THE SPATIAL ENABLING OF INFORMATION PARADIGM

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ABSTRACT

Information Technology with the Internet and increasingly high-bandwidth wireless communications has become the backbone of the new world economy. Software-hardware-communications. Data-information-decisions. They all have become interlinked to create a new world order and as such, new work-flow paradigms and tools are required to effectively integrate and transform data into useful information to make decisions.

With the maturing of geospatial technologies such as GIS, GPS, Digital Photogrammetry, and Remote Sensing, locational facts have now become a key component of the decision-making process. Beyond system to system integration, the embedding of locational facts requires the design, development, and implementation of new solutions that integrate geospatial, information and communications technology aimed at optimizing process work flows, improve the decision making process and reduce operating costs in an innovative way. This integration process is defined as the "*spatial enabling of information*".

Coupled with these mature geospatial technologies, the advent of high-resolution imagery and new -more "intelligent"- technologies for the automation of pattern recognition and feature extraction, based on expert systems and object oriented technology, paves the way for a work-flow paradigm shift in the automated process of transforming data into information.

This paper presents the most relevant paradigm shifts in information and geospatial technology, it illustrates the three cardinal principles of postmodern technology: miniaturization, digitization and synthesis, and how they relate to innovative information-centric solutions. As part of the digital convergence paradigm, this paper elaborates on the power of the concept of "spatial enabling" and how it applies to new work-flow processes that encompass integrating evolving technologies to more effectively transform spatially enabled data to information.

KEY WORDS
Geospatial technologies, Automation, Software-hardware-communications, Data-information-decisions.

1. INTRODUCTION

With all the wealth of information and with the speed that it is reaching us, for those of us in the Information Technology field in general, and GIS in specific, it is not difficult to see what is coming. One thing for certain is that "it" will keep getting smaller, faster, and comparatively cheaper.

A true visionary will see beyond that sea of information, a Jules Verne or Leonardo Da Vinci type (flying before any one had conceived airplanes, going to the moon before the existence of rockets). Man is a true wonder when it comes to the creation of artifacts and pushing the threshold of the discovery.

In the early days of the radio a survey was made to ask users how they felt that the radio could be improved. Many came with suggestions like bigger knobs, better lid display, and others. Yet, nobody requested to see the person that was talking. This is part of envisioning where technology is going. But eventually someone did come that not only requested to see the person talking but made it happen.

GIS is a part of this scientific discovery journey. GIS is a result of the Geographer wanting to go beyond paper maps and into more complex and productive spatial reasoning. Leave the number crunching behind, let the machine do it, and take the new available time to more reasoning and making better decisions. But this is not unique to GIS. This is also part of what information systems in general are all about: organized data, organized information.

The evolution of certain technologies is a cascading effect. Take for example the airplane. The basic principles and fundamentals have not changed. Advances in scientific knowledge, methods and tools in aerodynamic tunnels, numerical and CAD systems, atmospheric and space physics, propulsion systems, and so forth, have produced a more advanced, but very similar looking to the early concept, airplane. (Note: we will not need the airplane once teletransportation systems "a la Stark Trek" are invented.)

The reason I take the airplane example is because that is how I see GIS evolving. Cascading technologies that will improve and affect the evolution of GIS. There are two areas of domain that we can talk about GIS. On the one hand there is the R&D side of it and on the other, there is the use, application, of the technology. Again, this duality is not unique to GIS, but a result of being a technology.

1.1. PEOPLE AND TECHNOLOGICAL ADVANCES.

Of all the information technology advances, the one that marked the transition from a potential to an information revolution was the discovery of the microprocessor and with it personal computing devices. The microprocessor revolution resulted to be the enabler: hardware companies pushing the threshold of what could fit on a silicon chip as well as to what could be done with it. This path of miniaturization continues today.

PCs gave way to the Work Station market, and yet more even powerful PCs to the point where from the practical point of view it is hard today to distinguish one from the other. Xerox's research center, PARC, became the center of what was going to revolutionize the way how people interacted with computers (Kearns and Nadler, 1992). PARC forged the future for today's windows graphical user interfaces (GUI), the mouse, the laser printer, the bit map display, Ethernet, multimedia, the work station and concurrently with IBM the reduced instruction set computer (RISC). In those days Xerox was able to develop more new technology than it could commercially launch. Companies such as APPLE, INTEL and MICROSOFT thrived under this revolution. SUN gave way to the era of the workstations and the likes of Hewlett Packard and Silicon Graphics gave it presence and permanence in today's competing markets.

GIS in the midst of this revolution (70s, early 80s) had to tackle problems of primary algorithmic nature: solving the polygon overlay problem, line generalization, vector intersection, efficient spatial indexing and searching, and others. Like PARC for hardware and software, places like the Harvard Computer Graphics Laboratory and the GIS Laboratory at the State University of New York at Buffalo were the crib to what was to become GIS.

During the mid 70's and early 80's GIS was looking for its own identity attempting this by borrowing concepts and methodologies from Computer Science, Management Information Systems and other related disciplines. Today there is still no holistic body of scientific knowledge that can be termed as "a GIS discipline". Part of the problem is that we tend to confuse GIS as a tool from GIS as a discipline. The tool is the enabler. The discipline is not one but multiple disciplines. GIS is a multidisciplinary tool, hence the body that contributes to the R&D of GIS is also of the same multidisciplinary nature.

Advances in computational geometry, data base management systems and more powerful central processing units (CPUs), more random access memory (RAM) and more disk space allowed, GIS in the early 80's to finally come to life as a practical technology. So where is GIS going in the twenty first century and the years to come?

2. TECHNOLOGICAL CONVERGENCE

GIS technology is part of a larger picture of technologies called Information Technologies (IT). The one particular thing about GIS is that its data is of spatial nature: a spatial datum is locatable in a given space under a predefined coordinate system, it is relate able to other spatial datum and the spatial datum can be described. Other than this, GIS faces the same kind of problems than any other IT system, more so with the growing presence of multimedia systems, where the spatial component is one more of the data sources that it must handle.

GIS has borrowed from mathematics (topology), geometry (computational geometry), computer graphics, computer aided design, data base management, geography and other related disciplines, to cast its technological purpose. This is at the core of what GIS is all about: an integrating technology. A technology unto which many other technologies converge.

Today's GIS have reached a level of functional technological convergence that makes it hard for the potential user to distinguish one commercial product from another. This is a sign of maturity. This maturity has been reached via various iterations of research and development. The first concern was that the technology actually worked, that it was reliable and robust. Later users began to demand a level of increasing functionality as their level of sophistication in using the technology also increased. The drawback of this increase of functionality was added complexity in learning and using the system. This created the pressure to simplify usage and make the systems more amicable and easier to use. GIS in this respect still remains largely in the domain of the specialist. This problem remains at the crux of making GIS available to the masses.

However, as we will see, certain technological shifts are providing the momentum to allow for GIS to migrate to the masses under a form that it is not any longer necessary for a common person to know how to use or what it is GIS. The underlying technology in the product being used just "tells them", where they are, how to get there, or describe the surroundings, among other "spatial things".

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3. HISTORIC TECHNOLOGICAL SHIFTS

The advent of the PC product, beginning with the APPLE MAC, gave way to a new computing paradigm that empowered the masses to know about computers and to undertake and solve more intricate problems with the aid of PCs. Early PCs however did not have the power necessary to run GIS software. The introduction of the INTEL 286 processor and later on the family of Intel processors in the MHz speed domain, made the potential for GIS to become a ubiquitous technology, a reality.

The benefits that the MAC and later on the WINDOWS software products brought is that they made us, the GIS R&D people, realize that unless there was an adequate metaphor to handle the real world in the computer, that users would have a hard time, hence a higher level of resistance, to using computers. The des top world, a finite and well-defined set of tools and activities were castled to graphical user interfaces that became intuitive with time and accessible to just about all computer neophytes.

It was not until the mid to late 80s that GIS companies began to adopt GUIs as their front end. However, most of these interfaces were just a "translation" of the command version of the system, to a graphical point and click version. These interfaces lacked the metaphor that has made Desktop computing so popular. Part of the reason is that handling the real world "real world" (not just the desk top real world) is a much more complex endeavor and representation. Part of the problem also is that GIS until now has only automated processes, and until recently, not really changed how we do things.

For instance, maps are still being done in many ways in the traditional sense. The difference is that instead of using drafting tools, we use digital tools. How a map is produced and used has not in essence changed. Hence our way of thinking in this respect has not changed very much either. There is however a wave of new technologies that may change forever how we produce and deal with maps. There is also a paradigm shift in how information technology is reinventing the enterprise. These shifts are affecting the evolution of GIS.

3.1. PARADIGM SHIFT

In his book "Paradigm Shift, the New Promise of Information Technology" Don Tapscott with Art Carson (1993) points out that many business leaders are working hard to reinvent their enterprises. The organization of old is considered in trouble. The command and control hierarchy established centuries ago is often bureaucratic, inwardly focused, unresponsive, unproductive, and stifling.

It is said that to meet the coming global challenges that the new enterprise has to be dynamic and be able to respond quickly to changing market conditions. Its structure is radically different by being flat, eliminating bureaucratic hierarchy. It is based on commitment rather than control. Business processes are reengineered for productivity and quality. It is open-focused outward-and networked redefining the traditional boundaries of the company.

The challenge to change the way the enterprises work entails a holistic view at five key components which mark the success or failure of any company: 1) talent, 2) time, 3) technology 4) tools and 5) tasks. GIS is concerned with these five issues and it will play an important role in the new technology paradigm, the new business environment, the new geopolitical order (relevant because of the strong geographic component) and the new enterprise. Figure 1 summarizes what these new situations mean (after Tapscott 1993).

These new situations challenge the current order of 1) technology, 2) organizations, 3) people and 4) methodologies and processes.

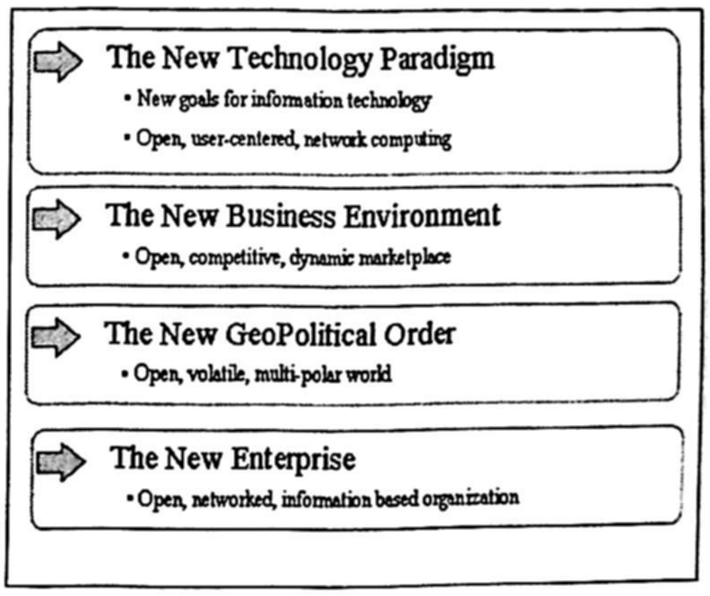

Figure 1. New Shifts.

The importance of looking at GIS under this light resides on the fact that, as previously mentioned, that GIS belongs to a larger array of technologies termed Information Technologies (IT), hence how the overall scope of IT affects the way companies become more efficient impacts the way GIS is evaluated. Also, GIS because of its spatial nature, is a tool that can readily support decision-making at many levels of this spatial domain.

For many years and until recently, IT has been primarily used to automate existing ways of working and existing business process, hence it is of no surprise that GIS has followed a similar path. Confronted with overgrown and inefficient corporate structures, the latter part of the 90s saw with great disappointment what was though to be a failure on the part of information technology.

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As corporations worldwide began an intimate inner look at how to improve themselves, pioneers such as IBM began to develop a series of measures that coupled with a more adequate use of IT has yielded tremendous results. This pioneering work gave way to a new paradigm based on three critical shifts in the application of information technology.

The new IT enables enterprises to have 1) high-performance team structure, 2) to function as integrated business despite high business unit autonomy, and 3) to reach out and develop new relationships with external organizations.

All in all, these new trends are redefining the person-computer relationship into a paradigm that basically lays the principles and foundation for what this relationship is all about: the human-centered computing paradigm.

The human centered computing paradigm has as a center theme that computers learn about their users and adapt to their needs. It is a shift from GUIs to VUIs (voice-driven user interface). VUIs will go beyond "light on/light off" scenarios into complex communication protocols. Figure 2 depicts the impact of VUIs in the human-centered paradigm and GIS.

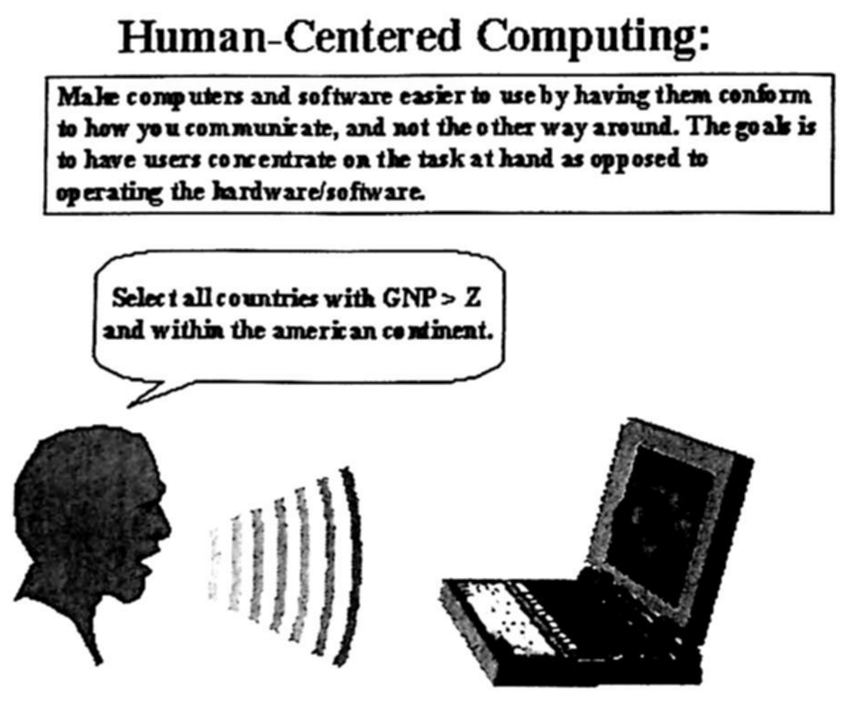

Figure 2. Human-Centered Computing.

GUIs from PARC and VUIs from concurrent and convergent technological shifts. Let us now examine the key technological shifts that will impact the evolution of IT in general and GIS in particular (shifts summarized from BusinessWeek, July, 2001):

3.2. SHIFT 1 - FROM TRADITIONAL SEMICONDUCTORS TO MICROPROCESSORS BASED SYSTEMS

The microprocessor, a computer on a chip, is at the center of this human centered computing paradigm. Traditional semiconductor technology, which twenty years and as recent as ten years ago, filled the cabinets of the mainframes and minicomputers in corporate data centers is being replaced by intertwined sets of microchips. Microprocessors are continually dominating leading edge computers (and "gizmos") of every size.

The microprocessor established the precondition for the new way of computing; it has changed everything we know about computing, the applications that are possible, computer architectures, and technology policy, not to mention the IT industry itself. Most important, the microprocessor enables empowered, distributed computing architectures to support the empowered, networked organization.

3.3. SHIFT 2 - FROM HOST BASED TO CLIENT/SERVER SYSTEMS

During the "first era of computing" devices interacted in a master/slave framework. Mainframes or minicomputers had slave terminals attached to them, typically dumb terminals with cryptic alphanumeric user interfaces. The enterprise also became populated with islands of personal computers, some attached to local area networks that enabled the simple sharing of files and devices like printers.

Now, because of the spectacular power of the microprocessor and the maturity of networking technology and standards, a fundamentally different style of computing has emerged, generally known as client/server computing, the approach coupled with Internet-based technology provides users to the access of a wide range of information, applications, and computing resources without worrying where they are or where they are connected.

Most importantly, software is processed not only on a host, but wherever it makes most sense. Software is not limited to one machine, but can be processed "cooperatively" on various computers across the network.

This client-server approach allows to integrate information across the organization. Client/server computing, like organizational empowerment, moves intelligence out into the enterprise. It enables powerful new multimedia applications that integrate data, text, voice, image, and video. This enables to have architectures that exploit the power of concurrent microprocessor technology.

For the years to come, the computing world will be a hybrid of very large servers (some kind of new generation of mainframes) and a new generation of mobile computing devices (more than just a PC as it is known today). Because mobile computing devices (specially wireless) offer clear advantages, such as speed, flexibility and enormous utility as a creative tool, these devices will allow to create "more intelligent computing" as they become part of a complex futuristic network.

3.4. SHIFT 3 - FROM VENDOR PROPRIETARY SOFTWARE TO OPEN SOFTWARE STANDARDS

One of the cornerstones for the success of the new paradigm in computing has been Open Systems, systems that are open to interconnectivity, interoperability and scalability. This shift has occurred to try to put an end to the "computing Tower of Babel". The open systems approach has laid the foundation for clear conceptual work and an understanding of the objectives pursued. Lets briefly define the various terms embraced by open systems of interconnectivity, interoperability and scalability.

Interconnectivity refers to hardware/software platform connectivity, i.e. all hardware/software connects and communicates to all hardware/software available in a user "transparent mode". In the client/server model, processing is distributed rather than centralized. Centrality if necessary can be created via "virtual" centers, centers that are distributed but perceived by the user as centralized.

Application *interoperability* refers to applications and computers from different vendors to work together on a network. This environment nurtures the portability of applications, data and people.

Application *scalability* allows the use of same application and system software on all classes of computers (from mobile devices to super computers).

The most important aspect of open systems is that it has the potential of shifting paradigms by actually changing in a more effective way how people do their work.

The move toward open systems can redefine workflows and changes people's work patterns through immediate and universal access to the information needed and processes to complete a given task. Consequently, decisions about migrating toward open systems require an organizational perspective in addition to the view of a technologist ("The Government Executive Open Systems Handbook", GT Publications Inc., 1993).

Open systems, based on industry standards not controlled by any one vendor, are transforming the computer industry and presenting a monumental challenge to commercial organizations alike. Standards are arising in all areas of computing, including communications, databases, user interfaces, operating systems, and software development tools.

Open systems result in information and software being portable, i.e. they can run on any hardware platform regardless of size or make. More important, standards also enable different systems to interoperate or communicate with each other.

Openness is not black or white. Standards and products have various degrees of openness, based on criteria such as vendor neutrality, platform availability, compliance with formal standards, and market penetration.

It is true that there are many competing standards, an oxymoron, indeed. But leading companies have concluded that adequate clarity exits to embrace the concept.

Research has showed that open systems have far-reaching advantages over the traditional approach. Standards are necessary to be effective in the new competitive business environment. Standards are required to link customers', suppliers', and competitors' systems. And standards are required to achieve integration of information. Standards in general and open systems in particular do not simply provide benefits. They are becoming imperative to create the kind of modular, flexible, powerful, networked computing architecture required by the new business environment (Tapscott 1993)

Standards are also transforming the computer industry by preventing the reinvention of wheels, as software suppliers include standard components and interfaces in their products.

3.5. SHIFT 4 - FROM SEPARATE DATA, TEXT, VOICE AND IMAGE TO MULTIMEDIA

In the early years of computing and even until recently, the immaturity of the various technologies involved and the absence of open standards meant that these four forms of information, data, text, voice and image, were separate and that separate technologies were needed to manage them.

Data processing systems handled numerical data. Word processing systems handled text. Telephone and dictation systems handled voice data. Photocopiers and microfilm systems handled image data. As the information contained in these systems becomes digitized, and as standards grow, the opportunity to integrate them is unfolding.

Multimedia computing is natural computing. These systems work the way people do, by integrating these forms of information into business processes and daily life.

3.6. SHIFT 5 - SOFTWARE DEVELOPMENT, FROM CRAFT TO FACTORY

Software has gone through a fundamental transformation. It has become an engineered profession using factory-of-the-future production techniques. Developers have moved towards an approach that enables the efficient reuse of software components (object oriented). Object-oriented computing allows programmers to create blocks of software called objects instead of large, complex, monolithic, tightly intertwined software programs. Objects are developed in standard ways and have standard behaviors and interfaces. These Lego-like pieces enable the rapid assembly of software rather than its laborious crafting.

With the advent of visual programming and computer aided software engineering, the software industry has become a parts industry, and through standards, software vendors create standard parts that enable customers to rapidly assemble computing environments.

This object-oriented paradigm has three components: object oriented analysis and design, object oriented programming and object-oriented databases. Of these three one and two are the best understood and applied. Object oriented databases are still conceptually and practically evolving as they attempt to encompass the relational model as well.

4. IMPACT OF TECHNOLOGICAL SHIFTS ON GIS

It has been over two decades since the first successful introductions of commercially available Geographic Information Systems (GIS). There has been many a contributor to make it happen, but none more so than people like Roger Tomlinson (the person who first coined the term "GIS") and Jack Dangermond (the person who led GIS to become a practical reality).

In conjunction with the Information Technology business, there have been significant advances in Geographic Information Systems since the term was first coined over three decades ago.

While GIS is certainly a subset of IT, the treatment of spatial data from a technology and organizational perspective has always been distinctly separate. For example, it is still quite common to find an Information Services Department and a GIS Department within any given organization. Since these early systems emphasized the importance of Geographic data with lesser importance given to the underlying information technology, we apply the designation <u>Gis</u>. Due to Gis' unique language, skills, and data processing, organizations have traditionally created user communities outside of the main IT domain. Fortunately, with the advent of newer technology and the acceptance of spatial information in the decision-making process, this Gis and IT trend is merging. In more recent years, we've entered the GIS era where processing of spatial information has become less dependent on proprietary software and data structures and now embraces common mainstream IT architecture to the point that completes incorporation of spatial data processing into the IT realm is at hand, hence the designation "**<u>gIS</u>**".

From a historical perspective, the changes from **Gis** to **GIS** to **gIS** have occurred in roughly ten-year cycles. During the 1975 to the 1985 period, **Gis** was dominated by unique, costly, computer systems that offered little more that automated mapping capabilities. In fact, a significant achievement in this era was the simple capability of linking attribute data to line geometry was considered "state-of-the-art". People associated with the systems of this era were traditionally geographers in search of tools to perform their mapping task, which resulted in a tenuous relationship between the geo-processing and traditional data processing groups.

During the 1985 to 1995 period, significant geo-processing advances such as spatial analysis, attribute posting from relational databases, and high quality cartographic output from the systems evolved. However, these systems were still dominated by unique, proprietary software code and underlying databases, not to mention the high cost of obtaining and maintaining this technology. For these reasons, GIS was usually found only in organizations where the financial and human resources could support the system operation. Because of this esoteric nature of GIS technology in this period, full incorporation of spatial information into the organization's decision-support process was never fully utilized.

With the dawn of major IT advances in the 1990's, such as powerful relational databases, miniaturization of the hardware platforms, and easy-to-use operating system, the business of geographic data processing began to evolve at a more rapid pace. The cost of ownership dropped dramatically and the number of system users rose in proportion. Incorporation of spatial information into the decision-support process became commonplace to the point that maps delineating the various geographic features are common communication tools. Because of this incorporation of mainstream IT tools into the GIS platform, this era is referred to as **gIS**.

All indications are the trend will continue to the point we enter an era referred to as **gIs** where the emphasis on *Information* is dominant and the underlying IT and spatial tools are a of secondary importance. There are a number of technical and social factors that support this assumption, with perhaps the most important being industry statistics.

The following graphic can summarize this evolution:

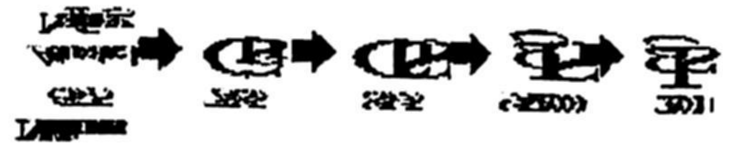

Figure 3. GIS evolution.

Gis depicts the era when geographic methods (in principle mainly cartography) were attempting to move to the computer, automated domain. During that period the computer industry, and in particular database technology (the relational model) as maturing and preparing for a paradigm shift.

GIS depicts the convergence of mature information systems technology with geography. Hence geographic information systems start to become a practical technology (a tool if you will). During this period GIS' systems approach is geocentric –everything revolves around the GIS.

gIS defines an era where it is recognized that geography as important as it may be, is part of a larger whole. The focus is on the information system and this establishes a GIS implementation approach that is more system-centric.

gIs defines the beginning of an era that is information-centric. The essence of having a GIS or any information system is to have information easily and readily accessible. The effort is focused in data integration, data warehousing, data mining –the conversion of data into information. I call this "the power of I". The following diagram illustrates the concept.

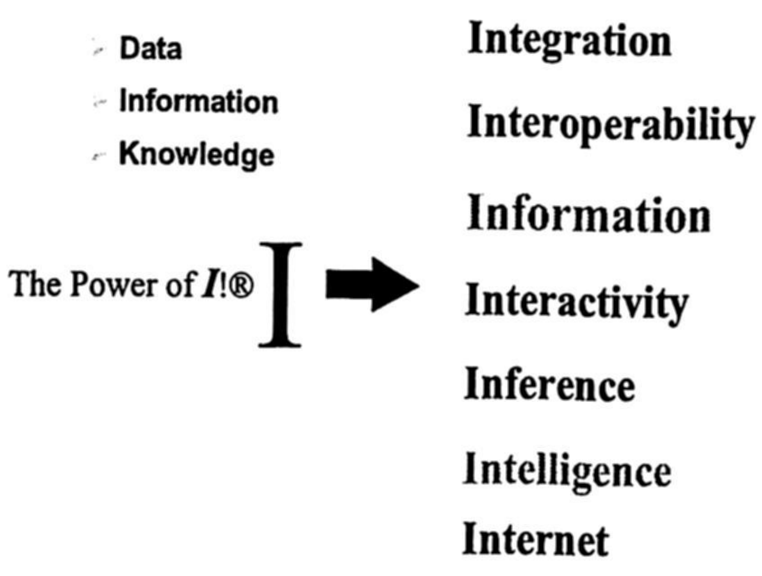

Figure 4. Different elements to integrate "I".

4.1. THE SPATIAL ENABLING OF INFORMATION®

We can summarize that the three forces that have driven recent information technological shifts are:

1. Miniaturization – electronics getting smaller and more powerful
2. Digitization – all data sources are now digital
3. Convergence force 1 and 2 coming together

These three forces have allowed to move from a data-centric world, to an information-centric world. As such, it is also the case of GIS, moving from a geocentric systems approach, to an information centric systems approach. Information Technology with the Internet and increasingly high-bandwidth wireless communications has become the backbone of the new world economy. Software-hardware-communications. Data-information-decisions. They all have become interlinked to create a new world order and as such, new work-flow paradigms and tools are required to effectively integrate and transform data into useful information to make decisions.

With the maturing of geospatial technologies such as GIS, GPS, Digital Photogrammetry, and Remote Sensing, locational facts have now become a key component of the decision-making process.

Beyond system to system integration, the embedding of locational facts requires the design, development, and implementation of new solutions that integrate geospatial, information and communications technology aimed at optimizing process work flows, improve the decision making process and reduce operating costs in an innovative way. This integration process is defined as the ***"spatial enabling of information®"***.

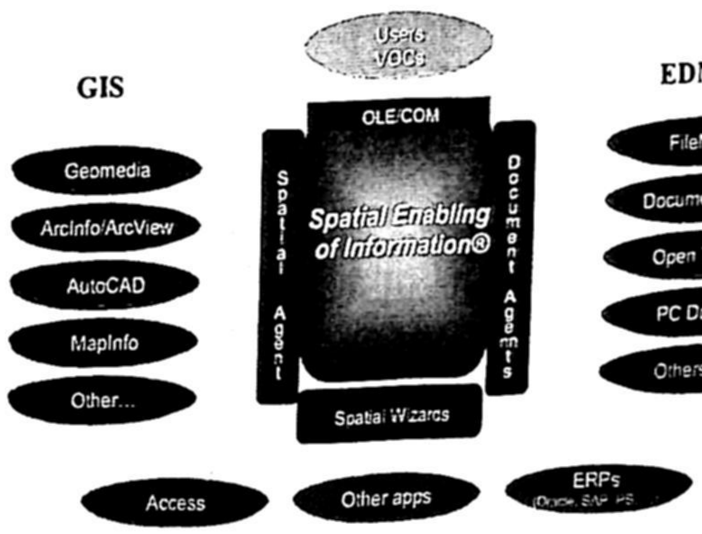

Figure 5. Spatial Enabling of Information.

Coupled with these mature geospatial technologies, the advent of high-resolution imagery and new -more "intelligent"- technologies for the automation of pattern recognition and feature extraction, based on expert systems and object oriented technology, paves the way for a work-flow paradigm shift in the automated process of transforming data into information.

The future GIS tools will become increasingly transparent to the user much like the IT business in general. Furthermore, it will have the capability to mold around the user's workflow instead of placing rigorous restraints on operations.

5. CONCLUSIONS

Visionaries, those that always ask "why not?".

In the quest for making a better world, indeed GIS has played and will continue to play a major role as a data integration tool. But beyond the tool, within an information centric view, GIS has provided the underlying bedrock to support a new emerging paradigm known as the "spatial enabling of information". This paradigm leverages more than anything does the force of convergence, the power of I, the power of transforming data into information readily and rapidly accessible to make decisions with an underlying spatial context.

In this paper we have outlined several technological shifts that have acted as forces in shaping the GIS of the future. GIS has matured in the far speeding highway of information technology. Its maturity lies in making this powerful integrating spatial technology "transparent" to the end user. The technological shifts presented have paved the way for GIS to enter into the next level of acceptance, as part of spatially oriented commodity products (the spatial enabling of information paradigm in action), in for example, a scenario like this:

"The airplane is about to land into an unknown city to me and it is early afternoon. I grab my handheld WCC (wireless computing and communication device) and "tell it" that I am hungry and want to have some sushi. That afterwards I want to see a movie near by, an action type, and then I want to go to my hotel. I sign off from the device. In the meantime my WCC has automatically "connected itself" to the local restaurant and cinema database and found out what I requested. Minutes later as I get my rental car I plug in my WCC into the car's WCC port. The car gets driving directions from my WCC. The car hops into the electronic highway and takes me to have some really good sushi, "it" has bought tickets and drives my car to a cinema to see an action packed movie. Afterwards it instructs my car how to take me to my hotel for a good night sleep. No need to check-in, the WCC has already made the arrangements."

Underneath all of this is a technology called GIS. For all I know it could stand for *great and Imaginative stuff.*

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