TELECOMMISSION

Study 5(g)

Problems in Data Transfer with Particular Regard to Visual Data

The Department of Communications

STUDY 5 (g)

PROBLEMS IN DATA TRANSFER WITH PARTICULAR REGARD TO VISUAL DATA

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Ottawa, 1971

This Report was prepared for the Department of Communications by a project team made up of representatives from various organizations and does not necessarily represent the views of the Department or of the federal Government, and no commitment for future action should be inferred from the recommendations of the participants.

This Report is to be considered as a background working paper and no effort has been made to edit it for uniformity of terminology with other studies.

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TABLE OF CONTENTS

Terms of Reference

Visual information is becoming increasingly important in the spectrum of communications. Technical developments of recent years (film equipment, television, videotape, computer-controlled display terminals, microfilm systems, etc.) have made the transfer of such information possible on a larger scale and the transmission of such information over voice-grade and wideband telecommunication channels desirable. The complexity and volume of data that institutions in our society have to deal with today makes the use of graphic techniques of data presentation imperative, as one picture can be more valuable and easily understood than pages of lineprinter output.

This study should outline not only current situations, but focus also on future potentials and problems and recommend policies to encourage the utilization of these potentials as well as methods to overcome the problems.

Among other developments the recent capabilities of computers in the visual area have far-reaching implications. There are three major media for displaying moving images: motion picture film, television and videotape, and computer-controlled display. Though these have different technical requirements their uses should be considered together. In fact, the computer can serve as the integrating link, since scanning and recording of documents, graphics and film are now possible by computer, and the same is true of videotape.

The programmed versatility of the computer in future graphic systems will add a new dimension. In addition to conventional pictures, such systems will be capable of dynamic data display to help us visualize our information with regard to its development in time. Thus, we will be able to view on a map, for example, changes in population, income, transportation, pollution counts, housing, data communication, etc. in the form of continuously changing images.

Such computer-generated moving images can also be simulated to depict situations and environments which are abstract or only conceptual, and provide new insights into urban planning, architecture, animated film and television productions, etc. The images can further be stored in a central memory from which they can be processed, retrieved, manipulated and viewed remotely. Should reproduction be required, they can be electronically typeset for printing and recorded on film and videotape.

The study should be broader, however, and should consider the needs and applications of the current users of visual data communication, as well as projects on computer graphics which are now being developed in universities, government and industry.

1. Describe the status quo with regard to the generation, transformation and transmission of different forms of a visual information. To that end:

   (a) Outline the various methods now in use for the generation, transformation and transmission of visual information;

   (b) Outline the various applications of these methods;

   (c) Outline the various capabilities of present methods of generating, transforming and transmitting visual information;

   (d) Outline the problems arising from the status quo.

2. What are the present requirements imposed on our telecommunication facilities for the transfer of data to support the current needs in visual communications?

3. What are the future requirements imposed on our telecommunication facilities for the transfer of data to support the expected and potential needs in visual communications?

4. What new services may emerge in the next decade?

5. What are the potential social effects of an increasing demand for and utilization of visual information communications systems?

A Graphical Overview

<u>Conventional</u>

Displayed visual information is one-way, content is same for all viewers and cannot be altered.

<u>New</u>

Displayed visual information, depends on the individual's instructions and can be manipulated by the user via the computer.

1. Television
2. Films
3. Printed Materials

Visual Data Display

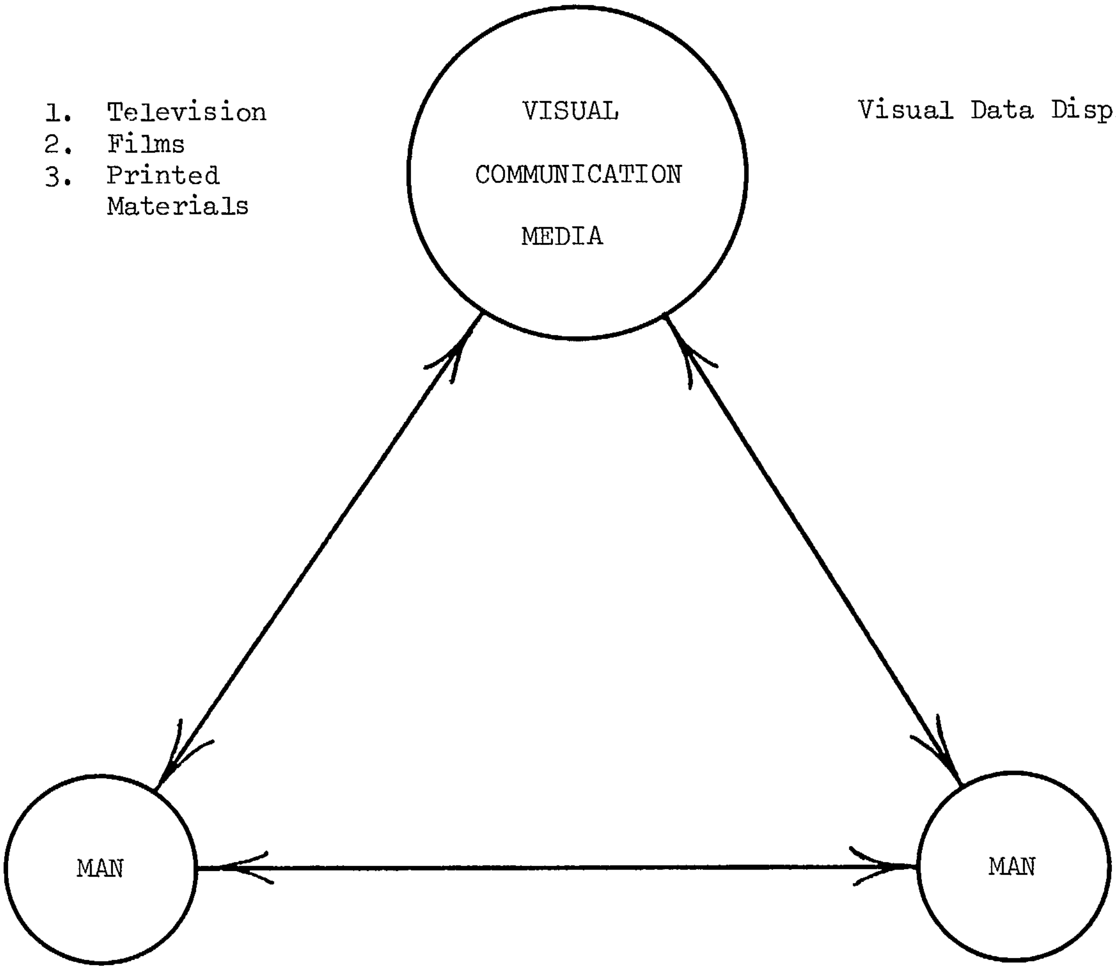


Figure 1. The Enhancement of Man to Man Communication through Visual Media

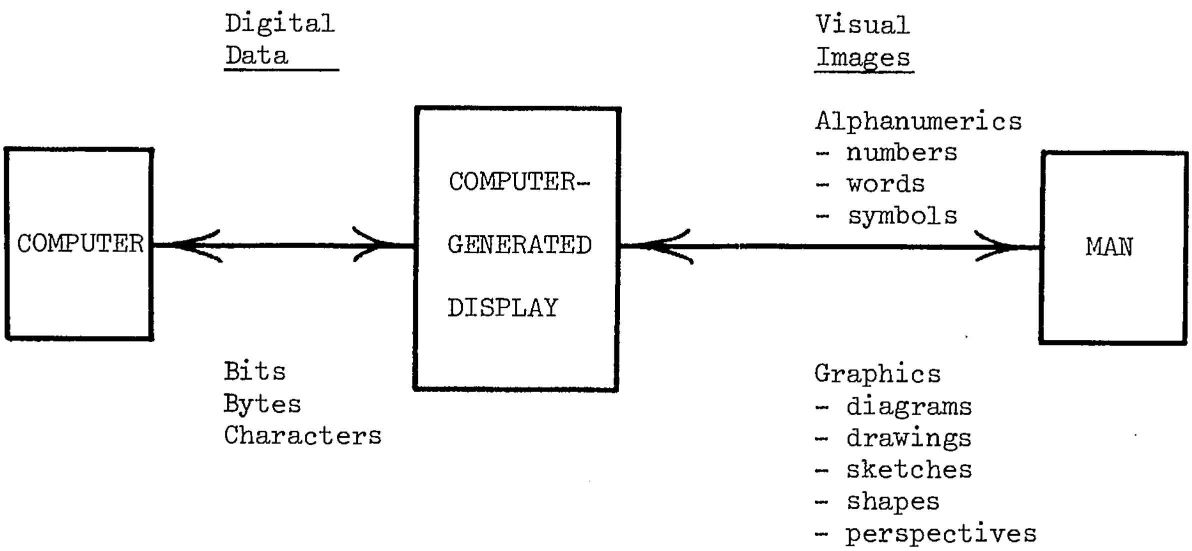


Figure 2. The Enhancement of Computer to Man and Man to Computer Communications through Visual Display

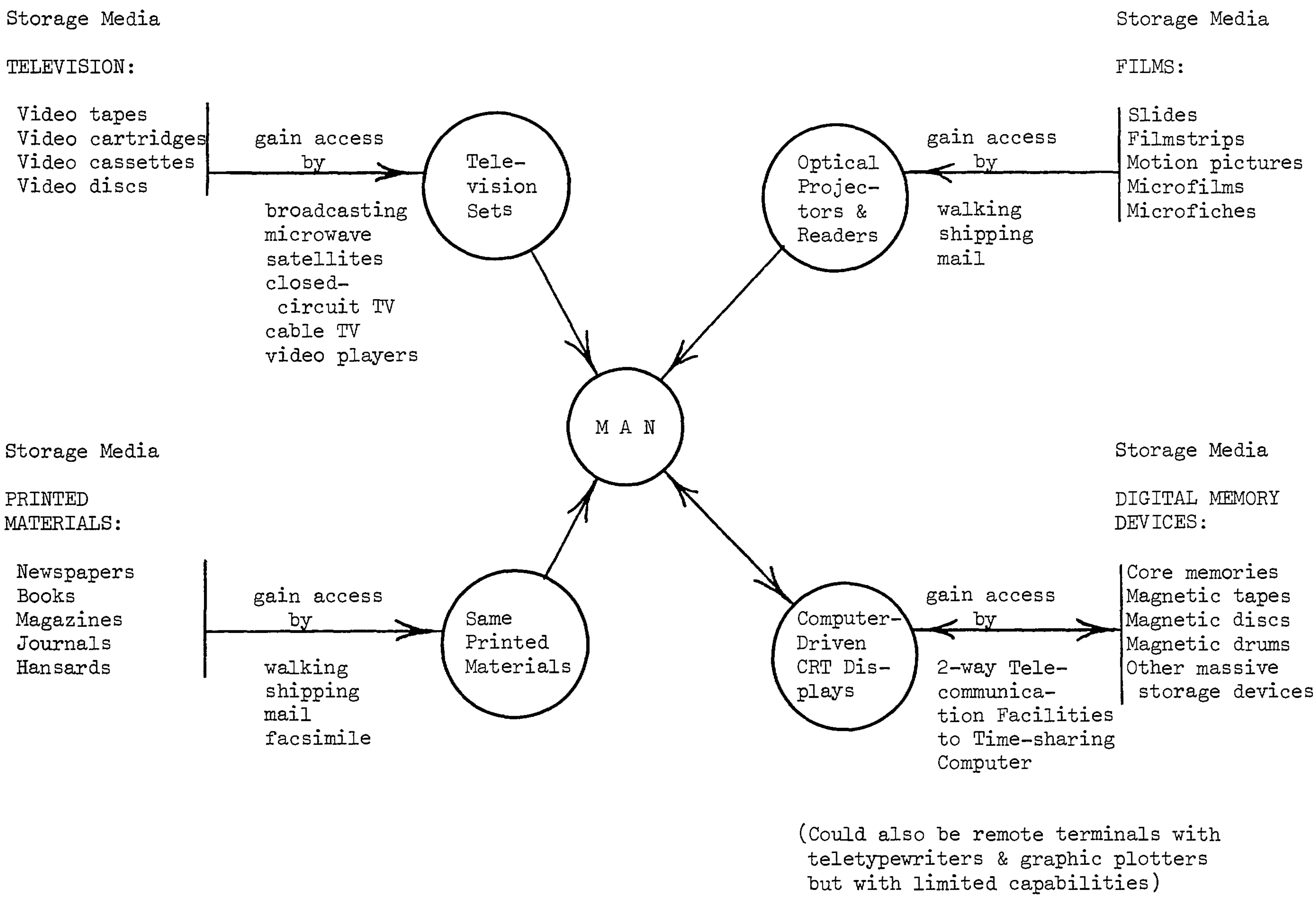


Figure 3. Different Forms of Visual Information Transfer

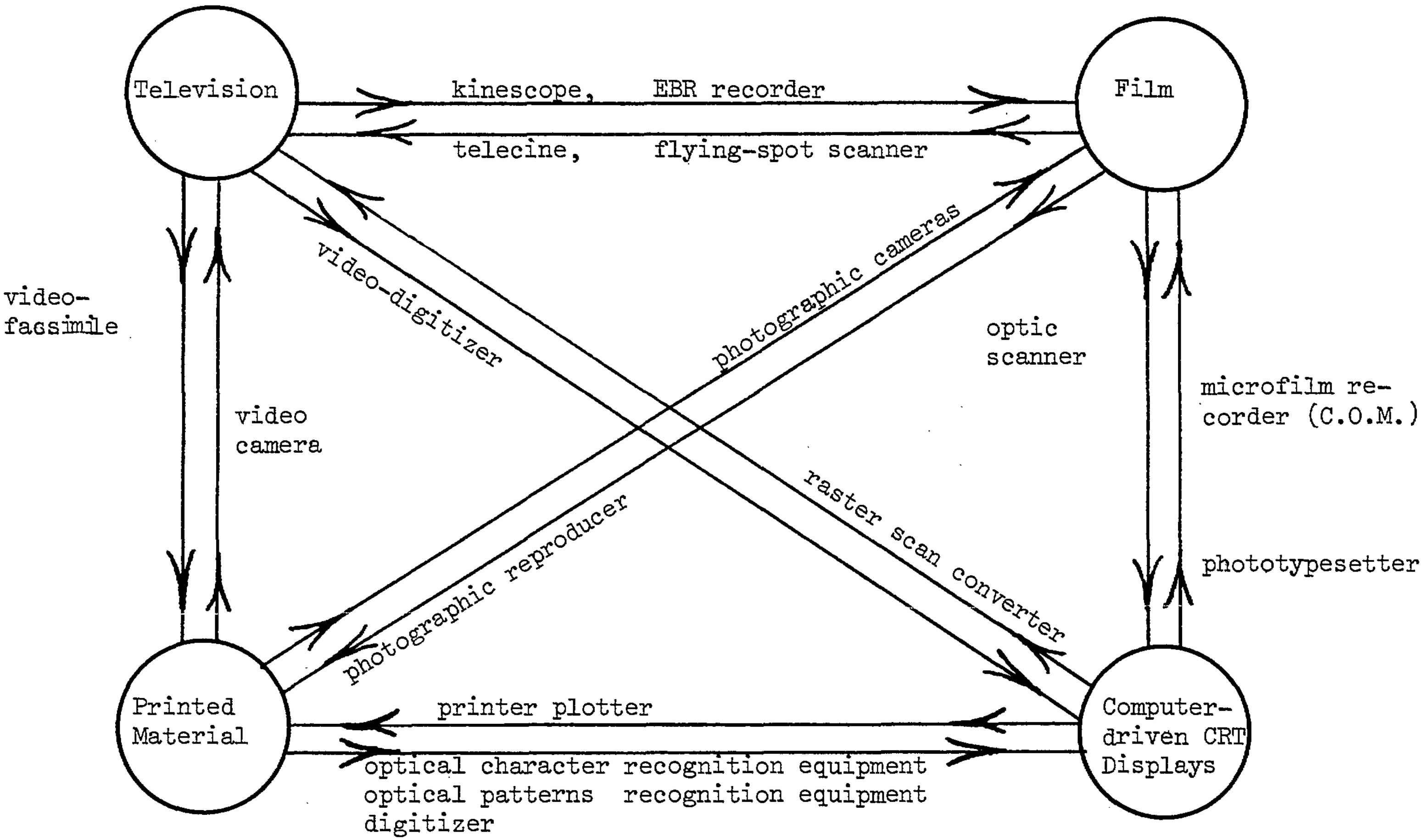


Figure 4. Different Transfer and Conversion Processes
for the Interchangeability of Visual Media

Status Quo of Visual Information
Relating to:
1. Visual Data Display

A visual data display is a new form of visual medium and it can be defined as any device which converts computer output data into alphanumerics and graphics. Such visual display devices cover a tremendous variety, from the simple electro-magnetic numeric indicators to holographic display systems. In between, there are many others, such as electric typewriters, high-speed electrostatic line printers, large display boards employing hundreds of electro-magnetic discs for flight information and stock market quotations, and the $16\frac{1}{2}$' x 42' light board used for message displays at EXPO '67.

However, it is the continuous development of radar and television that has provided the cathode-ray-tube (CRT) as the most promising computer output display for use today and, most likely, for the next decade. The CRT, with its associated electronic display control, permits the "drawing" of visual data on the face of the tube at electronic speed. Thus, it can be used as a very efficient man-computer interface, and is particularly suitable for many on-line applications, such as the monitoring of industrial processes, airline reservations, stock quotations, etc. The study leans more heavily toward CRT developments, not only because of its capabilities and versatilities as a display device but also its use as an imaging device in the microfilm recorder and phototypesetter.

Much of the CRT display technology is derived mainly from applications developed for early military command control systems, such as in the SAGE (semi-automatic ground environment) air defence computer system and, recently, for the Mission Control System at the NASA Manned Spacecraft Center. In these systems, operational personnel must monitor over the face of the CRT displays all real-time data in easily readable visual forms, such as pictures, diagrams, symbols, numbers, and words; as well as be able to interact and instruct the computer by pushing function keys and by simply pointing, with a light pen at the appropriate information on the display. Though developed at tremendous cost, such computer-driven CRT display systems have demonstrated their value and efficiency as tools for man-computer communications. The capability for immediate showing of results in visual and easily readable forms reduces the time and improves the soundness of decisions.

During the past few years, the computer-driven CRT visual data display systems have found increasing numbers of scientific, technical, educational and commercial usages. Today, such visual data display devices are used in a variety of areas representing multiplicity of disciplines, such as in management information, process control, air traffic control, simulation, computer-aided design, computer-aided instruction, information retrieval, pattern recognition, graphic arts, printing, publishing, computer-produced motion pictures, TV, etc.

Type of Display

Depending on applications, three types of displays are in general use: alphanumeric, graphics, and large screen. They differ in size as well as in functions.

"Alphanumeric displays" generally come as tabletop size, with small CRT display screen, and are ideal for the single user. They are used to monitor computer-processed output, as 'soft copy' display, are noiseless in operation with limited keyboard facilities in communicating with the computer. Such alphanumeric type displays are gradually replacing the much used teletypewriters as a remote terminal in time-sharing computer systems, as evidenced in airline reservation and management information systems.

"Graphic displays" generally are housed in a console with a much larger CRT screen and can be viewed only by a few people at the same time. Such displays are capable of presenting both graphic and alphanumeric data. They are used mostly as a stand-alone system but are now slowly developing as a remote graphic system, on-line to time-sharing computers. Usually, very flexible facilities are included: keyboard, function keys, light pen, track ball, joy stick and line-drawing device (data tablet). This enables the user to interact very effectively with the displayed visual data.

"Large screen displays" are designed for group viewing. They are used mostly in military command and control systems and at NASA where graphic and alphanumeric data is optically projected onto a large rear-projection screen. Although the large screen display has similar capabilities as the graphic system mentioned earlier, it is used mostly for visual monitoring purposes. Only very recently, a limited number of such large screen displays has been made available for non-government users.

Display Generation

Three types of visual data are generated for display purposes: point plotting, line or vector plotting, and alphanumeric characters. The display can generally be considered as a peripheral connected to a central computer through an electronic display controller. Information processed and digitally encoded by the computer, or stored on magnetic tape, is transferred to the display through the controller. The information can be visual data representing the numerical results from computer computations, or can be encoded information transferred from a data set in time-sharing computer system. It can also be information transferred locally, via keyboard, tape and light pen. The information is then decoded and converted to analog voltages to direct a beam of electrons to write the visual information onto the CRT screen for display.

The commonly used methods to form visual information on the CRT screen are: random-beam positioning and raster scanning. In random-beam positioning, the screen is usually divided into 1024 x 1024 points to form a matrix. The electron beam is directed toward a specified position, and a blanking function turns on the beam when that position is reached. The random positioning method offers high precision, good resolution and tremendous flexibility, but is costly to build.

The raster scan method uses the familiar television scan scheme in which a fixed raster of evenly spaced horizontal lines is drawn across the entire screen. Visual information is displayed with a sequence of unblanking horizontal lines. Such raster scan-type display is much less expensive to build. Visually, the image quality is much lower than the random-beam positioning type but a rather inexpensive television monitor can be used as the display.

For alphanumeric data to be displayed, a character generator can be used to convert digitally coded signals into analog voltages for controlling the deflection of the CRT to form a prescribed alphanumeric character. The entire set of characters can also be stored as an etched stencil, which is mounted within the CRT. The electron beam can then be directed through the stencil for displaying the chosen characters on the screen. Another method of character generation uses a programmed dot matrix with a fixed number of dots to form each character. The character is displayed on the CRT screen by blanking all but those dots needed to form the specific character. Another method of character generation is to produce a number of strokes with specific orientations and magnitudes in forming the desired characters. However, the general rule is that visual quality and legibility of the alphanumeric data display is proportional to the cost.

For the line and vector type of data to be displayed in creating graphics and pictures, a considerable amount of data and graphic software storage is required. To reduce such storage and to speed up the graphic plotting, a vector generator can be used to link two defined end points with a series of closely-spaced dots or a solid line. Similarly, a complete circle can be drawn automatically by an electron beam with a circle generator by simply specifying the position of the center and the radius of the desired circle.

Methods and problems on display refreshing and manipulation will be discussed under "Computer Graphics" -- "Output Devices".

Remote Display

Visual data display devices are used increasingly as remote terminals to the time-sharing computer system. Through telecommunication facilities, geographically separated man and computer are linked together. The type of visual terminals varies from the simplest, with primitive CRT display and keyboard, to that of the sophisticated stand-alone computer-driven display with a complement of interactive devices. At present, most of the remote display systems for use in a time-sharing environment are designed to interface with telephone lines through data set or acoustic coupler.

Hardware, software, and communications needed for remote display are still costly. At the same time there is also a speed-cost mismatch problem involved. On one hand input data entry from keyboard is limited by typing speed of user. Consideringan average typing speed of 50 words per minute, that is still well below the data transmission speed of the voice grade telephone lines. On the other hand, most display terminals demand much higher data transfer rate from computer in order to make efficient hardware utilization. A combination of low speed and high speed data transfer rates between time-sharing computer and visual display terminals are desirable but such asymmetric line is not yet available.

However, depending on the way a particular display terminal is intended to be used, not all users require high speed display. Schemes have also been developed to reduce data transfer from the computer so as to be more compatible with data transmission rate of telephone link for three types of applications: monitoring, inquiring, and man-computer interaction.

In "monitoring", visual information is presented to the user and no feedback is required. Modified commercial television monitor can be used as visual display. Data transfers from the computer can then be converted to raster scan type video signals and be recorded and stored on video magnetic disc. With each track on the disc storing one picture for a display, a large number of television monitors can then share the same rotating disc memory for picture refreshing as well as storage. Data transfer will not be necessary, unless of course a change in visual information is required.

In "inquiring", some limited interactive capability is needed and a keyboard is usually provided. Specific inquiry is keyed in to the computer and a display with relevant but limited visual data is generated. Very simple CRT display with delay line for local picture refreshing is used, and the quality and the amount of visual data required for display is purposely set low. In addition, no graphical information is needed for this type of application. Therefore, the demand for transfer from the computer is much reduced.

In "man-computer interaction", where a display of characters, vectors, and curves are needed, generators capable of drawing these graphics can be employed. Since they are still costly, high speed digital circuits have been used in order to allow a number of local display terminals to time-share one single generator.

Much development work is still necessary to bring about a more favourable trade off between the remote display terminal cost and the amount of data to be transmitted over the telephone lines from the computer.

Multi-media display

There are many other traditional and conventional forms of visual data display techniques which can be used not only effectively as in present practice but can be integrated with computer-generated visual data as a multi-media form of display.

One method has been described earlier in which conventional television images and computer-generated visual data are electronically mixed and displayed over one or more of television monitors and receivers.

Slide and film projectors can be computer-controlled and the projected image optically mixed with computer-generated visual data display. Film is still a remarkable visual data storage medium, capable of retaining vast amounts of information in colour and well-defined detail. For many applications, information recorded on film or slides, such as maps, complex diagrams and elaborate scenes has been projected as static background material; while dynamic computer-generated visual data, requiring constant updating and interaction, has been displayed and optically combined onto a common viewing screen. The saving on memory storage requirements is very significant.

Such methods have been used mostly by military command and control systems, NASA, and air traffic control. They have also found some applications in computer-aided instruction and information and retrieval systems.

Future Display

Many new display devices are currently under active development in the U.S. and Canada, and there is continuing improvement in CRT-type displays, as well as those employing new techniques and new material. Flat panel displays, using glow-discharge scan and light intensification techniques, electro-luminescent matrix, plasma, liquid crystal, magneto-optics and others are already showing promise. With the advent of time-sharing computers, the remote visual data display terminal is becoming one of the fastest growth areas. The aim is to lower the cost of such terminals by providing both display and storage capabilities to the new devices, with added color features.

However, over the next few years at least, the raster scan-type TV-display will continue to be an attractive visual data display device. This is particularly desirable in that computer-generated visual data can be distributed through coaxial cables to a larger number of conventional TV monitors. In addition, with the use of scan conversion tube or conversion logics, the random beam-positioning type of display can be converted to a conventional raster scan-type TV display. If the scan converter is located near the central computer, coaxial cable can then be used for visual data transfer. It is thus apparent that with conventional video processing techniques, computer-generated visual data and television programs can be electronically mixed. The combined visual information in a variety of forms can reach a number of remote users through coaxial cable.

Status quo of Visual Information relating to: 2. Computer Graphics

"The graphic method, with its various developments, has been of immense service to almost every branch of science, and consequently many improvements have of late been effected. Laborious statistics have been replaced by diagrams in which the variations of a curve express in a most striking manner the several phases of a patiently observed phenomenon, and, further, a recording apparatus which works automatically can trace the curve of a physical or physiological event, which by reason of its slowness, its feebleness, or its rapidity, is otherwise not accessible to observation.

"Language is as slow and obscure a method of expressing the duration and sequence of events as the graphic method is lucid and easy to understand. As a matter of fact, it is the only natural mode of expressing such events; and, further, the information which this kind of record conveys is that which appeals to the eyes, usually the most reliable form in which it can be expressed."

From E. J. Marey, "Movement",
D. Appleton and Company,
New York, 1895.

"Vision, our creative response to the world, is basic, regardless of the area of our involvement with the world. It is central in shaping our physical, spatial environment, in grasping the new aspects of nature revealed by modern science, and, above all, in the experience of artists, who heighten our perception of the qualities of life and its joys and sorrows."

From Gyorgy Kepes, "Education of Vision",
Vision and Value Series,
Braziller, 1965.

"Computer Graphics" deals with the input, generation, storage, transformation and display of visual information, i.e., data in two or more space dimensions. It has often been said that true man-machine communication which is convenient for man will involve a large element of graphics. In addition to displaying the results of calculations and accepting procedure definitions graphically we also want computers to process pictorial material. Since the visual information must be coded for the computer numerically (coordinates of the points, etc.) it also becomes a candidate for remote transmission. The following categorizes the field into four logical sections according to the type of transformation involved:

Data to picture	e.g.	output of calculations, data display
Abstract to picture	e.g.	graphic simulation, picture generation
Picture to abstract	e.g.	picture analysis, pattern recognition
Picture to picture	e.g.	visual design, digital picture processing

Interactive and Passive

The two major modes of communication with the computer are "interactive graphics", corresponding to real-time conversational computing, and "passive graphics", corresponding to batch processing, where the result is not immediately seen. Although interaction offers great advantages, passive graphics also has a vast potential, and is generally simpler and cheaper.

Output Devices

A limited range of graphics can be achieved on a line printer or teletype, for example the SYMAP program for contour maps. Pen on paper "electromechanical plotters" are the most popular graphic output devices, ranging from inexpensive ($5,000) units to large, highly accurate drafting tables ($200,000). These may be operated remotely, with the plotting commands transmitted over a communications line. The "microfilm plotter" displays the information on a cathode ray tube which is automatically photographed, by a built-in asynchronous movie camera with the frame advance of the film being under program control. This results in an increase of speed of the order of one hundred, and results in a very condensed form for voluminous outputs.

The cathode ray tube itself is becoming widespread for alpha-numeric displays. Storage tubes with picture drawing capabilities are also inexpensive, on the order of a few thousand dollars. The interactive display systems use a fast decay phosphor so that the image can be altered rapidly, and the individual parts of the picture may be identified easily. This requires a "refresh" system (regenerating the picture about 40 times per second) using a buffer memory, or tying up the whole computer. In addition usually a "light-pen", "function keys", typewriter keyboard, etc. are also included.

Other devices for sketching and manipulating the pictures are available, such as "Rand tablets", "mice", "joysticks", etc. These systems start at around $100,000. There is a limit on the number of points or lines which may be displayed in one refresh cycle; exceeding this causes an unpleasant flicker. For real time motion to be displayed the picture has to be recalculated rapidly; some systems are beginning to offer built-in hardware to speed up the basic functions, such as rotation scaling and translation of three dimensional objects. The software available is still crude, and the "data structures" needed (often organized as "linked lists" or "rings") tend to be too complex for efficient calculation.

The digitally-controlled machine tool may be considered to be a three dimensional graphic output. Other devices may be controlled by digital (or analog) output from the computer. Such techniques will likely become popular in the multi-media environment type of art, for example, where the program can react to the environment perceived by various "sensors" (for temperature, pressure, smell, etc.) and control the action of several "effectors" (projectors, lights, sound synthesizers, etc.).

The latest developments are moving toward standard video output on standard TV sets, providing a cheap and readily available output device and making it possible to use color directly. The major problem is to transmit the large amount of information needed for video scan rapidly enough; this is being accomplished by means of drums or disc storage.

Input

The graphic information may be generated by program without any input, as is the case when we use the results of some calculations which are to be plotted, or the generation of basic geometric shapes where only the parameters need be supplied (e.g. the center and radius for a circle). For "line drawings" only the coordinates of the end points of the lines which make up the picture are required. These could be coded manually and entered on punched cards, or a semi-automatic "digitizer" may be used. These devices, costing about the same as plotters, generally include some type of stylus (like those on planimeters) which the operator guides over the curve. The coordinates of points along the curve are automatically recorded on punched cards, magnetic tape, or directly in a computer. Some automatic line followers are also available, useful only with simple line drawings, such as a plot of X vs Y or a seismograph tracing. The "flying spot scanners" (in the $250,000 range) scan a transparency such as microfilm in a TV type scan, recording the gray level at each spot. For 1,000 by 1,000 resolution 1,000,000 points are generated. The programmable scanners give over control of the scan to the program, so that with line following algorithms, for example, the amount of data recorded can be cut down drastically. This digital picture processing technology is still in an early stage of development.

Some of the devices for interactive input have already been mentioned. Other digital or analog inputs may also be arranged to control the procession. For example, in one system the motion of an "anthropomorphic" harness worn by a man can control the image on the scope, as can sound input such as music. It is in the area of input and output devices that we can look forward to the greatest changes in the next few years. Although these will bring great improvements, it is not yet clear whether they will also produce significant cost reductions.

Subfields of Computer Graphics

Computer graphics is one of the new fields of computer application. Various areas have been developing separately, with not much unification between them.

I. Plotter Graphics:

The relatively inexpensive equipment and the ease of programming for simple applications has made plotters quite popular in the scientific and engineering world. Plotting a function of Y against X is the obvious example. In Canada most plotters will be found in the West used mainly for plotting contour maps in geophysical exploration. Some projects for mapping city streets, etc. have also begun. The glamour of interactive graphics has retarded the acceptance of plotters more generally. Many people are aware only of the interactive graphics and when they find this too expensive and complex for their applications usually abandon further consideration of it. However, beginning with passive graphics is a good way to obtain experience in this field, and much useful work can be done with it, such as sales charts, market studies, etc.

II. Alphanumeric Displays:

A proliferation of devices which display numbers and text is appearing on the market. Although the development of the equipment is part of graphics, their programming and use does not require anything more complex than the use of line printers. They are often used to replace teletype printers in time-sharing computing.

III. Interactive Design:

With one or two exceptions no large scale interactive design systems in day-to-day production are available in Canadian industry. Elsewhere a limited number of installations exist for circuit design, automobile, ship and aircraft design, and some other engineering fields, such as piping layouts. No production installations exist anywhere for architecture, graphic design, typography, art, etc.

IV. Computerized Typesetting:

As with alphanumeric displays, the computing aspects of preparing text for typesetting machines, be they conventional or phototypesetting, are not really graphical in nature, dealing only with linear strings of alphanumeric characters. Some systems are being developed for on-line layout and editing (Queen's Printer), and illustration may be added eventually.

V. Computer Animation:

Since the output of a microfilm plotter is directly onto film, by varying the picture frame to frame a motion picture can be easily created for any process which can be suitably programmed. Alternatively, a camera can be placed in front of a display tube. The result of a video display can be recorded on videotape. A number of educational, scientific and art films have been produced in the United States, particularly at the Bell Telephone Laboratories, though progress has been slow due to the lack of software, the cost of the equipment, and a lack of appreciation of the benefits to be gained. Recently a real-time, shaded, colour display of simulated objects has been demonstrated by NASA. This is an active field in Canada, with experimental work having been done at the University of Toronto, the National Research Council, the National Film Board, the University of Waterloo, and the University of Montreal.

The following is taken from a research proposal to indicate the widespread applications possible with various computer animation techniques:

a. Data Display

> Data display promises to become an important area of computer graphics. Visual presentation of information allows us to perceive many relationships which are difficult to deduce from tables of numbers. There are many situations in which the relationships we seek are not only distributed in space (e.g. the population of various centers) but also in time, since we are interested in the development of these relationships over some period. These include data available as time series (population statistics, pollen counts, per capita income, sales figures, etc.) transportation data (automobile traffic, telephone calls, information transfer, etc.), stochastic events (traffic accidents, births, and deaths, war casualties etc.), dynamic processes (evolution, blood circulation, weather systems, the operation of a computer under program control, etc.). Such information is best displayed in the form of moving pictures.

Although microfilm plotters have been available for about six years, progress with computer-generated movies has been slow. This has been due in part to the lack of good software in the form of problem-oriented higher-level programming languages with large subroutine libraries. The design of these movies requires a large amount of work, since even a five-minute film will include a large number of different sequences which have to be painstakingly analyzed, programmed and tested.

An interactive display system should speed up the programming and debugging process considerably. By viewing selected frames on the display tube the output can be more quickly visualized and modified. By viewing some of the sequences on the tube (even if only in slow motion, or even if the images have to be simplified for this purpose) the effectiveness of the programmed motion can be studied. If a large number of operations are preprogrammed, including the more common figures and motions used, some or all of the programming may be accomplished by means of the light-pen, function keys, and alpha numeric keyboard.

b. Geographically distributed time series (Population Data)

Vast amounts of data exist in the form of series of values over a period of time (years, days, seconds, etc.) for a large number of locations on a map (of the world, Canada, Ontario, one suburb, etc.). The values at any point of time can be displayed on a map by means of a number of techniques such as circles proportional to the value (the black dots of demographic maps); histogram-like rectangular boxes (or pyramids); figures representing the variable (stick figure for people, dollar bag for money, etc.); shading; elevating a particular region proportionately to the given value,etc.

Between any two successive points in time the data can be interpolated and the appropriate number of intermediate frames generated, resulting in continuous change when the film is shown by a standard film projector. A calendar (or clock) can be added to provide a frame of reference.

Such a moving picture will make evident not only the rate of change of the values, but also the changes in the rate of development (sudden spurts, the levelling off of the increase or decrease, etc.). Furthermore, the developments at the various locations on the map will be seen in relation to each other. The westward spread of population in North America is an obvious example. Techniques for showing more than one variable at a time (e.g. population and income) can also be developed.

The fields of potential application are widespread. Demographic and economic data, medical and educational statistics, production and sales figures are a few of the major types. In the case of many of the developing problems of our society the figures would speak for themselves with dramatic impact through such films; for example water and air pollution, the increasing incidence of lung cancer and traffic accidents.

In addition to the use of the actual data, this technique may also be used to display the effect of various alternative predicted figures, as well as for data obtained from simulation programs.

c. Transportation Data ("Traffic")

Arrows between locations can be used to display volume of traffic. The width or the intensity of the arrow can indicate the volume, and this can be made to change continuously on the resulting moving picture. By showing small objects (arrowheads, boxes, cars, stick-figures) in motion (their number proportional to the traffic density) the velocity of movement can also be indicated.

This type of data can be superimposed over the "population" type of map, so that, for example, the immigration and emigration rates can be shown together with the dynamic population map.

Any type of "traffic" can be displayed including vehicles, telephone conversations, employee transfers and data communication between computers.

Exceptional events can be superimposed in the form of a bright flash, for example, to indicate traffic deaths, communication breakdowns, births, etc..

Both the "population" and "traffic" type of programs will require the following input:

(i) A coded representation of the map boundaries, and the internal dividing boundaries (counties, regions, etc.).

(ii) A list of locations to be used (city, center of a region, etc.) together with their map coordinates.

(iii) The values of the variables at each point (or between each pair of locations), together with the name or code for the location, and the time (or period of time) to which the data applies. In many cases this data will already exist in a computerized data bank, and only reformatting will be necessary. A library of coded maps can also be set up.

d. Graphic Simulation

Simulation of dynamic processes of other types (e.g. blood circulation, evolution, kinship relations, cash flow, movement of the planets, weather systems, topological transformations) require different programs, each depending on the particular problem.

As an example we may cite the visualization of computing concepts. We see only the static initial condition of the stored program, but must imagine it in a dynamic, changing form to understand it. This has to be done in conjunction with the visualization of the data on which the program operates. We have flow charts, but usually need to trace through them with specific sample data to understand them. To demonstrate a complex sorting routine, for example, we cover large chalkboards with numerous columns of variable data (current inputs and outputs, the state of each index, etc.). In some situations, such as the communication between an operating system and the tasks it is supervising, a dynamic visualization of the process may well provide new insights to the system designer. In other cases such moving pictures will serve mainly as educational and training aids.

e. Cartoon Animation

In addition to the abstract graphic symbols indicated previously, stylized renderings of real entities (human figures, birds, cars, trees, etc.) have to be used. The motion of these must seem believable. A demonstration of the laws of gravity by means of a circle representing a bouncing ball is graphic simulation, but to show two boys playing ball would be cartoon animation according to this terminology. (However, the whole field of computer-generated moving pictures is often referred to as computer animation.)

Cartoon effects can add a human element to educational movies, providing the appeal to feelings which many educators consider essential to real learning. The commercial potential of cartooning is extremely large. However, production costs are high and animation results are generally poor - as one can judge by tuning a television set to any channel on a Saturday morning.

Some primitive cartoon elements have been incorporated into a few computer-generated films, and one or two papers have appeared in the literature. The development of computer animation involves the solution of many interesting problems. It presents a good vehicle for studying various types of motion, such as the natural movements of men and animals.

On the simplest level the computer could be used merely for the "fill-in" task, interpolating between two given frames to provide the intermediate frames needed for the illusion of continuous motion. The animator could present the two pictures on the display tube. A better approach is to provide subroutines for the most common motions of the usual types of animated figures. To take an example, if the animator wants a flying bird, he would sketch the bird or retrieve it (in coded form) from the picture library (on disc), then draw with the light-pen the path to be taken. The "flying bird" subroutine would then be used to provide the motion, including the flapping of the wings.

Although the conventional cartoon consists of two-dimensional drawings, usually it has to simulate motion in three dimensions. A three-dimensional representation of the figures is necessary, so that perspective can be introduced, the figures can be presented from various angles, and the portions of the scene hidden by the figures can be eliminated. Representation of three-dimensional arbitrary surfaces, hidden line elimination and shading are very complex processes involving large amounts of computer time.

Although stress has been laid on recording the resulting "dynamic graphics" on film, this arises from current technical limitations. Display system with real-time capabilities will be able to generate the images (still or dynamic) upon demand, utilizing programs and pictures stored on mass memories. With a trend toward a "graphic processor" computer as a part of each display system, the display may be at a location remote from the central computer.

VI. Digitized Picture Processing:

This field deals with the computer processing of photographic transparencies. This has received its impetus from the US space program where the Moon and Mars pictures were transmitted digitally and processed through a computer at the California Propulsion Laboratory to "filter" the noise from the pictures and for contrast enhancement. Other applications, so far, have been largely in the scanning of photographs of "bubble chamber tracks" in high energy physics, and chromosome counts, nerve fibres, etc. in medicine. Some development has begun in Canada, for example at the Communications Research Centre. These techniques are necessary for full, automated picture analysis of aerial photographs, maps, x-rays, photomicrographs, etc.

VII. Pattern Recognition:

Closely related to the picture processing area is pattern recognition. Although a field quite distinct from graphics, where visual images are involved, a graphic preprocessing is necessary before further analysis. Character recognition is the most important area commercially, due to the computer input preparation problem. The infantile robot projects at M.I.T. and Stanford use video input for the visual system. The "scene analysis" required is fraught with many difficulties; currently only very regular objects with strong contrasts between faces can be handled.

Software

No full-fledged generalized programming languages for graphics have yet emerged. Most software systems are oriented toward a particular piece of hardware and a particular application area. Thus a potential user has to concentrate on various types of graphics problems instead of his application. Many of the potential users have no programming background at all and problem oriented higher level programming languages with graphic capabilities are required. It would appear that the best approach for now would consist of an "extensible language" in which one of the well known algorithmic languages (FORTRAN, APL, ALGOL, etc.) would have added to it the capability to deal with pictorial data and the basic graphic manipulations (translation, rotation, scaling, etc.). All program modules dealing with specific input-output devices would be separate, so that they could be easily changed for a particular installation. In addition, by means of an operator definition capability the graphics programmer could develop particular sets of problem-oriented operators for each application area. Thus out of the one basic system, languages using the terms familiar to particular applications could be rapidly developed and used by people with little programming skill. Such a graphics language would also be useful for communication between people in describing a particular problem or algorithm. A large number of operators could be stored in a subroutine library, so that the various users could share the development effort. An international workshop has been proposed to be held in British Columbia, which would be the first meeting on graphic programming languages.

In the case of interactive graphics, at the moment a great deal of attention must be paid to "picture regeneration", "attention handling", "menu building", etc.,etc.. Again, no software systems exist which make it simple to prepare an interactive procedure without attention to the many "bookkeeping"problems. The human factors involved in display organization, etc. also require further study.

Since many pictures of interest involve a large number of points or lines and characters, much attention must be paid to efficiency, otherwise even with our fastest present computers some applications become completely uneconomical. The efficient coding of the pictures (into coordinates) is one of these problems. The structuring of the data (into arrays, lists, rings, etc.) has also received much attention. The representation of three dimensional objects is particularly difficult, unless all sides have plane faces. Surfaces, for example, require appropriate mathematical expressions to be found, or a large number of contour lines stored. Research is proceeding toward efficient algorithms for a number of common problems for which straightforward brute force methods are easy to deduce, but require unduly large amounts of computer time. Some of these are the "hidden line problem", perspective projections, shading, finding whether two pictures intersect, "windowing", "clipping", "shielding", etc. Computers with large numbers of parallel processors would be a great help, even optical computers have been considered, but both of these are still far from realization. Picture libraries share the problems of information retrieval of other material but in addition are complicated by the two (or more) dimensional nature of visual material. A data bank of coded maps, for example, has to be accessible not only by index terms, but also by the geographic boundaries of the area to be retrieved.

Recently it has become apparent to many people working in the computer graphics field that most of the attention has been expended on these technical problems and not nearly enough effort has been made on the development of useful application packages for the many potential areas where graphics could make a significant contribution. Many practical applications with widespread potential are actually relatively simple. Within the next two-three years the "bandwagon" effect may well occur with respect to computer graphics, if the potential benefits are suddenly realized by a large number of users. Canadian organizations have an excellent opportunity to compete equally in the provision of the required software and services. This may well become a major industry within the field, and also open up many new areas to computer use, where calculations and data processing are not the major requirement. Accelerated progress can also be expected in the development of improved input and output equipment, and relatively small organizations with good ideas will be able to make their mark in this field.

Status Quo of Visual Information Relating to: 3. Transmission

Telecommunications Network

Until this decade, the nationwide communication network carried primarily three distinct types of traffic, namely telegraph, telephone, and television. More recently carriers accommodated a variety of attendant services like teletypewriters, telescript, and facsimile. Today, on-line business machines have superimposed a data transfer requirement on the telecommunication networks that range from hundreds of bits per second to megabits per second. These speeds are being met by some judicious rearrangements of existing equipment and the introduction of certain new items like data sets.

The majority of these customers now have business machines which operate at speeds that can be handled on the telephone network. This has afforded many of them the additional feature of random access which is a feature of the nationwide telecommunication network. They can dial nationwide and are usually billed on the basis of time and distance.

It is becoming possible to offer customers random access switched network service for business machines operating at speeds into the kilobit region, and eventually will become possible in the megabit region. The same dialing methodology applies as to customers on the telephone network. In fact it involves the same switching control equipment.

Nearly all the new business machines connected to telecommunication channels in recent years operate in the digital mode. The choice of analogue or digital type telecommunication technology is a matter of economics to interface with these machines, whether they are analogue or digital. A customer business machine can usually have its information pass through a converter to match either basic type of facility. The long term goal is to move progressively to digital type facilities.

In the meantime, there will continue to be improvements in reliability, security, and transmission quality on existing facilities. Hence, most customer data applications can be accommodated over existing facilities until the long term goals are realized.

Many of the more recent business machines appearing on the market are for displaying visual information, television and alphanumeric data. We have attempted to show that communication facilities are readily available to transfer data between these machines. It is difficult to see what impact the associated software would have on point to point telecommunication channels. Perhaps none.

Different Ways of Transferring Data

There are two basic ways of transferring data from one location to another if switching is involved. One is line switching and the other is store and forward switching. Both types have been in use by the communication carriers since the 1930's. Nearly all telecommunication services use line switchers. Information is transferred from one communication line to another through the contacts of relays or other devices. Line switchers thus provide a continuous metallic electrical path which can be tailored to handle extremely wide bandwidths. Some line switchers are designed for television quality requirements.

Line switchers operate under control of dialed or push button tones originated by the user. The common control equipment which responds to these signals employs wired or programmed (computer type) logic to operate the line switches.

Store and forward switching, unlike line switching, operates under control of teletype or similar terminals. For many years the common control was done by electromechanical means. Recently, commercial computer equipment has been built into the network to do this job. A customer's information passes through the computer central processor. There is no continuous metallic electrical path. Switching communication lines through a computer, instead of line switches, provides several advantages and disadvantages. Computers can manipulate customer information to alter, store, or retrieve it. Unfortunately, a computer's ability to switch high speed customer information is very limited. This becomes evident for visual data that approaches television quality requirements. Computers are not used for storing or forwarding television programs, although less demanding alpha-numeric display information is now easily handled by them.

Two things are apparent. Computer methodology is being applied to both line switching and store-and-forward switching (including retrieval services) but in very different ways. And, computers can store and forward visual data economically only if the information content is low.

Computer Programs

When hundreds of customers access computers on-line, they are sharing some of to-day's largest information systems. Large systems have several million "lines" of systems and applications programming. Faults and idiosyncracies occur which cannot be predicted. Programming techniques are needed which will result in controlled, partial, or "soft" failures to avoid a complete shutdown of the whole installation.

Whereas, in the past, failures were inevitably attributed to hardware, the cause of most failures to-day has shifted to the operation system, usually the executive control programs.

The chief reasons are due to their current size and complexity. Some are 50,000 words in length. The overhead in computing capability required to execute the executive routines has grown in size until it is almost unmanagable.

The programmer is no longer dealing with a monolithic deterministic system. Tasks are no longer straight forward. No one programmer or user knows how all aspects of the computer system operate. Many are patching up existing sub-systems leaving less time for the new. Does this lead to an upper limit on the size of a new system ? Perhaps more wired logic will help the programmer's task.

We ask the same question about an upper limit or topping off of computer logic hardware which also includes wired logic circuits. Robert W. Keyes *, covered the technical constraints of building larger logic circuits. His conclusions are worth repeating.

> "Transistorized computer logic has made steady progress towards higher speeds by reducing the dimensions of circuits and devices. However, even though circuit and device speeds have increased by three orders of magnitude since the introduction of the transistor into computer logic, the voltage, current, and power levels have remained about the same. Power densities and current densities have been increasing rapidly as logical circuitry becomes faster and faster. The dissipation of power at increasingly high densities seems to be leading to difficult thermal problems that eventually will limit the progress of logical circuitry toward higher speeds. An estimate of the limit on speed, based on extra-polation of present technology, indicates that the thermal limits derived in various ways are about the same and that they lie about an order of magnitude beyond the speed of the fastest contemporary circuits. Progress beyond this point can only be made by radical deviation from the current lines of development. The most straightforward new method seems to be lowering the temperature at which the circuitry is operated."

In his discussion of speed, size, and power dissipation, the various physical limits derived are not fundamental or ultimate, but technological. Although his examples are taken from transistorized logic, many of the considerations also apply to logical circuits based on any kind of electromagnetic device.

*Keyes, Robert W., "Physical Problems and Limits in Computer Logic" IEEE Spectrum, May 1969.

We have covered a number of computer software and hardware problems. We have focused our attention on the computer core. Its speed and size ultimately places a ceiling on the number of remote peripherals, and on the quantity of information which remote terminals demand. Since pictorial data has a much higher information content than alphanumeric data, it will be the most demanding on time-sharing type computer hardware and software. Will better executive programs help ? To what extend will the application of wired logic help in programming such visual data systems ?

Analogue and Digital Transmission Systems

Data can be transferred over analogue or digital transmission systems. Both are in use to-day.

If the terminal employ s digital circuit technology there are economic advantages to use a digital transmission line. The same is true in matching an analogue display terminal, like a Picturephone station, with an analogue facility. Converters can be inserted to match analogue to digital circuits.

There is rapid growth to-day in the types and numbers of digital terminals because of the proliferation of digital computers. Some people may feel that a digital network should be constructed. Analogue facilities, carry telephone and television services have also grown rapidly since 1940. And, when we are reminded that the telephone network is currently carrying most of the computer oriented business, users and suppliers of visual data display terminals will perhaps wonder what is the long term trend.

The Trend in Data Transfer Capability

We have said that data can be transferred over digital and analogue transmission facilities. We have indicated that it is becoming possible to provide random access to users for the transfer of data at ever higher speeds.

As already indicated we are referring to speeds far in excess of 1200 or 2400 bits per second. Speeds in the kilobit and megabit regions will enable users, with the proper visual display terminals, to obtain greater detail, faster scanning, and colour. User access on demand can extend into the television spectrum. For example, an experimental system is in operation to-day which provides users with dial access television retrieval service. The customer may call a library of video films and view them remotely at his own leisure.

Hitherto most non-telephone communications services were handled exclusively over private lines. The current trend is to provide random access to a switched network for an ever increasing variety of data services. Costs are more closely tailored to usage. This leads to greater customer acceptance of on-line data systems. The software requirements for private line terminations are different from and probably simpler than the software needed for random telecommunication access of computer "ports".

Transmission of Various Forms of Visual Information

Visual Output	Methods & Applications	Capabilities	Remarks
1. Teleprints	- voice or sub-voice grade facilities - switched or P/L* - via analog and digital channels	- speeds seldom higher than 100 words/m - telephone network at least an order of magnitude faster - channels available for any computer peripheral printer	- telephone network can bring service economically into any business or ho-me - service can be provided rapidly
2. Telescript	- voice grade facilities - telephone network analog channels	- existing telephone facilities adequate for handwriting speeds	- rugged simple method to transmit written messages - output can be flashed on a screen to complement talker

* Private Line

Transmission of Various Forms of Visual Information

Visual Output	Methods & Applications	Capabilities	Remarks
3. Scribblephone (a concept as yet)	- provides an electronic pad for two remote users to sketch on - probably use voice grade analog facilities - candidate for switched telephone network - not a service offering	- a two way visual service which can be carried by voice grade facilities - probably requires two wire facility for data - distance not a problem	- excellent for communicating audio visual ideas - technology probably available but unexploited
4. Facsimile	- usually voice grade facilities - either switched telephone network or P/L	- takes 3 to 6 minutes for letter size sheet over voice grade channels - as brief as 30 seconds for same on wideband channels	- speed dependant on shades and resolution - colour facsimile a problem - terminal device not using capability of line to optimum extent

Transmission of Various Forms of Visual Information

Visual Output	Methods & Applications	Capabilities	Remarks
5. Visual-audio Convertor	- computer reads printed matter and talks - voice grade facilities	- still in experimental stage - useful for the blind - teaching aid	- expensive - great potential for translating into another language with audio output - not yet exploited
6. Alphanumeric Computer Display	- voice grade facilities - switched telephone network or P/L	- distance no problem - facilities readily available - seldom requires wideband channels	- clusters of remote display units sometimes utilize high speed telecommunication channel
7. Graphic Displays	- usually voice grade channels - via analog or digital facilities - short haul PCM probably economical	- more demanding of telecommunication facilities than alphanumeric systems because of speed requirement - P/L often required	- good candidate for wideband switched telecom. network - speed ranges from one kilobit to one hundred kilobits per second

Transmission of Various Forms of Visual Information

Visual Output	Methods & Applications	Capabilities	Remarks
8. Videophone	- via conditioned paired facilities over short distances - PCM over longer distances - combined with telephone channel - conference viewing is voice controlled	- picture details comparable to television - applications not fully explored - good for data applications	- sometimes called Picturephone (R) - requires a one megahertz channel - initial market is business oriented
9. Television	- video cable in large urban centers usually to broadcast studios - long haul over microwave radio across nation - voice channel segregated from picture channel for continuity of service - some switching en-route	- not compatible with voice facilities - capable of handling nearly all visual needs - these are normally 6 megahertz channels	- conference studio human-engineering problems no longer serious - higher resolution desirable - channels not efficiently used PCM perhaps better

Transmission of Various Forms of Visual Information

Visual Output	Methods & Applications	Capabilities	Remarks
10. Movies	- is converted to television type signal and carried on same facilities as television - visual display unit is standard TV receiver	- same parameters as television	- movies have become adapted to the television media - this can become a limitation to higher resolution and innovation
11. Holography	- home colour television reception of holographic programs can be done by pressed pictures on tape	- a coaxial cable, waveguide, or laser beam are three possible means to transport holographic programs	- much development is necessary to introduce holomission - extremely wide bandwidths required - bandwidth might be as high as one to six hundred thousand megahertz - a ten inch by ten inch screen requires about 10^{10} picture elements. Conventional home TV has about 10^5 elements

Status quo of Visual Information relating to:
4. Storage and Reproduction

The consolidation of the modern digital computer in the last decade 1960-1970, as a powerful tool in many areas of our culture is a fact. Every day one hears about new industries for which computer systems are being developed, and of new applications in those areas where the computer has already become commonplace.

Paralleling the application of the computer to process control, and other specialized applications, has been the marrying of communications systems with computers to provide the computer utility industry. The product of this industry is the capability to make available to a remote subscriber the use of an extensive computer facility via a communications link.

The Data Bank

One is inclined to believe that the major use of the work computer facilities by remote subscribers is to carry out lengthy and complex mathematical computations to which the computer is, of course, well suited. While such use is made of these facilities it has been found increasingly that the computational function is secondary to that of a storage function for large volumes of data which must be accessed in order to retrieve information quickly, and/or to update it. A new term is finding some favor for this type of operation, i.e., an information utility.

Where the information stored is of interest to more than one subscriber, a library situation is discernible. One may then refer to a bank of data upon which a large number of subscribers might wish to draw in order to satisfy their individual requirements.

Technical Limitations

Ideally, the data-bank, or visual information store, should have infinite capacity and be capable of being accessed and searched by any subscriber in a neligible time.

Modern computer technology has not yet created a storage system that is ideal, but a hierarchy of storage systems exists, at different costs per unit of storage.

Closest to the ideal are the random-access systems. The main computer memories are of this type. Ferrite material has been the most widely used in this application, but recent advances in plated wire technology have produced random access memories of comparable speed and reliability at lower cost. The situation has not yet resulted in a clear-cut exit for the ferrite core memory technology. Recent papers in symposia devoted to the computer sciences have shown how highly automated production methods, that reduce labor intensive costs by eliminating labor-dependent operations from the manufacturing process, may prolong the competitive position of the ferrite material random access memory for the next decade or more.

The cost of random access storage is generally very much higher than that on magnetic drum or disc file. The advantage is speed of access.

At the bottom of the list in terms of speed of access is that of magnetic tape storage, but it is by far the cheapest.

This discussion of the hierarchy of data storage systems enables one to speculate upon the possible trends that may be expected in the evolution of remotely accessed libraries of information; and of the role of information stored on film in such systems.

The current random access memory technology, briefly reviewed above, indicates that the costs associated with this category of storage, while decreasing, will not in the foreseeable future achieve a level at which bulk or high density stores could economically be implemented around them.

At any time, there will always be particular system requirements that will need to be implemented with very large random access memories (RAM) but unless the cost differential compared to the magnetic drum or disc-file is justifiable, RAM will not be used in data-bank applications.

The current practice, for large data stores, is to use magnetic disc, or in some cases magnetic drums, for medium speed access ($\simeq$ 18 ms), the magnetic tape for the lowest cost storage.

The costs associated with any of these systems are still so high that only a relatively small number of institutions or organizations can afford them. It will require the innovation of new devices with a lower cost of storage and higher speed of access than the magnetic disc technology can at present provide. One device, recently announced by the Bell Telephone Laboratories, and called a "magnetic-bubble memory", holds considerable promise in this direction. Although there have been few technical descriptions released, it appears that a magnetic domain may be caused to migrate, or spill over, into an adjacent space, by pulsing electrodes at a barrier between the domains. The basic element of this device is a magnetic shift register, wherein the magnetic bubble is the bit of information and its passage across a boundary is detectable. One is thereby led to consider a serial, dynamic memory, with the information circulating in such a fashion that the information sought is accessed when it crosses the detection boundary. The device is non-volatile and hence need not be constantly circulating, and may eventually be made reversible in the shift direction, which could reduce average access time. However, the salient feature is that a data file, with a volume of a few cubic inches, and capable of holding 1.5×10^6 bits of information while consuming only 0.040 watts of power when being accessed may be available during the latter part of the 1970-1980 decade. The clock rates associated with such a device are expected to be higher than 2 MHz. Thus the access times are variable, depending upon the exact configuration of the system employing the device.

If one tries to compare a magnetic bubble memory with a disc file capable of storing 10^6 bits, and with an average access time of 15 ms, then one needs to achieve a clock rate of $\simeq$ 30 MHz for the bubble memory (8 in parallel) to provide competitive performance. The research effort required to increase this important performance parameter will no doubt be forthcoming and it is likely that the boundary detection problem is the main area in which the work will be done. The magnetic bubble is inertialess and hence, aside from the usual stray electrical parameters, cannot be of major significance in determining the currently announced 2-3 MHz clock rates, expected for the first laboratory devices.

The Data Terminal

Thus far, the remote subscriber to the data-bank or library has not been considered in terms of his capability to handle the information that he might retrieve from that store. It is important, however, in attempting to predict an evolutionary process to see the whole system. The kind of terminal equipment at the subscribers end will be of paramount importance in determining at what point major steps will be taken to implement libraries.

At present the cathode ray tube (CRT) has a predominant role in data terminal technology. Research in solid state display technology has made some progress in number display, but it is not likely that high density, high resolution displays, that are competitive with CRT displays, will appear before the end of this decade. Nevertheless, the coupling of the aforementioned magnetic bubble memory, with integrated circuits and CRT, constitutes a viable base upon which to predict the evolution of subscriber terminals of reasonably low cost with high local storage and digital processor capability. The simultaneous expansion of communications facilities to meet the demands of the computer-utility and data-bank industries will bring about an environment in which the remote-access library concept can grow.

Information Stored on Film

The discussion of the techniques by means of which information stored on film may be communicated[1] pointed out that film recorded array densities of binary data thus far achieved are in the order of 20 x 10^6 bits per square inch. No other recording technology can even begin to approach this figure. Five feet of film may contain as much information as a reel of magnetic tape. There is, of course, an important difference, the film cannot be updated or changed as can the magnetic tape, and this may be a disadvantage in the presently conceived data-bank operation, but not in the remote-library access situation.

In addition, the information on the film may be in pictorial form. The communications systems' capability to provide on-line wide bandwidth links between subscribers and the remote library are not likely to be so cheap or profuse as to represent a viable basis of operation. Rather, the information in the library will be interrogated via a relatively narrow channel, probably 4 kHz bandwidth, and replies will be sent over the same channel, or in special cases over 50 kilobit/sec switched lines that are likely to be available on a large scale during this decade.

In cities, over relatively short distances, higher capacity channels may become available, but it is doubtful if efficient use can be made of such links without a good deal more research effort to determine how to employ them.

Different Forms of Information

In a general sense, all forms of information recorded on film are visual. To satisfy the appellation, it is sufficient to specify that the information be capable of modulating transmitted or reflected light so that the presence of the modulation be perceptible to the eye of an observer. Information, then, qualifies as visual by its physical presence alone, even if it is not comprehensible to the observer.

Information may be recorded on film in several ways; we do not refer to the photo-chemical process here, but to the form that the information takes. A first category is easily described as pictorial, and the usual description of what a scene or picture contains in the way of form might be lengthy. It is convenient, therefore, to treat this as a general category, and to describe only other categories of images that have special properties.

The set of visual images that belong to the second category are commonly referred to as computer-graphics, that is pictures which may be generated or "drawn" by means of firmware, or computer software, which control of election beams or laser beams, and thus recorded on film. The stipulation is not in the means of generating the images, but in the intrinsic characteristics of the images themselves. A sufficient description of this category is that the image is "synthesized", it is constructed by the linkage of finite number of generated lines or contours.

To clarify the foregoing, consider a computer-generated cartoon. The images themselves may be the work of an artist, but the dynamics are essentially what is controlled by the computer. According to our definition, if a set of programmable functions cannot be used to control an electron beam or laser beam in order to reproduce the image, then the information contained in the visual data belongs to the first category and not to the second.

A third category embraces all those images that contain only symbols or characters comprising the alphanumeric set. A simple example is a picture of a page of a book containing only word text, no illustrations. Aside from the proper specification of scale and language, the visual image is comprehensible to an observer, in a different way than that of images belonging to the first two categories.

A fourth category may be assembled from those visual images consisting of arrangements of spots, opaque or transparent to light in fixed or varying degree, and in which the information resides by virtue of the order in which the spots are created or recorded.

This fourth category is really the most general, because in principle, images of the first, second and third categories can be recorded on film in this manner and reproduced with an exactness or resolution limited only by the particular technology employed.

Recording Methods

Alphanumeric information may be recorded on film as a direct image of (a) a page printed or typed, or created on the face of a display device such as a cathode ray tube, in which case it is said to be "computer generated", or (b) as an arrangement or matrix of spots or holes, opaque or transparent to light, and in which the information resides by virtue of the "order" in which spots or holes are created.

In the first case (a), the information is immediately conveyable to the human intelligence if the image of the material is reproduced optically or electronically for visual accession by the human. For the latter case (b), the information must be translated into the form acceptable to the human.

If the information is to be transmitted from the physical location of the film to a remote or physically removed human, then a translation process is required in the former case (a) as well. In this instance, the translation of the two dimensional image of the material must be from the alphanumeric set to appropriate electrical signals or codes to be transmitted to the destination location, where the human intelligence is assumed to be.

Reproduction and Translation

In order to translate information recorded on film by means of the alphanumeric set of characters, for forwarding or transmission, the material must be scanned, and decisions made on a character by character basis. The result of the scan, line by line, character by character, is to create a time-ordered sequence of codes that may be used to reproduce or re-create a replica of the image recorded on the film.

In the case (b), a scan similar to that used in the recording process, would result in the same time-ordered sequence of codes being generated, and at this point, in the communications system, there is no way of distinguishing which of the two possible origins is responsible for the signals.

The difference between the two methods is apparent only on the film upon which the information has been recorded. The advantage of the direct image for local usage is offset by the need to do more with the information or data if it is required to be transmitted or communicated to a remote user.

Flying Spot Scanner

A particular technique used to carry out one of the steps in the translation process, is to employ a cathode ray tube with a short persistence phosphor, and a means of focussing the spot of light created by the electron beam onto the film transparency; the light modulated by the picture function is collected at a photomultiplier.

An optical reference channel is provided by means of a partially silvered mirror, an identical lens system and photomultiplier and a neutral density transparency.

The control of the electron beam position as a function of time, may be exercised by means of a specially wired system, or small general purpose computer. The reference channel may be used to provide a comparison signal to correct for CRT phosphor intensity variations as a function of variation of x and y (the beam position).

The output of the photomultiplier tube is an analogue time function corresponding to the modulation introduced by the image 'function'.

Line Scanner (Vidicon)

Another technique is to employ a special tube called a vidicon. The image on the film is reflected or projected upon the face of the vidicon, and the intensity of light at every point affects a space charge associated with that point. The output current from a collector electrode is proportional to the light intensity associated with the position coordinates of the electron beam. The control of the scan or positioning of the electron beam is subject to the same considerations as the flying spot scanner. Again the output current as a function of time corresponds to the modulation imposed by the image 'function'.

Laser Beam Reproducer - Recorder

The density of points associated with spot sizes achievable with electron beams is limited by the physical laws that determine the operation of those systems, to a maximum that is a good deal less than that obtainable with a new technology, which employs mono-chromatic polarized high intensity laser light beams in the recording process, and a lower intensity laser light beam in the reproduction process.

The laser recorder may operate in analog or digital fashion. For our purpose we may consider the digital methods as being particularly relevant to the recording of the codes corresponding to the sequence of alphanumeric characters that comprise the material to be recorded on film.

We are thus led to consider a process whereby a metallic layer on film is perforated at certain points by the presence of a high intensity, laser beam for a brief instant according to a definite format. The net effect is to produce on a micro-miniature basis, the same organization and methodology as is incorporated in the present punched paper tape systems that have been with us for many years.

The densities thus far achieved are 20×10^6 bits per square inch. A comparison with magnetic tape shows that a 2000 foot reel of film may store 8.6×10^9 bits of data; it would require 400 reels of magnetic tape to hold as much, at densities of 850 characters per linear inch of (1/2") tape.

Facsimile

A straightforward, horizontal scan may be used to sustain a translation and transmission of the image sufficient to reproduce a replica at the receiving end. The usual TV image belongs to this classification of 'Facsimile'.

Normally, these are on-line methods, with the translation, transmission, reception and reproduction all occurring simultaneously (except for transmission time delays).

The translated information, in the form of electrical signals may be linear or digital. If the scan is continuous, and intensity variations of the image from point to point are measurable according to some 'grey' scale (scale of shades ranging from opaque to translucent) then these same variations may be modulated onto an electrical carrier signal as phase variations, frequency variations, or amplitude variations, on a linear basis. If some scheme of limiting is resorted to, the modulation is non-linear but, nonetheless, the reproduction of the scanned image at the receiving end will still be possible and, in some circumstances, somewhat improved over what would be obtainable without limiting.

If decisions were made (electronically) at regular intervals in the time during the scan as to the intensity (averaged over the preceding interval perhaps), then a corresponding binary coded number could be generated to carry that information over the communications system to the receiver, where the intensity for reproduction would be determined at that instant by that number.

If the information is dynamic in time, on a frame by frame basis, as in the case of motion picture films, the same technique applies, as it does too for the case of a static frame situation.

Communications Savings in Non-Facsimile Methods

Considerable savings in the total amount of information communicated may be realized when images in categories two or three are concerned. A good deal of the time a 'null' information would be involved and if the content of the image could be discerned, transmission data relevant only to the content would represent a quite different quantity compared to that generated in an unrelated sequential line scan as in the facsimile case.

Category three information, involving only alphanumeric characters, may be transmitted in facsimile mode, but considerable savings in communications are achievable, by a factor of 50 to 100, if the information is first translated via optical character recognition techniques into communications signals, in, say, ASCII Code.

On a more modest scale, some savings in the case of category two information may be realized, if certain features in the image were recognized by a process called 'feature-extraction', and clues as to the manner in which these features are related in the images are thus communicated as basic information to be used by the receiver to reconstruct or computer-generate the image.

In cases when the image is not dynamic or changing with time, the ability to regenerate the image in non-real time, from stored clues,and to update the information as required or requested by the receiver, can lead to very large savings in communications.

For the case of category four images, i.e. ordered arrays of dots, several alternatives may be followed, depending upon the information content. Modern techniques of laser-beam recording make it possible to record pictures of category one with good resolution; or record images of category three with high density of storage after translation of the alphanumeric content into the communication codes. The dots in the ordered array could very well be the bits of the codes themselves, and one frame might contain a good deal more information than is ordinarily found on one book-page of text.

Future Research Areas

Before the remote-library concept can become a commonplace, it will be necessary to have low cost bulk storage available at the subscribers terminal in order to carry out several functions. The first of these is the provision of an executive processor to serve as 1) a communications terminal; 2) a display controller by means of which data-graphic or pictorial displays are created on the display device (likely to be a CRT for the next decade), and 3) a local storage device so that a large volume of information may be quickly accessed from a central store, stored and examined in a time scale suitable for the human interface, and amenable to intervention by the subscriber operator.

The problem of low-cost local storage is an important research area. The development of a low-cost processor is another. The development of LSI techniques have not indicated that all the problems in this area are solved. The development of miniature computers with powerful instructions for the military,using MSI electronics, shows what may be done, but new processor organizations and manufacturing assembly methods as well as new algorithms must be developed if the labor intensive operations and total cost are to be held to acceptable levels.

The display device itself, dependent upon CRT technology for at least the next five years, would benefit from a solid state implementation in terms of bulk and longevity of the device itself. The main requirement is to reduce the cost, but the complexity of conversion systems from digital to analogue current or voltage, and the attendant limitations on display time or rate of display of points may be significantly reduced in a solid-state system, and that is certainly a research objective.

Finally, turning our attention to the central store itself, one can visualize a variety of intermediate evolutionary steps towards the ideal: i.e., an unlimited store of information, pictorial or alphanumeric, all easily accessible to the remote subscriber through his data terminal, communicating through a port in the central system.

The storage method in that central system is most likely to be "information stored on film" because of the high density with which binary information may be stored on a film transparency, and of the capability of the method for pictorial information as well.

The intermediate steps are, of course, system implementations about disc files and magnetic tape which must yield to the 'magnetic-bubble' memories towards the end of this decade, and overlapped by the development of EBR (Electron Beam Recording) and other recording and reading methods using laser light and photo-sensitive film.

When these system building blocks have reached the proper development, system designers will start implementing systems around them, and if the capital sources of our country are equal to the occasion, funding for the successful innovation of such systems should see them growing in use and size by the end of this decade.

Telecommunication Facilities for Data
Transfer in Visual Communication:
1. Present Requirements

Holding Times - Short, Long

The average holding time for a subscriber on the switched telephone network is 2.4 minutes. This has held constant for half a century but may now be increasing. The average holding time for a subscriber of a large Canadian computer time-sharing service in 1967 was measured to be 29 minutes, from a sample of one thousand calls on the switched network. Today some subscribers are interested in polling data terminals just long enough for the terminal to acknowledge itself and send a "yes" or "no" answer of several characters to the computer. This type of holding time is in the range of one to ten seconds. Credit card validation is an example.

Table 1

Column	I	II	III	IV
Service on Voice grade facilities	Subscriber Holding Time in Minutes	Percent of Total Time the Common Control equipment is engaged	Circuit traffic loading assuming	
			1 call per hour CCS #	2 calls per hour CCS #
Polling	0.1	70%	0.06	0.12
Telephone *	2.4	10%	1.44	2.88
Time-sharing	29	1%	17.4	34.8

* Combined residential and business subscribers

\# call-hour = 36 CCS = 3600 call-seconds

Two features stand out in this table. Firstly, polling service places a high demand on the common control equipment in a switching office (local exchange office), but the volume of traffic in terms of call-seconds is very easy on the outside plant compared to telephone service. Secondly, time-sharing service, of the problem solving type, places a low demand on the common control equipment but puts a heavy load on any cross-section of communication lines. Visual display usage resembles the problem of solving time-sharing traffic. Both of these kinds of traffic can be accommodated by existing types of telecommunication facilities. On-line computer centers have sprung up in many cities like Toronto, Montreal, Ottawa and Calgary. Their telecommunication requirements are being met. Early cooperation with the common carriers will lead to a better traffic integration of telecommunication facilities and new on-line computer systems.

Setup Times

This is the time required to initiate a call. For telephone service it is the time interval between the off-hook condition at the originating end and the off-hook condition by the answering party. This time averages out to 38* seconds and includes the time to dial at least seven digits and wait for the distant party to answer the call. Immediate automatic machine off-hook at the receiver can reduce this setup time by as much as 22 seconds.

Most data systems require some form of validation of both parties following the setup time. The control processor is seldom involved until the remote terminal is identified as an authorized station. Validation time must be added to the setup time before information is permitted to flow.

Setup time is critical in polling systems. According to the above Table 1 this accounts for possibly 70% of the total time. The setup time is not critical in most time-sharing systems which use the public telephone network. Alphanumeric and vector display systems come in this class. Setup time is often less than one percent of the total time the remote terminal is on-line.

Negligible Transmission Errors

The objective of the telecommunications carriers is to provide satisfactory error performance at reasonable costs. When required, additional protection is possible with error detection and correction equipment. The number of errors can be reduced but not eliminated. Acts of God, such as lightning, are the ultimate barrier to error free transmission. It is a barrier which can be approached but with accelerating costs for both carrier and user.

Beyond technical solutions for solving the error problem, there is much scope in the computer software and system design phase of applications where good procedures can do much to provide error safeguards.

Certain transmission objectives are recognized in the telecommunication industry. There are error performance objectives for digital information and television grade facilities. The objectives and measuring instruments are different for each. No performance objectives seem to be available for graphic communications. In a sense, graphical errors are not as critical as errors in alphanumeric information since single bit errors can change the intent of alphanumeric information, but it might take an error burst to destroy a significant part of a graphical display.

* This average is for local and toll calling

Access from all Points in Canada

About 95% of all households in Canada are equipped with at least one telephone. With rare exceptions these five million main station telephones work out of dial (or push button) exchange centres. Each location is a candidate for on-line data service of some kind.

Satellites will enable additional Canadians to obtain long haul telephone and data services. The transmission quality should be good but propagation time will affect some systems. Those systems which require a return signal will be severely affected unless computers can be programmed to allow for delays which will exceed half a second. Systems which transmit blocks of data at a time, and polling systems may need to be redesigned if communication by satellites is anticipated.

Multicom wideband data service was introduced 1 June 1970 between many major cities in Canada. The service is aimed at those located within seventy miles of major urban centres, since this is where most computers are installed.

Random Access

Random Access means the ability to call any point in the system. Telephone service is a good example. It has had a long history of development.

Various data services appear to be evolving rapidly into random access systems. They are economical and virtually eliminate queueing for service. Random access is therefore desirable but only becomes economical if many users share the costs. Many users access a common telecommunication network like telephone service. The other situation occurs when a single large user might justify his own private random access system such as an airline reservation network.

It is becoming possible to dial a connection and communicate at 4800 bits per second, 9600 b/s, 50 Kb/s, 100 Kb/s or at other intermediate speeds. Higher speed channels will certainly become available into the megabit per second region as demand evolves.

The trend in data communications is toward random access switched network telecommunication service. Potential users include those who are interested in transferring data to visual display terminals.

Flexible $ Rate Packages

There are a number of different ways to charge for telecommunication services. Examples are:

flat rate
fixed basic charge plus usage
flat rate based on distance

volume
time of day
etc.

New packages usually follow demand. Geography and community of interest sometimes shape the way in which services are charged. There are many factors which determine a rate schedule. Recently, new technology, new user requirements, new patterns of usage and innovative rate concepts have led to to the introduction of a variety of new rate schedules by the Trans-Canada Telephone System.

To illustrate some of the existing telecommunication facilities in use, the following list briefly summarizes the data and associated inter-exchange services as provided by the Trans-Canada Telephone System.

I. Inter-exchange communication services

a) for voice or data transmission

1. All private line services

- private lines
- data - signal and telegraph channels
- Telpak

2. Services utilizing the public telephone network

- WATS, INWATS, Telpak, tie trunks, foreign exchanges, etc.

b) Primarily for data transmission

1. TWX
2. Dataline I, II, III
3. Data-FX, Datapak
4. Multicom service covering voiceband and wideband
5. Message switching data service (MSDS)
6. DATAPHONE service

II. Terminals for data transmission

a) Teletypewriter and associated equipment

b) TWX and DATAcom terminals

c) Dataspeed, Inktronic

d) DATAPHONE, data sets

e) Push button for data, etc.

Attachments and Interconnections

For further details, see Telecommission Study 8 (b).

Developmental Cooperation

The common carrier will support a variety of developments but primarily those which promote the use of telecommunication facilities. Cooperation in the past has led to field trials to test the feasibility of a new technology or service. Laboratory or simulation models are usually inadequate. Stand alone systems have been known to work well until integrated with other systems. The remote display terminal, data set, communication facilities, computer multiplex terminal and the computer itself must function together.

Field trials go beyond reducing a new system to practice. It is important to determine the overall system reliability, traffic performance, maintenance requirements, etc. before further decisions can be made.

Response to User Needs

Telecommunication services are either standard or special assemblies. If there is sufficient customer demand for a special assembly then this service may become standard.

The special assembly approach is a method of responding to a request for service which is unusual or never offered before. For the potential customer its major purpose is to provide him with a prompt reply about the service charge and availability of such a service.

Occasionally the requested service is novel enough to warrant a field trial of the equipment. As mentioned above, the field trial tests the economic and technical feasibility.

Speeds on the Network

When data processing entrepreneurs sought to expand their business by going on-line in the mid sixties, it was fortunate that the public telephone network was available. Previously, those who sought to transmit digital information used teletype channels. Computers were not involved and so speeds of several hundred words per minute were adequate.

Since then because of computers, about fifty different types of data sets have been standardized which not only convert information between digital terminals and analogue telecommunication facilities, but enable users to boost the bit rate at least ten fold above the capacity of teletype channels. Users could now dial a connection and transmit at least 1200 bits per second with good error rate performance. Some people considered this broadband transmission.

Data service is considered wideband if the speeds involved are beyond the capacity of a nominal four kilohertz telephone channel. Speeds as high as 14.2 kilobits per second have been demonstrated on a 4 kilohertz channel. The upper limit of a 4 kilohertz channel is determined by the signal to noise ratio. The higher the ratio, the greater the capacity. Interface devices provided by the common carriers limit the signal strength to avoid interference on adjacent telecommunication channels, and to reduce electrical hazards to carrier equipment.

For those who wish to transmit data beyond the top speed of the public switched telephone network, it is now possible to do so. Multicom service is being introduced across Canada and will enable users to dial (or push button) a distant connection and transmit data ten times faster than has been possible so far. This wideband service is integrated with the existing public switched network for maximum customer convenience and economy. The calling and accounting methodologies are similar. The same dial capabilities will be extended into the megabit region if the demand is sufficient.

Changes in Data Set Features

The most important data set feature is speed; the right speed. This depends on the business machines connected to these data sets. There are hundreds of different types of business machines which can be connected to telecommunication facilities. It would be unfortunate if a unique data set must be designed for each one. The common carriers encourage cooperation with the suppliers of various machines which might be connected to the telecommunication facilities.

Data sets usually have the following features:

signal conversion
supervision
control
test
interface
line protection

All this circuitry could be built on one chip*. However, until data sets are manufactured in large quantities they will remain as expensive as some business machines. The potential on-line market is covered in Section 5 (d) of the Telecommission.

* New metallurgical and electronic manufacturing techniques now make it feasible to integrate many electrical circuits on a small wafer the size of a button called a chip.

Videophone Facilities 1970-1971

This service will become a reality. Its acceptance will probably be greater in large urban centres. The existing telecommunication plant can be employed immediately. The initial systems will use analogue transmission. This service has great potential for added data features.

The feasibility of using the video station as an interface between man and computer has already been demonstrated. The station displays characters generated by a data set connected to a standard commercial digital computer. Access to the computer is obtained in the same way as a call is made to another videophone. Once the connection is established, the computer is interrogated by depressing buttons on the push button pad of the telephone set. Simple instructions for use of the computer are included as part of the visual display.

A field trial of Videophone is scheduled for 1970-1971. The trial should help indicate the future shape and penetration of the Canadian market. The Americans expect to have between 500 and 1000 units in service by the end of 1970. Videophone set requirements for Canadian market is estimated to be 100 beginning of 1973 and in the range of ten to fifty thousand per year by 1984.

Facilities for CATV Operators

A community antenna television station or system receives signals off the air from broadcasting stations and distributes them by coaxial cable to subscribers.

The Trans-Canada Telephone System Companies provide transmission facilities to CATV operators. Virtually all coaxial cables are in urban centres.

For almost two decades CATV operators have used as many as twelve television channels per coaxial tube. Twenty channel systems are now commercially available and thirty or forty channel systems look feasible.

Information Retrieval Television

A field trial, conducted by Bell Canada, is underway in Ottawa where a number of schools are served by a library or video tapes. In this trial the service is carried on coaxial cables and currently utilizes standard television transmission equipment. People in various buildings and classrooms dial this library and then view their choice of program on a standard television receiver. Many of the transmission techniques are identical to those which serve the broadcasters. The supervisory and control features are vastly different.

The supervisory and control features are exercised by the user with a dial or push button pad. The purpose is to offer each customer the means to access any one of hundreds or thousands of different television records when he wishes.

Requests for service are handled manually or with the assistance of a small computer at the library today. Automatic retrieval of video tapes within the library will be necessary before this service can be offered on a large scale. This appears to be at least three years away if development is begun immediately.

The service need not be restricted to viewing television recordings. Why not permit the user to dial up a live stage or sport performance and be automatically billed by the provider for the service as with telephone service? Any high resolution computer display system could be accessed over this network.

It is therefore evident that considerable technological development is required in two vital areas of IRTV service before it can be fully automatic. A technique must be found whereby a great number of different television quality records can be rapidly accessed within a library. Secondly, a switching system is needed so the user can dial an idle television channel which leads him to the correct playback equipment in the library.

Nationwide Television Networks

The Trans-Canada Telephone System is the principal carrier of broadcast television in Canada. This communication network feeds the various licensed television stations which reach about 95% of all households. Hence any television type visual information can be immediately accommodated between urban centres across the nation. The type of local distribution depends on customer requirements.

Moreover, should the transmission characteristics of a high resolution visual data system not conform to the same specifications as standard broadcast television, these long haul wideband telecommunication channels can be adapted by interposing suitable data modems.

Telecommunication Facilities for Data Transfer in Visual Communication: 2. Future Requirements

Future Capabilities

The emphasis is on capabilities rather than services. While no one can predict customer requirements with clarity over the next twenty years, each day the telecommunication carriers in Canada invest over a million dollars in physical plant, which will probably be in service for twenty years. The most economical way to minimize the risk associated with this uncertainty regarding future customer services, is to design telecommunication plant which can be readily adapted at some later time.

Capital risk can be minimized by good design and judicious placement of the telecommunication plant. Design is controlled by technological innovation and immediate customer needs. Canadian research in telecommunication technology is being applied to produce good designs. This research is often influenced by Canadian distances and climate.

We believe three parameters will govern telecommunication capabilities over the next decade. They are the physical modularity of equipment, bandwidth, and circuit signal to noise ratio. These three parameters apply especially to digital communication channels.

Modularity might best be explained by an example of some existing equipment. The telecommunication industry have in operation an increasing number of pulse code modulation (PCM) digital transmission systems which carry at least twenty-four telephone channels on a serial digital binary carrier at 1.54 megabits per second. The terminal equipment is so arranged that the telephone multiplexing channel equipment can be removed and replaced by data terminal equipment. A family of data terminal units are available and more are coming. The basic twenty-four channel PCM terminal can accommodate, say, one 500 kilobit channel unit, two 250 kilobit units, or eight 50 kilobit units, etc. This is one way of preparing for the future. The PCM system we have described operates over paired telephone wires. Not much has been said about PCM and other high speed systems which might operate over coaxial tubes, other than standard television. Transmission capabilities of coaxial cables are poorly used today. Some carry several thousand telephone channels or twelve television channels, but coaxial tubes could handle much more if suitable amplifiers and terminal equipment were available. This is an area where more research and development will be done in Canada.

Equitable $ Rates

A study in depth of tariff rates is out of place here. This subject is covered in other sections of the Telecommission especially 7 (ab).

Accessing Telecommunication Networks

Before 1962 the Canadian telecommunication network was known as "the telephone network". Since then Dataphone, TWX, Telescript, Datacom, and other services have been added. In fact, part of the basic long haul structure has carried broadcast television since 1952. The physical makeup of this nation-wide random access network is evolving to encompass related services. We have already mentioned Videophone and Multicom which are voice-data services. Dial-up high resolution video may be next.

The telephone set no longer completely defines a telecommunication service. Business machines, computers, display terminals, acoustic couplers, data sets, interface couplers, etc. now terminate many telecommunication circuits. These electrical gadgets function and interconnect with the communication facilities in increasingly complex patterns. Several forces strongly influence the environment. Firstly, new types of terminal hardware continue to flood the market while some current models die prematurely. Secondly, adequate industrial standards are non-existent. Perhaps with greater awareness between industry and the common carriers the peripheral computer business will mature into a family of excellent machines during the next decade. Some species will disappear while others will continue to evolve.

The common carriers expect to develop better data sets and interface couplers together with suitable technical specifications. We also hope industry will modify more computer peripheral machines so they can also operate over telecommunication facilities. Medical machines, computer peripherals, like tape drives, printers, plotters, visual display units, etc., are candidates in many instances. Suitable interface co-ordination could accelerate better use of existing resources.

Higher Speeds

Time sharing is now a highly developed on-line commercial data service. At the end of 1969 there were at least 88 companies providing this service in the U.S.A. and 25 in Canada. Table II illustrates the shape of the American business in terms of types of terminals. Low speed teleprinters dominate. Nearly every company uses them. High speed teleprinters, using voice band or higher grade facilities, are used by 25% of these companies. Close to half of all companies use cathode-ray-tube display terminals or graphic display terminals. Only 10% use card readers.

The teleprinters and visual display terminals (with keyboards) are primarily for interactive purposes. The graphic plotters and card terminals are output units. Most alpha numeric display terminals are not candidates for high speed service (above the present voice band speeds of 2000 words per minute) for most of us cannot comprehend that fast.

There is no clear cut boundary between low speeds, voice band speeds, and higher speeds. Minimum installation effort and expense is involved by the common carriers to place a 1200 or 2000 word per minute telecommunication facility in service to one of the above terminals.

Specially conditioned voice grade facilities will handle any of these terminals to at least 10,000 words per minute or its equivalent in terms of bits per second. System planners who wish to employ visual data display terminals will be attracted to higher speed facilities. However, speeds beyond the capabilities of an unconditioned voice grade line will cost more. Data sets, transmission facilities and the corresponding line switching systems must meet tougher transmission specifications which result in higher costs. However, costs do not increase at the same pace as the speeds handled by the communication facilities.

Visual display terminals require higher speed facilities than any other type, except perhaps, direct computer-to-computer transmission. Dynamic displays with fast moving events will require facilities which operate at megabits per second.

Asymmetric Circuits

A voice facility is a two-way arrangement to carry information of equal capacity in both directions. A television or audio broadcast facility is unidirectional. In the on-line data terminal world, some units, like card punchers, or line printers are always in the receive mode. Consequently a two way channel is sometimes unnecessary.

An increasing number of communication terminals require asymmetrical transmission facilities. These are high speed in one direction, and low speed in the reverse direction. Visual display terminals are an excellent example. We have shown that visual information tends to require a high speed channel.

Table II
88 U.S.A. Time-sharing Companies (End of 1969)
Types of Terminals

Low Speed		Hi Speed		CRT Displays		Graphic Plotters		Card Readers	
Models in Use	No. of Cos.	Models in Use	No. of Cos.	Models in Use	No. of Cos.	Models in Use	No. of Cos.	Models in Use	No. of Cos.
Teletype 33	75	IBM 1130	10	Computer Comm.	18	Calcomp	37	Hewlett-	
Teletype 35	74	Univac 1004/5	8	Computer		Complot	3	Packard	4
IBM 2741	40	Univac		Display	4	Data Inter-		Univac	4
Dura	38	DCT2000	8	RCA 70/752	4	face	2	Motorola	2
Datel	35	Univac 9000	7	Tektronix	4	Computer	1		
Teletype 37	32	IBM 2780	6	Burroughs	3	Computer-			
Friden 7100	26	G.E.115	3	ARDS	2	vision	1		
Friden 7102	12	IBM 360/20	3	Datapoint	2	Houston	1		
Omnitec	12	IBM 360/30	2						
IBM 1050	11	XDS 7670	2						
Teletype *	7	CII Cope	1						
Burroughs		G.E. 400	1						
TC500	5	Honeywell 200	1						
Terminet 300	5	IBM 360/40	1						
Typagraph	5								
Datanet 730	4								
Teletype **	4								
CDC Marc	3								
Execuport	2								
Olivetti									
TE 300	2								
ADS 715	1								
Tycom 20/20	1								
Viatron	1								
22 models	83 Cos.	13 models	22 Cos.	7 models	35 Cos.	6 models	38 Cos.	3 models	9 Cos.

* Inktronic ** Portable

The reverse channel is for the operator's use or for supervisory and control purposes. These speeds are seldom more than 100 words per minute. Thus an asymmetrical circuit might be a six megahertz television grade channel in one direction with a telegraph grade channel in the opposite direction. It is technically feasible to build such an asymmetrical telecommunication facility where the difference in transfer rate is as high as ten thousand. But it is uneconomical. Hence where there is such a great difference in speed, each direction will be carried by the most economical means regardless of the reverse direction.

Advertising via Visual Display Terminals

The home viewer of broadcast television pays for most of this entertainment at the supermarket. Will the visual display terminal user accept commercials on his remote terminal in lieu of telecommunication charges? Here, the advertiser would pay the common carrier charges in the hopes that the viewers will buy his products.

While this concept is not new, perhaps its application to visual displays is new. Picture a fifteen second flash on the user's display screen extolling the services of, say, the Oxford-Webster software company every time the data bank, computer, or television retrieval library is dialed. It is easy to think of other examples, but are viewers willing to reduce their costs this way? It could depend on the quality of the advertisements.

Urban Beams

Urban beams may be an economical alternative to coaxial and other cable facilities in certain situations. Beams include microwave, lasers and other means of carrying information through space between two or more buildings. These locations might be several hundred feet or several miles apart. The necessary equipment is no larger than an air-conditioning unit on a window sill.

Some disadvantages are, damage to the eyes and body from laser beams, fog, rain, and lack of privacy from off the air pickup.

There are definite advantages. The common carriers can implement a high speed system very rapidly, and, adapt to a fast evolving urban communications environment. When such beam systems proliferate beyond certain economic limits they might be replaced by coaxial or other secure plant such as waveguides.

Future Blackouts

Telephone service is a residential, business, and thread-of-life service. A great deal of capital expense is incurred by the common carriers to prevent failures in telephone service. Buildings are protected, outside plant is designed to withstand the elements, transmission is backed by auxiliary power plants, and employees are trained to cope with emergency restoration.

The public is generally not conscious of the fact that telephones are powered from the local telephone office. Ordinary telephone installations are not connected to local batteries or alternating current outlets. A local power failure will not interrupt the service. Since this is considered to be an essential service the carriers are not expected to change the continuity of service policy.

This policy does not apply to the more complex telephone services and the other user terminals. Light indicators on the telephones, remote teletypewriters, visual display units, card readers, etc., are powered locally and subject to failure during an electrical blackout. Terminals located in data processing centers may be immune to public power failures if standby power is built into these centers. If these data centers depend on remote terminals then the remote terminals should be supplied with auxiliary power. Most are not, and probably will not be protected because of the additional costs.

As we have related several times, visual data service tends to employ medium or high speed telecommunication facilities. It is economical, for example, to run television grade services via coaxial cables in urban centers. Amplifiers are built into these coaxial cables at intervals of several thousand feet. If these amplifiers are powered by a local electrical utility and there is a power failure in the neighbourhood, service on these coaxial cables will fail too. Such a situation is not as serious as telephone service failure, because the local users' television receivers have also stopped.

Software Inaccessibility

The problem here is not privacy of information but the immense size of software systems. We are aware that some computerized systems are so huge that programming is beyond the individual's imagination. Maintaining the human skills on site to trouble shoot, up-date, and remodel immense software systems may reach a natural barrier within the decade. Firmware, i.e. wired non-destruct readout logic will only extend the barrier to a new but impending limit as to size.

From the user's point there is another area of concern covering software and computer programs in general. One obvious user question is "what are the rules of the game?" What assumptions have gone into the system which might affect the output of the user's data? Perhaps, unknown to the user, the system is handling his requirements in a very costly manner because of the way in which the software is structured. There may be no rival service organization to point this out.

Potential Applications of Computer Graphics in Next Decade

The potential scope of application of graphic techniques is virtually unlimited. We will stress in this report those areas where remote communication of the data is likely to become an important factor.

Map Production and Dissemination

Our cities do not have reliable base maps of the street layouts, the lots and buildings, nor of the various utility conduits. We have already described some of the statistical type of data which can be tied to a map, and displayed visually. Topographic maps, contour maps, etc. are other items in widespread use, and are expensive to produce.

Display of Statistical Information.

Information retrieval systems from large data banks will in many cases require graphic output. Even from non-muneric data banks, the distribution of occurrence of various items which can best be presented graphically will often be required.

Computer Assisted Instruction and Other Educational Materials

Regardless of the material being taught one rarely sees a chalkboard in a classroom with only English text and numbers. We turn to pictorial representation time and again to explain ideas and relationships. Educational technology must take this into account, and educators must realize that this is not merely an "arty frill", but a necessity. Most of television programming is radio with a camera attached, we see almost no graphics, except in the commercials. If rapid means can be found to visualize the news of the day and statistics of the many situations reported on and if this can be done economically our public affairs broadcasting could be greatly enriched.

Engineering and Architectural Design

Circuit analysis, ship, car, plane design, training simulators, structural design, architectural layouts, display of chemical structures are some of the areas in which interactive techniques have already been applied. Graphic output of simulation programs, traffic studies, etc. provide other possibilities. These techniques will make possible the examination of a larger number of alternatives than currently possible, improving the design process. They will also allow the intervention of human judgement into the mathematical design methods emerging.

Medical Computing

Remote transmission of electrocardiographs have been demonstrated. Consultations without time-consuming personal travel require that the communication system offer visual possibilities. The number of microphotographs, X-rays and other material which modern medicine needs exceeds the availability of personnel for analysis. Medical doctors have available to them practically no statistical information; this could be easily provided with the computerized systems which have been proposed.

Air Traffic Control

Future systems can be envisaged which provide the air traffic controller with a real time three dimensional display of the airspace he is controlling, with the position of each aircraft indicated. He will be able to control the scale and point of view of the display. A similar display can also be installed in the cockpit of the aeroplane, together with a representation of the airfield to assist the pilot in instrument landings. The control of automobile traffic, and "automatic pilots" on automobiles will also require computer graphic techniques.

Visual Arts and Design

To quote Maurice Constant of the University of Waterloo:

"Computer graphics, a technique by which the computer generates images--still or moving, on paper, film or tape--has now passed through the research stage and entered the period of development. In consequence, the subject of computer-generated images has now become a matter of direct and immediate concern to the designer and film maker.

"In effect, one of the most powerful tools ever offered to the creative imagination is asking for direction from the user. What would you like me to do for you? What form would you like me to take?

"The sad fact is that up to the present, designers and film makers are hardly aware of the existence of this tool, much less its personal relevance, and where some interest has existed, too often the esoteric language and habits of mind of the computer scientist have discouraged further investigation.

"Nevertheless, some design-oriented minds, industrial designers and architects, have begun to explore the use of computer animation to evaluate structures and sequences. The architect or exhibition designer has been intrigued by the possibility of seeing on film an accurate model of the structure he has dreamed up. He can walk around it or through it, examine vistas, spatial relationships, and evaluate the effect of sequential experiences.

"In general, it is not a matter of inventing a technology, but rather of taking existing technology and putting it together in a computer graphics system directed specifically at the needs of the designer and film maker.

"Hitherto, much of the relevant computer technology has concerned itself with the problems of the engineer, and the need to plot information in the form of a graph. Typical of this concern is the development of high contrast film techniques. However, let us consider the more sophisticated requirements of the film maker--these will include most of the concerns of the designer. Now we must broaden our interest in computer graphics beyond points and lines to somewhat more sophisticated requirements: shape, color, shading, tone, image quality, movement within the frame and from frame to frame ("shot to shot").

"All this implies, too, an interest in the means of manipulating these elements in a meaningful way, that is, according to the conventions of the film medium, and, as well, that the hardware involved be convenient, economical and, in general, more effective than existing film-making procedures.

"What do we wish to achieve? In general, to extend the film maker's powers to manipulate shapes and colors in space; to help him do the kinds of things he has been doing but better, less laboriously, more economically and with greater accuracy. In many cases the peculiar power of the computer make possible the construction of images which are beyond the scope of the film maker. For example, in the field of education, the subject matter of the sciences is full of expository material which suggests or sometimes demands visual capabilities beyond the present capacities of the film maker or the film medium. An obvious instance is the accurate rendering of complex movements or shapes governed by mathematical prescription or which require great numbers of laborious calculations and drawings.

"We must be prepared, too, (a most exciting prospect...) for the emergence of new techniques and modes of expression--based on the peculiar capaabilities of the computer--of whose possibilities the film maker is not aware and which he cannot even imagine. It is quite possible that the continued extension of the film maker's powers in combination with new display and projection devices and ideas such as multiple screen and total image envelopment, will produce not just a difference of degree but of kind--in effect, a new medium."

Many of the possibilities outlined here for the film maker could become equally useful to the visual artist, the art teacher, the graphic designer, the commercial artist, typographer, illustrator, industrial designer, landscape and interior designer, in exhibition and stage design, choreography, and so on. "Computers and Automation" magazine has conducted an annual Computer Art contest (in the August issues) since 1964. "Computers and the Humanities" since its inception in 1967 includes the visual arts in its annual bibliography (March issues).

A major public show: Cybernetic Serendipity was assembled at the Institute of Contemporary Art, London by Jaschia Reichardt. The work of Canadians has been shown in numerous exhibitions in many parts of the world. Canadian students won first and third prizes in an international "Plotter Art 1968" contest. The report of the "Telecommunications and the Arts Seminar" documents this area in more detail.

Our government agencies deeply involved in the visual media should become leaders in the uses of the new technology (e.g. National Film Board, Canadian Broadcasting Corporation, National Gallery, National Arts Centre, Canada Council, Information Canada, Dominion Bureau of Statistics, National Library, Queen's Printer, National Research Council, Communication Research Centre, etc.). Since the new developments break down the boundaries between media, interdisciplinary work is vital, and the different agencies must learn to work together, and also open up their doors and facilities to outsiders.

New Services Anticipated in Next Decade

Service

The user's terminal, the transmission path between this terminal and some remote point for either receiving or transmitting information, together with a timetable, etc., all add up to something called a service, which the user agrees to buy (directly or otherwise) from one or more providers. From the user's point of view no one part of this chain is a service. For example, the flat solid state television screen being developed at the University of Waterloo may lead to one but is not a potential service in itself.

Some Anticipated Services

Among the services we expect to see evolve in the coming decade are Videophone and Multicom wideband data service. These services will appeal to certain large segments of the population.

The long term prospects for computer services are covered in the report of Telecommunications Study 5(d).

Videophone service may be useful to some businesses, an attraction in some homes, and a necessity perhaps to deafmutes.

Three dimensional holography, voice print recording, interactive display terminals without lightpens or keyboards, and others, could lead to new services.

Modifications to Existing Services

Some coming events are modifications to existing services: better human-machine relationships, self service trends, e.g. direct dialing overseas, and better quality of services. This better quality expresses itself in terms of faster setup times, a variety of (data) speeds, low error rates, and costs which might be somewhat independent of distance.

Predicting New Visual Services

Everything technically possible will not happen. Social and geographic disparity, our value systems, monetary restraints, allocation of resources, and the policies of business and government will filter the possible and introduce the acceptable at times and places which can only be guessed at. Some trends make predictions easier. UHF television reaches over thirty million USA households. Its current introduction in Canada may spark the following events within five or seven years and top off about 1985:

- more television channels for the home
- more television sets per household
- greater acceptance of coaxial cable connections to homes
- thirty or forty TV channels per coaxial tube
- centres for switching television channels
- more local live talent
- automated film libraries
- home video recorders to capture TV programs
- accelerated changes in social goals and values
- further social pioneering by governments
- etc.

Delphi Study Results

Bell Canada is conducting a Delphi study to probe the educational, medical, legal, etc., fields for indications of trends in telecommunications. The study which is a method of arriving at a group consensus about opinions regarding the future, covers the next thirty years. Questionnaires have gone to hundreds of experts across the continent. Some of their opinions are now available. Here are a few views covering visual data services in the educational field.

1. Implementation of laser and hologram technologies for storage of vast amounts of digital and visual material in a very small area will occur during this century but not before 1985.

2. New computer logic systems will be developed which will not only store information, but relate it and so allow computer intelligence. This will occur sometime but not before 1986.

3. Retrieval, information retrieval TV, computer aided instruction, etc. will not make schools irrelevant before 1990 if ever.

4. Fifty percent of the respondents feel the following computer output capabilities will be in 20% of the locations designated sometime during the following periods:

	Output	location	time-frame
i)	computer voice reply	- homes - schools	1981-99
ii)	printed page	- homes - grade schools - post secondary schools	1981-97 1970-85
iii)	traditional television screen	- homes - primary schools - secondary schools - post secondary schools	1981-99 1981-90 1976-90 1976-85
iv)	large flat television screen display	- homes - schools	after 1986
v)	audio-video recorder for recording	- homes - primary schools - secondary schools - post secondary schools	1981-99 1976-99 1976-90 1976-85
vi)	Videophone screen display	- homes	1981-99

Social Aspects of the Use of Computer Graphics

Importance

We produce vast amounts of data by computers, and communicate great amounts of information. In some instances fork-lift trucks are needed to transport the computer printouts. These can only be understood, comprehended and used if they are organized into meaningful patterns. The most effective way of doing this is visually. The interrelations of the many factors we need to take into account in considering many of our problems can best be done visually. The complexity of our society and of our institutions makes the use of computers and of computer graphics real necessities. For proof we need only observe for a while most face to face communication where invariably sketching, drawing, plotting, outlining, etc., occur spontaneously.

Group Area

As the possibilities are realized and the needs felt this field promises to be a growth area within the computer field. Graphics will also serve to open the door to many new computer users for whom current communication means with the computer are unsatisfactory. Some research studies, for example, are moving toward the graphic specification of procedures for the computer. Before really widespread use will be possible the cost of equipment will have to decrease and the software will have to be provided to make its use easy. Due to the cost and complexity of maintenance central service facilities will be needed. The research and development effort should identify the areas most likely to be of help to society as a whole, and out of these begin with the ones easiest to achieve technically. The systems developed should have general applicability, rather than being for a specific application on a specific piece of equipment. Much can be learned from the development of the rest of the computer field, without going through the same painful steps with graphics. While we need to alert potential users to the possibilities, we must not oversell it, and promise things we cannot deliver--there is already much disenchantment with computers because of previous unfulfilled promises.

Visual Education

Our school systems tend to neglect the education of our visual sense. Many existing facilities in the graphic arts are underused because of a lack of appreciation of their value. In one university physics department a few years ago a list of physics films was circulated, which were to be made available without charge. Only one professor expressed interest. However, now the same department has a committee on educational technology, and is becoming interested in computer animation. They want to make their own! The filmmaking going on in the high schools is another positive sign. It also has to be recognized that most graphics serve their purpose in a short time, and need not be of a quality to be preserved for the ages. Gyorgy Kepes' Vision/ Value series of books constitute one of the best resources arguing the values of visual communication.

Future

The best uses of the visual data transmission possibilities will be to bring the non-numerate but inherently visual citizen into the picture. Those specializing in a field and intimately familiar with its intricacies can usually deal with it in an abstract manner, and are able to visualize the relationships and processes involved without external aid. They are not even aware of the needs of those less gifted in their field, which is one of the reasons why many teachers are less than illuminating to their students. For example, future mathematicians can absorb most of their mathematics exclusively by means of symbols, the rest need graphic visualization.

Information presented graphically tends to have a far greater emotional impact, it leads more often to a "Eureka" gut-feeling, an "Oh, now I see." And what we need if our data is to have any real value, our information explosion any real benefit is understanding, insight hopefully leading to wisdom in making our vital decisions. In a democracy we are committed to the principle that this cannot be delegated, that the whole citizenry should be informed, so that he can fully participate in the social process. This includes not only the interpretation of what has happened already, but also the prediction and evaluation of alternate future courses of action; we must all become futurists in a rapidly changing world, or we will lose control.

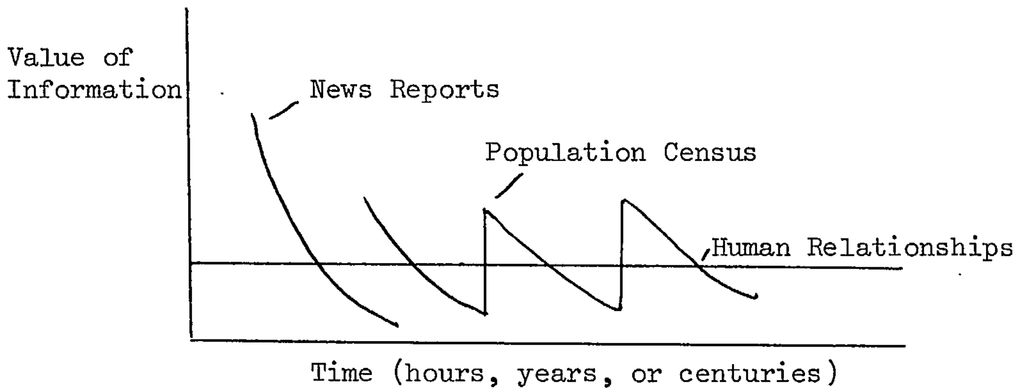
Everything that has been said so far refers to the near future, all these things are possible now, and will likely become economically feasible within the next five to ten years. In the more distant future other exciting vistas exist, but will only be mentioned here. We should remember that utopians and science fiction writers speculated about many developments fifty and even a hundred years in advance. It took 300 years from Pascal's machine to develop the computer. Many of the implications were foreseen by Lady Lovelace, considered to be the first programmer (to Charles Babbage and his Analytical Engine) one hundred years ago. Technological advances which make these things feasible are hard to predict. However, we can look in our crystal ball, and see the home entertainment and information center, with access not only to the supermarket and the world's libraries, the stock exchange and the race track, but also to the world's art collections, movies, video tapes. And this available not only to the megalopolis housewife, but also to the Arctic Eskimo, and the sailor on his ship. Not only will he be able to select what he wishes to see, but also interact with this and alter it. Each of us can be a "citizen artist" with the help of the new medium. We will be able to enter the communication stream ourselves, sending messages, poems, sonatas, pictures for others to see. These are worthy aims to move towards, but we will not have them within the next ten years.

Potential Social Effects of Increased Demand and Use of Visual Information

Information Decay

Information does not become more useful with time. It decays. Table III illustrates several kinds of information and the corresponding influence of time.

Table III



Most of us can act on "perishable" information only because of fast telecommunications, and the way in which the information is portrayed. Visual display equipment is very effective for this purpose. Television and Videophone services are powerful examples of how current information can be disseminated.

Computerized data banks operate with visual display terminals for reasons which go beyond the perishable nature of information. Information decays into data. Its value becomes relatively constant with time. If a sufficient amount of it is hoarded properly, it can be analysed and rearranged to provide interesting relationships, which might be interpreted as "new information".

Computers do an effective job of this only because they can store vast amounts and can be readily accessed. Let us add, however, that none of this happens without good software; software which is based on an efficient accessing scheme.

It seems we cannot have fast access to vast amounts of data without creating problems that require rigid control. Here are a few key items:

- Every citizen will not have the skills or the terminals to make meaningful use of these data bank facilities.

- Our national manpower resources will not permit a great deal of duplication of data in each data bank. It is expensive.

- Updating and purging are essential to remove dead data and minimize errors. Visual display terminals offer one rapid means to scan files, even on a statistical basis, for monitoring what is in data banks.

High Information Impact

Visual information has greater impact on individuals than audio or printed information for a given unit of time. As the rate of information is increased it becomes impossible for a person to comprehend every detail. One's psyche compensates for this problem by interpreting the vast amount of detail as it is presented. All the interpretations are transformed into a meaningful message to the observer. Since a visual display terminal can do this faster than any other type of output terminal, the impact of this medium is greatest.

Visual display units have their own hierarchy of impact which increases roughly in the following order:

- alpha-numeric displays
- vector displays
- Videophone
- television
- cinema
- 3D colour holography

Conditioning People Rapidly

One social consequence of the visual display technique is to condition viewers rapidly to new ideas. While the ideas might be good or bad the key is speed. The visual display medium is and will be instrumental in broadening our horizon of experience and shaping our value systems. The Japanese had a post-war population problem. Radio , television, and the newspaper media were used to bring the birth rate down as rapidly as possible. The message was simple although the consequences were complex.

The ecologists have acquired a large reservoir of data and are turning to television to proclaim the perils of pollution. Even the message is complex. Time may not permit them to present it any other way.

In recent decades, political electioneering has become expensive. The visual telecommunication media is being brought to bear to shorten this appeal for votes.

The Apollo 12 did not seem nearly as exciting as its predecessor. Apollo 13 did, of course, for unique reasons. People condition rapidly.

To cope with the information explosion, educators and business are hoping to employ more effective technology like teleprinters and information retrieval television for students, and, computerized plotters for industry. Visual display systems now present pictures which cannot be seen in nature. One example is a see-through three dimensional rotating object.

Learning how to read and write takes a long time. Getting life's messages by television first and learning writing and reading later may be a viable means to help the young, the poor, and those in remote areas. Satellite communication will offer a splendid opportunity. It is a large quantum step beyond transistorized radio receivers in remote areas.

Conclusions

Visual means of communication has been one of the most effective forms used to transform sensory data and abstract phenomena into meaningful and logical patterns for easier interpretation and understanding. Much of our human experience relates closely to both static and moving images. Their judicious portrayal offers a great deal in fostering an interpersonal relationship and in enhancing the transfer of ideas, concepts, thoughts and knowledge.

Our way of life has been influenced by conventional visual information that has been communicated to us by means of television, motion pictures, and printed material. The capability of the computer is continuing to progress rapidly. Input/output devices providing mostly alphanumerics are becoming inadequate as a means of communicating with the computer, particularly in an information and data systems environment.

As our society becomes more complex and the amount of information to be absorbed and utilized continues to increase, there is a definite and urgent need to convert computed data and problem solutions from computer output into visual data. In this instance, visual data is synonymous with pictures and graphics which depict static patterns (points, lines, curves, drawings, diagrams, graphs, charts, shapes, shades, structures, characters and colors) and moving pictures (time-dependent functions, changing movements, sizes, perspectives and forms) for more effective interpretation and decision-making. Such visual data display shares much of the communication effectiveness of conventional media, e.g., television, film and printed material.

For any information and data system to serve the many needs of man effectively, a closer partnership must be developed in order to blend the creative and reasoning capabilities of man with high-speed manipulation, processing, and large scale storing and retrieving capabilities of the computer. Both are required to closely interact with each other.

The visual aspects of information and data systems have been enhanced considerably by individual development of input, output, telecommunication, storage and computer technologies, as well as in computer graphic techniques. There is growing trend in combining these technologies and techniques in a variety of ways in order to provide a flexible and economical means of visual communications. This is also supplemented by new processes developed in conventional media and audio-visual devices.

Visual data display is an effective man-computer interface. It can improve the dialogue between man and computer to a level that is visually comprehensible. The trend of visual data display developments in the next decade will lean more heavily toward the cathode-ray-tube (CRT) than other types. This is due primarily to the many different applications of the display in transferring visual information from one media to another: e.g. as microfilm recorder, phototypesetter, scanner, facsimile transceiver, optical character reader, optical pattern recognition system, image converter, etc.

Such CRT visual data display will be used increasingly as remote time-sharing terminals for information retrieval purposes. Color, graphics and interactive capabilities will be gradually added to basic alphanumerics.

The television set or video monitor will be employed as a display device for low-cost terminals. It will become the most common type of input/output device for information and data systems to be used in office, schools and eventually in the home.

Computer graphics is a very important field in the realm of information and data transfer. Many new developments and rapid advancements have been made in its techniques which have increased computer applications and capabilities to a great extent.

Through the universality of pictures, computer graphics have proven most effective in the transfer of information between man and computer. It enables one to visualize abstract concepts and invisible phenomena. In addition, the quantity of transferred information is substantially compressed and is more readily interpreted, while the quality is vastly improved. In generating and displaying information in a dynamic form with a programmed and changing time factor, interrelating events and situations can be accelerated or slowed down to suit the individual's communication needs.

Potential applications for the interactive mode of computer graphics augment man's intellect and decision-making abilities. This gives him insight into old and new problems and provides him with a new and powerful tool. He is thus able to conduct wide-range exploration and applications for scientific, engineering, educational, governmental and artistic communities, particularly in areas of problem-modelling and simulation.

Through special graphic programming languages and subroutines, man and computer communicate in visually-oriented terms. This enhances the interdisciplinary approach to problem-solving as well as encourages solutions to be reached by trial and error or experimentation.

A more sophisticated method in computer graphics has been developed by converting computed data into conventional video signals. These are fed to television monitors or large screen television projection systems for display. Such a technique lends itself to the simulation of a variety of visual environments for training and pretesting of concepts; e.g. urban planning, transportation system study, air traffic control training, etc.

While optical character readers will be used to eliminate input delay by converting hand or printed characters into machine acceptable form, optical pattern recognition techniques will also become increasingly important as the development efforts in computer graphics continue to improve.

Another important factor in the rapid growth of computer graphics is the availability of the microfilm recorder employing CRT display to obtain graphical output in the form of hardcopies, microfilms or motion picture films.

Increasing use of the CRT and electron beam types of microfilm recorders will be made to convert computer output onto microfilm. Substantial savings will be achieved in time, cost and storage space, as well as easier retrieval. Microfilm is continuing to gain acceptance as standard information media by libraries and professional organizations, government and commercial companies. As the graphic quality of the CRT display continues to improve, more conventional printed material will lend itself to this form of micropublishing.

The microfilm recorder will also be used by research organizations and educational institutions to produce computer-animated motion pictures on scientific and engineering subjects in communicating research findings and serving as teaching aids. Uses will gradually be made by management in budget and manpower forecasting, etc. in assisting decision-makings.

Microfilm application to graphic arts printing and publishing is becoming important. Electronic phototypesetters employing high quality CRT visual displays are being used for generating hard copies by photographic or xerographic process.

In the printing industry, text processing and remote CRT display terminals will be used for on-line reporting, preparing, editing, retrieval, proofreading and page make-up, etc. Both texts and graphics will be composed on interactive display consoles. Central or remote optical character readers will be used to convert handwritten copies and other printed characters into machine acceptable form. A laser system will be used within the next few years to digitize graphic material for computer storage and processing, as well as for milling high precision plastic pressplates or for producing high quality film masters for lithographic printing.

As printed material and film images and computer data from data banks can be converted into coded information for transmission over telecommunication facilities, there are increasing efforts in applying information transfer techniques along with other technologies to meet various visual information retrieval and distribution requirements.

Increasing uses of portable facsimile devices to transmit hardcopy over normal telephone lines for remote reproduction: Microfilm is scanned and converted into digital form and presented over CRT display terminal for editing, updating and then recorded on a new microfilm frame; use of video tapes to store record files which, under computer control, can be remotely displayed, sorted, updated and printed out.

Conventional visual media such as film and television can also serve a variety of visual information needs. Many creative uses have been made of such media, not only to transfer information but to entertain, to convey human emotion and experiences, and to motivate social and political awareness. However, the very restrictive distribution methods of films and the rigid programming schedules of television have inhibited their accessibility to individuals as flexible information tools.

Recognition of increasing demand for a greater variety of visual information and freedom of choice in selecting the type of program one may wish to playback at any time over his home television set has resulted in recent developments in prerecorded video cartridges (EVR, SelectaVision, AVCO), video cassettes (SONY), and video players. These devices will become very important visual information tools for education, training, cablecasting, publication, knowledge industry, advertising and entertainment.

Rapid expansion will become significant in coaxial cable systems reaching increasing numbers of homes as a vast visual information distribution system. It can provide a variety of entertainment, educational, community-sponsored as well as informational programs, and with capability of upward of 40 channels, the choice of selection will no doubt be enormous. Coupled with a video recorder which is capable of automatically recording programs from any pre-determined time, the viewer has the ability to retain programs and other visual information for use at a later date.

A cable system is able to deliver to the home viewer a cleaner video signal and higher resolution (1000 scan lines). A video facsimile unit, coupled with a high resolution television set, can be used to produce hardcopies on transmitted graphical material.

Future two-way cable systems can also provide a means of on-demand selection and retrieval of a variety of visual information from a central storage. It can also be used as a high speed data link between a time-sharing computer and a remote graphic terminal, with the television set serving as a low-cost display unit.

Remote computer graphic techniques, dial accessible wideband data networks, multi-channel cables, video cassettes and cartridges, video recorders and players, coupled with television sets capable of high resolution and color, will have a tremendous impact on motion picture and broadcasting during the next decade. While 16mm and super

8 films, slides and filmstrips, continue to find applications in industry and education they will be increasingly challenged by the more flexible and versatile EVR, SelectaVision, VCR, and other similar systems.

Production of film as a contemporary art form will gradually trend toward a total visual experience creating sensory stimulation and feeling of involvement. It will integrate multi-media, sound, light and architecture. Excellent examples of this imaginative use of film and of the new designs in film equipment have been seen at EXPO '67 and EXPO '70.

Successful integration of information transfer techniques, time-sharing and computer graphics for visual information communication demand flexible, expendable and economical telecommunication facilities. Continuing developments are being made in Canada to design new and to improve existing telecommunication systems to accommodate a widening range of visual information services.

Common carriers offer a variety of data services which are carried by analog and digital type transmission facilities. Heavy investment in these facilities continues, with the emphasis on digital systems and faster switching capability. A switched telephone network may take the bulk of the lower speed data services across the nation but a random access switching service is being extended now to cover higher customer speeds.

Visual telecommunication services generally require at least the capability of a voice grade facility. Many alphanumeric and graphic applications come in this range. Displays depicting motion or great detail are normally carried by high capacity facilities. Videophone and television extend bandwidth requirements into the megahertz region.

There will be an extensive growth in the use of remote on-line computer display terminals during the coming decade. Videophone retrieval of computer information will be a service offering. Dial access television retrieval service is also a likely possibility.

Telecommunications is a capital intensive sector of the economy. A high percentage of equipment like towers, cable, and conduits will remain in service beyond ten years; a substantial part of today's plant will carry telecommunication needs for the next decade; the framework is already built and we can expect some telecommunication surprises in this time; technology, in the research stage today, may not penetrate the mass market by 1980. However, most important of all, is how we use our current resources.

In Canada, some commercial activity is being excited by essentially U.S.-originated plans to make use of a telephone-switched network for slow-speed inquiry and a coaxial cable network for high-speed visual display. Access to these facilities could be provided to business premises and individual households.

There will be a gradual introduction of inter-computer communication systems, such as ARPA (Advanced Research Projects Agency) computer network in the U.S. This would allow a large number of remote users to share and pool much of their computer resources, as well as permit many individuals working on graphic-oriented problems to exchange information and interact visually.

In a computer-based information service environment, a wide spectrum of users will be operating on both digitally and pictorially stored data. The next few years will see randomly accessible massive digital storage in use with film as the storage medium because of its high information storage capacity. Laser and electron beams will be employed to write, verify and read digital data stored on film. Pictorial images will be recorded on microfilm. Visual information will be retrieved by means of microfilm-to-facsimile techniques, and microfilm records will be digitized and read back to the computer for subsequent manipulation and display.

Laser and holography will have their impact on information and data systems. During the next decade a number of practical applications in image storage and display will be developed --- an holographic memory, capable of storing massive digital and graphical information, will give speed and economy to printing applications and computer-based libraries; two-dimensional laser color televisions will be refined into marketable form; three-dimensional holographic motion pictures will be used increasingly in research, and the first commercial three-dimensional motion picture will be demonstrated to the public.

Hardware, software, communication and transportation costs, as well as application, accessibility and freedom of making selection and utilization will determine the most viable visual information service in meeting individual needs.

The Canadian electronic industry appreciates that the communication of visual information is becoming increasingly important, and companies are therefore allocating much more effort to research, development, production and marketing of the range of equipment required.

The enormous growth of interest in this field by so many different organizations and individuals and the wide variety of their requirements indicate both the large potential and the problems a company encounters in deciding which product areas to develop, and the precise characteristics of selected products.

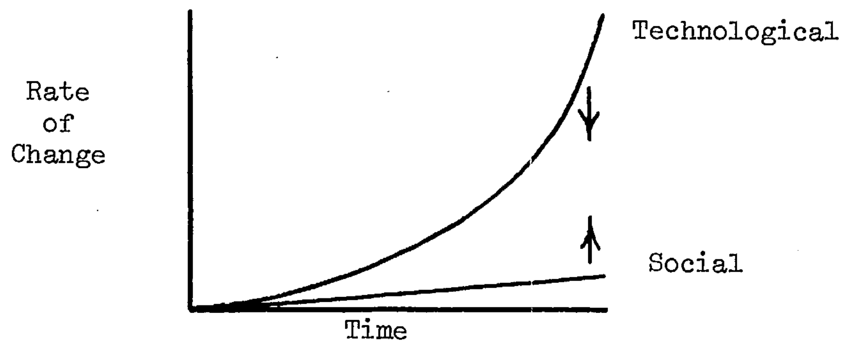
Also, in any rapidly developing field such as visual data, the Canadian electronics industry is sensitive to what is going on south of the border since, through its vast size alone, American industry is certain to come up with a wide range of products, some of which will be winners; whereas Canadian industry must be much more selective and the risks of failure are greater.

Canadian electronic industry is at present producing a range of visual display systems. Examples of these are: Flight information processing and display systems for airports; information processing, storage and display systems for stock exchanges, hospitals, banks, etc.; colour CRT display systems for process control for power utilities; various other CRT displays for computer interface, radar, etc., character generation equipment for characters up to 24" in size; development of a flat screen display. Data entry keyboards are being manufactured, and videophone equipment is under design. A selection of data transmission equipment is in production from low speed (teletype) data modems through 9600 bps, to pulse code modulation.

Problem Areas and Technical Objectives as identified by the Canadian electronic industry: The industry is most conscious of the need to reduce the cost of all system components for visual transfer, especially visual displays and hard copy, and optical character recognition. Resolution capabilities, stability, modularization, reliability and ease of maintenance are among the objectives in the display area. A variety of standard data terminals will be required, together with a considerable number of data banks. Concentrators, multiplexers and other interfaces require maximum standardization. Data modems up to speeds of 9600 baud, and digital transmission systems are required, together with measures to increase transmission speeds on switched telephone networks. Video information should be compressed to reduce redundancy, and the upper frequency spectrum utilized for transmission of video colour and digital data. It also appears that the development of a cheap and fast facsimile system for use on telephone lines into the home/office for remote correspondence and general information purposes may be a requirement. The industry appreciates that the expected general increase in visual communication will have a considerable sociological impact, which must be considered in the formulation of future policies and plans.

The complete field of audio-visual education will be influenced by widespread use of "visual data" communications and display. Training courses will be needed to qualify people to work in areas of human impact and social betterment. The "learning-program" concept, if implemented on a wide scale, will require thousands of people in the next two decades to research and create programs that may become schools of the future. Thus, there will be a need in Canada to provide useful employment for large numbers of technologists and scientists who will graduate every year. These people will have increasing knowledge in computer sciences and awareness in visual communications. Financially this will, on the one hand, be a great burden to the taxpayer, while on the other it will be most beneficial to the country as a whole.

There is a steadily widening gap between technological developments in visual communications and rate of social change. The privileged gain access to vast stores of information and continue to progress, while the less privileged remain deprived. We could lessen this disparity by developing in quantity and quality user-oriented hardware and software which would be more easily and more economically accessible.



There is need for Canadians to pursue actively all aspects of visual data telecommunications. Recent technological developments have clearly demonstrated the feasibility of the many possible applications, as outlined in the Study.

Much hardware is readily available at the present time, however there is considerable work to be done in areas of graphics-oriented software and applications. Such an enterprise would challenge as well as stimulate the imaginative and innovative capabilities of Canadians involved professionally.

Information and data systems and visual communications have good market potential and extensive social benefits. We should therefore make a concerted effort to assure Canada the leading role in this unique undertaking.

Some Recommendations

Information Assessment: Establish and maintain good communications for the interchange of information among government, universities, electronic industry, common carriers and service organizations in various technological and application aspects of visual information communications.

Active Involvement: Encourage those government departments and agencies that are involved in visual media to take an active role in exploring potential uses of new technologies and developing new applications.

Study Updating: Update the work of this study and the national goals and objectives derived therefrom. A multidisciplinary approach be adopted and full consideration be given not only to technical, economical, educational, cultural and social aspects but to the well-being of Canadian industry. There will also be federal-provincial government discussions in some areas of which education is an example.

Advisory Body: Form an independent advisory body to advance the many aspects of visual information communication as prescribed in this study; to formulate objectives and to promote all phases of research and development efforts to assure that Canada plays a significant role in application and utilization of these new technologies. It is proposed that C.R.C. (Communication Research Center) be instrumental in initiating this group.

Future Experimentation: Promote and implement trial or experimental systems that will serve several purposes:

(a) provide a basis for development of both firmware and software techniques relating to analysis and display of visual data.

(b) provide a basis for development and research into new hardware devices to exploit newly applied physical principles to improve the system.

(c) investigate feasibility of collaborative research and development programs between government, universities and industry to sustain a high level of competence and assure best possible use of available efforts and resources.

(d) promote development of "human-oriented" visual displays used in information and data systems by overcoming problems in hardware, software and systems operations.

University Research: Encourage and financially assist the formation of research and development projects conducted in universities. Devise ways of bringing these results through to a commercial reality.

Computer Graphics Industry: Encourage the growth of a computer graphics industry in Canada, particularly in hardware, software, low-cost display terminals and new services. This is potentially a high-risk industry but holds promise of innumerable applications and benefits. Industry will need increasing financial support from government, including some substantial government funded research and development projects.

Public Education: Improve methods of making the public aware of the many benefits of new forms of visual communication. For instance, computer graphic techniques in conjunction with visual data from meteorological and earth resource satellites can generate a variety of visual environments for the study of causes and effects of weather, pollution, etc.

Cultural Exchange: Encourage cultural interaction through new forms of visual communication techniques on a national and international level, particularly in exploring different approaches to various problems, furthering understanding, establishing new relationships, etc.

Arts and Technology: Promote the interplay between creative artists and computer specialists in the use of remote visual display and computer graphic techniques to engage jointly and interactively on a common program, such as development of new visual designs, sculptures, animated motion pictures, educational material, other interdisciplinary applications, etc.

Standardization: Develop standards of the characteristics of visual display terminals, interfaces, data sets, and transmission systems. Standardization will assure equipment compatibility and reduce the dissipation of effort on low-value special developments. The concentration of fewer products will reduce costs and accelerate growth of visual information systems. Establishment of standards will enable potential users across the country to communicate in this new visual manner in more sophisticated and complex ways.

Canadian Content: Maintain a prescribed level of Canadian content and regulatory control in the visual aspect of information and data systems of the future. Planning should start now for the use of government funds to supplement individual Canadian enterprise in its continuing struggle to survive economic and cultural tidal waves from south of the border.

Appendix

Radio and Electrical Engineering Division
NATIONAL RESEARCH COUNCIL

Data Systems Section
Submission to

Telecommission Study 5(g)
"Problems in data transfer with
particular regard to visual data"

1. Status quo with regard to generation, transformation and transmission of different forms of visual information.

Our discussion is limited to the field of computer-driven c.r.t. display data as this is the area in which we are active and knowledgeable.

Currently transmission of visual data is not widespread in Canada. Visual data is usually generated and transformed in large time-shared computers and transmitted to c.r.t. for display. The display terminals range from inexpensive character display terminals through 10K storage tube terminals to fast dynamic displays with a local computer such as IBM 2250 display and IBM 1130 or IBM 1800 computer. The NRC system with a stand-alone medium sized computer is not typical.

Hardware for display of 2D projection of 3D images and rotation of images is available either as analog gear (Adage) or digital (Evans/Sutherland) costing $150 to $200 K. The NRC system employs vector hardware and 3D and rotation software for these tasks.

Efforts are in progress in several places to develop interactive graphics in raster displays using TV monitors. Stanford Research Institute uses standard TV format and an analog scan conversion system. IBM and Rand Corporation are developing raster systems using high resolution (875 line) TV monitors and a special vidicon for scan conversion.

Computer driven displays of the simplest type are used primarily as input/output devices for time-sharing systems and handle alpha-numeric data. Storage tube terminals have only recently become available and are used for test editing. NRC will be investigating CPM/PERT analysis on a storage tube terminal. The more dynamic displays are applied in circuit design and analysis, simulation, modeling mechanical and engineering design and architecture. At NRC work has been concentrated on means of communicating efficiently with a computer for non-programming users such as researchers, animators and musicians.

The problems arising from the status quo are:

(a) cost -- computer driven displays of all degrees of complexity are too expensive for many potential users. This is particularly true of dynamic displays which have the greatest potential in interactive and creative applications.

(b) capabilities (e.g., reproduction of surfaces are not yet fully developed. Improvements in both hardware and software are needed. The use of raster scan format for transmission and display of computer generated graphical information is likely to increase because of the availability of proven hardware (television, facsimile). Furthermore, the use of raster scan will likely lead to an economical way of representing surfaces, one of the major problems in computer graphics.

2. Current requirements (in Canada) for transfer of visual data from c.r.t. displays by communications systems are met by dial-up telephone lines or dedicated lines. Dynamic displays have not reached the state of development and use to need broadband communications between them. Transmission of static visual data such as computer generated drawings or computer stored graphs, tables, catalog information, could take place over dial-up lines, but use is not yet common.

In the U.S.A. the Advanced Research Project Agency is sponsoring a project for interconnecting large computers in major research centres such as Stanford, M.I.T., Harvard, Illinois, Utah, Rand Corp. into a network of dissimilar computers forming a resource sharing distributed utility. Problem areas here are the message processors that are needed for a multi-point, high capacity fast response communications system. The establishment of sufficient compatibility between dissimilar centres is also a major difficulty.

3. Future communications requirements are almost certain to include a resource sharing network of the kind supported by ARPA linking all major centres in Canada.

A greatly expanded network of dial-up data links for data (including visual data), transmission for many kinds of visual information systems, library, technical and catalog information, business information, artistic and cultural information and educational information.

4. The major new service in visual data transmission that we foresee in the next decade is a resource sharing network like that supported by ARPA. Even so, only interchange or sharing of static data will take place at first. Eventually interchange of dynamic visual information between selected users will be required.

Computer generated or computer processed visual data will be more and more common in data banks. Facilities for retrieval and transmission, as contrasted to sharing will be needed. These needs, however, can be met by extension of existing dial-up and dedicated telephone lines and should not need a new service.

5. Social effects of increasing utilization of visual information communication systems of the kind to which we have limited our discussion will be small in comparison with the effects of say television. Even at the end of the next decade utilization will not be widespread. There will be an increase in productivity in some creative activities: more effective engineering and research, richer more interesting artistic output, greater availibility or retrievability of many kinds of visual information for education and business or government administration.