21ST CENTURY TECHNOLOGIES:

Challenges and Opportunities for Africa

by

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ABSTRACT

As we approach the 21st century, global attention is focused on exploiting the new and emerging technologies such as computers, communications and associated information systems, space science and technology, genetic engineering, new materials, energy, photonics, superconductivity and nanotechnology. This preoccupation is driven by the potential of these technologies to greatly enhance the productive capabilities and wealth of those countries, including their public and private entities, that have the foresight to make judicious and appropriate investments in them. This paper examines these technologies and notes their implications for the global economy. These technologies offer a future that is rich in untold opportunities that could breathe new life into agricultural productivity, give adequate and timely information about Africa's physical environment and its natural resources, and place at Africa's disposal, new medical remedies for most human ailments. Africa faces a number of fundamental challenges it must faithfully address, including the creation and sustenance of an enabling environment, in order to ensure the full participation and contribution of its citizens to these unfolding developments. Africa can and should experience a better economic future. To achieve that goal, Africa and its citizens must appreciate, understand, master and judiciously apply and adapt these technologies to first meet their own needs. Thereafter, we can dream of the industrialization of Africa and of our participation in the global economy of the future that will be driven by these new and emerging technologies. These efforts must be rooted in clear national policy formulations, long-range decisions and honest commitments that are based on the priorities of all the citizens of each African country.

WHAT IS TECHNOLOGY

Technology is a tool (hardware/software) used in translating knowledge into economic productivity - a capacity that depends on the individual and the institutional character of a nation. Together, science and technology continue to transform our world. Discoveries and new explorations are ripe and continuous - revealing in the process, mountains of information in the service of humankind. In this last decade of the 20th century, global attention is focused on exploiting the new and emerging technologies in order to better serve the needs of the human race. Most of these technologies owe their origin and development to the cold war era, a period characterized by the use of much talent and unlimited financial resources, particularly by the United States and the former Soviet Union, to support the development of a variety of advanced military technologies.

As we approach the 21st century, the private industries that arduously contributed between the 1960s and the 1980s to these developments, are giving new and heightened impetus to the commercialization of military induced-technologies (and their by-products) which they helped engineer. In most of the industrialized countries of the world, including the industrially emerging ones, such as Brazil, China and India, concerted efforts are sharply focused on harnessing the economic opportunities and the social benefits that will certainly accrue, in particular, to those societies that can master and productively exploit these technologies to address the myriad of problems and needs of the global community.

In the forefront of these needs are the development of drugs and vaccines for a variety of human ailments, production of food and shelter for the teeming global population, reduced deforestation, effective solutions to global environmental problems, development of alternative sources of energy and substitutes for non-renewable resources. The needs in Africa are in no way different from these.

While the geographical size of a nation may endow it with a given amount of natural resources and thus a manifestation of its potential power, today, the real power of a country is measured in terms of its economic progress, that is, the proven capacity of that society to translate scientific knowledge, through its judicious and determined exploitation of technologies, into economic productivity.

TECHNOLOGY IN THE SERVICE OF HUMANKIND

For most of the 20th century, a variety of conventional techniques have been developed and applied to tackle the day-to-day human crises of our time. The magnitude of these problems suggests that alternate approaches are warranted; this is where the new and emerging technologies could provide much relief and many benefits.

Genetic Engineering (human health)

For example, air travel and the building of mega-cities, such as Cairo and Lagos, are escalating the spread of infectious diseases. How can we provide a healthy environment for our population particularly in the absence of effective low cost drugs? In major medical institutions and pharmaceutical research establishments, attention is now sharply focused on developing vaccines and on genetically designing drugs that can successfully combat such major maladies as cancer, AIDS, sickle-cell-anaemia, Alzheimer's disease, malaria, hypertension and asthma. The ability of the scientist to master the genetic codes of plants and animals and understand the molecular interactions that underlie diseases holds great promise for human health. With this knowledge, engineered-drugs and vaccines are being "custom tailored to their targets; they tend to be more potent, more specific and less toxic than remedies discovered in other ways". 1/

Researchers at the Naval Research Laboratory in Washington, DC recently acknowledged that they are in the process of "creating electronic microchips that use living brain cells".2/ Since all ailments suffer from misarranged patterns of atoms, application of a ***nanomachine*** with such a microchip may hold promise as a means of rearranging and correcting these atoms by selectively destroying such bacteria, cancer cell or virus. While microelectronics is microtechnology in practice, the technologies of the future will be at nano-scale (i.e. pinhead size); ***nanotechnology*** will provide humankind with the ability to manipulate individual atoms and molecules to build structures to complex atomic specifications (molecular engineering). 3/

Genetic Engineering (agriculture)

Furthermore, the world population surpassed the 5 billion mark in 1990; it continues to grow. Demographers expect this figure to reach 6.2 billion by the year 2000, and to pass 10 billion by the year 2050. Thus, one of the questions being asked today is, "What is the carrying capacity of planet Earth"? 4/ Our population in Africa rose from 199 million in 1950 to 682 million in 1992. A projection of 856 million is foreseen for the year 2000. Much civil strife, over-grazing, over-tilling, deforestation and salinization - the latter built-up through irrigation - have combined to reduce the productive capacity of Africa´s farm lands and to escalate the problem of food insecurity in the continent.

In order for Africa to feed herself, we would need to farm more efficiently using conventional and well-known techniques, as well as farm in a "smarter" manner with the aid of genetic engineering. Today, genetic engineers in other lands are conducting research on how to develop healthier foods by isolating genes for proteins that have superior nutritional properties, and by subsequently inserting such genes into crops. Crops that can survive under harsher conditions than those prevailing in their natural environments have been genetically engineered. Amongst these are alfalfa, corn, carrots, lettuce, peas, peppers, potatoes, rice, sugar cane and tomatoes.

New materials

Because of the non-renewable nature of mineral deposits including iron ore, and the fact that steel rods corrode with the passage of time, the tendency today is to simultaneously engineer human safety and reduce escalating construction costs by developing composite materials that are more durable than any of its component elements. With the experience gained in the development of organic polymers and other composites by the aerospace industry for the construction of the fuselage and wings of attack air planes, the stealth bomber and the Space Shuttle, a variety of organic polymers are currently being tested in bridge, highway and housing construction. In bridge construction for example, the composite, carbon fibres in an epoxy resin, would form a shell into which concrete could be poured, thus eliminating the need to use steel bars to reinforce the concrete. Similarly, research has shown that the addition of fibres glass, carbon or steel to cement can reduce the propensity of highways to fracture under stress. Thus, in an earthquake, pylons of this composite material might bend instead of break. 5/ Fibreglass, reinforced with plastics, has also displaced metals in the manufacture of products such as automobile bodies, aircraft parts and fishing rods. Because of its high carrying capacity, insulating quality, light size and weight, security advantage (no signal leakage), ease of installation and low maintenance cost, optical fibres, the ultra-pure glass fibres, no thicker than a human hair, has largely replaced copper wire and the coaxial cable as a means of transmitting communications signals. Other advanced materials of the future which will find a wide variety of applications globally include new alloys, biomaterials (such as biodegradable plastics), and a variety of composites such as ceramic metal matrix composites and electric plastic. And because of escalating costs and concern for the environment, recycled materials of all kinds are now featuring in housing construction.

Energy

Future generations will be more conscious of the environmental impacts of human activities, and could thus decelerate the construction of hydropower systems for energy generation. To some extent, such a consciousness will also affect the use of petroleum as an energy source; in fact, petroleum may be needed only for the manufacture of lubricants and petrochemicals in the future. Super-conductivity will result in hybrid gas turbine/electric cars that may attain over 200 kms per gallon of gas. 6/ Electricity for cooling, heating and lighting will be generated by fission fragment and large arrays of photo-voltaic cells (solar energy). Africa's geographical position is a major asset that needs to be tapped for solar power generation. Many countries that are not so favourably placed, geographically, are investing, with significant rewards, in such systems. Similarly, given the rural nature of the African landscape, it is advisable that we study the examples of biogas production, particularly in Asia, for appropriate adaptation in rural Africa.

Spin-offs from SDI

The end of the cold war is also bringing high-priced military technologies developed with the aid of super-computers (within the framework of USA's Strategic Defence Initiative - SDI), into the commercial market. 7/ Sensors, developed to help a military aircraft detect and jam enemy sensors, are being adapted to alert drivers of obstacles on the road, including automatic collision avoidance. In this category of emerging products is the Intelligent Vehicle Highway System (IVHS) which is being tested in some car models. Computer algorithms developed for military target (e.g. an incoming missile) recognition, are also being applied, medically, to three dimensional imaging of moving systems such as cell movement or embryonic development in the human body. The magnetic resonance imaging (MRI) system, which has become an indispensable diagnostic tool in the delivery of health care services is also a beneficiary of this effort.

The Global Village

Today, Africa and its peoples certainly recognize that this is an era when the power of space technology with its orbiting and geostationary communication satellites have combined with terrestrial and computer networks to break down all political and penetrate all geographical boundaries. In essence, it has reduced the world to one giant global village. We, Africans, have two choices: to be part of this global village, or to be isolated from it. The rest of this paper will focus on developments in space, computer, communications and related information technologies, their strategic, economic and social implications for Africa, the challenges that Africa faces in the process, and how it could address these challenges.

SPACE TECHNOLOGY AND ITS IMPACT

The space age, the global village, the digital world and the information age - these and a few other expressions have been used in the past two and a half decades to describe the technological developments of our time.

The space race between the USA and the former USSR in the late 1950s and early 1960s, sparked by the successful launch of SPUTNIK-1 on 4 October 1957 by the USSR, met with widespread global actions and reactions, and triggered long-term scientific research and technological development programmes, particularly in most of the industrialized countries of today. This race has since matured into one of greater international cooperation; nevertheless, national economic security remains one of the main motivating factors, and economic leadership is the prize. Specifically, a number of these countries are aggressively pursuing a variety of scientific and technological challenges and are equally focusing on the corresponding economic opportunities that could accrue from these efforts.

Justification

In space exploration, a majority of the industrialized countries share a philosophy similar to that of France. 8/

> "... the challenge France now faces is to win a share of the international market for commercial satellites particularly in countries without a space capability, i.e. the so-called open export market. This objective will only be achieved through a sustained technology development effort conducted in co-operation with the firms concerned and with the support of a strong national programme."

In the early 1960s, Argentina, Brazil, China and India followed suit and invested their manpower and financial resources in their respective national space research programmes. The subsequent achievements of Brazil, China and India in electronics, satellite development and propulsion technology have led to their being collectively referred to today by the industrialized community as "the emerging industrialized countries".

Earth observation

Through the observation of the Earth and its immediate environment from the vantage point of outer space, satellites can provide copious data that can be processed, analyzed and subsequently used by African countries in making decisions on how to address a variety of issues on the environment and natural resources (including fisheries and weather forecasting) of the continent. This technology is being used by those who have invested in it to carry out commercial fishing along the coast lines of Africa particularly in the northwest, in the Bight of Benin and along the shorelines of South Africa and Somalia. In 1972, Landsat-1 had 80 metre resolution, today it is 10 m. on Spot systems (France); the Russians have 5 m. resolution images of different parts of the world obtained by their space cameras. In the future, sensors for Earth observation satellites, such as future optical-electronic remote sensor systems, would have a finer resolution within the range of 1 m. to 5 m. Radar sensor systems are being perfected as demonstrated by the recent tests carried out on board the Shuttle Discovery in April 1994. Such sensors will be of value to resource surveying in Africa particularly because of their cloud and rain-penetrating, as well as night and day monitoring capabilities.

The only remote sensing ground receiving station located on Africa's soil is in Johannesburg, South Africa. South Africa is also developing a remote sensing satellite ***(GREENSAT)*** of its own. In addition, a variety of Earth-observation programmes have been developed as part of the US Earth-observation system. Similarly, the Japanese are contemplating a World Environment and Disaster System (a constellation of 32 satellites) which will undertake an around-the-clock monitoring of the Earth's environment and the disasters that are occurring therein. 9/ The utilization of the data from these and other systems should enable Africa to participate in the international programme on Mission to Planet Earth, a series of internationally coordinated space-based programmes which will chart pollution, deforestation, the greenhouse effect, ozone depletion and other threats to the Earth's environment.

Communications, search and rescue, and geo-positioning

In communications, the race is on to build a future world that is wireless; to achieve this goal, three private entities in Europe, Japan and USA are planning to place a total of 994 communication satellites in the low-Earth orbit before the year 2000. 10/ These developments will enable customers to receive calls anywhere in the world except the North and South poles. Electronic mail from laptop computers and personal communication devices will also become a reality. And if successful in its on-going negotiations, Egypt could be the first country within the African continent to have its own communication satellite (***NILESAT),*** placed at the geostationary orbit, with a 24 television channel capacity as well as a radio circuit for telecommunications.11/

Today, 23 countries from all the geographical regions of the world, except Africa, belong to the COSPAS-SARSAT organization which runs the Cospas-Sarsat system. The latter owns 6 satellites in low Earth orbits and 7 replacements are being built; 635,000 distress beacons have been installed globally and the number of beacons will exceed 720,000 by the year 2000. Its main mission is to provide assistance in rescue missions and distress. From September 1962 to the end of June 1993, the Cospas-Sarsat System provided assistance in rescuing 3,470 persons in 1,217 search and rescue missions globally. 12/ Similarly, geo-positioning, the technology of knowing where you are, at any time, on Earth or in space, is now a reality - made possible by USA's Global Positioning Satellite (GPS) system with a constellation of 24 satellites in low Earth orbit (11,000 km altitude), and by Russia's constellation of 12 satellites (24 in 1996) within its Global Navigation Satellite System (GLONASS). These satellites are being used in a variety of human activities, but specifically for position (stationary or mobile) fixing in the military (for submarines, aircraft and soldiers in the field), by merchant ships on the high seas, fishing ships, the trucking industry, pedestrians, by airport control towers to guide the landing of aircraft, and for cartographic and geodetic surveys.

Space industrialization

Future space systems would vary in shape, size and mission. More nations and entities would own, launch and operate their own satellites for a variety of purposes; and there would be a wide array of launch vehicles to choose from. Today, the list of space-capable countries continues to grow with many more achieving launch capabilities. International cooperation in space is being manifested through several collaborative arrangements. The most prominent of these is the joint effort by Canada, Europe, Japan, Russia and USA, together or in groups, to build the space station, the platform that will make space industrialization, within the micro gravity environment of outer space, a reality, in the first decade of the 21st century. It is now believed that high value materials such as precision latex micro-spheres, electronic materials, various kinds of pharmaceutical products, optical fibres, and highly specialized alloys can be produced, in their purest forms, in the micro-gravity environment of outer space.

Space industrialization also holds promise for the production of new antibiotics, antibodies and other treatments for cancer, malaria and other diseases including the growth of collagen fibres to be used in the repair and replacement of human connective tissues. Of major interest is the performance of various lubricants and the growth of crystals in outer space for semi-conductor devices. These possibilities would certainly improve the efficiency of the production process as well as the quality of goods produced on Earth. The attendant economic impact could be very significant and far-reaching. 13/

Economic impact

Human venture into outer space has introduced new dimensions into many Earth-based processes and procedures. For example, limited space on board a space vehicle requires that all instruments and tools be as light and compact as possible without any loss of efficiency. These requirements have resulted in the accelerated development of integrated circuits, with each new component, such as microchips, performing several functions, components which have found subsequent applications particularly in computer technology. The offshoots of these developments is a host of miniaturized, inexpensive and versatile consumer products -such as television sets, radios, cameras, video-games, micro cassettes and portable receive-only TV antennas. 14/ These technology development and exploitation processes suggest that future economic systems here on Earth would be based on a redistribution of both Earth-bound and space-based resources and other benefits associated with space exploration and utilization.

THE SCRAMBLE FOR NEW AND EMERGING TECHNOLOGIES

As we approach the 21st century, the competition is tightening and major technological foundations that will take human-kind into the future, are being laid. The challenge for those that have begun the race as well as those that are still on the sideline is how to secure a technological and an economical competitive position, and thus ***escape domination in any form in the years ahead***.

Racing into the 21st century

Indeed, a three-way technological race is now in progress between the United States, Europe and Japan, in all areas (and many more) described in the section under "Technology in the service of humankind" in this paper.

Leading the ***USA's*** input in the race are the Government's Advanced Research Projects Agency (whose earlier military technology research efforts are now heading for the commercial markets), the micro-electronics entities in California's "Silicon Valley", the major research centres in a number of American Universities, and the major technology-oriented establishments - such as AT&T, Motorola, Boeing, General Dynamics, Pratt and Whitney, Hewlett Packard and Rand Corporation, - to name just a few. As an example, gaining a competitive edge in digital communication motivated AT&T to recently establish a 45,000 square metre Solid States

Technology Centre in Pennsylvania where over 800 scientists and engineers are developing laser transmitters and receivers, photonic components and light-work. 15/

The focal point of ***Europe's*** competitiveness and entry into the 21st century is the European Strategic Programme (for research and development) in Information Technology -(ESPRIT), with special focus on advanced micro-electronics, advanced information processing, computer integrated manufacturing (automation) and automation of the home and the office. 16/

Japan's laboratories are similarly forging ahead. Long-range strategic planning, research and development are among the portfolios of ***Japan's*** Ministry of Trade and Industry (MTI) and its Science and Technology Agency (STA). In 1980, MTI founded Tsukuba, popularly known as Japan's "Science City". The latter, the largest research centre in the world, is made up of research institutes from all corners of Japan. Tsukuba's attention is particularly focussed on being the leader in "advanced materials, super computers, super-conductivity, space planes and molecular manufacturing". 17/

Australia, Brazil, Canada, China and India are not sitting on the side-lines. In 1984, for example, Brazil reorganized its Law on Informatics and subsequently established: (a) the Centre for Informatics Technology near the Universities of Campinas and São Paolo and (b) the Research and Development Centre in Telebras. 18/ These establishments and several others that are located in São José dos Campos, Brazil's Silicon Valley and home of its Space Research Institute known as INPE, are concentrating on the development and manufacture of automation, advanced instruments and electronic products to meet the country's needs as well as feed the foreign market.

The ***Canadian*** technology triangle centres around the cities of Waterloo-Kitchner, Guelph and Cambridge and their respective universities in the southern part of Ontario province. Specialty fields include micro-electronics, automation, sensor technology, software development and communications. 19/

The location of the Indian Space Research Organization in Bangalore, eleven years ago, gave that city an edge as the country's Silicon Valley where over 100 local and transnational computer hardware and software companies have also found a home. With the support of the Governments of India and Singapore and the cooperation of India's science and technology establishments, the 58-acre Bangalore Information Technology Park, which was conceived by the heads of states of the two countries in 1992, was born in the fourth quarter of 1995. 20/ The Park provides facilities for research, development, design and manufacturing in electronics, computers, and telecommunications.

The Pyramids Technology Valley (PTV) Project is an initiative taken by the Government of ***Egypt*** in the late 1980s. 21/ The aims of the project are to "stimulate the development of high-tech industries in Egypt, and to create an environment where innovative ideas can flourish". A fund to support the project is being established. One of the priorities of the PTV project includes "supporting faculty development and establishing research centres in fields related to high-tech industries", including "engineering, micro-electronics, microbiology, biotechnology, materials and pharmaceuticals".

The ***Space Plane*** provides an insight into the on-going global science and technology competition. As a rehearsal to the development of the Space Plane whose orbital speed is expected to reach Mach 25, and which could deliver spacecraft into low Earth orbit just as the space shuttle is doing, Europe, Japan, Russia and USA are now racing towards the development, design and construction of the Mach 3 to 5 High Speed Civil Transport. 22/ It is expected to enter into service after the year 2005. Such efforts are costing the USA over $15 billion a year in basic research.

From the above, it is apparent that major policy decisions have been made by a number of key countries and group of countries (Europe) regarding their future technological and economic outlook. What are the plans of Africa for the future?

THE COMPUTER

The microelectronics era began in 1948. That was the year when Bardeen, Brattain and Shockley of Bell Laboratories in the United States invented the transistor, the brain cell of all computers, as a replacement for vacuum tubes in electronic circuits. The transistor and its offshoot, the integrated circuit, soon became indispensable components of large technology related facilities that were subsequently developed for specific applications, including the design of novel equipment with unprecedented performance and price levels.

Today, computers are able to do many things, and in the immediate future, will become very well integrated into our daily lives. For example, Computer aided design (CAD) began in the late 1950s and early 1960s, as a simple exercise "to display and manipulate lines and shapes instead of numbers and texts" on the screen. CAD has revolutionized the design of cars, air planes, architectural layout of buildings, and a variety of electronic products. Computer Aided Manufacturing (CAM), which logically followed (CAD), is a programmable automation process used on the factory floor to manufacture products, using a numerically controlled tool (the robot) and a flexible manufacturing system. Robots are now routinely used in material handling (e.g. transporting explosive parts), machine loading/unloading, spray painting, welding (in the manufacture of cars), machining, and assembly (e.g. rivetting of aircraft parts). Today, many experts look up to ***Artificial Intelligence (AI)*** or ***Expert System*** as the key to automating parts of the manufacturing process.

Artificial intelligence (AI)/expert systems

Expert systems (softwares) consist of hundreds of rules on how to process a specific set of data; the latter is collected through a detailed interviewing of human experts. The goal of such an interview is to enable the system to capture most of the intricacies of how consultants/experts/advisers/professionals arrive at decisions or make judgements. The resulting programme or software acts as a helper by generating, investigating and recommending possible actions with justifications for such decisions. Such systems can be designed for a variety of applications including (1) failure diagnostics and maintenance of equipment, (2) handling of oil or chemical spills to avoid disaster, (3) management of administrative systems, and (4) helping farmers to produce better crops. 23/

Over many decades, tens of thousands of overseas consultants have offered Africa their services and ideas in various aspects of human endeavour, and have been instrumental in the purchase and installation of all types of equipment, machines and structures that are now in the continent. These consultants always leave our shores with their ideas. However, when the facilities these consultants have installed stop functioning, the usual practice is to call for the original or a substitute consultant from the same entity that was initially responsible for the project. This has always been a very painful, frustrating, time-consuming and expensive exercise. Appropriate Expert Systems can be designed to address these types of problems, thus eliminating the need to require the physical presence of the consultant. A significant amount of savings can be achieved in this manner. An Expert System can guide an inexperienced user through a consultation in a field in which he/she is not an expert.

Computer applications

At home and in the offices, close to 100 million mid-size and personal computers are assisting in the execution of various chores. In fact, in the industrialized countries, the office secretary is becoming an endangered species, because that person is being replaced by the computer. Similarly, millions of products have become part of our normal lives - cars, television sets, electric irons, stereo-components, cameras, telephones, as well as many services, such as electronic banking and electronic security in doors of buildings, which we now take for granted - they all have various micro-computers, with different capabilities, built into them. The piloting and landing of today's commercial aircraft are major beneficiaries of the advances in computer technology.

Computer imaging and scanning are now common tools in the identification of criminals amongst piles of thousands of photographs. And in order to provide badly needed relief in general and particularly for the disabled, sensors and microchips are now becoming part of shoes, chairs, beds and pillows. A system, known as ***intelligent surface technology***, seeks to "improve the fit and shock absorption of shoes, prevent bed sores for hospitalized patients and relieve the discomfort of drivers, office workers and people in wheel chairs". 24/ Appliances are being embedded with microchips and appropriate software which will alert the manufacturer's Service Department that a particular part of an appliance has become defective; the built-in microcomputer can be programmed to place an order for a replacement part, and also to provide its own location including the address and phone number.

The computer has become an indispensable tool in many areas of human endeavour resulting in increased productivity and better quality control. The ability of the computer to process, store and retrieve information has been widely exploited by most institutions including government departments and agencies, communications establishments, transportation industries such as the airlines and railways, the defence industries, immigration and security services, hotels, newspaper organizations, educational institutions and libraries, to name just a few.

Integrating computers into human lives

Wristwatches that are now available to the consumer, such as Data Link, Swatch and Message Watch are indicative of future trends - i.e. multi-purpose tools. Indeed, wristwatches of tomorrow will not just tell time; they will also serve as key devices for communication, able to receive messages and news, and act as personal organizers (over 1 billion watches vs 150 million PCS today).

Today, computer games have become the toys of choice for most children, particularly in the industrialized countries. And in late 1995, the first computer generated film "Toys Story" made a successful debut in movie theatres across the USA. At Xerox Palo Alto Research Centre in

California, efforts are also in progress to ensure that, like writing, computers of the future will fade into the background, be indistinguishable and become fully integrated into peoples' lives. Such computers, such as wallet personal computers, which can still be wired to the conventional ones, could take the form of tabs (inch scale), pads (foot scale) and boards (yard scale). The harbinger of the inch scale (tab) computers is the ***active badge*** which contains a small microprocessor and an infrared transmitter. 25/ The badge broadcasts the identity of the wearer, as in ***Star Trek*** (the ***TV programme***), and thus can trigger automatic doors, automatic telephone forwarding and computer displays customized to each individual reading them.

Computers of the future

In the last 20 years, there have been dramatic improvements in the cost performance of computers and communication technologies, each growing independently, at an annual rate of 25%. Computers have also become very powerful (because of their speed of operation) and cost-effective that they can be found almost everywhere doing almost everything. Super computers, with the ability to process billions of commands per second, assist in weather forecasting and in the complex analysis of medical images. Before the year 2000, such a computer might hold a microchip that conducts a trillion operations per second. In order to prepare the USA for the computer dominated future, and "make sure that all our children have access to the finest education through technology", President Bill Clinton, on 13 February 1996, "proposed creation of a US$ 2 billion federal fund to help bring computer technology into all classrooms in the United States".

Computers of the future will be more powerful (i.e. faster) and more versatile than those of today. The speed of a computer depends on the character of its microchip. In March 1994, Intel and Apple Computer introduced new and faster silicon chips - Power PC (Apple Computer) and Pentium (Intel). However, the microchips of today are so tiny that the physical limit of silicon technology has become the subject of debate in the electronics industry. How to extend the performance of silicon-based circuitry is now a major concern. In response, IBM and Analog Services are developing new "exceptionally high speed transistors", made of an alloy of silicon and germanium (SAG) - two well known semi-conducting materials. 26/ Another attempt at addressing the "physical limit" of silicon chips is the on-going development of gallium arsenide chips (GAC). 27/ The latter is being used to "increase the processing speed and memory capacity of some types of chips".

There is a brewing controversy concerning the performance of these two chips. The proponents of GAC believe that gallium arsenide is a better insulator than silicon, and that its circuits could operate at optical frequencies and thus help to bridge electronic and visual technologies. Conversely, the silicon-germanium faithful believe that a chip built of their new alloy matches the speed (one billion conversions per second) of the best circuit built of GAC, and that it operates on a fraction of the power required by GAC. The future will tell.

INFORMATION TECHNOLOGIES AND OPPORTUNITIES

By definition, information is knowledge, fact or data that is acquired or shared in any manner. The information element itself could be stock prices, taxes, software, an invoice, a text of a speech or document, news, any form of instruction either for a military action, to a pilot from the control tower, or from a teacher to students. There are many modes in which information can be communicated - through human messengers, postal service, newspapers, reports or books, radio or television, telephone, telex, fax, electronic mail or data transfer and teleconferencing. Each mode has been helped by technological advances to transmit the required information. The information technologies of the future will be in digital mode using micro-electronics and photonics (light-wave communication systems). The latter uses tiny lasers to pulse bursts of light at millions of bits per second through ultra-pure glass fibres (optical fibres). Thus, information system refers to the message and the medium/media used in communicating it - i.e. computers, satellites and optical fibres.

With the aid of appropriate software, advanced computers and high capacity optical fibres are able to transmit, switch and process voice-data, text, graphics and images by converting them into streams of binary code (digital) impulses. There are a large variety of software products including the "multi-tasking, multi-user operating systems" which provide users with more functions and offer them the opportunity to simultaneously shuttle among different tasks and run different applications such as word processing, graphics and spreadsheet analysis.

Communications and computer linkage

The convergence of computers and communications around microelectronics is forging global human interaction, stimulating new inventions, and is creating new business opportunities unprecedented in human history. It is bringing new capabilities to the workplace, and to the home; indeed, it has shrunk the world to a global village.

Today, local area facilities/networks are indispensable in government establishments, factories, hospitals and research institutions, just to name a few. The wiring of buildings and neighbourhoods together allows for a rapid exchange of ideas and information on a project between supervisors and staff, and it enables a foreman on the shop-floor to communicate with the supervisor for further instructions. At present, the computer-communication linkage is creating a new cadre of workers -"work at home", who for a variety of reasons, such as the need to provide child care, or because of disability, cannot endure the rigour of a formal office environment.

The emerging information infrastructure is already helping business in many ways - through business communications, which reach their destinations in seconds or minutes instead of days, electronic transfer of bank data and money, and the organization of business meetings among staff in different locations. Such a process is bound to enhance productivity by ensuring speedy performance of assigned tasks. It will also save many trees from being cut down for the manufacture of paper; this will reduce paper filing and subsequently save space.

Electronic mail. The first computer network (ARPANET) was designed for the former Defence Advanced Research Projects Agency (DARPA) of the United States to link scientists at various universities and research institutions in order to gain easy access to computer machines and databases that were not available locally. 28/ An added feature of this facility was an electronic mail (E-mail) system which enabled researchers to exchange communications among themselves. However, it soon became apparent that E-mail was the most popular feature of ARPANET. E-mail made it possible to coordinate activities with project members as well as stay in touch with funding agencies. Today, this particular E-mail system has grown into a world-wide system known as **INTERNET** with links to an estimated 1,500,000 computers, through over 10,000 networks in 60 countries. Individuals can subscribe to Internet through a local network for about US$ 9 to $ 20 per month based on the service requested and offered.

Regional or local networks connect to Internet every 10 minutes, and 5 out of every 10,000 Norwegians are linked to the system. It is possible to access a variety of bulletin boards and receive information from over 4,000 discussion groups that address every conceivable issue such as politics, science and energy, African culture, architecture, food and recipes, antique autos, image processing, religion, computers, books. On 2 March 1993, President Bill Clinton of the USA, in discussing the advantages of an "information super-highway", felt it necessary to use E-mail (Internet) to demonstrate its capabilities to the country and also to the world. The Internet system alone is expected to serve over 125 million users by the year 2000.

Today, commercial users of the Internet system outnumber academic and government users. In an announcement on 12 April 1994, the major USA Silicon Valley companies, with funding support of $12 million from the US Government, established a new regional network, ***Commercenet***. 29/ The latter is linked to Internet and will "permit companies and individuals who are connected to the Internet to buy and sell goods, look up and exchange information and collaborate on engineering projects. Buyers and sellers can now meet on the network and trust each other". Bank of America referred to the system as, "a virtual bank, ... a major opportunity to expand outreach around the world".

Since the civil acquisition of Earth data from satellite altitude began in 1972, an overwhelming number of data has been acquired particularly by the managers of the LANDSAT and SPOT systems. The price of these data, either in film, print or tape, is quite high for the developing countries. Shipping and delivery are time-consuming, costly, and from time-to-time, unreliable. Internet is being invited to come to the rescue. A Cooperative Agreement Notice (CAN) issued by NASA on 9 March 1994 solicited proposals "to stimulate broad public use, via the Internet, of the very large remote sensing databases maintained by NASA and other agencies to stimulate U.S. Economic growth, improve the quality of life, and contribute to the implementation of a National Information Infrastructure."30/ The success of this initiative will pave the way for making electronic communication the future channel for gaining access to Earth resources data bases.

Through electronic mails, remote printing of papers, books and reports has become routine. For example, the Secretariat of the Association of African Universities in Accra, Ghana, speedily responded by E-mail to our request for the addresses of all universities in Africa. In fact, escalating costs of publication are forcing many publishers of reputable journals to electronically make available to the world community, at a reduced cost, the texts of their journals; prominent amongst these are Aviation Week and Space Technology, Space News, the Washington Post, the Guardian, the Wall Street Journal and the Economist. With the aid of a computer and a functioning telephone system, any African can gain access to these publications.

In Africa, where financial resources are scarce, centralization of badly needed journals and books might be desirable. With the aid of scanning and E-mail facilities, researchers and educators in remote locations can have access to such a central depository. Africa's social and physical scientists as well as government entities can gain electronic access to more than 1800 data bases around the world, such as the UNEP-GRID system, the International Geosphere-Biosphere Programme (IGBP) databases, and many specialized research centres and libraries. E-mail also offers African researchers that are working on similar subjects the opportunity to link up with one another and share experiences.

For example, the ***Current Awareness Service*** database provides the latest information on what is being done globally, on any given subject/programme/technology/discipline, by whom and where. In Europe and North America, by linking communication infrastructure, computer and farmers, ***teledata*** has become a reality. 31/ Through the latter, farmers are provided with information on their crops, the sowing season, type of soil, weather, type of crops that can flourish in a specific geographical location, and suggestions on the choice of pesticides, including the amount and timing of application. In Africa, such a functional teledata system, linked to a reliable agricultural data bank, will certainly enhance our agricultural productivity and ensure food security.

Electronic servants and services. The information network of the future will provide a variety of services; most of these are still in the"idea" stage, others are being experimented upon; voice recognition technology can also play a role in the venture but software technology is the key. For example, it has been demonstrated, illegally, that ***viruses,*** such as specifically designed software programmes, can travel around the world, within the global telecommunications network, unsupervised, install themselves on distant computers and perform preselected tasks. Through this experience, albeit illegal, a new agent, known as ***Knowbot*** for ***Knowledge robot***, has been developed for Internet to assist in finding E-mail addresses of over 20 million users of the Internet system. 32/ ***Knowbot*** is able to travel from database to database in Europe and the United States in search of a specific name. When it finds it, it reports back to its master on his/her computer.

The success of ***Knowbot*** may give birth to a commercial ***Agent***. AT&T, Motorola, Inc., Sony Corporation, Apple Computer and Nippon Telegraph and Telephone Corporation of Japan have teamed up to develop ***Agent***. IBM is working on its own version of agent. ***Agent*** is a specific software that "knows something about its master's taste, budget and schedule and takes care of his/her personal chores". It is a ***personal emissary*** that moves across communication networks in order to run errands for its master. Agents under experimentation can locate E-mail addresses, make hotel, airline, and restaurant reservations; future agents are expected to do much more in order to make the information age a reality.

To achieve that reality, services that are being provided to the general public by specific entities will need to be part of the electronic age, such as the department and grocery stores, book stores and other areas that affect our common lives. That is already happening albeit on a limited scale. At most airports in Europe, on-going global weather forecasts are conspicuously on display on a number of TV screens. In Paris, the telephone directory called ***Minitel*** is now on-line; at the request of a guest at a hotel in Paris for a local telephone number, all the hotel has to do is to consult its own computer - its linkage to the information system in Paris. Similar systems are being installed in cities in the USA. In Europe, USA and Japan, and in a large part of Australasia, ***tele-banking*** is now normal. In a number of American cities, people are also finding jobs through the ***America's Job Bank*** by consulting computer banks designed for that purpose at specific locations.

Paying for use of the electronic super highway. Most of the services to be offered by the information super highway of the future will need to be paid for, and how to execute such payments is being addressed by bankers, particularly in Belgium, Denmark, Spain and the United

Kingdom. A new ***plastic payment card***, embedded with a microchip and known as ***Mondex***, is being developed in the U.K. Card-reader phones (public or at home) and teller machines will be equipped to increase the money balance on the card. 33/ The same card-reading telephone will also be able "to debit the cost of each service from the card balance. At the same time, the service-company's computer would electronically credit its own Mondex account".

TELECOMMUNICATIONS SYSTEMS IN AFRICA

Today, only about three African countries are adequately connected to the global INTERNET system. Educators and professionals in most other African countries connect to the INTERNET and its associated world wide web using radio links to connect to the communication facilities of their European and American partners. Future communication programmes/proposals that may affect Africa include the following:

1. Africa Optical Network by AT & T (US$ 1.9 billion)
2. A number of Low-Earth Orbiting Satellite based communications systems-
    - GlobalStar (48 satellites) Lockheed Martin and Loral Corp.
    - Teledisc (840 satellites) Bill Gates & Craig McCaw
    - Inmarsat's ICO Global Space Communications Ltd.
    - Iridium (66 satellites) Motorola-led consortium
    - Odyssey (12 satellites) TRW and Teleglobe Inc. of Canada
3. AT & T - (12) geostationary orbit satellites accessed through small antennas
4. Euro-African Satellite communications (EAST) by Matra Marconi Space, UK

POSSIBLE CONCERNS FOR AFRICA

During the cold war era (late 1940s to late 1980s), unmitigated attention was devoted by Europe (East and West) and the USA, in their highly capitalized military-industrial complexes, to perfect their war machines for ***mutual assured destruction* (*MAD*)**. Today, swords are being beaten into plowshares and the factories that were previously designed to provide battlefront supplies during the cold war era, are now being retooled to produce essential consumer goods. The same goes for the use of any other technology - it is simply a policy decision backed by essential capability and capacity - to produce guns ***or*** butter. The existing military infrastructure will become an economic liability to their owners if the ability to convert them to peace-time uses is not there. Similarly, in the absence of any clear policy decision and honest commitment in Africa by Africans, particularly to understand, master and judiciously adapt the new and emerging technologies for the benefit of the continent and its populace, these technologies will become threats to our existence and survival.

Economic implications

What are these threats? As shown earlier, the microprocessor that will be in the forefront of most future technological developments is already in many products we consume now - from wrist watches to television sets, from motorbicycles to cars, trucks and air planes and a variety of communication infrastructures. Although Africa currently spends over US$ 2 billion annually on new communications plants and equipment, 99% of these facilities is imported. The same is true of many other sectors of our economy. The economic consequences of our foreign purchases include the flight of capital and expertise to foreign lands, unemployment for Africa's scientists, engineers and technicians and the loss of the indirect benefits of such investments on the local economy. In the final analysis, we are contributing to the wealth of other societies at the expense of our own. ***Such a scenario will certainly widen the development gap between Africa and the industrialized world.***

From the colonial era, most of Africa's raw materials such as copper, rubber, iron-ore, palm products, cocoa, ground nut (peanut), timber, kolanuts and crude oil have and are being turned into finished products by the industrialized countries in their own lands and then resold to Africa. These raw materials may be marginalized in the future as new materials, developed as composites or through biotechnology, take their place as components in the manufacture of goods and in the delivery of services for the global market. ***The subsequent economic consequences are too dire to predict.***

External influence

From Cairo to Lagos, from Dakar to Nairobi, and from Harare to Yaounde, all our roof tops, front and backyards, and even in some cases, the shoulders of roads in the residential areas of our mega cities are littered with every conceivable type and size of receive-only television antennas. One could easily conclude that these huge investments reflect our desire for knowledge through the global information network. True, but the information filtering through these communication networks originates, to a large extent, from other lands. Indeed, we need to know about other cultures and lifestyles, but how much of Africa's cultures, beliefs, lifestyles, and development programmes is channelled through these same international airwaves to other lands? And how do the values being fed to Africans, daily, through these same airwaves heighten their expectations beyond their level of affordability? Our mastery of the emerging information technologies will enable us to force ***information sharing***.

Security

Any technology can be abused, be it old or new. Computer ***hackers*** have the competence to introduce viruses or illegal agents into the information network, but the capability also exists to track the individuals responsible for such crimes. While the information age will provide an unprecedented global communication freedom, with the opportunity to access an unlimited number of databases, particularly through E-mail, ***the system can be tapped or can be used to commit other criminal acts, particularly if such actions have economic or other material value***. These and other possible misuses of technology should be of concern to those who intend to benefit from this channel of communication since such a system can also be used for sensitive negotiations. ***An adequate knowledge of the technology is an essential shield.***

A number of ideas are being developed by manufacturers to protect the computer systems and ensure their security. In an attempt to detect individuals who fraudulently use the electronic mail network to commit their crimes, the US Government is pressing the computer hardware and software companies "to adopt a new ***encryption technology*** called the ***Clipper Chip*** that would allow Federal (USA's) investigators to intercept coded transmissions over computer networks".34/ Computer companies are adamantly opposed to such a proposal, since adopting it would undermine the confidence and trust of foreign customers in a machine with a coding technology developed by the US Government. In the meantime, concerned companies are continuing their search for a high security solution.

Africa - the last frontier

As we approach the 21st century, Africa remains the last global frontier to be positively impacted by the wave of science and technology developments that are bolstering social and economic growths in other lands. Indeed, the general perception of the international community about Africa, and of Africans about our home land, can be summarized as follows: A technological desert; left out of the global information society; little communication across ex-colonial lines; plagued by extensive under-utilization of equipment; ridden with failure of major technology-based projects; poor infrastructural support (water, electricity, telephone, transportation); pre-occupied with turn-key and application projects; little inclination towards research and technology development programmes; littered by poorly defined technology policies and strategies; mis-utilisation, under-utilisation and non-utilisation of human resources; saddled with debilitating regulatory policies; overwhelmed with incessant civil strives; paralyzed by external debts and debts-servicing; and in search of visionary leadership.

AFRICA'S CHALLENGE: PLANNING FOR THE FUTURE

To begin with, we Africans must reflect on what we are doing to Africa. Among such reflections is our need to take a stock of the incalculable consequences of constant civil strifes on African soil. And on the science and technology front, we equally need to assess the direct and indirect contributions we are making to the wealth of other lands at the expense of our own, actions which, as stated above, include capital flight and expertise, unemployment for educated and skilled professionals, and loss of investment in the local economy. Our main challenge as Africans is the urgent need for visionary leadership that can provide political stability as well as create and sustain an enabling environment that will encourage Africans to invest in their own future and in the future of the continent as a whole. Such an environment should allow Africans to: (a) fully and actively participate in and contribute to the unfolding science and technology development and associated economic evolution; and (b) subsequently partake in the untold opportunities, thereof, that lie ahead. Addressing Africa's challenge also demands clear policy formulations, long-range decisions and honest commitments at each national level in Africa by Africans.

Given our natural endowments, we have a number of national and regional institutions that can be called upon or reoriented, adequately funded and strengthened, to lead us to the future. And in order to help us reach that future, new institutions can also be established with specific agenda, as may be necessary. In so doing, it should be understood that we are ***not*** taking these steps to prepare for a race with any one but ourselves. Our challenge also requires that we appreciate and understand, master, and judiciously apply and adapt the old, the new and the emerging technologies, as may be appropriate, to meet our needs and satisfy our priorities and aspirations.

(i) Appreciating and understanding technology

We will succeed in adopting the new and emerging technologies ***only*** by our relearning what technology is all about, and by a drastic re-definition of our concept of ***technology transfer***. As practised in Africa today, technology transfer has resulted in ***turn-key projects***, and the exchange of our money for foreign manufactured equipment. By their very nature, turn-key projects do not contribute to intellectual stimulation. Technology is the tool used in translating scientific knowledge into economic productivity - a capacity that depends on the individual and the institutional character of a nation. Developing that tool and making it work efficiently requires investments in time, talent, labour, patience and money. Accordingly, it has a proprietary value. ***No entity, government or private industry, freely transfers any technology to any other country, be it developing or industrialized.*** Furthermore, a technology that is transferred into an environment will survive in the recipient environment if the latter nurtures a science and technology culture. That nourishment is very critical for the survival and continuing exploitation of what is being transferred.

In this connection, Griffin and McKinely1 noted that global distribution of technological capabilities is even more unequal than the global distribution of income, or the global distribution of physical capital. As a way of addressing this problem, they called for an international policy that would increase the technological capabilities of developing countries as a whole, through the creation of a broad based scientific and technical knowledge among the population. Important aspects of such broad-based knowledge, they conclude, include learning-by-applying, learning-by-doing and learning-by-using. Skills produced through such informal processes / aptitudes contribute to and enhance technological innovations.

In Africa, most technologies that are in use are often imported or transferred from their respective development centres. In the immediate future, this trend will continue. While a number of African countries have established mechanisms that would ensure that imported technologies are appropriate, most have not done so. Continuous interaction and sharing of experience and expertise among African countries and between African and other developing countries would ensure that African countries adopt technologies that are appropriate for their own economic and social development process. To be appropriate, a given technology should be relevant to the solution of the problem at hand, it should have the least possible negative impact on the locale where it is applied, and should be understood by the indigenous people that it is supposed to help. In addition, it should also be easily maintainable and monetary affordable and should have the potential for further development. Above all, it should be demand and user driven.

If a given technology is to be used properly, it must be thoroughly experimented with, understood and evaluated for all its possibilities for failure and success. Japan is a typical example of this. Understanding a given technology requires not only a pre-occupation with what that particular technology can do; equally important is a sound knowledge of why and how it works the way it does. That understanding will ensure the nurturing and sustenance of any technology that may be transferred or imported for local adaptation.

Lessons from other lands

In entering the industrial age, Japan recognized that it had a large labour market and very limited natural resources. It subsequently chose to buy, ***not the latest, but the used and working models*** of the technologies in Europe and USA. It trained its large labour force and perpetually kept these machines in working condition, through trial and error and the re-tooling of replacement parts. The process paid off, and Japan gradually acquired the necessary knowledge,

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1 Griffin, Keith and Terry McKinely (1996). New Approaches to Development Cooperation. Discussion Paper Series 7, UNDP, New York.

through investments, experimentation and patience. Japan applied this principle to its automobile industry - and has repeated it in many other areas including space technology. After buying and using USA developed and manufactured rockets since the launch of its first satellite in 1970, Japan attained an independent space propulsion capability in 1994. Indeed, it is now predicted that Japanese satellite manufacturing entities will emerge as full-fledged competitors by the late 1990s, but definitely in the 21st century.

Africa does not have the resources of Japan; the orientations and the needs of the two societies are also not the same. But there is a lesson in the systematic approach and the commitment of the nation's political leadership and succeeding governments, its private industries and its people to a given goal. In its rise to its current preeminent economic position, Japan received much cooperation from abroad, learnt to use its own natural endowments properly, established achievable objectives and persisted in attaining them. Africa can do the same.

India attained its capabilities through internal discipline, foresight, commitment and cooperation with USA, Germany and Russia. Brazil is cooperating with China to build a remote sensing satellite (CBERS); the first in this series might be launched in 1996. .Brazil attained its expertise through cooperation with appropriate research institutions around the world. Today, Indonesia is building parts for Boeing 737 and for helicopters that are finally assembled in different parts of Europe. And the Industrial Revolution era that is often quoted in history books is replete with knowledge sharing and purchases (legally or illegally) between Europe and North America. And "between 1956 and 1978, Japanese corporations paid $9 billion to acquire technology that cost America between $500 billion and $1 trillion to develop". 35/ A commitment to sustained investment in the aforementioned approaches by the countries of Asia, including the appropriate utilization of their human resources, has enhanced the skills and capabilities of their aeronautical industries to such a point that they have been emboldened to technologically challenge, as a group, the dominance of leading aerospace companies, such as Boeing and McDonnell Douglas (USA) and Airbus Industries (Europe), in Asia's commercial aircraft market in the next two decades.

(ii) Mastering technology

The capacity of a nation to absorb technology, new and old, lies not only on the intellectual level of training of its citizens, but also on its institutions. Thus, there must be plans for alterations in institutional structures, operating procedures, human resources utilizations and reward systems if African scientists and engineers are ever to be effectively instrumental, not only in the adoption of foreign developed technologies, but also in the evolution and development of technologies that can be gainfully employed within the African community.

Recognition and appropriate utilization of indigenous talents

In Africa, we continue to complain of ***brain drain,*** but we have not addressed it. India, Indonesia, China and Brazil also complained of the same problem, but they all did something about it and are reaping the rewards today. First, they all recognized that without ***well educated and disciplined human resources***, they could not attain their respective national objectives. They also recognized that one of the serious aspects of ***brain drain*** is the multitude of qualified and capable individuals who are idle in their own countries. In several instances, their talents remain unrecognized and therefore unutilized, unchallenged and hence under-utilized or misdirected, and therefore mis-applied. 36/ The Asian and Latin American countries targeted their qualified talents at home and abroad and accepted and adopted the prescription proffered by Bhattasali, (former Executive Director, National Productivity Council of India) which he coined in these words: "***the quality and the character of a man's perceptions as well as his subsequent responses are determined in part by limitations imposed by, or opportunities available in his environment. If he is to manifest any real growth and reach his higher potentials, his creativity would need nourishment from his environment".*** 37/ In pursuance of this goal, it should be remembered that life offers few pleasures more invigorating than the successful exercise of our faculties. Once in action, it unleashes energies for additional work. Thus, we Africans must become very conscious of the fact that ***the goal of a nation is the collective aspiration of all its people***. A nation that aspires to be the master of its own destiny, must place a premium on the talents, abilities and the creative capabilities of its citizens.

Information sharing-knowledge building

Adequate information is a major pre-requisite to gaining knowledge in any field of human endeavour. In Africa, urgently needed is adequate information to help cure illnesses, bring food, bolster production, foster education about latest technological developments, research trends and results, applications, products, services, equipment; and for formulating social and economic policies.

The information age is demonstrating daily that our neighbourhoods and where we do business or play, do not necessarily have to be limited to our immediate physical environment. The information technologies offer us the freedom, as individuals or corporate entities, to form electronic tribes and partnership that can span the globe. Today, in societies that have begun to invest in the future, many people base their hopes for education, profit and competitiveness in the ability of information technologies to provide the necessary electronic connection. By becoming a part of this global communication connection, Africa will shed its isolation and be able to acquire necessary knowledge in various areas of human endeavour very cheaply and easily, and simultaneously share its own knowledge of its environment, politics, culture, development programmes and goals with the global community. Africa can accomplish these with the least sophisticated elements of the information system.

Just as an isolated human being is unable to share his/her thoughts or ideas with any one else, nor benefit from the ideas of others, in a similar manner, a stand-alone microcomputer has many limitations. It cannot share information in its memory with any other user at a remote location, and it cannot receive or access information from any other source; it is isolated. Similarly, and partly because of poor communication or infrastructure, most of the computers in Africa today are standing alone, unconnected. However, if they are linked with other computer network systems, the users can interact with one another, and sharing of knowledge becomes easy and rewarding.

Africa needs technology development

In carrying out our programmes for the future, we will need genuine external support. Agencies and funding institutions that are helping Africa must also reassess their technology transfer efforts in the continent to date, and need to appreciate and respond to the urgency of promoting technology development in the continent. Among the steps being taken by the United Nations, through its Space Applications Programme, in response to this need, are (a) the development and subsequent implementation, with the support of European contributors, of a project proposal called **COPINE: A Cooperative Information Network Linking Scientists, Educators and Professionals in Africa**, and (b) the establishment of a number of regional ***Centres for Space Science and Technology Education.***38/ The COPINE system will focus on the collection, transmission, distribution and exchange of information among African countries and their institutions as well as within international communities, particularly in such areas as health care, agricultural research and development, management of natural resources and environment, education/tele-education, and science and technology. Given the urgent need to improve health care in Africa, the application of the COPINE system will initially be directed towards health care and tele-medicine in a number of African countries; the system would subsequently be expanded to cover other application fields as identified above and other countries in the continent. The regional centres shall focus on in-depth education, research and applications programmes in communications, Earth observations (satellite meteorology and remote sensing), and upper atmospheric research. Participants in the programme of each centre shall include university educators and research and application scientists. The Centre for French-speaking African countries is being established in Morocco; similarly, the Centre for English-speaking African countries is being established in Nigeria. UNESCO has also reacted and responded to Africa`s technology development need by creating, in February 1994, the ***International Fund for the Technological Development of Africa*** and providing it with an initial donation of US$ 1 million.39 / In announcing the establishment of the Fund at a symposium on Science and Technology in Nairobi, UNESCO's Director-General said: "Africa must evolve its own blueprint for development and must no longer depend on external models. Your continent possesses the necessary talent and resources. What it needs is the knowledge and expertise to realise its human and natural potential." Indeed, industrialization of Africa must recognize that intellectual activities in African universities are undeniable sources of industrial innovation. Similarly, the skilled human resources available at Africa's polytechnics are begging to be utilized effectively in the industrialization of the continent.

(iii) Judiciously applying and adapting technologies

A successful industrialization of Africa requires not only financial investment but also sustained scientific and technological experimentation that could nurture the industries into full maturity. Paramount in this approach is the determination of Africans to first curb their own propensity for foreign made products, with a parallel effort in long-term investment in home grown industrial development. In this connection, it is appropriate to reflect on the 1979 commentary on "Britain and innovation" by Mr. John Stansell 40/ when he assessed the economic power of his country and proudly concluded that: "Everyone knows that we are an industrial country, that our wealth is based on adding value to raw materials, and that our trained engineers are our lifeblood." It is no exaggeration to state that Africa still remains a large supplier of the raw materials alluded to by John Stansell.

Building essential infrastructure

Africa cannot afford to be isolated from the global community. But it may be isolated, if a number of its essential infrastructures are not designed to function efficiently. Africa's telephone services are very unreliable, and they are the most expensive in the world. In the period 1978-1988, the Transport and Communication Decade for Africa, ended with only 1.1 per cent of the world telephone lines being located in the continent, and more than half of these lines (4.3 million) were and are still located in South Africa. 41/ We should invest in a telephone system that will serve the total community - only a few can afford cellular phones. The situation with our electric power supply is the same; the multitude of stand-alone individual power generating units (particularly from Honda) that litter the African landscape at homes, in educational institutions and corporate and government establishments, and the array of candles in Africa's hotel rooms are a testimony to the unpredictable power supply in the continent. The third essential element is the availability of well-trained local technicians that can breathe life into the machines and equipment when they break down. For example, because of lack of spare parts and maintenance, Africa has become the graveyard of countless surveying equipment. Commerce and industry are deterred by such instabilities in communication, electrical power systems and maintenance potential, and are only attracted to wherever they are reliable. The same is true of the new and emerging technologies; they will thrive in those environments where infrastructural elements are stable and dependable.

CONCLUSION

The entry of each African country into the 21st century must begin with a reassessment of itself, its institutions and their mandates, its attitude and approach to old and current technologies, its educational institutions and the relevance of their programmes, its capacities and the manner it utilizes its human resources, and the roles of government, educational institutions and the private sector in the affairs of the state. Ministries of Trade and Industry as well as Science and Technology are championing technological development growth in Asia, Europe and North and South America. Similar arms of the governments of African countries must do the same.

The future is rich in untold opportunities that could breathe new life into agricultural productivity, give adequate and timely information about our physical environment and the natural resources therein, and place at our disposal new medical remedies for most human ailments.

But first, African countries and their political leaders should link their priorities with the needs and the aspirations of *all* their citizens. Africa should satisfy its own needs, beginning with reliable and efficient electric power supply, communications systems and transportation infrastructure. It should invest in high, mid- and lower level manpower development and ensure their judicious utilization. It is only thus will it be able to contribute to international trade of the future which will essentially depend on manufactured products and services made possible using the new and emerging technologies.

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