Committee 1
The Information Revolution,
Higher Education and Research

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INFORMATION TECHNOLOGY, HIGHER EDUCATION, AND RESEARCH

by

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The intention of this paper is to provide an overview of the topics to be considered by ICUS Committee 1, that is: 1. The impact of information technologies on higher education and research, 2. Information technologies and inter-institutional collaboration, and 3. A global network for education and research. The paper focuses on some of the issues, which are considered in more detail in the other papers that will be presented before the Committee, and on which the Committee may offer some concrete suggestions.

For the purpose of this paper I shall use the term *education* to mean the process of providing well established knowledge, and the term *research* for the process of generating new knowledge, both in an organized, systematic and effective way, for which scholars, books, laboratories, and now computers are essential.

The generation, transmission, storage and dissemination of knowledge have been the traditional roles of higher education institutions and research centers. For knowledge to be useful it has to be encoded in a way that can be manipulated, constituting what is called *information*. As D. N. Langenberg, chancellor of the University of Maryland, has said, information is the elemental material of education and research. In turn *information technology*, or *infotec* (IT) for brief, refers to the different means or technologies used for encoding and decoding information. For information to be useful, both provider and recipient must agree to use the same coding or encryption method, in other words the same infotec.

Infotec has existed since prehistoric times and has evolved continuosly, gradually becoming more elaborate and effective, but each stage in this evolution has continued using the previous ones.. The first and simplest form of infotec has been *language*, either *oral* (sounds) or *visual* (signs). Oral language is essentially a synchronous infotec, that requires physical proximity. Although oral language allows communications, the information can be stored only in the brains of people and thus disappears with them unless transferred to other people (oral tradition). That means that oral language is not a very efficient or precise infotec and its social impact is relatively slow. However it is still the essential and basic form of communication.

A second step in the evolution of infotec, with great social impact, has been *written language*, which allowed the long term storage and asynchronous transfer of information, thus contributing to the precise distribution and preservation of information. *Graphs* are in a sense a form of written information. The printing press using movable types, consolidated in the 15th century in Europe, was an important step forward in written language because it facilitated the massive diffusion of written information (books, documents) making reading an important tool of life. At the same time two groups of people resulted: those who can read (literates) and those who cannot (illiterates).

Oral and written versions of infotec are essentially *local* because they require the physical proximity of the user with the source of information (persons, books), which in a sense has been a limitation for the diffusion of information. Until recently these have been the two forms of infotec used in education and theoretical research, although education and research have also depended on experimentation and observation, requiring the physical presence of students in an institution of higher learning.

The next crucial step in the evolution of infotec has been the *electromagnetic* stage (EM), made possible by the discovery early in the 19th century of the phenomenon of electromagnetic induction, and later on of electromagnetic waves. There are several types of EM infotec for transmission (telegraph, telephone, radio, television) and for storage and retrieval (audio and video tapes and disks) of information, but all have in common that the information can be transmitted with the speed of light to distant places. This means that EM infotec is essentially *global*, allowing the access by people all over the world to synchromous transmission and asynchronous storage and retrieval of information, transforming the world into a *global village* with the associated social consequences. However I would say that until recently, when it became combined with the next step in the evolution of infotec, EM had limited impact on how education and research are carried out..

The most important and profound evolution of infotec began over 50 years ago and it is still going on. It is the *quantum electronics* stage (QE), which is a combination of several technologies for manipulating electrons and photons in different materials and devices (transistors, lasers, optical fibers, integrated circuits, etc.), while still making use of the previous infotec stages, particularly EM infotec. The ubiquitous component of QE infotec is the computer, which is a tool for manipulating information composed of several devices (micro-processor, modem, hard disk memory, CD-ROM, etc) and logical instructions. Computers have superseded, but not replaced, books for handling information. In fact being able to effectively use a computer is today as important as writing and reading. Consequently again two new kinds of people are emerging, QE infotec literates and illiterates, with the associated social effects. Some papers in this Committee will elaborate on the future of QE infotec.

One thing that is at the core of QE infotec, which makes it particularly useful, has been the use of digital instead of analog encoding of information, using sets of *binary digits* or *bits* for encoding. Digitalization of information allows fast and precise, synchronous and asynchronous, passive and interactive, mainpulation of information, thus making it possible to amplify the power of the human brain for certain functions, particularly logical and mathematical operations. An open question is whether eventually it will be possible to develop other features associated with intelligent systems, replacing humans for those functions. Some rather simple functions already exist such as searching networks for specific topics or concepts.

The major consequence has been that QE infotec has affected many human activities, and in particularly education and research. QE infotec is already at the heart of education and research, whether we like it or not, and we better be prepared for it. That means that higher education institutions and research centers have had to adapt to the new situation, something that has been difficult in some instances. This is an aspect considered by some papers in this Committee.

The three main functions that make QE infotec so useful and important for higher education and research are: 1) mathematical calculations, 2) modeling and simulations, and 3) networking. The capability of computers for performing these functions has increased dramatically over the years. The challenges for continuing improving these functions are higher speed microprocessors in the gigahertz range, substantially larger bandwidths of the order of megabit/s, larger memories of the order of terabits, more compacts chips with millions of transistors using perhaps other materials instead of silicon, and appropriate software.

1. *Mathematical Calculations*. The first application of QE infotec and computers, that made them particularly useful, was to perform at great speed and with high precission not just basic arithmetical calculations, as hand calculators can do, but rather complex mathematical operations, particularly numerical integration of differential equations, such as Schrodinger's equation for many particle systems or the equations of motion for the trajectories of space probes, which otherwise would have been time consuming or even impossible. Mathematical calculations are perhaps the most important application of QE infotec, and even modeling and simulations depend on prior mathematical calculations.

2. *Modeling and Simulations.* The possibility of modeling and simulation using QE infotec offers a new way of learning about nature, besides experimentation and observation and theoretical research, or even of reinventing nature. As indicated in Fig. 1, the three methods of enquiry complement each other, rather than being independent alternatives. Using QE infotec we may test nature without interacting directly with it in what we may call *virtual* laboratories, imagining the results of an experiment before carrying it out in a real laboratory and analyze phenomena in an interactive way that we can not do in the laboratory.

An example has been the modeling and simulation of the production of top quarks before trying to produce them in the Tevatron. As another example, modeling and simulation allow the analysis of the properties of materials at several levels of atomic or molecular aggregation, resulting in what is now called micro-, meso- and macro-physics. In astrophysics modeling and simulations help to study the evolution of stars and galaxies. Modeling and simulations are extremely important in biological research, avoiding the need in some cases of using living systems (humans, animals) and mimicking biological functions, and in archeological research, helping to reconstruct fossils and imagine their biomechanics. In architectural and industrial design modeling and simulation are very helpful, as it happened with the development of Boeing-777 airplane. A project of unprecedented level of computation and simulation, with potential ramifications and applications in other fields, is the Accelerated Strategic Computing Initiative (ASCI), aimed at virtual testing and prototyping of nuclear weapons; the project is being implemented by Lawrence Livermore, Los Alamos and Sandia National Laboratories.

It is obvious that mathematical calculations, modeling and simulations are very important educational and research tools. This is true in particular of education at all levels, and there are available many excellent educational programs using QE infotec. However it is still important for the intellectual development of students that they learn how to carry out some calculations by hand and perform hands-on experiments. It is very nice to travel by car but we still have to know how to walk. (It is interesting that the US Department of Education has recently recognized that students that learn mathematics in the old fashioned rigorous way are more likey to succeed when they join the workforce)

3. *Networking.* QE infotec based on isolated computers, no matter how powerful, is not sufficient to produce an information revolution. What has made the revolution possible has been the two-way linkage or networking of computers, allowing fast and interactive communication and exchange of information. This is designated *computer-mediated-communication* (CMC), which can be synchronous and/or asynchronous, and not only written but also visual and acoustical.

CMC can be carried out in a variety of ways (e-mail, teleconferencing, chatting, etc.). I do not need to elaborate on this matter because it is well known and everybody is familiar with or uses both Internet and the Web. The important point is that networking offers a new modality for associating people and institutions for learning and research and is a tool of inquiry, linking information sources (persons, documents) over the world. However the effective use of networking requires new methodologies that have to be mastered by the users.

Networking is important for higher education because, as already said, it brings together resources (scholars, institutions, libraries, museums) scattered geographically. For that reason networking is bound to profoundly affect the way universities operate or research centers cooperate. Just to mention one example of many, the group called The MAAD Coalition (Molecular, Atomistic and Ab-initio Dynamics) is composed of IBM, Harvard, Brown and NRL laboratories, which are quite distant from each other but can maintain close communication in real time using QE Infotec. We will hear more about inter- and intra-institutional networking in other sessions of this Committee.

Networking is particularly important for the future of higher education institutions and research centers. For that reason the rest of this paper will deal with this matter. In the future I will use only the term "infotec", with the understanding that I mean "QE infotec and related technologies".

Higher education is currently facing several well known and serious challenges. Some are:

1. The accelerated rate of progress of several scientific and technological fields, which shows no sign of slowing down and demands frequent updating of curricula and initiating new lines of research.
2. The growing interconnections between several academic fields, which require more contact between scholars with different areas of specialization.
3. The increase in cross-cultural relations, which requires looking at higher education in a more holistic way.
4. The need to prepare students for this rapidly evolving world, particularly the development of their awareness of the technological issues that modern societies confront.
5. The ever increasing cost of running higher education institutions and research centers, which requires a careful selection of the areas in which they can operate, or even their downsizing.
6. The demand by knowledge intensive societies for an elite workforce, that must be upgraded regularly, which means offering new educational options as needed and which are often hard to foresee.

7. The difficulty of countries with limited resources to offer quality higher education or sponsor research projects.

To all this we must add the natural inertia of educational institutions to radical changes and their tendency to ignore inculcating in the students the proper values needed for their professional performance.

The above leads to a critical question that the Committee may wish to address: How can infotec contribute to meet those challenges?.

In the first place infotec offers new methodologies for learning that, as I said before, will in no way replace books or personal interaction with teachers. Rather it provides new oportunities and styles for learning, particularly through the use of interactive multimedia systems and electronic educational materials. At the same time it is essential that infotec educational methodologies support objective critical thinking, which requires adequate software.

One important effect of infotec is that proximity is no longer a requirement for learning or exchange of ideas, although to a certain extent physical proximity is more desirable for education than for research. In fact, computer networks can substantially contribute to the rapid diffusion of ideas, overcoming intellectual and cultural isolation. Using infotec students and scholars can easily communicate with each other and link with sources of information regardless of their locations, thus allowing geographical dispersion. On the other hand an unintended effect of infotec has been an explosion in information, often making it difficult to locate and screen what is appropriate and relevant.

This leads to several important questions the Committee may wish to address:

1. Is the location independence of infotec based communications making the physical situation of a higher education institution or research center irrelevant?.

2. Will the widespread use of infotec result in a decline in person-to-person contact (not just student-teacher but also teacher-teacher and student-student), which is very important for education, as well as for research?

3. Do these new means of communication improve the efficiency and reduce the cost of education and research

4. Does infotec open new oportunities for learning by providing access to a worldwide pool of experts and services?

5. Does the above means that instead of jet-set visiting scholars what is needed is access to a virtual community of electronically linked scholars?

6. Is infotec an effective instrument for meeting the diversification of higher education required by modem societies?

On the practical side it is conceivable that by using infotec a student requiring a certain professional preparation does not need to be restricted to a single institution, or he may not even attend any university. Instead he might take, at his own pace, on-line courses from several networked institutions, as well as have electronic access to his on-line teachers, tayloring his education to his personal needs or interests. In a sense the student is attending a *virtual* university. Of course the student may need some guidance for organizing his curriculum. Accreditation is a key issue and some *real* institution or entity must take the final responsibility of granting a degree or a certificate. There are already many examples of programs that do not require that the students ever come to a campus.

On a more restricted fashion, an institution can offer regular courses using infotec, which is what is presently called *tele-education* or distance leaming. There are several formats for providing tele-education, although some subjects requiring hands-on experiments or training and tutorial assistance are more difficult to offer through tele-education than others. Some papers in this Committee deal with this matter.

From the social point of view a great advantage of tele-education is that it facilitates *continuing education*, thus contributing to upgrade the educational level of the population in general or help some professionals, such as rural medical doctors, to stay up to date in their fields. An example of the first is the PBS project "Going the Distance", and of the second are some programs of FEPAFEM (Pan American Federation of Associations of Faculties of Medicine), both to be discussed in the Committee.

However networking is of more far reaching consequences for education and research institutions. Since most higher education institutions can not excel in all fields of enquiry, by joining a network they can make available to their students supplementary courses and services, such as access to digital libraries and computational facilities as well as facilitate participation in research projects, tele-conferences and on-line seminars, which otherwise would be very difficult to carry out. In this way each institution can concentrate or specialize in what it can be more competent or has adequate resources, without restricting the options of its students. We may visualize this network as a *global interactive university network*, or simply a *global university*, constituted by a set of collaborating institutions and scholars linked electronically, some highly specialized and acting as focal points for providing information and services in specific areas to other institutions. scholars or students participating in the network. By means of proper agreements for consultations and services they can complement each other in a number of fields. Of course in addition to the electronic linkage, there may be occasional exchanges of faculty and students.

I realize a global interactive university network means substantial institutional changes, both administrative and conceptual but I believe it is the only way ahead. Some people may say that there is no need for this kind of network, because internet already offers a lot of educational materials, but they are not well organized or oriented toward formal education or research projects. Rather I visualize the network as a sort of a specialized intranet, similar to those that have become popular in large corporations.

There are already several examples of university networks. Just to mention a few, the Western Governors University, comprising 10 states in the US, is a project in the suggested direction but of a much more limited scope because it is directed toward coping with the increase in student population. The Agricutural Satellite Network, involves about two dozens agricultural colleges in the US, exchanging course offerings to reduce duplication. An example of a research network is the Southeastern Universities Research Association (SURA), comprising 41 institutions, including the Thomas Jefferson National Accelerator Facility, in Newport. On the technology side the UNISPHERE Institute has established a global network of diverse professional organizations, offering their clients technological assistance pertinent to their respective business, something that obviously can be applied to universities. A project of special interest is the high speed network that will link about 30 universities and internet centers across Russia, financed by the Soros Foundation and the Russian government. It is worth mentioning the efforts of UNESCO's International Advisory Council on Global Scientific Communication toward facilitating communications in science. The OAS has provided assistance to its member countries for establishing a science and technology information network and facilitate their full access to internet and the Web, .

We may raise now a second critical question for the Committee: How can a global interactive university network contribute to meet the educational challenges mentioned earlier?

The concept of a global interactive university network will be analyzed in detail by Panel 3 and I hope the Panel, as well as the full Committee, will examine in detail its feasibility and desirability, and that specific suggestions will emerge. It is important that the network does not duplicate or interfere with other similar efforts, but rather complements them.

Assuming the establishment of a *global interactivre university network* is found desirable and feasible, there are many organizational details of the network that have to be considered carefully, such as membership and participation in the network, financing, possible programs and activities (seminars, conferences, courses), methods of accreditation, operational costs, and governing body. In any case the network should be flexible and institutions and scholars may join or leave according to their needs. There is also the possibility that commercial enterprises may enter into an agreement with the network for supplying some materials and services. Access to the Internet and the Web will be important, but the university network must be much more: a fully integrated cooperative academic effort.

Obviously the university network can be established and function as an independent entity, but it might be more desirable to establish it as the operational arm of the proposed World University Federation. The Federation has a larger scope, and may include programs such as seminars, publications, exchange of scholars and students, etc. oriented toward achieving an education centered on four basic themes: Harmony, Purity, Peace and Unity among the peoples of the world, themes that I consider worthwhile but that many institutions may not know how to incorporate them into their curricula. In addition I foresee that both WUF and its university network will contribute to the unity of the sciences, which are the goals of ICUS. The Committee is welcome to comment on this matter.

Once the World University Federation is formally established, many of the organizational aspects of the university network may be decided by the Executive Board of the Federation with the assistance of the Advisory Council, for which the suggestions of Committee 1 will be of great help.

In concluding, institutions of higher learning and research centers will continue to exist because they are the best way to carry out those two important functions, essential for society, but they will have to change and adapt to make the best possible use of the oportunities offered by Infotec. Many institutions are beginning to do so worldwide.

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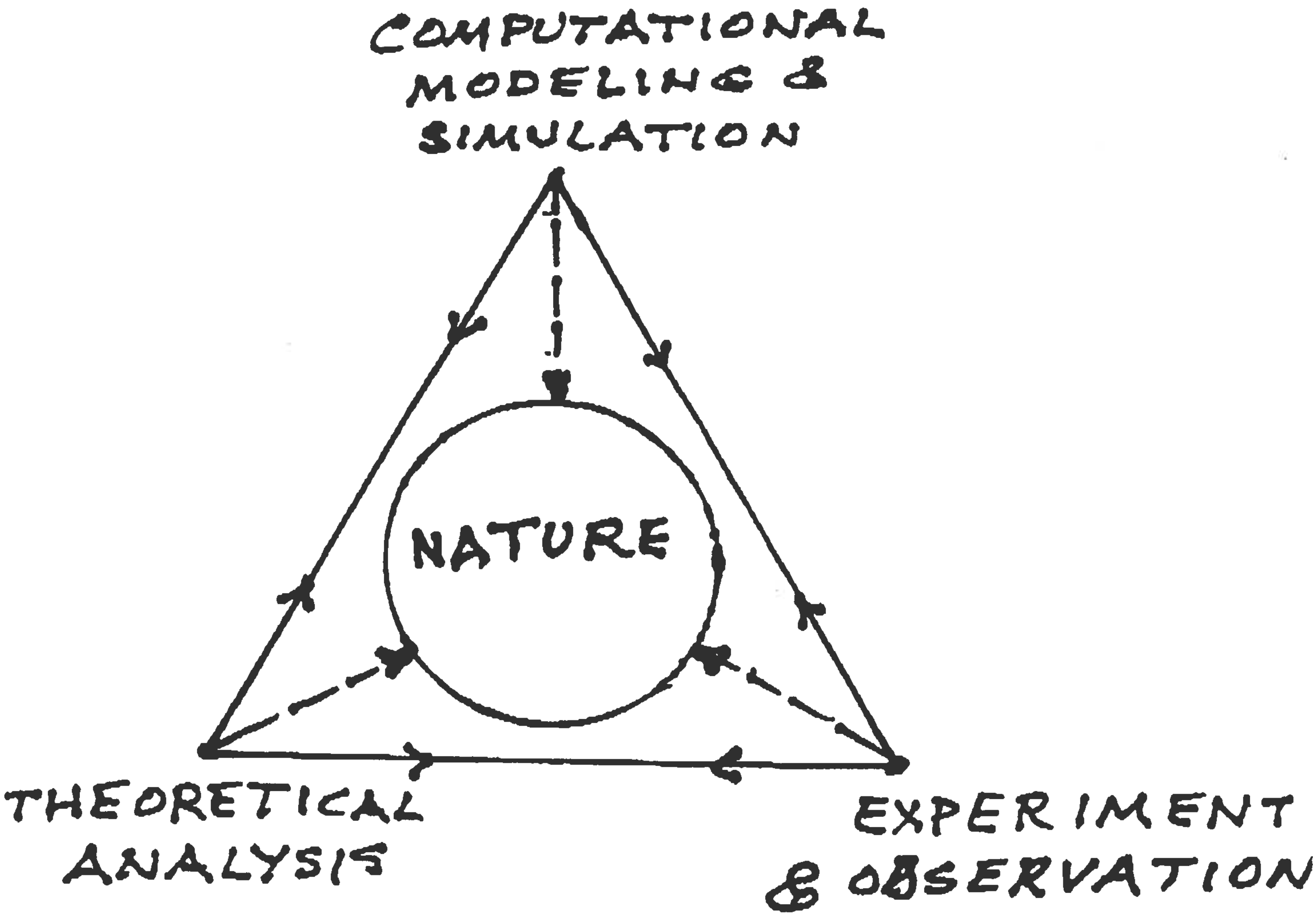

THREE METHODS FOR INVESTIGATING NATURE

Fig. 1