gothic, Princeton University Press (Princeton, NJ), 1984.

57. Kahin, B., The NREN as a Quasi-Public Network: Access, Use, and Pricing, J.F. Kennedy School of Government, Harvard University, 90-01, Feb., 1990.

58. Kahn, A.E., The Economics of Regulation, MIT Press (Cambridge, MA), 1989.

59. King, D.W., Griffiths, J-M., Evaluating the Effectiveness of Information Use, Evaluating the Effectiveness of Information Centres and Services Conference, AGARD France, p 1/1-5, Sept 5-6-1988.

60. Kirstein, P.T., An Introduction to International Research Networks, IEEE Int Council for Comptr Comm, Ninth International Conf, pp 416-418, 1988.

61. Kohno, H., H. Mitomo, Optimal Pricing f Telecommunications Service in Advanced Information Oriented Society, Proceedings of International Conf on Info Tech, pp 195-213, 1988.

62. Kolmogorov, A.N., Three Approaches to the Quantitative Definition of Information, International Journal of Computer Mathematics, Vol 2, No 2, pp 157-168, 1968.

63. Konsynski, B.R., E.W. McFarlan, Information Partnerships - Shared Data, Shared Scale, Harvard Business Review, pp. 114-120, September-October, 1990.

64. Kraus, C.R., A.W. Duerig, The Rape of Ma Bell, Lyle Stuart (Secaucus, NJ) 1988.

65. Kuhn, T.S., The Structure of Scientific Revolutions, Univ Chicago Press (Chicago), 1970.

66. Lawrence, P.R., D. Dyer, Renewing American Industry, Free Press (New York), 1983.

67. Luce, R.D., H. Raiffa, Games and Decisions, Dover (New York), 1985.

68. Mandelbaum, R., P.A. Mandelbaum, The Strategic Future of Mid Level Networks, J.F. Kennedy School of Government, Harvard University, Working Paper, October, 1990.

69. Markoff, J., Creating a Giant Computer Highway, New York Times, Sept. 2, 1990.

70. McGarty, T.P., B. Pomerance, M. Steckman, CATV for Computer Communications Networks, IEEE CompCon, 1982.

71. McGarty, T.P., Business Plans, J. Wiley (New York), 1989.

72. McGarty, T.P., Financial Data Networking and Technological Impacts, INTELCOM, 1980.

73. McGarty, T.P., G.J. Clancey, Cable Based Metro Area Networks,IEEE Jour on Sel Areas in Comm, Vol 1, No 5, pp 816-831, Nov1983.

74. McGarty, T.P., Growth of EFT Networks, Cashflow, pp 25-28, Nov.1981.

75. McGarty, T.P., L.L. Ball, Network Management and Control Systems,IEEE NOMS Conf, 1988.

76. McGarty, T.P., Local Area Wideband Data Communications Networks,EASCON, 1982.

77. McGarty, T.P., M. Sununu, Applications of Multi-MediaCommunications Systems to Health Care Management, HIMSSConference, San Francisco, Feb. 1991.

78. McGarty, T.P., Multimedia Communications in Diagnostic Imaging, Investigative Radiology, April, 1991.

79. McGarty, T.P., Multimedia Communications Systems, IMAGING, Nov.1990.

80. McGarty, T.P., Network Infrastructures for the 1990s, HarvardUniversity, Kennedy School of Government, November, 1990.

81. McGarty, T.P., Personal Correspondence to M. Dertouzos, February,1991.

82. McGarty, T.P., R. Veith, Hybrid Cable and Telephone Networks,IEEE CompCon, 1983.

83. McGarty, T.P., S.J. McGarty, Impacts of Consumer Demands on CATVLocal Loop Communications, IEEE ICC, 1983.

84. McGarty, T.P., S.T. Treves, Multimedia Network Architectures,SPIE Conference on Fiber Optics, September, 1991.

85. McLean, M., The Gutenberg Galaxy, Univ Toronto Press (Toronto),1962.

86. McLean, M., Understanding Media, NAL (New York), 1964.

87. Morton, M.S.S., The Corporation of the 1990s, Oxford (New York),1991.

88. Moses, J., Complexity, Flexibility, and Organizations, MITReport, December, 1990.

89. Muroyama, J.H., H.G. Stever, Globalization of Technology,National Academy Press (Washington, DC), 1988.

90. Murphy, A.H., Ye, Q., Optimal Decision Making and the Value ofInformation in a Time-Dependent Version of the Cost-Loss RatioSituation, Monthly Weather Review, Vol 118, No 4, pp 939-949,April 1990.

91. Noam, E. M., Network Tipping and the Tragedy of the CommonNetwork, J.F. Kennedy School of Government, Harvard University,Working Paper, October, 1990.

92. Nugent, P.M., User Objectives in the Development of InternationalTelecommunications Policy, Inf. Age, Vol 7, No 4, pp 200-202, Oct1985.

93. O'Hara, S., The Evolution of A Modern Telecommunications Networkto the Year 2000 and Beyond, IEE Proc, Vol 132, No 7, pp 467-480,1985.

94. Pindyck, R.S., D.L. Rubinfield, Microeconomics, McGraw Hill (NewYork), 1989.

95. Porter, M., Competitive Advantage, Free Press (New York), 1985.

96. Porter, M., Competitive Strategy, Free Press (New York), 1980.

97. Porter, M., The Competitive Advantage of Nations, Free Press (NewYork), 1990.

98. Quarterman, J.S., The Matrix, Digital Press (Maynard, MA), 1990.

99. Raisbeck, G., Information Theory, MIT Press (Cambridge, MA),1963.

100. Roberts, J., Battles for Market Share: Incomplete Information,Aggressive Strategic Pricing, and Competitive Dynamics, Advancesin Economic Theory, No 12, pp 157-195, 1987.

101. Rouse, W., On the Value of Information in System Design: A Framework for Understanding and Aiding Designers, InformationProcessing & Management, Vol 22, No 2, pp 217-228, 1986.

102. Rutkowski, A.M., Computer IV: Regulating the Public InformationFabric, Proc of the Regional Conf of the International Councilfor Computer Communications, pp 131-135, 1987.

103. S. 898, U.S. Senate Hearings on Telecommunications Competition,Serial No 97-61, June, 1981.

104. Salton, G., Some Characteristics of Future Information Systems,SIGIR Forum, Vol 18, No 2-4, pp 28-39, Fall 1985.

105. Schalkwijk, J.P.M., On a Quantitative Definition of Informationand Its Impact on the Field of Communications, Reports on theProgress of Physics, Vol 45, No 11, pp 1213-1260, 1982.

106. Schell, G.P., Establishing the Value of Information Systems,Interfaces, Vol 16, No 3, pp 82-89, May-June 1986.

107. Shubik, M., A Game Theoretic Approach to Political Economy, MITPress (Cambridge, MA), 1987.

108. Shubik, M., Game Theory in the Social Sciences, MIT Press(Cambridge, MA), 1984.

109. Silverman, K., Semiotics, Oxford(New York), 1983.

110. Sirbu, M.A., D.P. Reed, An Optimal Investment Strategy Model forFiber to the Home, International Symposium on Subscriber Loops tothe Home, pp. 149-155, 1988.

111. Spulber, D.F., Regulation and Markets, MIT Press (Cambridge, MA),1990.

112. Szewczak, E.J., King, W.R., Organizational Processes as Determinants of Information Value, Omega International Journal ofManagement Science, Vol 15, No 2, pp 103-111, 1987.

113. Tannenbaum, A., Computer Communications, Prentice Hall (EnglewoodCliffs, NJ), 1989.

114. Temin, P., The Fall of the Bell System, Cambridge Univ Press(Cambridge), 1987.

115. Thorelli, H.B., The Future for Consumer Information Systems,Consumerism: Search for the Consumer Interest, pp 115-126, 1980.

116. Tirole, J., The Theory of Industrial Organization, MIT Press(Cambridge, MA), 1990.

117. Tjaden, G., CATV and Voice Telecommunications, IEEE ICC, 1984.

118. Toffler, A., The Adaptive Corporation, Bantam (New York), 1985.

119. Toy, S., Castles, Heinemann (London), 1939.

120. Turoff, M.. Information, Value and the Internal Marketplace, Technological Forecasting and Social Change, Vol 27, No 4, pp357-373, 1985.

121. Vickers, R., T. Vilmansen, The Evolution of TelecommunicationsTechnology, Proc IEEE, vol 74, No 9, pp 1231-1245, Sept 1986.

122. Von Auw, A., Heritage and Destiny, Praeger (New York), 1983.

123. Von Hippel, E. The Sources of Innovation, Oxford (New York),1988.

124. Von Neumann, J., O. Morgenstern, Theory of Games and Economic Behavior, Wiley (New York), 1944.

125. West, E.H., et al, Design, Operation, and Maintenance of a MultiFirm Shared Private Network, IEEE MONECH Conf, pp80-82, 1987.

126. Wiener, N., The Human Use of Human Beings, Avon (New York), 1967.

127. Wiener, N., God and Golem, MIT Press (Cambridge, MA), 1964.

128. Wiener, N., Cybernetics, MIT Prss (Cambridge, MA), 1957.

129. Wilkes, M.V., The bandwidth Famine, Comm ACM, pp 19-21, Vol 33,No 8, Aug 1990.

130. Williams, M.E., Highlights of the Online Database Industry andthe Quality of Information and Data, National Online MeetingProceedings, pp 1-4, 1990.

131. Winograd, T., F. Flores, Understanding Computers and Cognition,Addison Wesley (Reading, MA), 1987.

132. Wirth, T.E., Telecommunications in Transition, U.S. House ofRepresentatives Committee Report, Nov, 1981.

133. Wolfe, T., From Bauhaus to Our House, Simon and Schuster (NewYork), 1981.

134. Zuboff, S., In the Age of the Smart Machine, Basic Books (NewYork), 1988.

12.0 Figures

Figure 1: Information Value

Figure 2: Information Business Elements

Figure 3: Information Architecture