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ABSTRACT

This document--intended to help technology education teachers plan their classroom curriculum for secondary school and college students--contains units on getting to know technology; problem solving; systems and subsystems; how technology affects people and the environment; controlling technological systems; how resources are processed by technological systems; problem-solving tools; and the impact of technology, including the choices and decisions it necessitates. The sociocultural impact of each of those topics and its relationship to the common elements of technological systems are covered in each unit. Units also typically include narrative information, line illustrations, photographs, a constructional activity, examples of how math and science can be used to support the students' constructional activities and provide the motivation for students to make the connections between technical education and math and science, a student quiz, possible student outcomes, and references. (CML)

RESOURCES IN TECHNOLOGY 5

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Getting to Know Technology

A technology teacher should teach a planned curriculum with students understanding and applying technological concepts to solve human problems. The key to teaching technology education is to teach problem-solving. Humans have used technology to modify their environment and improve their lifestyle for thousands of years. The problems they have solved may have been protection from the elements, storage of food, or softer bedding on which to sleep.

Today's problems have become more complex, but daily routine have created problems to solve for the citizens of the developed and underdeveloped world. While a technological problem may be the development of safer booster rockets for the shuttle, scientists, engineers, and technicians also strive to find tastier convenient foods and soft drinks or to invent gadgets or souvenirs people will buy while they are on vacation.

These are real world problems. What makes them content for technology education is that tools and materials are used to solve the problems. However, technology is more that tools and materials used to solve problems. It is also accumulated knowledge or "know how" for solving problems.

To build a house, special knowledge is required in addition to having a power saw, hammer, framing square, level, nails, studs, shingles, etc. Knowledge must exist in financing, designing, planning, and constructing. Knowledge of the implications or impacts of building the house must also exist. Will it meet the needs of the family, be durable and cost effective, provide adequate shelter, meet the standards of the neighborhood, alter the environment, or have a resale value?

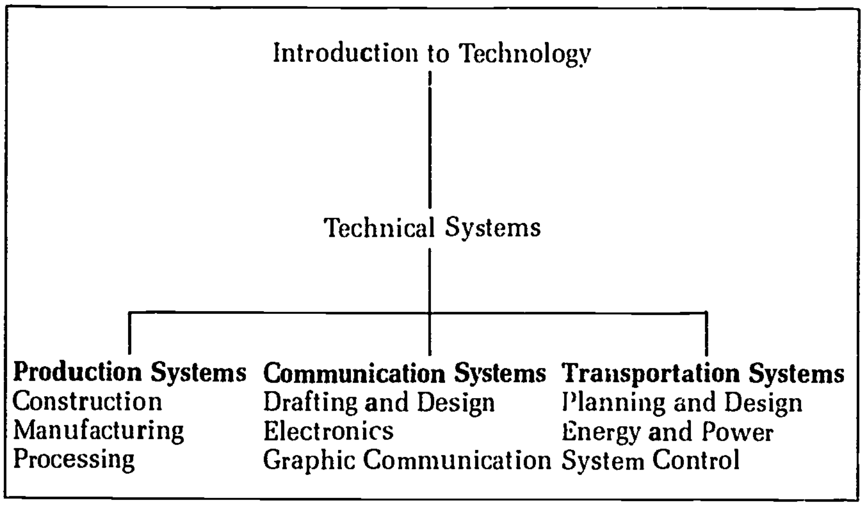
This is what technology education is all about. It encompasses applying tools and materials to human problems and analyzing the impacts of their solution on individuals and the environment. This is what we must do to transform our industrial arts programs into technology education programs.

Don't stop reading now!

It is not that hard a task if the content of your program is current to today's students and the technology of our society. There are two ways of going about the task of changing our industrial arts program to a technology education program. One way is to restructure the entire curriculum. The other is to add technological activities to your current program.

If you choose to structure your entire

FIGURE 1
Technology Education Sequence



curriculum, you need to become knowledgeable of our major technological systems. These include production, communication, and transportation systems.

At the lower grade levels you may modify your course to be an introduction to technology. Here you would provide students with knowledge and activities about technology and instruct them on the basics of the three technical systems: production, communication and transportation. Following an introductory course, you may offer basic courses in the technical systems of production, communication or transportation technology.

At the high school level, courses may become more specialized. A communication technology program sequen could focus on drafting and design, graphic communication, or electronic communications. However these courses should provide a broad knowledge base and use tools and materials to solve problems. Figure 1 displays an overall program sequence for technology education at the secondary school level. Examples of specific units to be covered in a technology education electronic communication course might include:

- Introduction
- Basics of electronics
- Telecommunications
- Light communications
- Acoustical communication
- Broadcasting
- Data Processing

State and local school systems are current developing and revising curriculum materials that aid in teaching the above technological systems. A summary of materials developed through 1985 is included in ITEA's *Directory of Curriculum Guides and Other Key Resources*, edited by Terry J. Squier. Following are the names of other guides and how they may be secured.

Illinois
Communication Technology Curriculum Guide
Production Technology Curriculum Guide
Transportation Technology Curriculum Guide
Available from: Robert Metzer, Industrial Arts Supervisor, State Department of Education, 100 North First Street, Springfield, Ill. 62777

Indiana
Industrial Communications
Available from: Robert Thomas, Industrial Arts Supervisor, Department of Public Instruction, Division of Vocational Education, Room 229, State House, Indianapolis, Ind. 46202

New Mexico
Communications
Manufacturing
Available from: Juan Lucero Industrial Arts Supervisor, Department of Education, Education Building, Sante Fe, N. Mex. 87501

Oklahoma
Exploring Construction Technology
Exploring Communications Technology
Exploring Manufacturing Technology
Exploring Transportation Technology
Materials and Processes Guide
Available from: Roger Stacy, Industrial Arts Supervisor, Department of Vocational and Technical Education, 1515 W. Sixth Street, Stillwater, Okla. 74074

Tennessee
Materials and Processes Technology
Communication and Media Technology
Transportation Technology
Available from: Ron Hoffe, Industrial Arts Supervisor, 128 Cordell Hull Building, Room 209, Nashville, Tenn. 37219

Texas
Construction Technology
Transportation Systems
Available from: Neil Ballard, Industrial Arts Supervisor, Division of Program Development, Texas Education Agency, Austin, Tex. 78701

Virginia
Communication Technology
Exploring Technology
Modern Industry
Transportation Technology
Materials and Processes Technology
Manufacturing
Available from: Thomas A. Hughes, Jr., Associate Director, Technology Education, Department of Education, P.O. Bo.. 6Q, Richmond, Va. 23216

West Virginia
Construction
Manufacturing
Transportation
Available from: Alta Davis, Coordinator, Career Exploration and Industrial Arts, State Department of Education, Capitol Complex, Charleston, W. Va 25305

In addition, publishers are producing textbooks that analyze our technological systems. Davis Publications, Goodheart-Willcox, Southwestern Publishing, Bennett & McKnight, and Harcourt Brace Jovanovich have textbooks that can help you. Other useful resources are *Implementing Technology Education* edited by Jones and Wright and *Industry and Technology Education* by Wright and Sterry.

[If a reader knows of other guides at the state or local level, please notify Tidewater Technology Associates at the address at the end of this Resource so that they may be listed in future ITEA publications.]

Infusing New Ideas

For the "new" technology teacher, the revision of your entire curriculum may be too much at the onset of change. The infusion of technology activities into your program may be your choice. In this revision process, you would teach your current units of instruction, but add technology activities to replace some of your projects or tool usage/skill activities.

As an example, in a metals course you may want to add activities that deal with the characteristics of metals, the study of industrial processing methods (ECM, CAM, laser inspection), the location of metal mineral deposits, an analysis of metal products design, the operation of a CNC lathe, the separation of metal using ECM, or a visit to a machine shop. These activities are a little different than those we traditionally do in metals class. However these activities should not be project or skill oriented. They must be knowledge based, focus on problem-solving, and look at the impact of their application on individuals, culture, and the environment.

Technological activities that might be integrated into a woods class include analyzing wood stucture and recommended uses, visiting a construction site, pricing woodworking supplies, identifying finishes, and analyzing pollution factors related to finishes and solvents.

Figures 2—4 contain suggested activities to include in industrial arts courses to make them a study of technology. As you can see, some of these activities are the same as we have been teaching for years in industrial arts programs. The key is to make the program knowledge based and to use tools and materials to

FIGURE 2
Activities for Production Courses

Woods
Identify woods for usage
Visit a construction site
Calculate and order project supplies
Analyze hand power tools for purchase
Study pollution factors related to finishes and solvents

Metals
Student characteristics and uses of metals
Research metal resource locations
Analyze processes for making products
Operate a CNC lathe
Visit a machine shop

Materials and Processes
Describe careers on an engineering team
Conduct destructive tests
Master technical skills
Establish an enterprise
Trace the history of manufacturing systems
Use a computer for typesetting
Publish a community cookbook

The study of lasers is appropriate content for technology education. Math and science concepts can easily be associated with their use.

FIGURE 3
Activities for Communication Courses

Drafting
Describe the use of mechanical drawings
Operate a CAD system
Practice sketching
Reproduce drawings
Identify schools for drafting careers

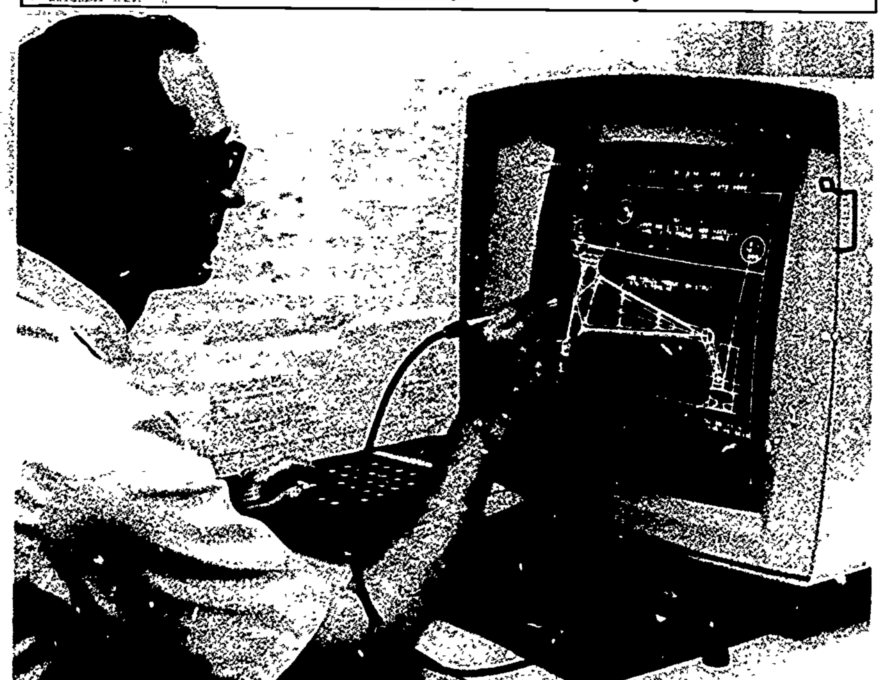
Graphic Communications
Design logos
Form an enterprise to screen print products
Make a photo collage of the impact of the radio

Electronics
Identify applications of EMF's
Use measurement instruments
Analyze how products operate
Construct an AM radio
Discuss the impact of cable TV

FIGURE 4
Activities for Transportation Courses

Power Mechanics
Experiment with energy sources to drive mechanisms
Service lawn mowers
Construct a project which uses an electric mower
Read home electrical meters

Power and Transportation
Cite energy sources used by industry
Discuss impacts of energy usage on society
Experiment with fluid controls
Design a transmission mechanism
Design transportation systems for your community



If you introduce CAD into your program, you must do more than teach skills, you must teach how industry is using the system. What impact is CAD having on industry, employment, job training, etc.?

solve technological problems.

For ideas on additional technological activities secure the following documents:

New York
Technology Learning Activities
Available from: William Brudreau, Industrial Arts Supervisor, Department of Education, 99 Washington Avenue, New York, N.Y. 10012

Utah
CAD
CAM
Computer Technology
Laser Technology
Photovoltaic Technology
Robotic Technology
Satellite Technology
Contemporary Analysis
Available from: Jerry Balistreri, Technology Education Specialist, Department of Education, 250 East 200 South, Salt Lake City, Utah, 84111

In industrial arts programs, our emphasis has been on procedures. These have include tool usage, industrial processes, and making projects. Technology education programs continue to use these instructional methods but do not focus on them for their entire content. Technology education programs teach about the technology in our environment.

All technology is used to solve problems. The airplane solved transportation problems. The house provided safety from the environment. The telephone enabled us to communicate over distances. These things were created to solve human problems.

To be a technology education program, the content must meet certain criteria. The program or activities should address the technological systems of production, communication or transportation. The program should be knowledge based, not just tools and processes. It must look at the social/cultural impacts that technology has on people, cultures, and the environment. Finally, the program must be activity based using tools and materials to solve problems. This problem solving may well apply scientific and mathematical relationship such as aerodynamics, mechanical advantage, cost effectiveness, chemistry, Ohm's law or hydraulics to mention a few.

Social/Cultural Impacts

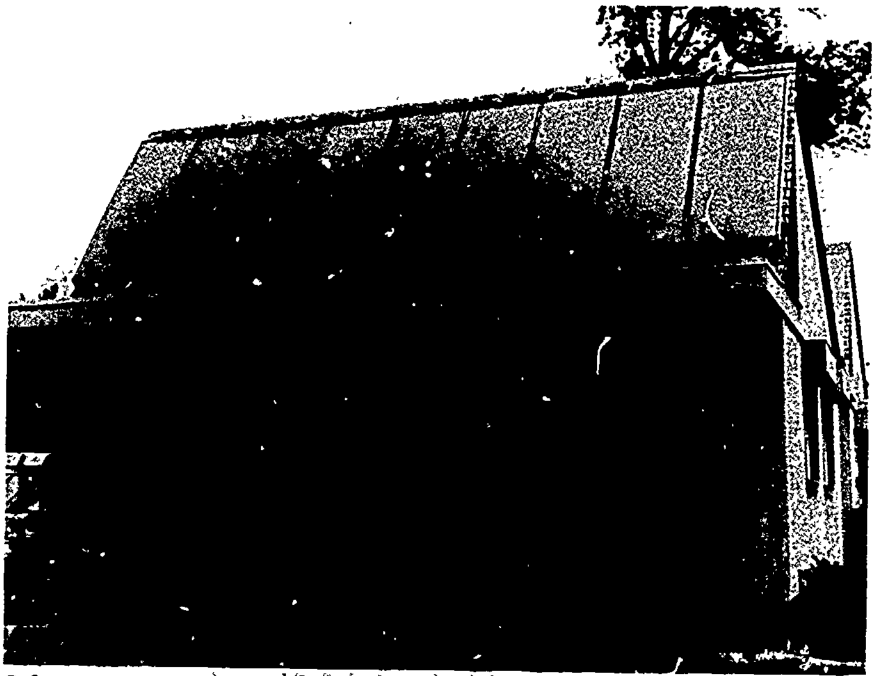
Social/cultural impacts are the result of applying technological systems. All technology affects individuals, societies, cultura, and the environment in some way. This is knowledge that must be analyzed in a technology education program. Often we think of this as the attitudinal domain of learning. Air conditioners, convenience foods, manufactured housing, motorcycles, space shuttle, polyester fibers and plastics have all had an impact on us and the environment.

In studying technology we must study its social/cultural impacts. We must look at its history, how it has improved life, products and processes, and how and why it is used. How does it impact the environment through energy and resource depletion? How does it effect the economy? Does it provide or take away jobs? What are its effects on our global society?

Figure 5 contains a list of social/cultural issues that might be blended into a technology education program. For other ideas write ITEA to purchase the professional monograph titled, *Math/Science/Technology Projects* by Donald Maley. Inventions and their social and environmental impacts are reviewed through student projects in this publication. *Technology Education: A Perspective on Implementation* is another useful document available from ITEA to aid in revising your program.

FIGURE 5
Social/Cultural Issues

Resource Depletion	Entertainment
Careers	Environmental Impact
Population	Unionization
Diverse Goods and Services	Job Skills
Conservation	Automation
Urbanization	World Trade
Pollution	Manipulation
Recreation	Global Society
Affluence	Loss of Life
Politics	Information Overload
Congestion	Altered Beliefs
Better Educated	Lifestyles
Family Ties	Recycling Future Changes



Solar energy was one of the first new "high technologies" to gain wide spread use. These types of problem-solving solutions provide excellent content for technology education programs.

Constructional Activities

The laboratory activity continues to be important in the technology education program. Emphasis should not however be on making projects for the sake of using tools and materials and developing specialized skills. Tools, materials, and technological knowledge should be used to solve problems.

We need to rethink our instructional approach. We want to have as our mission the development of intellectual as well as psychomotor skills in applying technological knowledge to solve problems.

Suppose we had recycling as a problem in our woodworking or materials and processing classes. Each year industry and technology teachers dispose of tons of wood shorts and scraps. This can become a very good technology education problem solving activity to integrate into your classes.

To lead into the activity it would be important to present facts on the amount of materials we consume or waste. Figure 6 cites some examples.

This should help to emphasize the need to conserve and recycle. Have the students talk about products thrown away daily in their households. Examples could include newspapers, grocery bags, beverage cans, plastic bottles and milk containers. Have students "brainstorm" to think of ways these items might be recycled.

After this activity, have students divide into groups of three to generate ways of solving the problem of recycling the wood shorts and scraps you have accumulated.

One solution would be to manufacture decorative wooden sleighs to use as planters or table decorations. Figure 7 shows plans for the manufacture of this product. Figure 8 shows a flow chart for construction. The class may wish to form an enterprising company to mass produce and sell the sleighs (or other ideas they may have) to solve the recycling problem. Other problems that may need solving in this activity include the development of fastening techniques, jigs and fixtures, and finishes. The recycling of household milk or beverage containers can also be brought into this product. Bottoms of containers might be used as planters to fill in the space created by the box on the sleigh. Again this could raise another ecological problem. Can the class raise plants to put into the containers?

FIGURE 6
U.S. Consumption Rates

50—60 gallons of water per person per day
500 pounds of metal per person per year
200 pounds of synthetics per person per year
5.5 pounds of refuse per person per year

FIGURE 7
Plans for A Decorative Sleigh

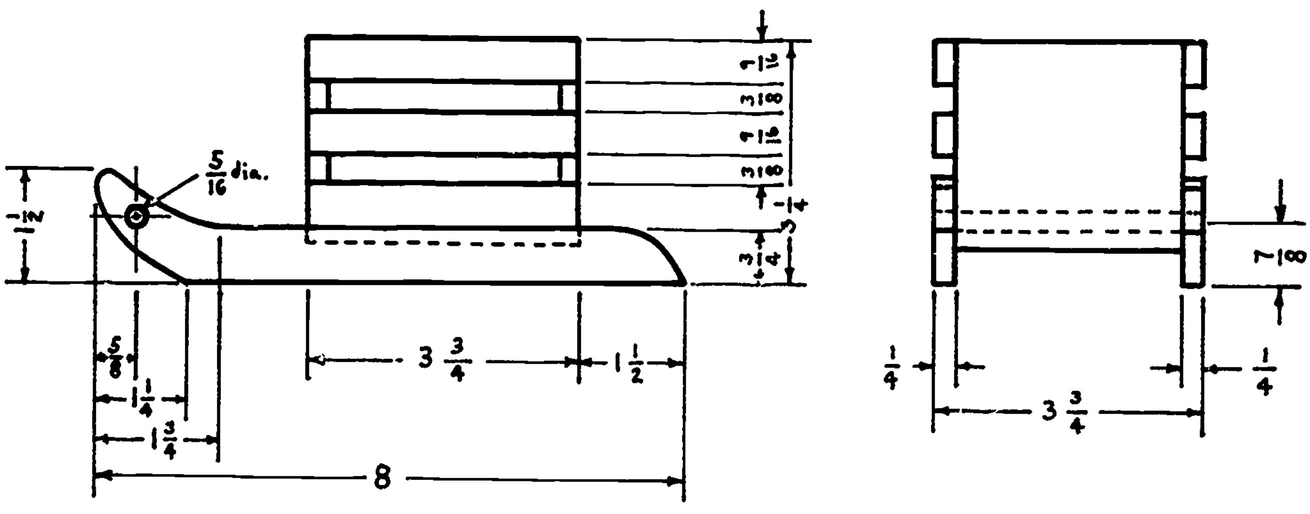
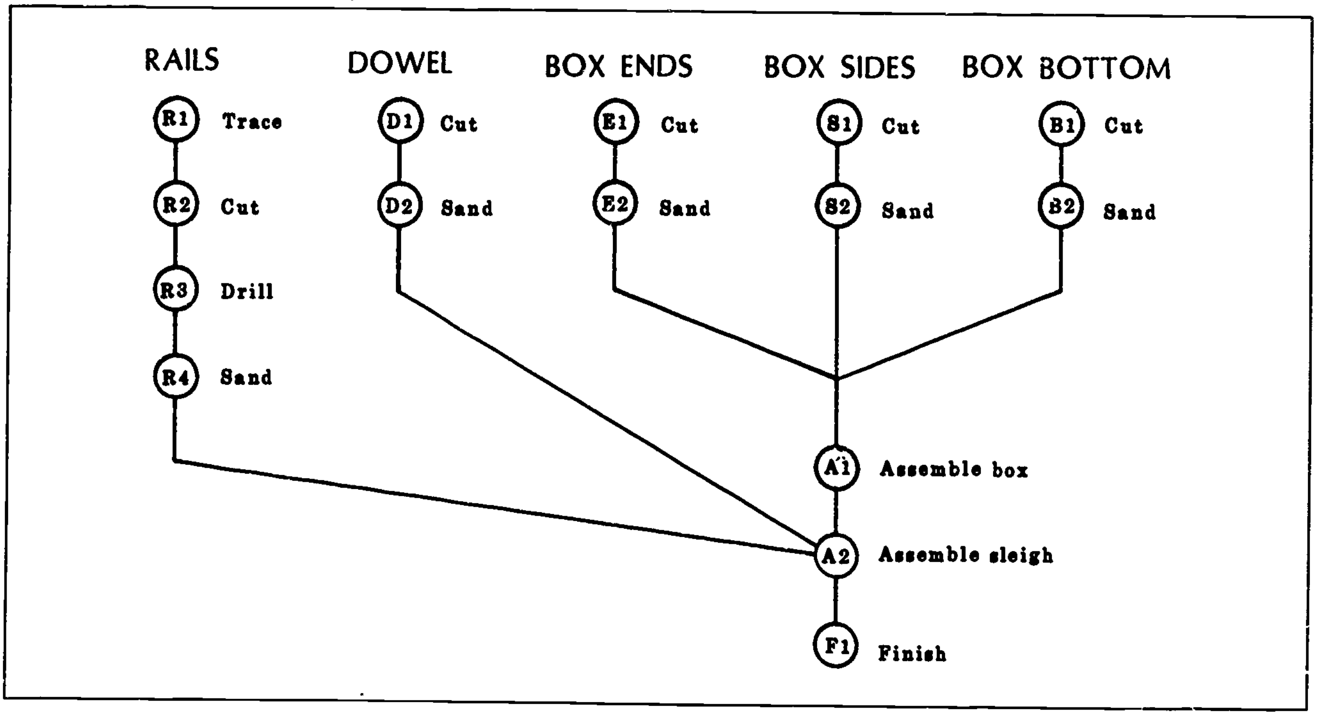


FIGURE 8
Flow Chart for Decorative Sleigh



Math/Science/ Technology Interface

As mentioned earlier mathematical and scientific concepts should also be integrated into your technology education program if they are related to what is being studied. We have done this all along in the study of electricity (e.g. Ohm's Law, resistance, inductance, etc.), and power mechanics (e.g. torque, horsepower, and pounds per square inch).

Examples of the application of math and science to technological problems are numerous. We might study work efficiency, mechanical advantage, velocity, Newton's laws, Bernoulli's Theorem, effort, momentum, adhesion, cohesion, focal point, lift, aerodynamics, thermodynamics, chemical composition, strength, reflection, energy, cost, or pressure.

Look at the science and math books your students are using. Can you reinforce what they are doing in other classes in a more practical way? Again Maley's monograph, *Math/Science/Technology Projects* is an excellent reference. Also past issues of "Resources in Technology" contain examples of math/science/technology interface applications.

In the recycling activity mentioned earlier, a number of math/science/technology relationships must be considered to solve the problem. Examples might include how much paint will be required to finish 100 sleighs. Students would be required to calculate the square footage of each color required and divide this by the square footage of each color required and divide this by the square footage coverable per quart of paint (usually 100 square feet per quart).

What type of fastening technique to employ is a scientific question?

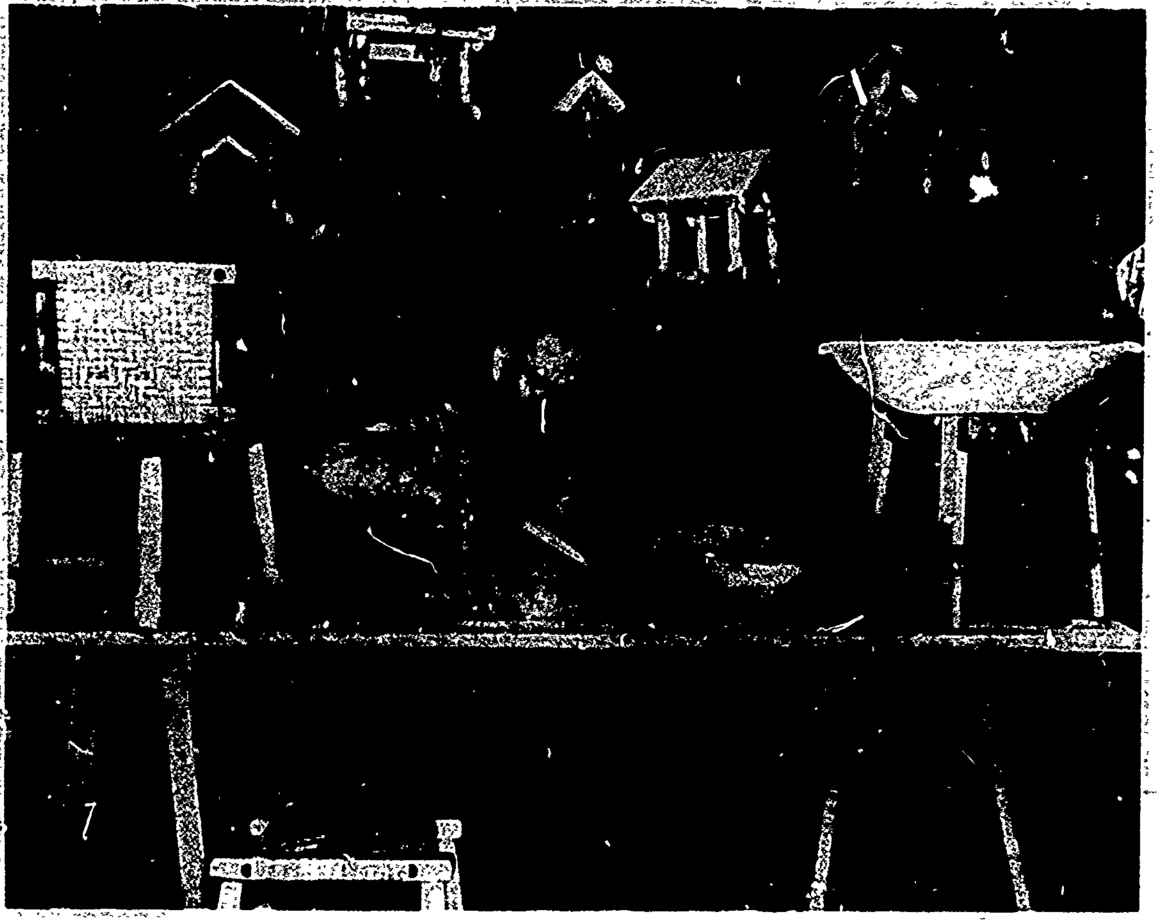
Should adhesion or mechanical linkage be used?

How many brads will be required for 100 sleighs?

Would hot, epoxy, or white glue be appropriate? Which cures the quickest so the product can be worked on further? Will it hold up? You can probably think of other math/science/technology applications to this problem.

Summary

Technology education is different than industrial arts education. In a technology program the "arts" or skills are no longer the end product. The key to technology education is to study and apply technology to solve human problems. In its application we need to look at its impacts or significance. When you begin to incorporate content and activities of this nature you will make that transition to a technology educator.



Arts and crafts have been a tradition in industrial arts education. However, society has changed and so should the content of our programs. Today we live in a technological society. Our programs should reflect the activities of that society.

References

Jones, R.E. and Wright, J.R. (Eds.).(1986). *Implementing technology education.* Encino, CA: Glencoe Publishing Company.

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Problem-Solving

Why Learn About Problem-Solving?

Technology education aims to provide students with a broad conceptual view of the technological society in which we live. The advantages and difficulties which are part of our society are products of science and technology. Technology education students should have a feel for what science and technology are about so they can see the relationships among the many components of technology. Problem-solving is basic to all aspects of technology; education must teach problem-solving skills to insure our citizens will be able to adapt to the ever changing world, to meet personal needs, as well as needs of the whole society.

What are problems?

The word problem in the term problem-solving refers to a need which must be met. These needs constantly exist in every aspect of our society, world, and universe. Needs may be as simple as an individual's need to get sleep. The need may be as complex as a necessity for our earth to relieve internal pressure as seen in earthquakes. Some of our universe's needs involve constant evolution as stars are born in the form of supernovas, exist, then die as they collapse into black holes.

Some of the needs may be solved by the individuals who encounter them: a sleepy person might lay down on the spot and rest. Other needs are beyond the individual or even all of humanity with present knowledge. We cannot stop earthquakes or prevent the universe from evolving; but we can study the problems, try to understand their consequences on us, then develop solutions or means to prevent the forces of our earth or universe from harming us.

Because humanity has always had problems to deal with, certain approaches to problem-solving have evolved.

- *Science* is the term which best classifies the study of forces in our universe.
- *Technology* is the term used to classify application of knowledge, tools, and materials to meet societal needs.
- *Engineering* couples science and technology with study and practice to economically utilize materials and forces of nature for benefit of society.

Unfortunately, science, technology, and engineering sometimes create very bad problems in efforts to solve other problems. For example, science's study (nuclear physics) of the atom led to the knowledge of how to control atomic and nuclear energy. While such knowledge was very promising for society, the choice

FIGURE 1
Semiconductor technology has evolved with knowledge of physics, chemistry, and materials science. Today, computer chips small enough to slip through the eye of a needle can store one million bits of information.

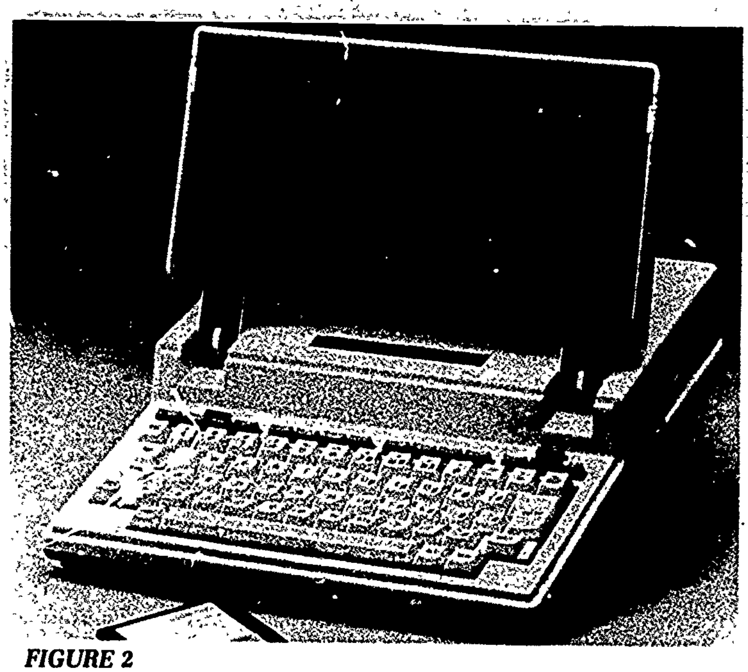

FIGURE 2
Computers have become so important in problem-solving that lap top portable computers allow members of the engineering team to travel with their computers.

to build atomic and nuclear weapons may destroy civilization. Even the peaceful use of nuclear generated electricity has created critical problems for disposal of "spent" nuclear fuel, loss of life with accidents, and major environmental problems.

Of course, nuclear physics has provided many useful benefits such as better understanding of engineering materials for development of semiconductors used in computers (Figure 1) and provided us with medical treatment for cancer, X-ray examination, and similar purposes.

With advances in science and technology, the world has become more complicated and thus a need for better problem-solving techniques exists. The computer has evolved as the most useful tool next to the human brain for problem-solving (Figure 2).

Artificial intelligence (AI) is another developing technology. AI is a means of programming computers to solve problems in manners only possible for brains of higher order animals. AI in the form of "expert systems" would emulate the specialized knowledge and reasoning power of specialists such as physicians, engineers or business people.

Much development is required before AI will actually have full reasoning power, but today, expert systems are aiding in design such as for oil refineries and in decision making for product marketing strategies. Developmental work on speech recognition is making it possible to interact with the computer with ordinary spoken English. AI has a long way to go but is sure to evolve to become a very important addition to the computer for problem-solving. (Davis, 1986)

Instruments for Problem-Solving

Through the ages we have developed instruments for organized approaches to problem-solving. The instruments are given such labels as the scientific method or the engineering method. How the instruments are applied depends upon the type of problem to be solved. Many specialized fields of engineering rely on design and manufacture or production or construction to solve problems. [Refer to "Careers in Technology" *The Technology Teacher*, September/October, 1985.]

Figure 3 depicts application of the engineering method. From research, needs are identified and basic scientific inquiry develops theories and principles to guide science and technology in their pursuit of accomplishments (Figure 4 and 5). Within the field of science are many specialized instruments and fields of study such as mathematics, physics, and chemistry. Each has its own set of principles which guides itself and related fields.

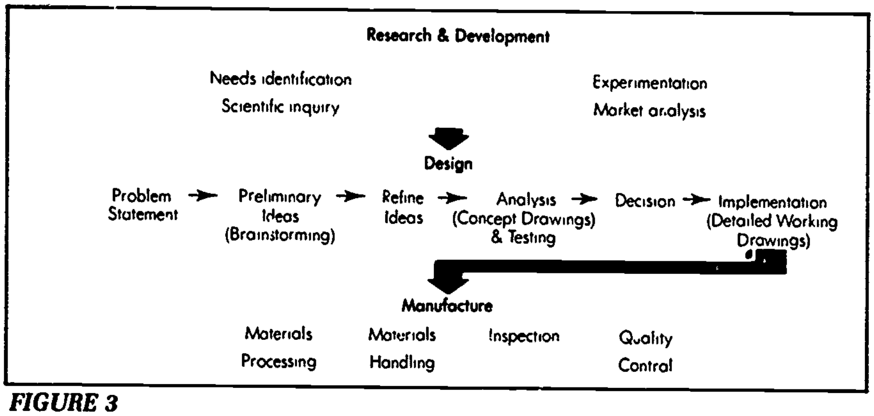

FIGURE 3
Application of the Engineering Method.

FIGURE 5
Research scientists, engineers, technicians, and craftspeople construct development equipment to get at problem solutions. Here scientists from AT&T's Bell Laboratories work with molecular-beam epiaxy (MBE) equipment which allows layer by layer growth control of semiconductors.

FIGURE 4
Scientists develop theories, models and experimentation to provide new knowledge for problem-solving. The model here represents the atomic architecture of a structure for semiconductors grown by molecular-beam epitaxy (MBE); a technique pioneered by Alfred Cho who is shown here with his son, Derek.

As we continue looking at Figure 3 we see experimentation is another instrument employed in problem-solving plus market analysis may be required if there is a concern for economic gains at the end of the engineering endeavor (Figure 6). Loaded with the results of the research and development (R&D) activities, the engineering or technological team is ready to proceed through the design activity and produce drawings and specifications which are the instruments that direct the manufacturing component in its work.

CAD (computer-aided design), CAM (computer-aided manufacturing), robotics and CIMS (computer integrated manufacturing systems) are new and developing problems-solving instruments that will bring design and manufacturing closer together and require members of the technological team to have a better knowledge of the entire spectrum of engineering. This goes through all phases from R&D to design to manufacturing and beyond. [See "Integrated Manufacturing Systems" Part 1 and Part 2 both in *Resources in Technology 3*.]

The commonly listed steps of the scientific method and the engineering method are listed below. The engineering method is an adaptation of the scientific method.

It should not be concluded that either the scientific or engineering method prescribes a simple, clear procedure for solutions to problems. Each problem requires its own unique approach; the methods listed above are guidelines learned by problem solvers.

SCIENTIFIC METHOD

1. Observation
2. Hypothesis
3. Testing

ENGINEERING METHOD

1. Recognize and understand problem
2. Accumulate facts
3. Select appropriate facts
4. Make necessary assumptions
5. Solve the problem
6. Verify and check results

(Adapted from Eide et. al. (1986). *Engineering fundamentals and problems-solving*. pp. 48–51. New York: Gregg/McGraw-Hill, Inc.)

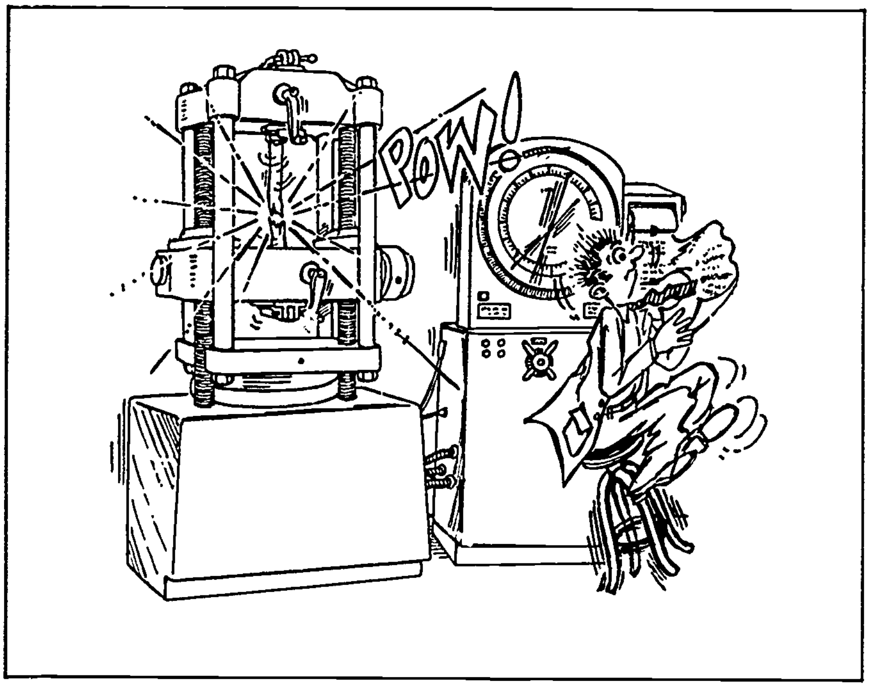

FIGURE 6
Mechanical testing by technicians and engineers provides information on the strength of materials.

Case Studies of Problem-Solving

In order for you to see how technology helps to meet societal needs, we will examine some examples (case studies) of certain needs that required solutions.

Problem in Transportation

Design a passenger vehicle that will suffer no external damage in very low speed front to rear collisions, protect passengers from injury at high speeds, and provide good fuel efficiency.

The above is but a simplified statement of the problem issued by the U.S. Department of Transportation in following the directions of Congress to make passengers cars safer in order to reduce the large numbers of deaths and injuries on the American highways. As you can imagine, thousands of elements of that problem required analysis with each requiring its own problem statement.

Figures 7 and 8 show one of the cars that were designed under government contract as Research Safety Vehicles (RSV). In Figure 7 note that the front bumper was designed as a soft front to reduce injury to pedestrians at up to 20 miles per hour (mph) and to sustain no damage to the bumper at 8 mph. Rear ends were designed to withstand impacts up to 60 mph without causing passenger death. Steering columns were "breakaway" to avoid penetrating into the driver and instrument panels and doors were padded to protect passengers.

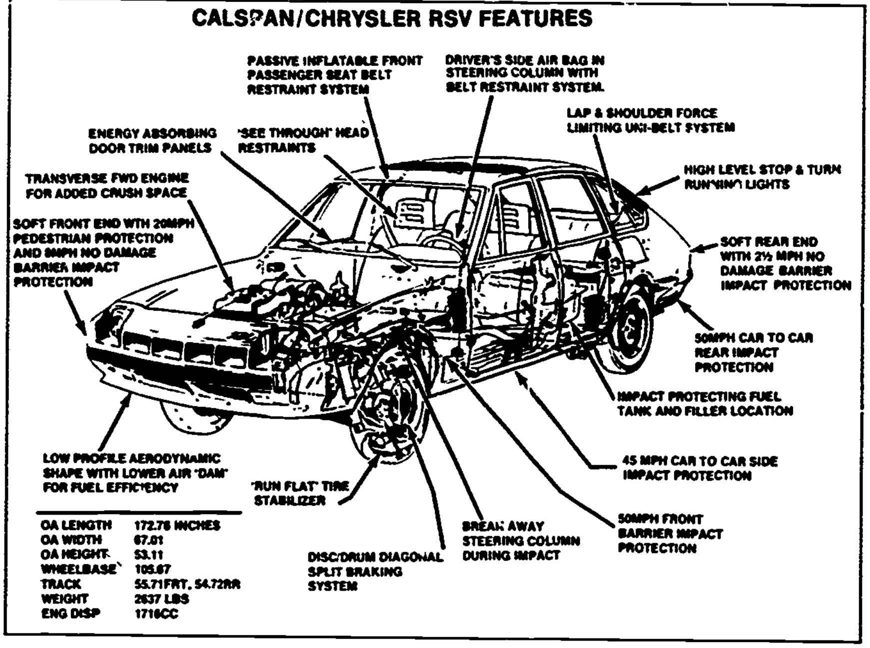

FIGURE 7
Chyrsler's Calspan RSV is one of several RSV's developed during the '70s in search for safer passenger vehicles.

In Figure 8 you can see the structural improvements to the car body such as use of stronger HSLA (high strength low alloy) steel around door openings and on instrument panels plus reinforcements in doors.

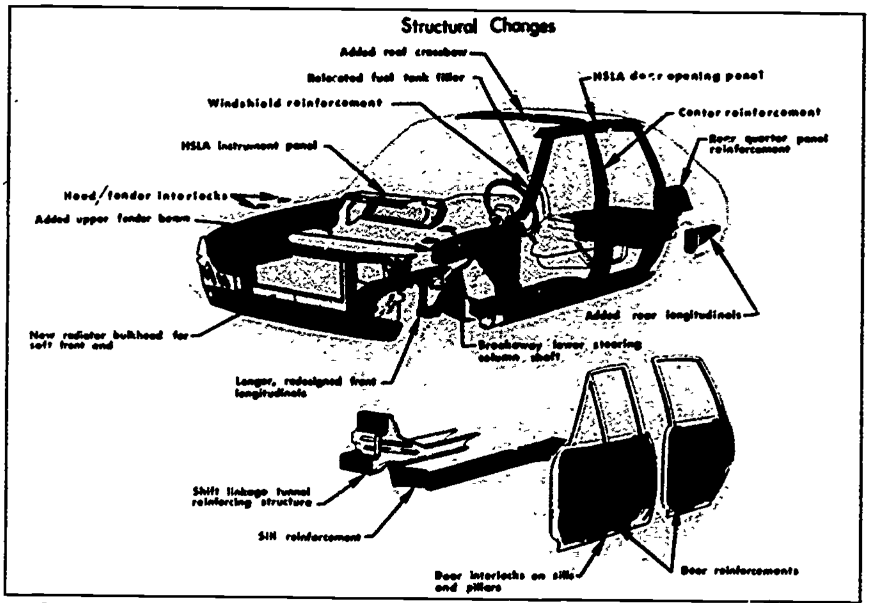

FIGURE 8
The RSV's gave the auto industry many good ideas for safer vehicles; some of which are used on today's cars, but many are not used.

The RSVs were made during the 1970's. Some of the design improvements are incorporated into today's automobiles. But unfortunately many of the improvements are not in our cars.

Why?

Economics is often a major factor in solutions to a problem. If the solution does not provide a design within the price range attractive to customers or if management is not willing to support certain enhancements is the design solution successful?

Obviously, the RSV project of the '70s have not given America the safe cars intended. For a class project, do some research in periodicals then discuss your

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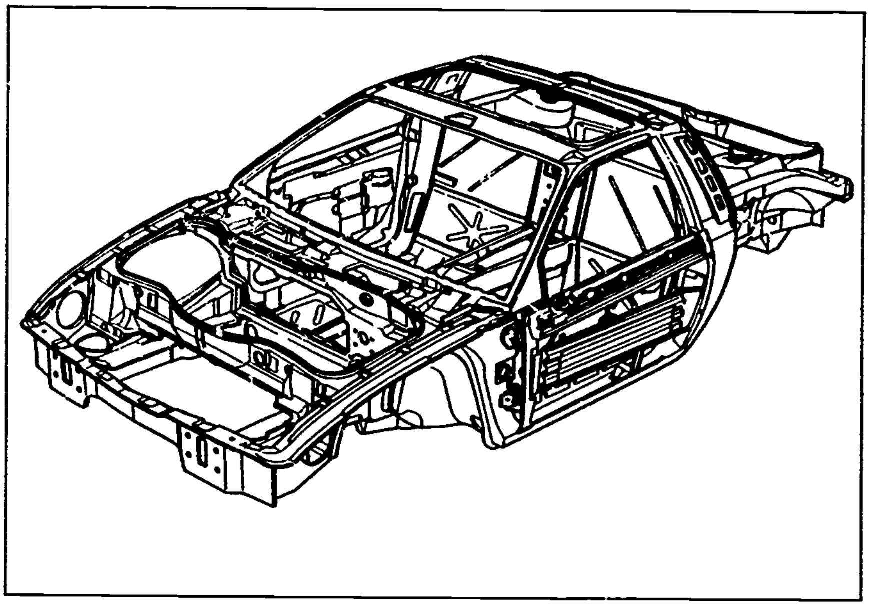
FIGURE 9
Fiero's space frame is a new development in body structure that lends to more efficient manufacturing and improved quality.



conclusions about the safety of today's passengers cars. Maybe you will be instrumental in giving society a safer car.

Problem in Transportation

Design a passenger vehicle that will be more competitive with foreign car imports.

Another problem for the American auto makers came from imported cars that took away customers thus reducing profits and eliminating jobs. Again, this is a very complex problem requiring many problem statements and solutions. One aspect of the overall solution was to make cars that had broad appeal in terms of style, fuel efficiency, cost, and quality.

The Pontiac Fiero offers a new concept in body style that provides a car that can be produced more economically with a high degree of quality. To accomplish this task the old style of frame that had steel body panels welded on was replaced by a "space frame" (Figure 9) onto which fiberglass body panels can be bolted (Figure 10).

Ford Motor is developing several body concepts to replace the current stamped steel frame with aluminum extruded frames much like aircraft (Figure 11) and possibly a fiberglass filament wound frame. Ford's Probe V design concept prototype vehicle boasts a drag coefficient of .137, projected holographic display of electronic instrumentation (speedometer, fuel gauge, etc.) and a unique tilt/telescoping steering wheel. As with the Fiero, Probe V uses a mid-engine; it has speciality car features of flush glass, wrapover sliding doors, a vertical stabilizer, enclosed underbody, and covered wheel openings.

These solutions to new passenger vehicles aim at producing cars more economically through CIMS manufacturing using highly flexible automated manufacturing with robots and equipment that is easy to change over when the time comes for vehicle design modifications.

The case studies of problem-solving on transportation technology shown above represent only a minute amount of problem-solving activity in our technological society. Communication, construction, and manufacturing technologies all demand ongoing problem-solving. While the above case studies were labeled transportation technology, you noted that several other technologies (design—communication; car making—manufacturing; and engine—power technology) were vital to the problem solutions.

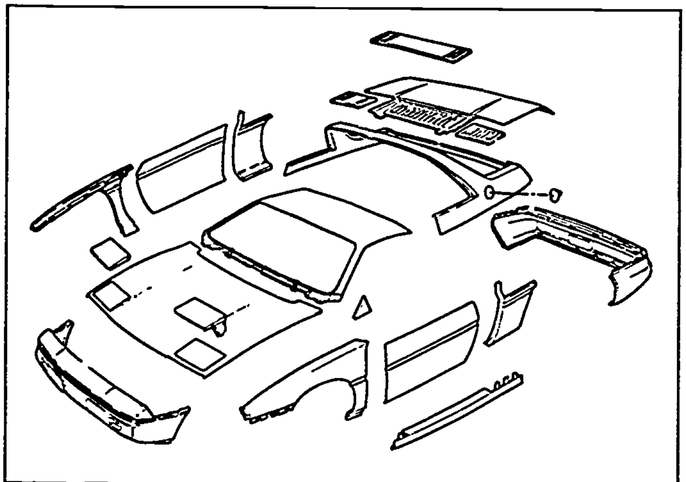


FIGURE 10
The "space frame" of the Fiero allows for attaching fiber reinforced (FRP) body panels which replace the conventional steel bodies on most cars. This venture is just one of many that will give us more cars with light, tough and rust free FRP composite bodies.

Even with computers and development of AI, there is a growing need for problem solvers on the technological or engineering team at all levels: craftspeople, technicians, technologists, engineers, and scientists. The promise of a better world rests with the quality of problem-solving. A sound technology education supported by a knowledge of communications skills, mathematics, and science will give you opportunities to make meaningful contributions to our future problem-solving.

Problem-Solving Activities

In this instructional module we studied aspects and examples of problem-solving. There are many examples in a variety of sources to provide you with a broad knowledge of problem solving activities. For example *Popular Science* magazine is full of "what's new" in technology and runs a regular feature, "Wordless Workshop," on simple problem solving and an annual contest on use of plywood and wafer board; contributors to the magazine features are paid for selected solutions. The bibliography at the end of this module provides other sources of study.

The Challenge

Apply your knowledge of technology and problem-solving in solution of a simple need with design and production of a product or system of your selection.

The Approach

1. Write a statement of the problem.

Examples:

- Determine the most efficient means of joining together a wooden, metal, and acrylic plastic set of book ends.
- Design a solar heating and storage system to provide hot water for a single family dwelling.
- Produce a bicycle trailer to transport a surfboard.
- Using any structural panel such as plywood, waferboard, particleboard, or a combination, design and construct a project according to the Popular Science/American Plywood Association contest rules and enter it in their annual contest.
- Design and construct a study lamp that will mount on both a desk and a bed. Use at least three different materials.
- Design a logo for your technology education department or student association.
- Select an efficient propulsion system to use on an experimental model vehicle.
- Apply plastic/polymeric materials and processes technology to problem solution.

2. Research the solution in technology education textbooks, periodicals, encyclopedias, and with knowledgeable people.

3. Draw conceptual designs in the form of sketches and instrumental drawings using CAD systems if available; make many sketches and save them. Specify materials and processes as appropriate.

4. Brainstorm the solution with parents, classmates, instructor, and other knowledgeable people.

5. Refine your initial solution based on feedback and brainstorming.

6. Test your solution through enactment of a plan or construction of a model, product, system, or prototype.

7. Present your solution to the consumer. This may be a group of students for a team project, the student association, instructor, parents or others involved in financing/consumption of the solution.

8. Enter your solution in appropriate contests or market for judging or consumption.

Below is a format to follow in problem-solving. Graph paper with light blue 1/4" grid is good for sketching out this procedure. Each item may require one or several pages.

- Statement of Problem
- Assumptions
- Calculations
- Sketches
- Conclusions

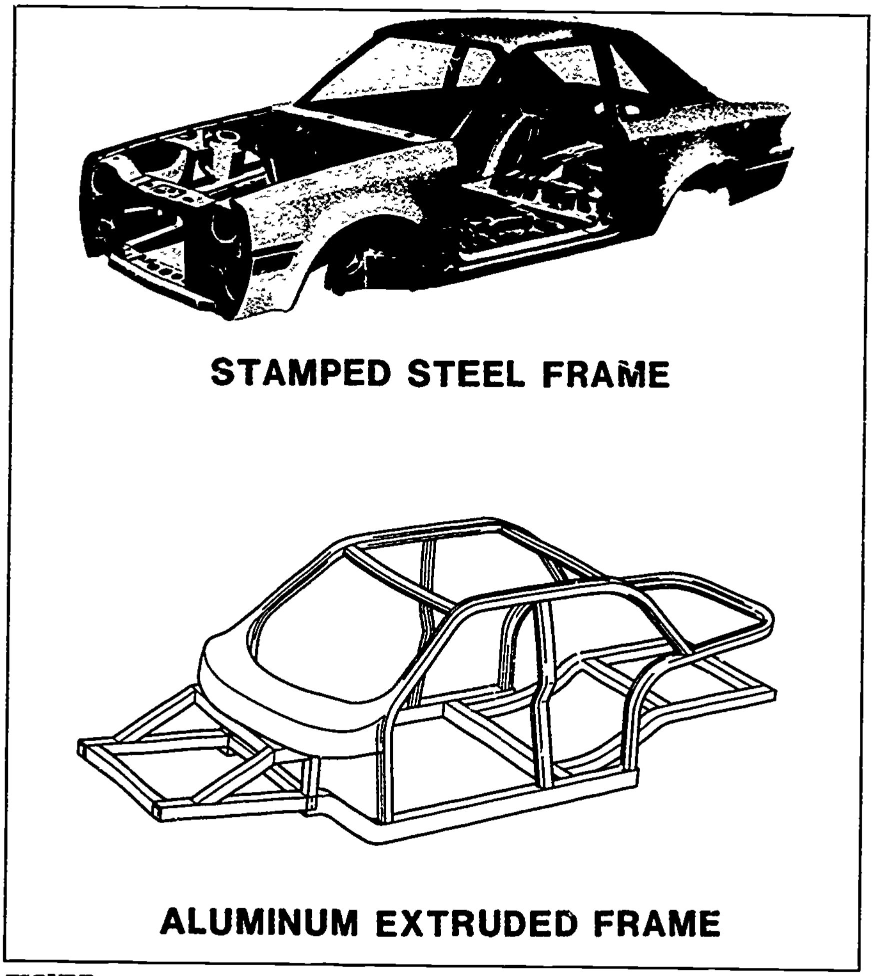


FIGURE 11
Ford Motor is developing new auto frames to replace the conventional stamped steel frame. Under consideration are lighter/stronger extruded aluminum frames.

Math/Science/ Technology Interface

The problem-solving activities above provide ample opportunity for students to interrelate concepts of mathematics, science and a variety of technologies.

Below is an instructor's product/process rating scale/checklist which may be used to evaluate students' problem-solving methodology.

Student(s) Problem

ITEM	*RATING** Acceptable	Unacceptable
1. Followed all eight steps for problems solving.		
2. Used appropriate format, neatly recorded data, and made neat sketches.		
3. Used appropriate materials		
4. Used appropriate processes		
5. Used appropriate references		
6. Processes were analyzed or tested before final selection		
7. Final solution reflects quality		

***Comments**

Final score: ____________

Possible Student Outcomes

- Explain the concept problem-solving and recognize who is involved in problem-solving.
- Describe who does much of society's problem-solving of technical problems.
- List the elements of the scientific method and the engineering method.
- Discuss some problems requiring solution by American auto manufacturers.
- Use a prescribed problem-solving methodology in solution of selected problems.
- Maintain an interest in further study of technology education with career considerations related to the engineering team.

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Student Quiz

1. Name four examples of common human needs.

Many possible answers: individual comforts and societal requirements.

2. Who must be able to solve problems?

(Every higher order animal.)

3. What is the name of the team who has the responsibility for technical problem-solving for much of society?

(The engineering team or technological team.)

4. Before proper problem-solving should begin, what is required?

A. Tools
B. Problem statement
C. Problem solution
D. Scientists

A

5. Name two instruments for problem-solving.

(Numerous examples including mathematics, physics, and CAD).

6. Arrange the terms in order for the engineering method.

A. Solve the problem
B. Accumulate facts
C. Recognize and understand problem
D. Make necessary assumptions
E. Verify and check results
F. Select appropriate facts

C. B. F. D. A. E

7. What are the elements of the scientific method?

observation, hypothesis, and testing.

8. What are two problems that need solving by the American auto industry?

(Numerous answers, e.g. vehicle safety, fuel efficiency, competing with imports).

Acknowlegements

Figure 1 courtesy IBM.

Figure 2 courtesy Radio Shack.

Figures 4 and 5 courtesy AT&T Bell Laboratories.

Figures 7 and 8 courtesy Chrysler Corporation.

Figure 9 and 10 courtesy Pontiac Motor Division, General Motors Corporation.

Figure 11 courtesy Ford Motor Company.

Resources in Technology

Systems and Subsystems

A Point of View

In the two most recent issues of *Resources in Technology*, the teaching of technology and the use of the problem solving approach for instruction were discussed. In addition to a rationale and teaching approaches, technology teachers need a definable body of knowledge for selecting teachable content. This definable body of knowledge provides structure to the technology education program. If we have a definable body of knowledge and utilize problem solving in addition to other teaching strategies, students are offered two paths to learning about technology.

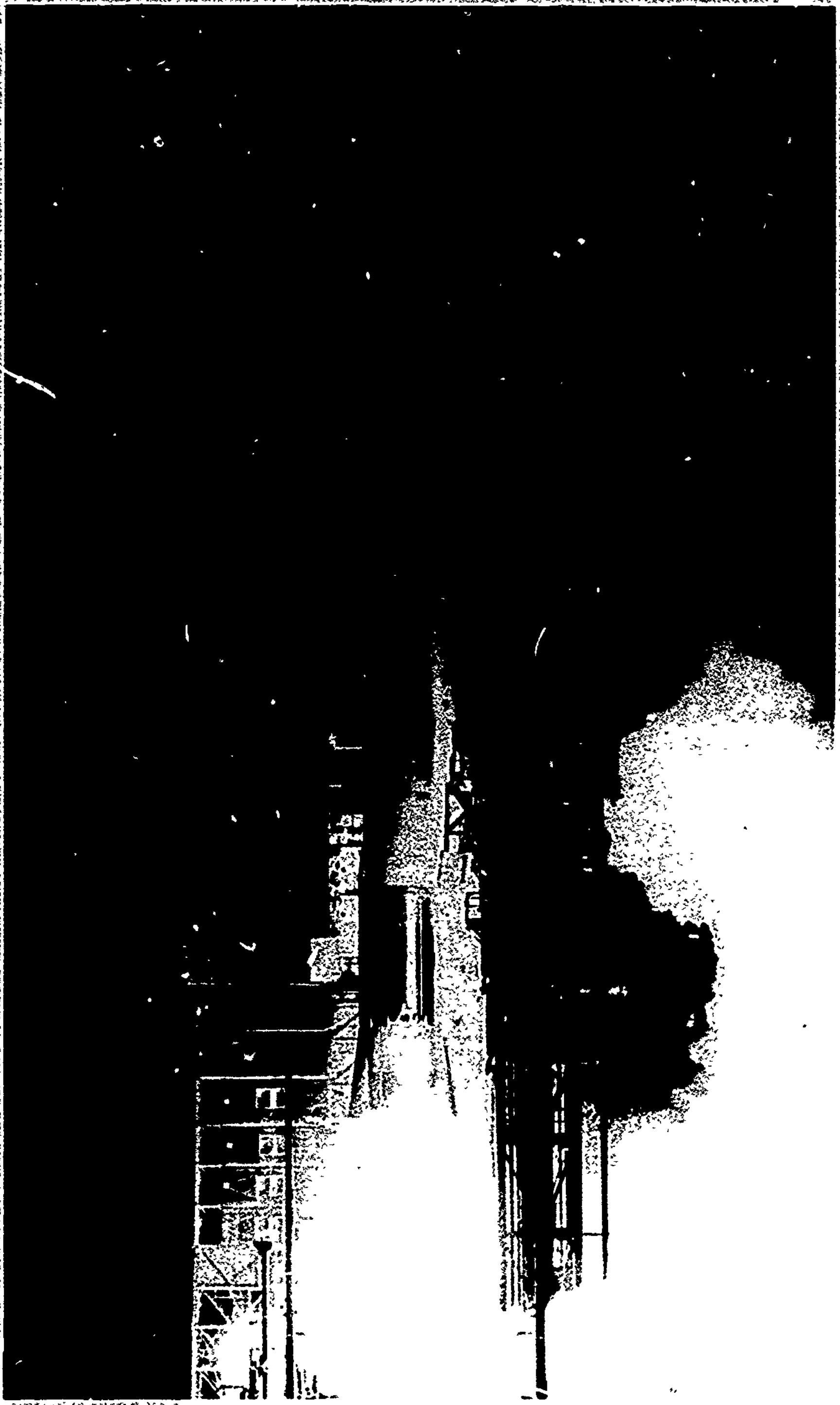
One being process-based which has lifelong usage in such areas as problem solving, planning, designing, calculating, and valuing to mention a few.

The other, content-based, is the systems used in technological societies to produce and transport their goods, services, and information. These systems are continually being refined and developed to meet the needs of industry and society. Some become obsolete while others are the results of new inventions. Technical systems have perspective that is directed by the needs of society.

Analysis of the technology used by humans to adapt to the needs of our changing world show that three distinct, but interrelated, systems of technology exist. These include our production, communication, and transportation systems.

If one studies industrial arts they would study the processes of industry. This is what we have done in the past. We have focused on tool and machine usage to build projects and develop machine usage and assembly skills. In studying technology one would analyze how technical systems are designed and operated and the impacts of their usage and products on individuals, society, and the environment.

So a technology teacher should use the technical systems of production, communication, and transportation as their body of knowledge for program design. We use tools and materials in our laboratories to design, construct, and operate technical systems, not to study them for skills and the projects we can make with them. This is the fundamental difference between technology education and industrial arts education.



Many times communication, production, and transportation systems must be integrated so that a technological objective may be attained.

Contemporary Analysis

Technical systems have been developed for humans to modify their environment and to produce products to make life better. The systems utilized to make these changes include production, communication, and transportation technology.

Humans have used these systems to construct houses and schools, air television and radio programs, to produce automobiles, appliances, and food products, and to transport grain and animals to market and people on vacations and business trips. These systems are made up of many complicated machines. However they must be organized and integrated into the needs of society and business to be efficient and useful.

This integration involves humans for design and operation, information to aid in problem solving, power to drive the system, and various materials to produce the products or services. All of these ingredients must be brought together to solve human problems if a technological system is to exist.

An airport is an example of a transportation subsystem. Jetplanes and airplanes are not very useful if other components of the transportation system are absent. We need schedules so flights arrive and depart as needed by society. Ticketing and baggage systems are required to coordinate the collection of fares and departing passengers and their cargos. Maintenance crews are required to fuel the planes and to ensure they are in good mechanical condition. Meals and beverages need to be provided for the convenience of passengers. If one airline had these services and their competition did not, who would get more business? As this example points out, many components go into the development of efficient technological systems.

To provide you with an overview of the structure of our technological systems, each will be outlined so that you can get a feel for the content that can be planned into our technology education programs.

TECHNOLOGY EDUCATION INSTRUCTIONAL DETERMINANTS

1. Define/describe the technological system/sub-systems.
2. Describe their impacts on individuals, industry, society, and the environment.
3. Describe the development of the system/sub-systems.
4. Explain how the systems operate and their use by industry/individuals.
5. Operate the equipment found within sub-systems.
6. Explain knowledge needed in the design of sub-systems (math, science, technology, social studies, etc.).
7. Identify career opportunities associated with technological sub-systems.
8. Project how technological sub-systems may change in the future.

FIGURE 1
Technology Education Instructional Determinants

Communication Systems

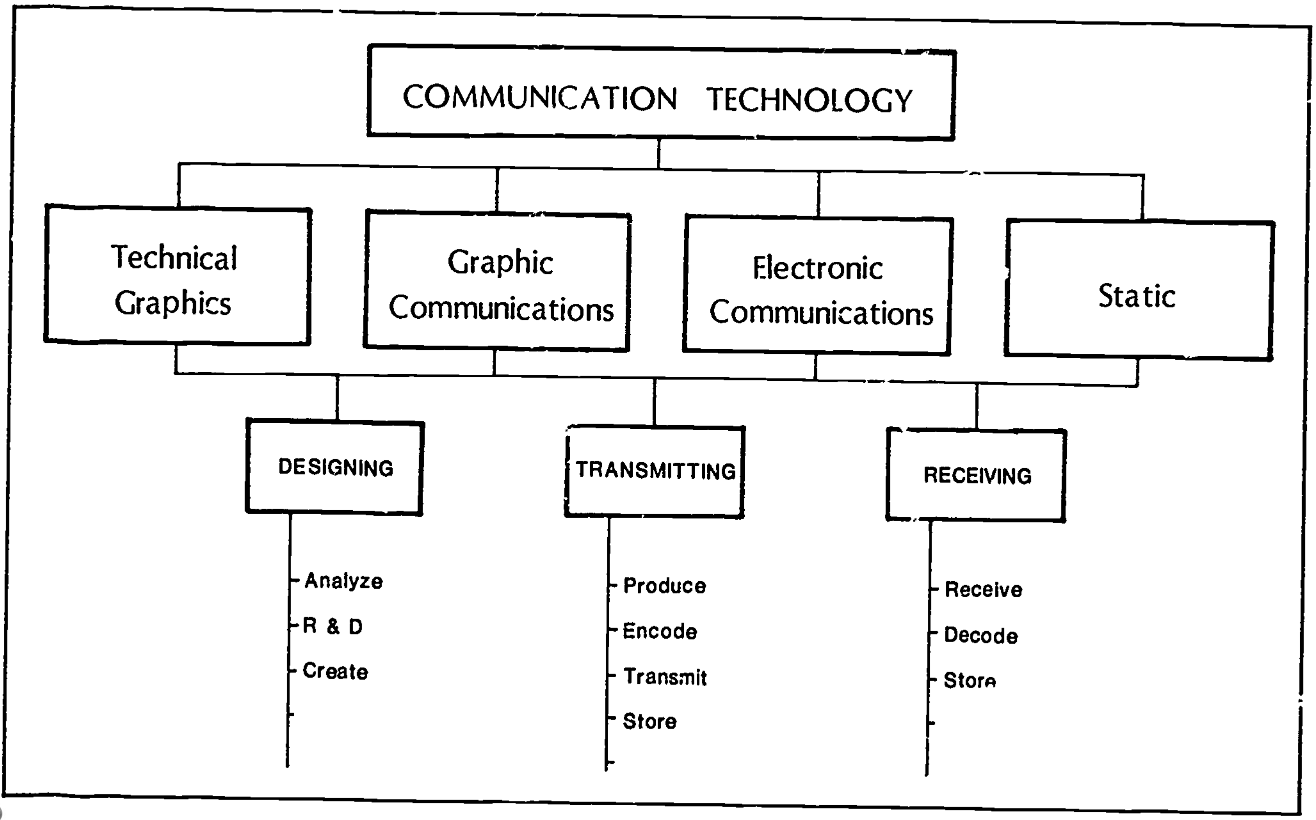
Communication technology systems aid humans in exchanging information. This is accomplished by audio, visual, and/or other means. We use our senses for the exchange of information.

Professionals in business, industry, and technology education have structured communication technology into the following subsystems:

- Technical graphics (drafting and design)
- Graphic communication (printed graphics)
- Electronic communication
- Static devices (bells, mechanical clocks, musical instruments, etc.) Static devices are usually not given great attention in the curriculum. However they need to be reviewed and shown that these means do exist and are used throughout cultures.

What might be studied as content in a communications course sequence? Remember that technology education differs from industrial arts education in that technology education includes the study of its impacts on individuals, societies, and the environment. So we must include the social-cultural impacts!

FIGURE 2
Communications Technology Systems and Subsystems



In course sequences we might wish to:

- Describe what communication technology is;
- How it effects us and business, industry, and society;
- How the systems and machines developed (its history);
- How the systems function and what they are used for;
- How the machines within the system operate and some skill in using them;
- What must we know to design the systems (scientific and mathematical principles);
- Various occupations related to the systems; and
- How might the systems change in the future.

These instructional determinants are summarized in Figure 1.

State departments of education, localities, and individual researchers have developed or are currently developing curriculum materials on the technological systems. Sources for many of these are listed in the September/October 1986 issue of *Resources in Technology*.

A structure that may be used to organize communication technology systems and select content for designing instructional programs is found in Figure 2. Notice that the content within the diagram is process based.

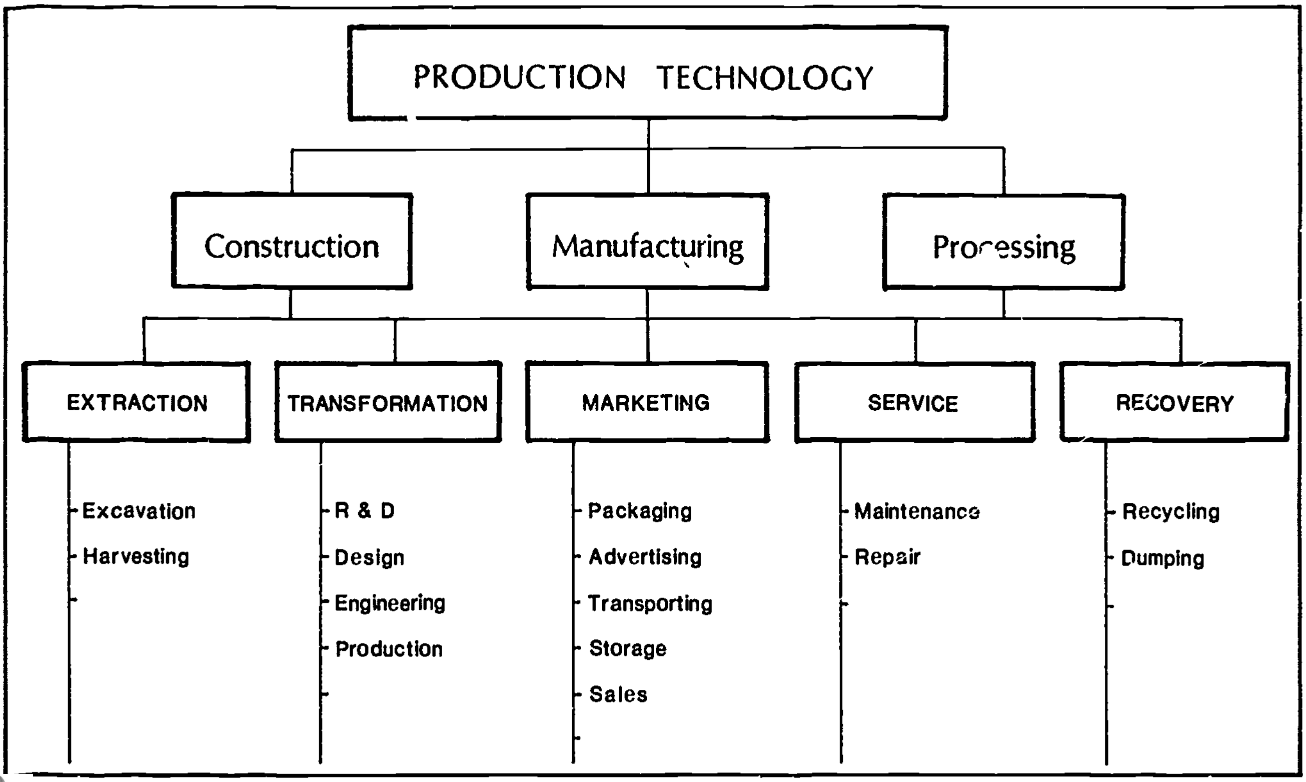
In some ways this content is not much different than that used in contemporary industrial arts programs. However in instruction you must remember to study what it is, how it effects society, how the sub-systems (say flexography) function and how they are used in society, how they operate, etc. These are the keys to studying systems and technology education.

Production Systems

Production technology systems are used to produce our goods and provide us with services essential for quality lives. Much production takes place in our factories. Services are usually provided by businesses throughout our neighborhoods such as appliance repair shops, hair cutteries, home and business painters, supermarkets, etc.

Professionals have also structured production systems so their content can be organized for educational purposes. The major subsystems of production

FIGURE 3
Production Technology Systems and Subsystems



technology include:

- Processing technology
- Manufacturing technology
- Construction technology

Figure 3 provides a structure of how this system may be organized. Remember that others have structured production systems in different ways. Examples can be found by securing the documents mentioned in the September/October issue of Resources in Technology.

Whichever structure you choose for organizing your program, youmust remember to use those instructional determinants found in Figure 1 to organize your program. Remember we want to study technological systems, not just processes and tools/machines used to make products.

Transportation Systems

This area probably seems to be the hardest for you to comprehend of all the technological systems. This is probably because you did not study it in your undergraduate teacher preparation program. Transportation technology systems are used to move cargos and people throughout the world. Their structure is usually organized into the environments through which they transport:

- Terrestrial
- Marine
- Atmospheric
- Space, and the
- Vehicles and support systems that enable them to operate

Figure 4 shows a structure for organizing the content to study transportation systems.

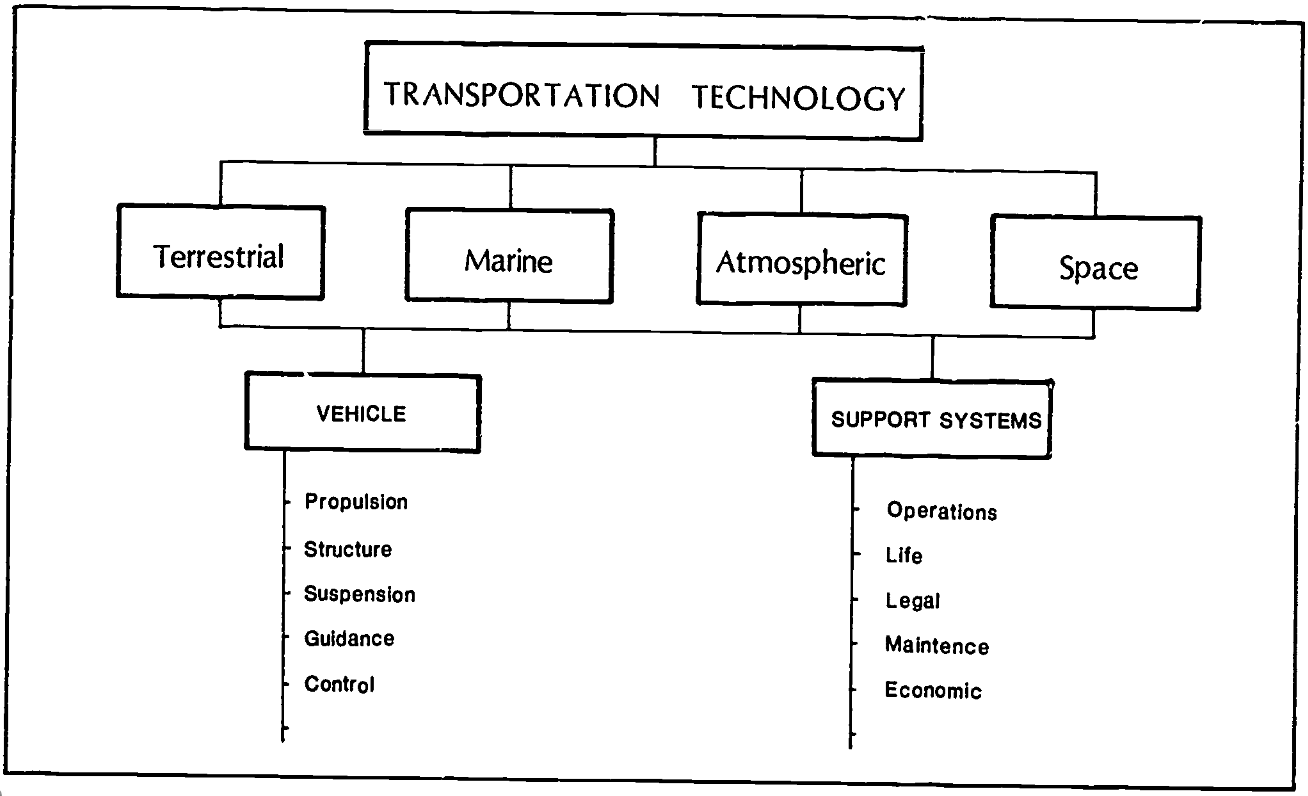
A point must again be made into how to study/present this information. If we are studying terrestrial transportation sub-systems, we should approach them as suggested in Figure 1. This will ensure we are studying technology, not merely vehicles and their power systems.

Universal Systems Model

To aid in studying technological systems the universal systems model may be used. As shown in Figure 5, its components are classified as inputs, processes, and outputs.

Suppose that we were going to manufacture a pair of shoes. What would be our inputs? Processed materials such as leather, rubber, thread, tacks, eyelets, glue, and laces would be used. People would be needed to perform and/or manage the operation. Tools and machines would be needed to cut and assemble the materials, i.e. sewing machines, presses to insert the eyelets, etc. Information would be required into the designs needed and the amounts of shoes to manufacture. Power would be required to operate the system and to keep the production environment acceptable to the needs of workers (light, heat/ac, etc.). Finally capital would be needed to purchase raw materials, pay wages, purchase machines, and provide a factory.

Figure 4
Transportation Technology Systems and Subsystems



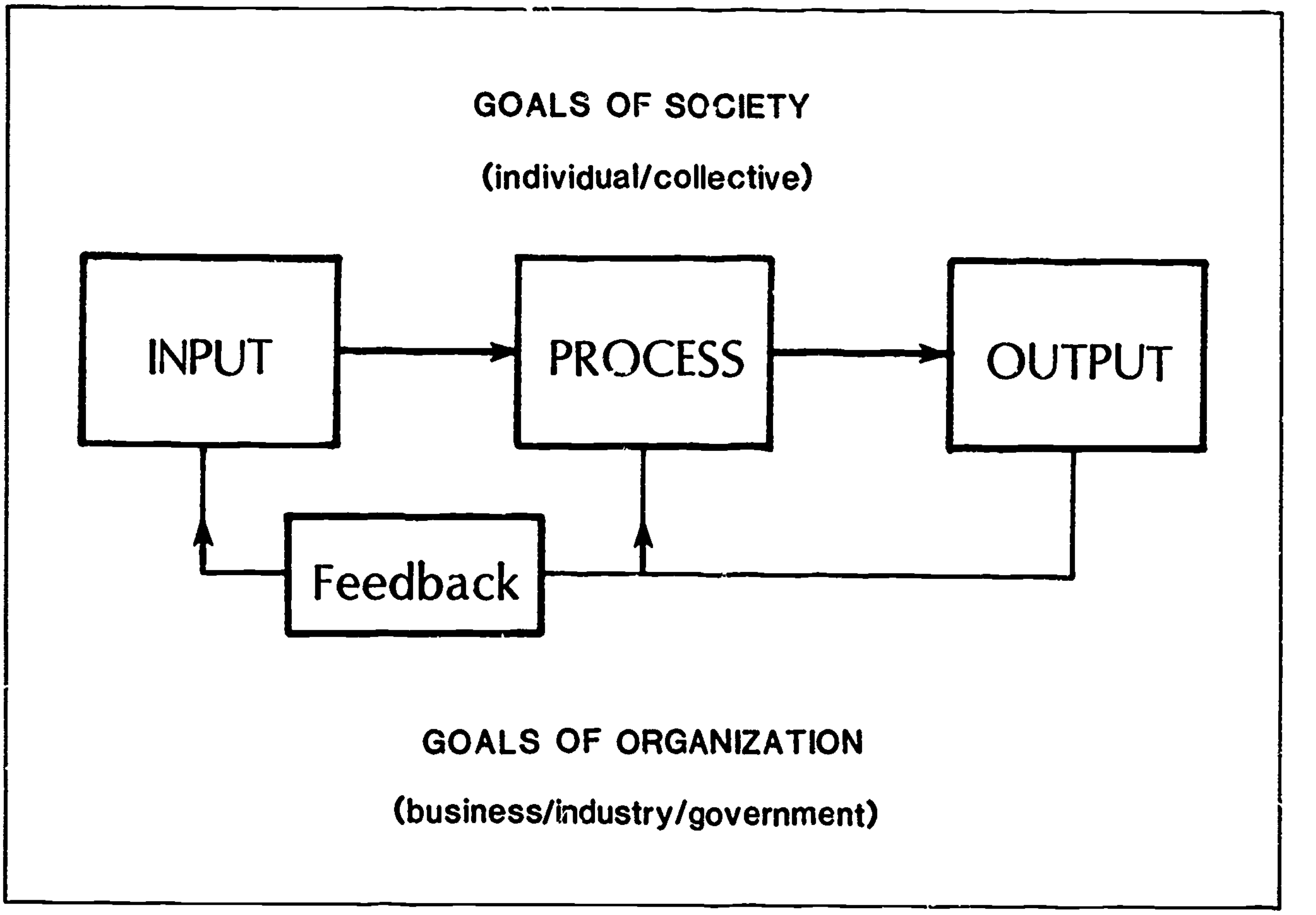


FIGURE 5
Universal Systems Model

The processes for the production of shoes would include material storage, design of patterns/styles, processing of materials, cutting, stamping, gluing, sewing, dying, assembling, packaging, inspecting, marketing, storing, and repairing (not all products are of quality the first time around).

The outputs of the systems would be shoes and waste materials. The waste materials may be recycled into other products or used as land fill.

By combining the instructional determinants found in Figure 1 with the contents of Figures 2, 3, and 4, and the universal systems model found in Figure 5, you should get a feel of what technology education programs can become. To further show how the systems approach to the study of technology can become a reality, two forms of instructional activities will be reviewed.

Instructional Activities

One type of technological activity for studying systems is the product/service analysis method. In this activity you would study the inputs, processes, and outputs needed to produce goods, services, or information. Suppose your product would be a cookbook. What are the inputs?

- *People*—recipe writer, typesetters, illustrators, printers, binders, advertisers, etc.
- *Material Resources*—paper, ink, photographic supplies, printing plates, cover stock,packaging materials, etc.
- *Information*—recipes, market analysis (types of recipes, purchasers, price, number of copies), etc.
- *Tools/Machines*—layout equipment, computer, typesetter, printing presses, collators, bindery equipment, etc.
- *Power*—drive equipment, ventilate building, lighting, etc.
- *Capital*—buildings, equipment, wages, and other overhead.

The *processes* used to produce the cookbook could include writing, photographing, illustrating, layout, platemaking, printing, collating, binding, and packaging.

The *outputs* of this communication process would be cookbooks, material wastes, profit and (probably) satisfied appetites.

Many product/service analysis situations can be created. These could include:

Communication Technology

- satellite communication
- laser communication
- newsletters
- computer telecommunications systems
- printed T-shirts
- catalogs
- money
- compact discs
- record album covers
- security systems

- television commercials
- television broadcasting
- house plans
- corporate logos

Production Technology

- gasoline refining
- automobiles
- paint
- microwave ovens
- baseballs
- tooth paste
- bridges
- airports
- manufactured housing
- plywood
- furniture
- lawnmowers
- rocket engines

Transportation Technology

- subways
- highways
- jetplanes
- pipelines
- submarines
- snowmobiles
- airports
- diesel engines
- elevators
- automated warehousing
- railway systems
- bicycles
- escalators

This activity can also be developed further into system design. As a constructional activity, you may require students to design and construct a technological sub-system.

First have them design the system through illustrations. This would be similar to the one for the automated warehousing system found in Figure 6. Inputs, processes, and outputs can also be identified and labeled on the illustrations.

Also the instructional determinants listed in Figure 1 should be analyzed in the design of the system, i.e. What is an automated warehousing system; how has it affected business, individuals, society, and the environment; how do they operate; etc. Under the various parts of the diagram, have students list inputs, processes, impacts (use of computers, reduction of the labor force, new ideas in warehousing, i.e. just-in-time inventory), careers, etc.

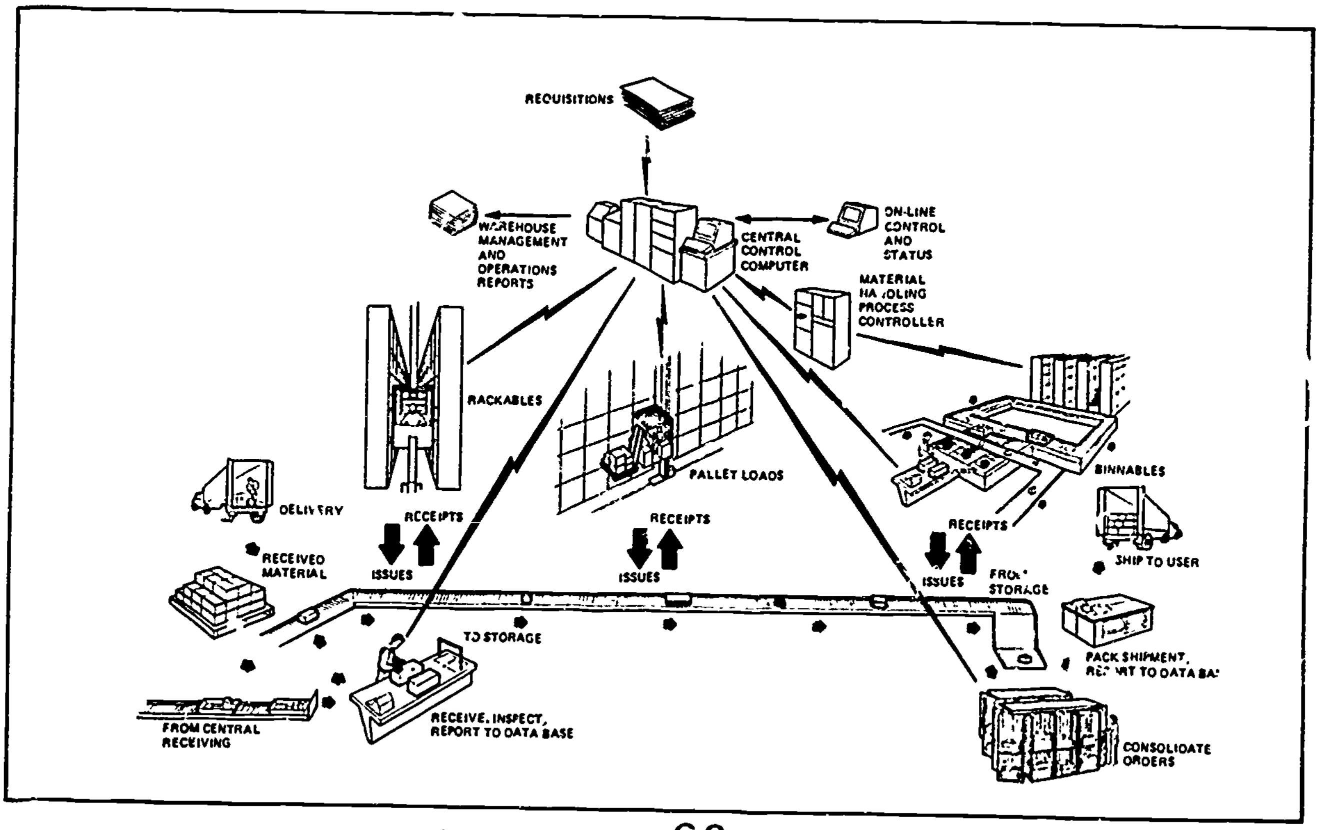
As a constructional activity have the students build models of the sub-systems they design. This would be as problem solving activity and could focus on any systems of technology: communication, production, or transportation. This type of constructional activity is not new to our profession. Donald Maley (1973) has professed this as the group project approach to the study of process and project industries.

Through activities of this nature students continue to use tools and materials to construct projects, but they also have an opportunity to study the technology that is in their environments and see how it operates and is used by both industry and workers.

Math/Science/Technology Interface

Through the study of technological systems additional opportunities are available for students to integrate the study of mathematics and science into their technology education programs. If systems are designed or their operation traced, it becomes evident that these two forms of knowledge are needed to develop full understanding of the systems.

FIGURE 6
Automated Warehousing Systems



If chemical or petroleum processing were studied, the effects of heat and pressure would need to be drawn from chemistry. Geological science is needed if the extraction of raw materials is to be studied. Physics aids us in studying machine operation and the effects of gravity, momentum, etc. on transportation vehicles. Biological science and chemistry are vital to the processing of food. The list of relationships of science and technology are endless.

Mathematics is also interrelated with the study of technology. The language of technology education is mathematics. Technology is always quantified using mathematics. We evaluate quality by using meters, inches, pounds, pounds per square inch, cubic yards, square footage, miles per hour, Rockwell numbers, price per copy, etc. To design systems or models, designers, scientists, engineers, technicians, and craftspersons are required to base quality on these measures.

In your laboratory analysis of technological systems, make it a point to include the use of these scientific and mathematical relationships in your instruction. Employers continually comment that workers need this basic knowledge in many of today's technical careers.

As an example, if you were studying the sub-system of construction, you could conduct an environmental impact study or assessment as an activity. This type of activity uses science and mathematics as its base.

What effect will the construction of new houses, amusement parks, office complexes, or industrial complexes have on the environment? These studies are usually undertaken by federal or state governments where federal funding is involved. However, with the increased concern over the deterioration of our environment, many municipalities are requiring private projects to be independently assessed. Why not have your class, in cooperation with the planning committee from your local community, conduct an environmental impact study?

The basis for environmental evaluations is the National Environmental Policy Act of 1969. What results is a statement that "defines and evaluates the effects on the environment of a proposed project or action and its alternatives ... It is a tool prepared to assist the decision maker in making sound rational decisions regarding the environmental effects of various [construction] alternatives" (Rosen, 1976, p.5).

When preparing an environmental impact assessment, an attempt is made to answer the following questions:

- A description of existing environmental conditions.
- A description of the proposed project.
- Proposed environmental impacts of the new project.
- Alternatives for the project to protect the environment.

The statement is usually prepared in the following format:

I. Description of the Area
   A. Regional
   B. Local
II. Environmental Conditions
   A. Physical Environment (acoustics, air quality, water quality, land destruction, ground water, scenic items and topography, wildlife, vegetation, historical and archeological resources, biological web, and recreational facilities).
   B. Socio-Economics (industrial levels, community form, land value, taxbase, employment levels, wage structure, housing supply, population trends, social overhead [health facilities, police, education], local advantages, etc.)
III. Description of Proposed Action
IV. Environmental Impacts
   A. Physical Environment
   B. Socio-Economic
V. Suggestions to Minimize Negative Impacts

(Rosen, 1976, p. 42)

To arrive at many of the environmental conditions and impacts, students will need to use and research many aspects of scientific (geology, biology, chemistry, etc.) and mathematical (income, population trends, salaries, taxes, etc.) knowledge. This knowledge and study will make them more aware of the impacts that technological systems have on their lives and environments and better prepare them to assume contributing roles in our technological society.

Summary

Technological systems provide the content for structuring technology education programs. Much research has been undertaken to structure the content of our technological system. This is available in our research and in curriculum materials produced by state departments of education. Much of the curriculum work has been catalogued in ITEA's *Directory of Curriculum Guides and Other Key Resources* (1985).

To make our programs more meaningful to students and society, we must begin to restructure our contents and activities. We must focus on the technological systems of communication, production, and transportation. We must also study the technical and social/cultural impacts of each system.

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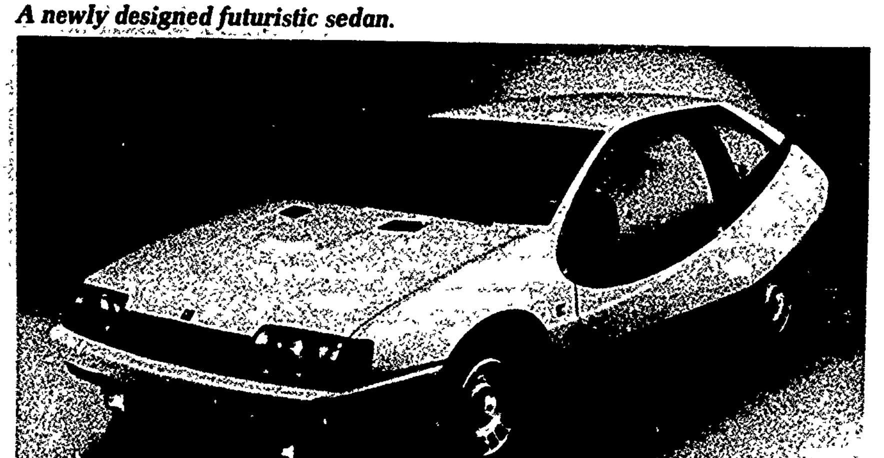
How Technology Affects People and the Environment

A Point of View

Technology is evident in every aspect of our daily lives. New developments seem to emerge at such a rapid pace that many are soon forgotten, as even newer ones take their places. For example, approximately 50 new chemicals are developed each year and each generally brings with it some tangible benefit. Unfortunately, many new developments also have some negative effects.

PHOTO 1
A newly designed futuristic sedan.



Technology has now enabled us to reduce our regular workweek from an amount in excess of 60 hours down to 40 or 35. Perhaps, it may even go below that number in the not-too-distant future. In providing this benefit, technology has also made boredom a factor in some jobs and, in some instances, even eliminated jobs. Off the job, the extra leisure time from the shorter work week has brought its own set of consequences.

This is just one brief example of the positive and negative effects new technological developments can or may have on people. The effects of each new technological development has on people and the environment must be examined constantly. We must seek to maximize the positive and minimize the negative effects. The role technology education can play in this vital process is obvious. Our future technicians will almost certainly come from your classes and those like it.

Why not divide your class into pro and con groups to discuss the possible social ramifications of the 30-hour work week or some other relevant issue? Let your students determine what subject(s) to examine.

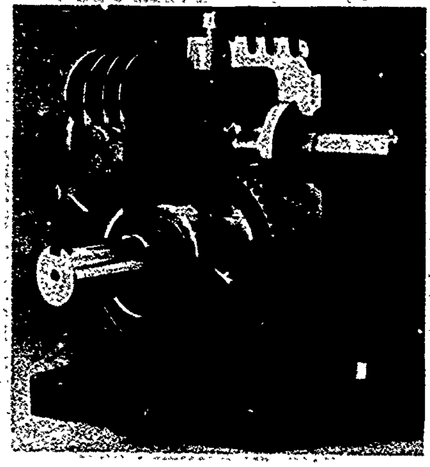


PHOTO 2
A cone drive speed reducer.

Socio-Cultural Impacts

An office worker of 25 years ago would be lost, perhaps unemployable, in today's technologically oriented workplace. The prolific use today of electronic devices to increase the efficiency of a business's daily operations stands in stark contrast to the typical paper shuffling of a generation ago. Workers today require an education that will prepare them for the technology they will surely encounter. This is true regardless of the nature of the occupation.

There was a time when workers who could not succeed at anything else could always go back to the land—back to farming. No more! Technology education is now as important in agricultural endeavors as it is everywhere else. Today's farmer must know how to operate complex machinery. A "tiller of the soil" must possess a working knowledge of a myriad of new chemicals. Today's agriculturalist must also keep abreast of farm prices, on both the national and international levels.

Like workers in so many other fields, the contemporary farmer may also need a good working knowledge of computers, since they have found their way onto the farm. In addition to keeping records and helping with the bookkeeping, the computer may be utilized to indicate what, when, and even where to plant. Without a sound technology-based education, the farmers of our decade can not hope to successfully compete.

With communications instantaneously available on a worldwide basis, people must be prepared for rapid responses to a wide variety of global problems. At one time, an urgent letter was sent by "fast" ship across the ocean. The resulting delay in response time allowed ample time for reflection upon any decision that may have been made.

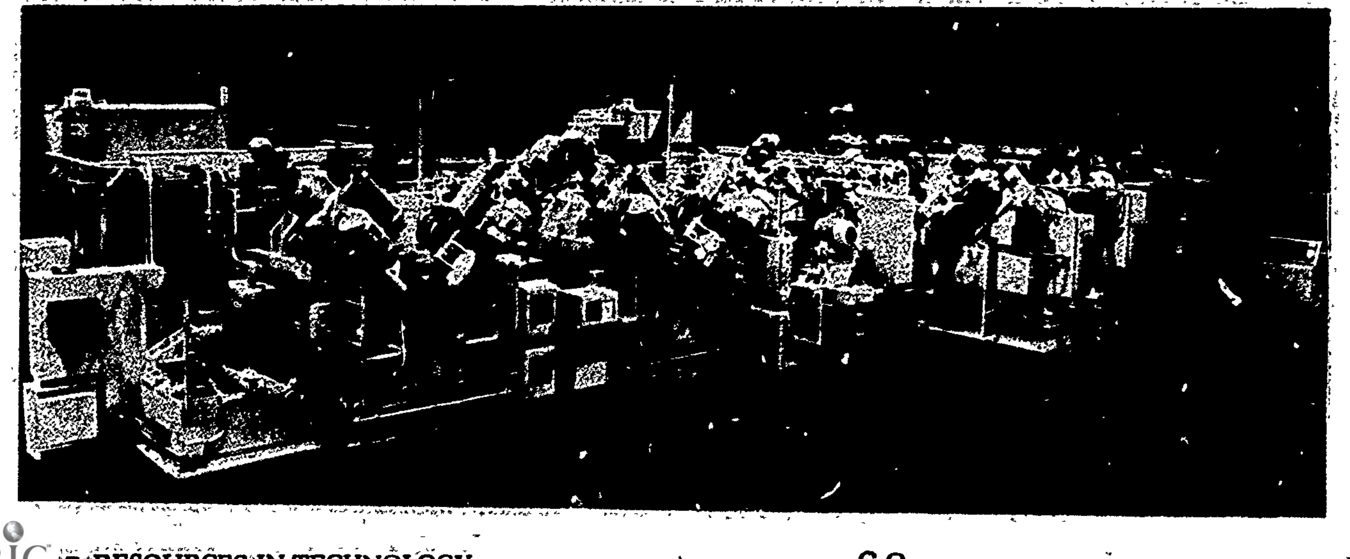
Now satellites allow no such luxury. Decisions now made necessarily in haste may have dire results affecting the fate of civilization. Again, the ubiquitous computer can (hopefully) come to the rescue. It can be utilized to sort through the countless choices and alternatives possible and still provide very rapid answers for us.

Some choices made in the face of new technological developments provide immediate and predictable results for people and their environment. The results of others, however, are not so readily apparent. Generations may pass before we really begin to see the full results of some earlier choices.

At one time, asbestos was used extensively in the construction industry. Today, because the dangers of prolonged exposure to the material are widely known, it is being rapidly removed from many of those applications. In those cases, the negative effects of asbestos have been proven to outweigh the positive ones.

In manufacturing and agriculture, many popularly employed chemicals do

PHOTO 3
An in-line transfer machine.



not simply go away. Many have found their way into our foods and water supplies. Some are at dangerous levels, giving mute testimony to this. Aquifers that for generations have provided water to some cities and areas are now in danger of being labelled as unfit for human consumption.

Our technology has given us access to more natural resources. We can now extract and bring up oil, gas, sulfur and other minerals from under the sea. On land, oil is now being pumped from wells that were once considered to be dry holes. Coal is being taken from areas once thought by experts to be totally depleted of their mineral wealth. Other minerals as well are being extracted from previously inaccessible areas, places once believed to be too cold, too deep, too hostile or not economically feasible for such operations.

Many of these operations may or can extract a very high cost in terms of the environment. The strip mining of coal, for example, once left an ugly blight on the landscape. Now better land reclamation methods employing technology from many fields are helping to restore such areas to productive use again.

Many government and private agencies are working together to protect our environment, while gaining the maximum benefit from our natural resources. Environmental Impact Statements (see "Resources in Technology," *The Technology Teacher*, December, 1986) are a tool used to examine the possible negative and positive effects of proposed projects and actions. Based on the findings, decisions are made as to whether or not to proceed in a particular direction.

Our environment, which people take so much for granted, is indeed a fragile one. Many of the operations humankind performs to sustain its existence can have a detrimental effect on it if not properly managed. It is our task, with the help of technology, to lessen the negative factors while capitalizing on the positive ones.

You and your class can read almost daily about some environmental crisis. Whether it is one of pollution, diminishing resources, nuclear contamination, or vanishing species, it seems that these crises are usually caused (or at least promoted) by people's actions. Anytime we mismanage some element in the environment, whether on land, in the sea or in the atmosphere, we run the risk of creating a new crisis.

Each part of the biosphere (land, water

PHOTO 4
Large sulfur extraction operation under the sea.

PHOTO 5
Coal mining employing new technology.

PHOTO 6
Construction of Glen Canyon Dam.

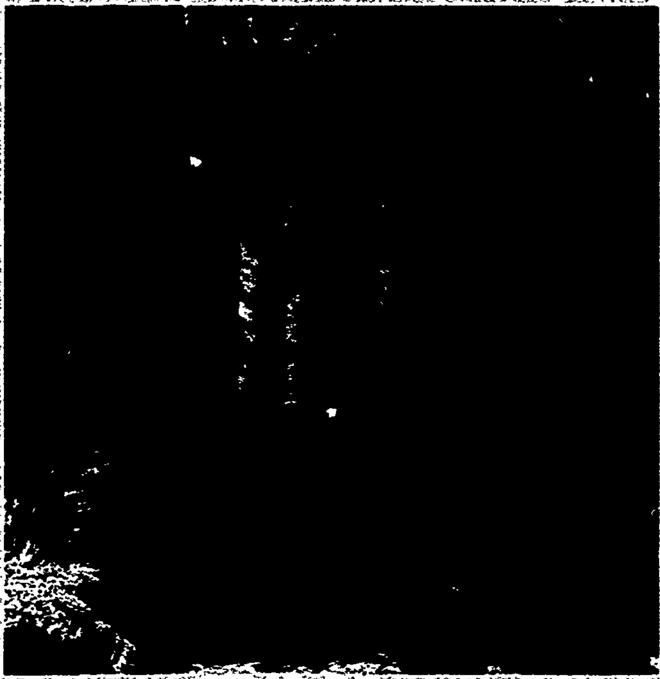


PHOTO 7
A forester hikes beneath giant Sequoia trees.

PHOTO 8
Workers quarrying minerals from the earth's surface.

and air) is dependent on the other to sustain life on earth. For example, rain falling on timberland that has been stripped of its natural growth will simply run off, rather than soak in. In so doing, it will take all or most of the valuable topsoil with it. Such eroded land will not support life for long, either plant or animal. The result, in addition to eroded land and an absence of plant and animal life, will be silted rivers running into polluted bays and oceans. This would all occur, remember, because the trees on the forested land that originally supported several forms of life were improperly cut.

Your technology education class can probably compose similar scenarios for almost any primary extraction process, oil or gas drilling operation, land development project or crop harvesting program. Any adverse effect on the environment ultimately affects the quality of life for all people. The proper application of our technology can help us to avoid such consequences.

PHOTO 9
A lumber clearing operation.

PHOTO 10
White-tailed deer browsing in specially planted wildlife clearings.

Contemporary Analysis

The positive effects of technology on people and the environment must always be weighed against the negative ones. On initial examination of a certain action, it may seem immediately obvious that the "good" outweighs the "bad." However, as concerned citizens as well as technicians, we must learn to look closer than that.

You might have your technology education class consider the following regarding new technological developments.

- Are the positive aspects of a certain technological breakthrough sufficient to justify its implementation?
- What if there exists the slightest chance that our future generations may suffer because of it?
- Do we really have the right to make such a choice?
- Can we not make the choice?
- Are we justified in our present actions because we are so confident that even newer technology will be capable of rectifying any problems our present actions may cause in later years?

As a case in point, consider contemporary society's massive dumping problem. We, as a civilization, generate tons and more tons of waste and garbage every day. For many cities on our seacoasts, the obvious solution to the problem would appear to be to dump their wastes off their coasts, out in the ocean. In fact, many do just that. Some incinerate their garbage and other waste products, but the main bulk of it is simply dumped.

Will future generations still find the same forms of sea life that we've grown accustomed to and now take for granted? Will their harvests from the sea be as great and as abundant as ours? Or, will some species die out and become extinct or unfit to eat because of the pollution our present society is now creating? Can qualitative technology education programs now help to solve our pollution problems in the future? Can they help to solve other types of problems regarding people and the environment? They had better.

Nuclear energy has been successfully used for years to generate electricity. Technologically, it is arguably an efficient and inexpensive means of producing all of the electrical energy we need for our complex society. Today, however, the world is experiencing the emergence of many activist groups that are dedicated to the elimination of the use of nuclear energy. Why?

They do so because of the vast potential for destructive power and contamination inherent in this type of energy production. Again, pollution is also a factor. Recent events at the nuclear power plant in Chernobyl in the Soviet Union have heightened their efforts. Up to this point in time, technology can control these negative aspects to only a limited degree. Some mechanical malfunction or human failure could still precipitate dire consequences for the entire world.

New technology is being developed to control or eliminate the negative effects of some of our existing technology. It is not being done nearly as rapidly, however, as even newer, untried developments emerge. It is of paramount importance that people maintain their grip on technology. Technology can then be used for the benefit of all mankind. Scores of doomsday novels have already spelled out only too clearly for us just what the misdirected application of technology can do.

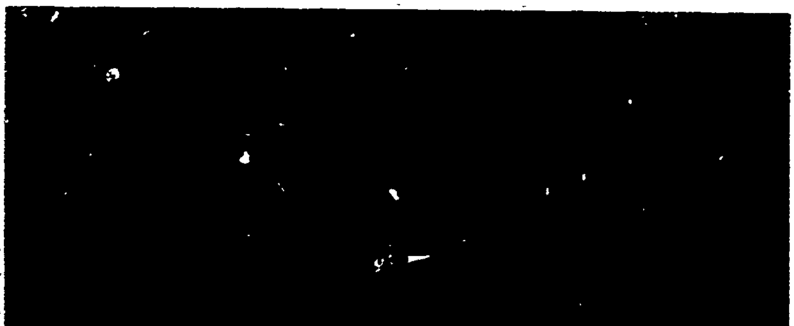


PHOTO 10
Helicopter carrying and distributing chemicals.

Constructional Activity

Our environment contains an enormous amount of water. There are over 300 million cubic miles of it. Unfortunately, 97% of that amount is salt water and therefore unsuitable for many of our society's purposes. The very small percent remaining, fresh water, water that is appropriate for human consumption and other industrial uses, is in many instances rapidly being polluted.

The major sources of fresh water pollution are sewage, industrial wastes and agricultural chemicals. Each of these pollutants must usually be removed from water before it is sufficiently pure enough for reuse. Unless the unwanted pollutants are removed, the water containing them may cause many problems, such as spreading of disease, despoiling recreational waters, upsetting various natural processes, and hurting humans through the long term effects of ingesting assorted dissolved chemicals and various trace metals.

As a constructional activity, you might have your technology education students perform one or both of the following experiments to demonstrate the possible presence or absence of zinc or lead in water. Traces of both of these metals are often found in our water supplies. A very small amount is considered acceptable in both cases, but what level is safe is frequently the subject of debate. All trace metals are toxic to human beings in large doses.

In the first activity, water will be checked to answer the following question: Will the zinc in our very commonly used galvanized iron water pipes dissolve in water? The second activity addresses the question: Does some of the lead in our water supply pipes sometimes pass into our drinking water?

Materials List for Activities

- Small beaker
- Drinking straw
- Small Pyrex dishes—2
- Eye dropper
- Mirror
- Steel wool
- Galvanized fitting
- Lead sinker

First Activity Procedure

1. Add oxygen and carbon dioxide to a beaker of soft water (rain water or distilled water) by blowing your breath through a straw into the water for about a minute.
2. Set aside, in a small dish, a small portion of water as a control sample.
3. Thoroughly clean by washing a small galvanized fitting (i.e. elbow, coupling, etc.) and place it in a second small dish with part of the water sample.
4. After 24 hours, place two or three drops of each water sample onto a mirror using the eye dropper. Remember to clean the dropper between sampling. The control sample should be placed on the right side of the mirror and the "fitting" sample on the left.
5. Allow another 24 hours for the drops to evaporate.
6. Compare the two samples. Have the class observe:
   - Is there a whitish deposit on the left side of the mirror? Explain (references might be required).
   - Are there sharp little crystals visible on the left side? Explain.
   - Is there a deposit on the right (control) side? If so, compare it to the one on the left side. Are there crystals present or only a whitish smear? Explain what the deposits on each side indicate.

Second Activity Procedure

1. Rub a lead fishing sinker with steel wool to make it shiny.
2. Wash the sinker to remove tailings.
3. Blow oxygen and carbon dioxide into a beaker of soft water with the straw for two minutes.
4. Save a small portion of the prepared water as a control sample.
5. Place the lead sinker in a small dish and cover with the prepared sample water.
6. Let stand for 24 hours.
7. After 24 hours, place two or three drops of each sample on the mirror (left side sinker water and right side control water).
8. Allow another 24 hours for the drops to evaporate.
9. Compare the two samples. Have the class observe:
   - Are there any deposits remaining on the mirror? Which side?
   - Which side has the heavier or larger ones?
   - Which deposit appears more crystalline? Explain.

These experiments will only give an indication of the presence of zinc or lead in the water. They will not prove the actual presence or absence of these materials. When the results are positive, however, they will show that a much more thorough test should be performed to make a definite determination. You might want to conduct the same experiments with your household tap water.

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Math/Science/Technology Interface

The evidence of the interfacing of mathematics, science and technology is quite obvious in most technological fields. Similarly, when we examine just a few of the many aspects of technology's effects on people and the environment, this interface can be clearly seen.

When considering the effects of a certain chemical producing plant's recent pollution of a nearby river due to a valve failure, numbers and calculations seemed to spring up from everywhere. How many parts per million (ppm) were in the river? How long could they be expected to remain there? Would the natural flow of the stream carry sufficient amounts of the pollutant away? How about the numbers of shellfish effected? And on and on.

The questions raised were almost always responded to using science and mathematics with applied technology. Numerical indicators were determined using various formulas, procedures and charts. Little could be learned, compared or expressed without them.

Let's consider the following specific example to further illustrate the interfacing of mathematics, science and technology. The extraction of some resources from the earth for energy production often causes problems with the environment. One very appealing partial solution to such problems lies in a more extensive utilization of wind energy. In addition to being pollution free, wind energy is practically cost-free, after the initial investment is made. Although several problems, such as inconsistency of supply and the storage of wind energy, have yet to be overcome, the concept seems to be very practical for some areas.

Let's look at a few figures. Scientists believe that a windmill can theoretically extract about 60% of the wind's energy. Realistically, most scientists feel that an efficient windmill might actually extract only 75 to 85% of that amount. The efficiency of a windmill can be measured in terms of the power developed. This is dependent on wind velocity, air density and the area swept by the blades. The formula is given in terms of kinetic energy.

The kinetic energy of a wind stream with a cross-sectional area, A, is given by the equation:

$\text{Energy} = \frac{1}{2} pAV^3$

where:

p = density of the wind (this is not likely to differ much from $1.1 kg/m^3$)

A = cross-sectional area swept by wind

V = velocity of the wind

When the meter/kilogram/second system of units is used, the resulting power comes out directly from the formula as watts. Given a predicted wind of 4.5 m/sec (about 10 mph), a cross-sectional area of one square meter and substituting in our formula, we have:

$E = \frac{1}{2} \times 1.1 \times 1 \times (4.5)^3$

$E = \frac{1}{2} \times 1.1 \times 1 \times 91.13$

$E = 50.12$ (or 50 watts/m^2 of the area swept by the windmill)

The importance of the interface of math, science and technology is manifest. Without it, many of our simplest tasks would be impossible. The complex ones could not even be considered, let alone be accomplished.

PHOTO 11
Geo-thermal plant in operation.

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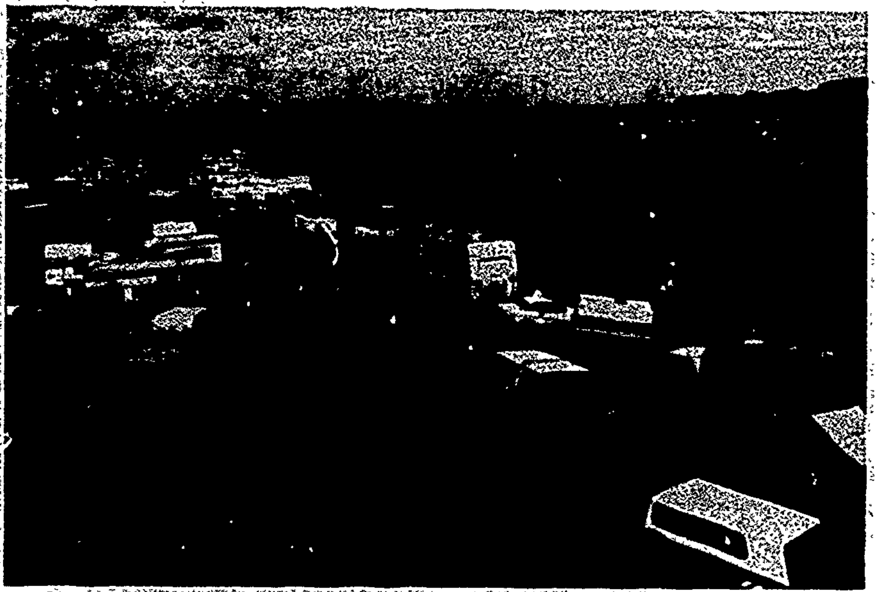

PHOTO 12
An over-crowded water use area.

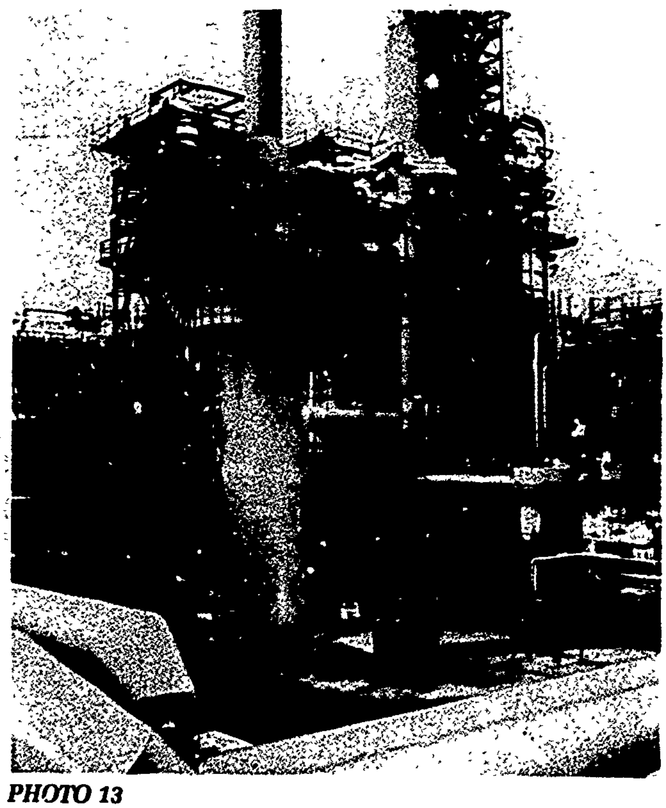

PHOTO 13
An oil refine-y in operation.

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Acknowledgements

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Controlling Technological Systems

Point of View

The control of technological systems extends the human capabilities beyond our natural capacity. Energy provides us with the capability to do work and provides us with heat, light, and motion.

Think about it!

We ride in automobiles, buses, airplanes; we take warm baths and showers; and we eat hot meals. We watch television and eat popcorn popped in a microwave oven. In each of these examples we are controlling some form of energy: heat, light, or motion. We use thermostats that control the temperature of our water heaters, electronic circuits control the energy produced by a microwave oven, fluid controls and electronic devices control the speed of transportation vehicles, and regulators and valves control the heat of gas stoves. A closer examination will show us that control can be exercised by humans to machines, machines to machines, and even machines to humans.

Control and its interface with humans and machines is what really extends our capacity and capability to do the kinds of things that we have come to expect as commonplace in our technological society. In this issue of Resources in *Technology*, we will examine some of the concepts that apply to the control of technological systems. We will look at the control of mechanical, fluid, and electrical energy as they are used in our technological systems.

These forms of energy can be thought of as resources available to us for producing the goods and services that we need so we can maintain our standard of living in our society. We will see, from a systems point of view, that each of the controls can be divided into three areas of:

- Input
- Control
- Transmission

Contemporary Analysis

Engineers and physicists are concerned with the design and theory of mechanical systems. Physicists deal with the scientific or mathematical relationships in how mechanical systems work.

Engineers, on the other hand are concerned with how mechanical system's theories can be applied to solve technological problems. Engineers design mechanical systems to solve real problems. In the area of mechanical systems, engineers find it useful to modify mechanical power to achieve a given result or solve a particular problem.

We usually think of machines as being sophisticated, complicated, or complex devices. However, from a conceptual view, engineers say that we have six basic machines from which we design mechanical systems. These machines are:

1. Inclined plane
2. Lever
3. Wheel and axle
4. Pulley
5. Wedge
6. Screw

It may sound strange, but each of these simple machines affect us daily in some way!

Did you walk up a stairway today? Did you use a knife when eating a meal? Or did you ride a bike or ride in an automobile? If you did any of these things, you used one or more basic machines!

A pair of pliers or scissors are examples of second class levers . . . a basic machine. Perhaps you were assembling a project in your Technology Education class using bolts and nuts or wood screws. These examples illustrate the principle of an inclined plane and using a technological system.

The basic machines that have been described provide us with mechanical advantage. Mechanical advantage allows us to modify force and speed to accomplish a given task.

For example, in removing a nail from a board with a claw hammer, the hammer handle provides a mechanical advantage in the form of a lever to withdraw the nail easily . . . in most cases. Try pulling a nail out of a board without the mechanical advantage provided by the hammer! This illustrates the control of a technical system.

Another illustration of mechanical advantage is the inclined plane. The example shown in Figure 1 illustrates how an inclined plane may be used to modify force and speed so that a task can be accomplished. This represents a low level of control. The person in the figure is supplying the power and control to the technical system to extend her capability.

Inclined Plane

The problem illustrates how we can "raise" a heavy object with less effort over a greater distance than we could ordinarily lift in a vertical direction. The amount of work is the same. Work is the product of force × distance.

In applying this concept to technological systems, we could consider using elevators and conveyors to move people and materials automatically from one location to another. Elevators move more people everyday than any other form of transportation.

How does the elevator know which floor to stop at? Or when to open its doors or how fast to travel?

Controlling a technological system is the key here. Elevators are electromechanical machines that have sensors to locate the proper position to stop at in a elevator shaft. The person selects the desired floor by using an input device or control panel and pushing the appropriate button. The control panel is the man-machine interface; it is how we communicate with the elevator control system.

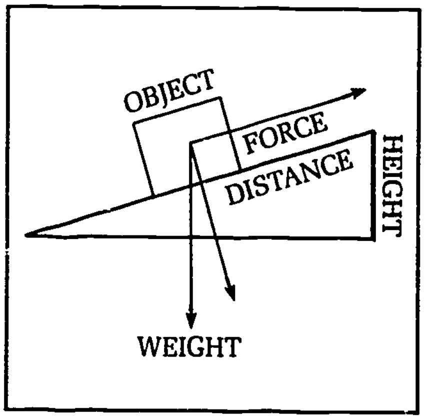

FIGURE 1
Inclined Plane provides mechanical advantage by moving an object over a greater distance to a given height.

Lever

Levers are used extensively in controlling other machines and mechanical devices. Levers are used to actuate door latches, tillers on sailboats, linkages for throttle controls on automobiles and motorcycles, caliper brakes on 10-speed bicycles, and the like.

The caliper handbrake uses a series of levers to apply force or pressure against

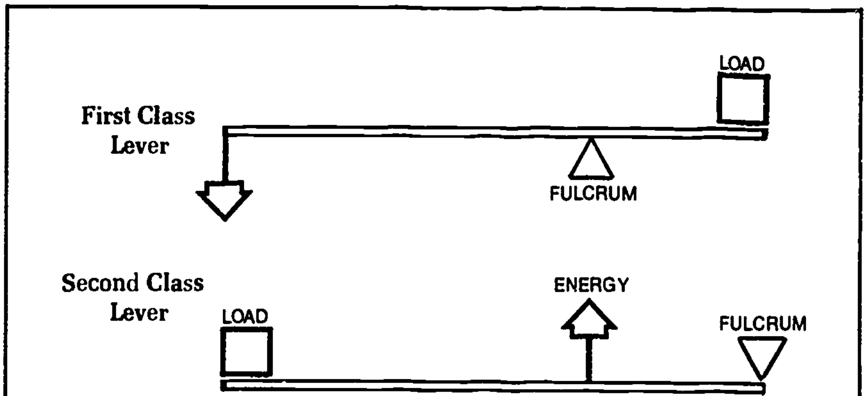

FIGURE 2
Three classes of levers that provides the capability to modify force and distance.

the rim of a bicycle wheel to provide a controlled stopping action. The lever on the handle bars provides the rider of the bicycle with means to apply force to the braking calipers. The rider controls the degree of braking action required—either to slow the vehicle or completely stop it. Thus the rider is controlling the technological system.

Levers are very common basic machines that we use to extend the of capabilities human. We use them to control other devices, such as an electrical wall switch, gear shift-levers in transmissions, or in direct applications like scissors and shears. Levers are divided into three classes: first, second, and third.

The class of a lever is determined by where the input force and output force are placed relative to the fulcrum or pivot point. Figure 2 illustrates each class of lever.

Wheel and axle

The wheel and axle may be considered a major machine that we are all familiar with. We see the application of wheels and axles in the design and construction of bicycles, skate boards, cars, trucks, and in reality most all transportation systems. Gears and pulleys are actually "wheels" that have been modified for special purposes. We use wheels and axles for tasks other than transportation systems though. Winches, conveyors, block and tackle, and material handling slides all use some form of a wheel to reduce friction and make the task of doing something easier.

Gears, forms of wheels, provide us with a wide variety of control over speed, force, and the direction of motion. Clutches are often used to control the power input or output of gear systems. A clutch provide us with the on/off switching of a power system.

The mechanical advantage of gears can be illustrated as two levers coupled together. An analysis of a gear system will show that we can modify force, speed, direction of rotation, and direction of the motion output. Gears provide us with a measure of control.

For example, the transmission in an automobile provides us with the capability to control the direction of travel (reverse or forward direction) and match the engine output with the load and speed of travel of the vehicle. Gears, levers, and inclined planes (screws) enable us to design devices that produce very complex motions.

The robotic arm shown in Photo 1 illustrates the applications of each of these devices. The control of the robotic arm can be exercised by an operator using a computer. The user has the option of controlling the device directly or through the use of a computer program to cause the robotic arm to follow a prescribed set of instructions. The robotic arm represents a controlled system. The control may be human-to-machine or machine-to-machine. When a person controls the robotic arm it is said to be a human-to-machine interface.

PHOTO 1
Robotic arm

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Mechanical systems are controlled in a variety of ways. We use gears, levers, cams, springs, and linkages to control the action or output of mechanical systems. For example, a drill press illustrates an example of several forms of control. The motor is controlled by an off/on switch, the speed of the chuck can be changed by shifting the drive belts to larger or smaller pulleys, and the chuck can be raised or lowered by means of a rack and pinion. These are all basic forms of control. Controlling machines is how we use them to do work for us.

Fluid Systems

Fluid power represents a very broad category of power control and transmission. We generally think of fluids as being liquids. However, scientists, engineers, and technologists view fluids as liquids and gases. Fluid power refers to the control and transmission of power through pressurized fluids. The fluid may be compressed air, nitrogen, or other inert

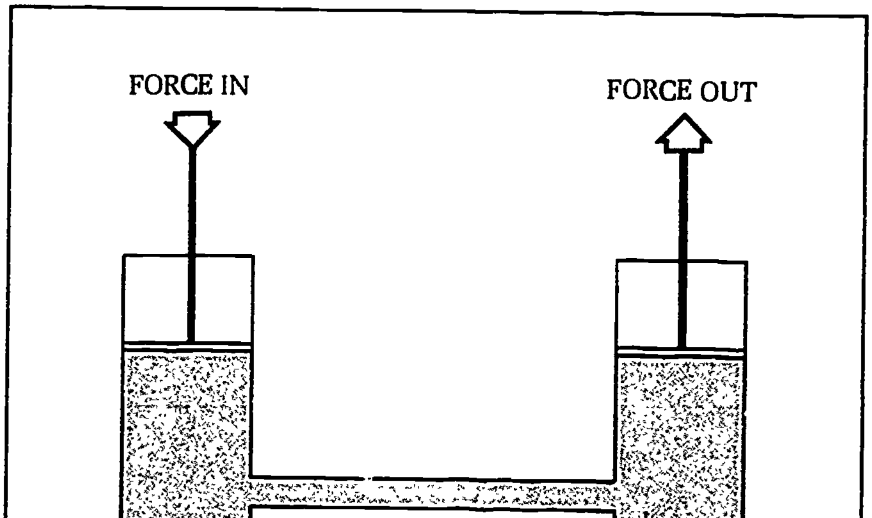
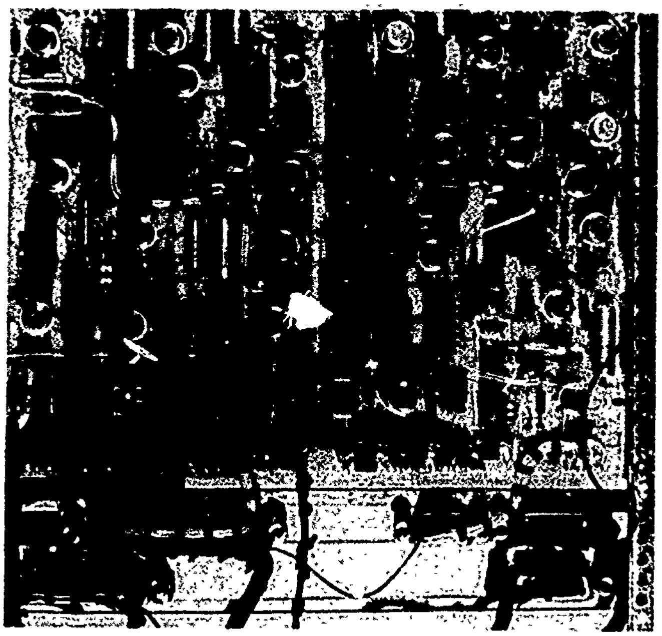


FIGURE 3
Two hydraulic cylinders connected together can transmit force through a fluid medium.

PHOTO 2
PC Board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gas or it may be a special oil or water. Pumps are used to create the flow of a liquid. The resistance to the flow developed produces pressure. If we apply pressure to the surface of an object, the force on that object may be expressed as pounds per square inch (PSI).

Figure 3 illustrates the transmission of force through a fluid in a hydraulic system. If we apply a force to cylinder "A", then the cylinder "B" will move a corresponding distance equal to the fluid displaced by cylinder "A." By changing the size of the cylinders, we can modify the force and speed in which it travels.

If we were to replace cylinder "A" with a pump and add a valve, then we will have added the control element to the system. The control element or valve can be actuated by a human to provide directional control of the system or the valve may be controlled by a computer or another mechanical device through a lever.

An example of a fluid system control would be the brakes on an automobile. The driver of an automobile applies pressure to a brake pedal (a lever) the force is transmitted to the piston rod of the brake master cylinder, which converts the mechanical energy to fluid energy that is connected to each wheel cylinder by fluid lines or tubing. The movement of the fluid through the brake lines causes the wheel cylinder piston to expand, and thus exert a mechanical force on the brake shoes which in-turn rub against the brake drums to stop the automobile.

In this example, the driver of the automobile is controlling the automobile with the aid of a fluid system. What would it be like to drive a car without any brakes (no control)? The human-machine interface is the driver's foot exercising control of the automobile braking system through a lever connected to a hydraulic (fluid) master cylinder. The machine-to-human feedback is how quickly or slowly the vehicle stops. The driver increases or decreases brake pedal pressure to meet the demands of the given driving situation.

Many of the automobiles today have anti-skid braking systems. These are electronic or fluid controls that sense the braking action of the automobile. Should the automobile start skidding, then the anti-skid sensors will reduce the skidding action by controlling the braking action on the wheel(s) causing the skid. Figure 4 is a typical anti-skid braking system. This illustrates a machine to machine interface.

Valves are used to control fluid systems. Their function can be very simple, on/off control, or very complex and control the direction and rate of fluid flow. Fluid controls are used extensively in heavy construction equipment. Four-way valves are used to control the movement of hydraulic cylinders that are connected to large scraper blades, shovels, and buckets. A special control device is built in to most hydraulic systems.

The pressure relief valve is a special safety device that controls the fluid flow when a fluid system is overloaded. The pressure relief valve provides an alternate path for the fluid when the maximum capacity of the system is reached. It is a type of automatic control. Without it, the system or operator could be injured should the system be accidentally or intentionally overloaded.

Electrical Systems

The diversity of electrically controlled power systems is hard to imagine. It is obvious that we have electric lights, motors, radios, and televisions. Electricity is our most flexible form of energy. It is relatively easy to transmit, control, and convert to other forms of energy. Electrical power can be controlled by switches, relays, rheostats, and solid-state devices including diodes, transistors, and integrated circuits.

We generally obtain electrical power from cells and batteries, alternators, and generators. However, the two most useful forms are alternating and direct current. Alternating current is most always produced from the mechanical conversion of another form of energy. Direct current may be produced by a chemical reaction, as in a battery, or a mechanical device such as a generator.

Circuit A shown in Figure 5 is a complete circuit. It contains a source of power, conductors, and a load. The same circuit, Circuit B has a control device added. In this example, a mechanical switch serves as a control element. We could change the operation of the control function by replacing the mechanical switch with another type of switching device, one that may be sound or light activated, or a switching device that is capacitive operated. The concept is that the switch is a control element in the circuit.

The control of electrical power is a major concern in the operation of electrical devices. If we could not control electrical power, it would be of little use in controlling technological systems. The electronic circuit board that is shown in Photo 2 is one of many electrical circuits that affects the operation of space vehicles. The control must be precise in order to perform a given task accurately and efficiently.

Building Automated Systems

The power systems that were mentioned above (mechanical, fluid and electrical) are the basic building blocks for automatically controlled systems. One or more of the power systems can be combined to satisfy a given need or task. In fact most automatic systems will include at least two of these elements.

In each of the power systems, we need a control element. Control is the key concept to making a system work for us. It is also the key to automated or automatic systems. Automation can be defined as the detailed control of a process or system without human intervention or decision-making at every point in the process. Automatic processes involve some form of feedback and are self-correcting. Sensors are used to obtain the necessary feedback to provide the necessary control to automate the process. Of course, the system must be capable of interpreting and acting on the feedback.

Automated Systems

Examples of automated systems are numerous! Previous *Resources in Technology* have covered automation in manufacturing and warehousing. However, automation can be found in businesses and products that we use daily. Many grocery and department stores have automatic door openers. These may be operated by sensors that sense the presence of a person by sound, light, or person's weight. Regardless of the type of sensor, each of the systems are programmed to open automatically and stay open for a sufficient period of time to allow a person to enter or leave the building.

Feedback from the sensors will keep the door open as long as a person or object is in the field of the sensor. Other examples include thermostats in heating systems, fluid level controls and timers in clothes washers and dryers, security alarm systems, and automatic "cruise controls" in automobiles.

Sensors are an important part of an automated system. They are part of a category of controls that may be called instrumentation. Instrumentation provides data or information for automatic systems to make decisions. The instrumentation may measure stress or strain, temperature, light, pressure, fluid levels, time, location or proximity, sound, motion, and other inputs. The key is that instrumentation or sensors provide feedback for an automatic systems to make decisions about its operational ...

Samples of sensors, also called transducers, include thermostats, photoelectric cells, and pressure switches. These devices provide the appropriate signals for temperature, light, or pressure operated systems to function according to their program instructions.

Aircraft have a vast array of control and automated systems. We see airplanes almost daily. But did you ever consider how they get from one desti-

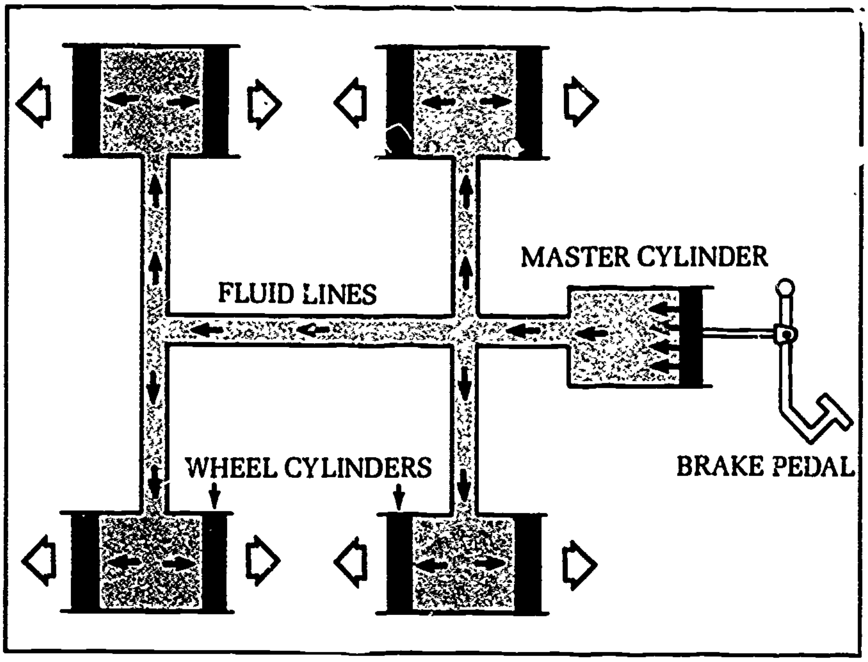


FIGURE 4
The brake system shown combines a mechancial system (brake pedal and lever) with fluid power system. By actuating the brake pedal, the operator extends his or her control of a vehicle via the brake system.

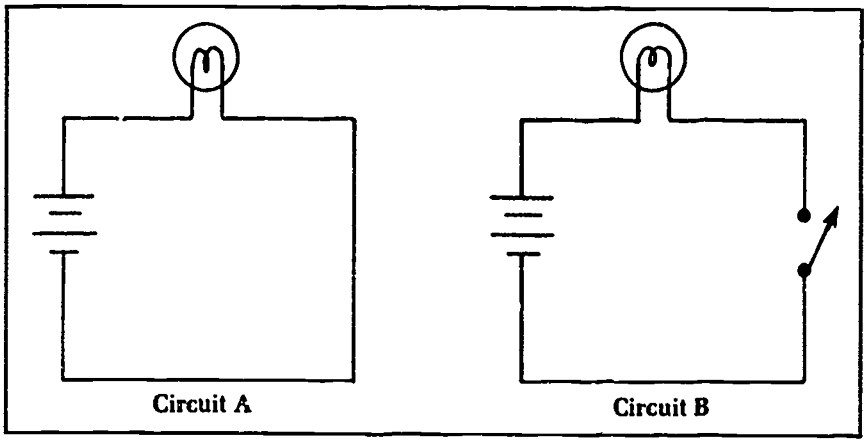


FIGURE 5
Circuit A illustrates a complete circuit without any control function. Circuit B includes a control element. The switch acts as a control element in the system.

40

nation to another? Some of the instrumentation on aircraft measures wind speed, altitude, direction, attitude, engine speed or thrust. The pilot may fly or control the plane manually or it may be automatically controlled. When the plane is controlled automatically, we say that the auto-pilot is "flying" the plane. The auto-pilot must simulate all the functions that a pilot would—controlling the direction, speed, altitude etc., of the plane.

Feedback is provided to the auto-pilot computer to make corrections in course direction because of wind speed and direction. The photograph shown in Photo 3 is a flight simulator located at NASA Langley. It shows some of the instrumentation, computer console, and displays.

The model aircraft shown in Photo 4 is remotely controlled by two NASA engineers. They are holding control devices that affect engine speed, rudder, elevators, and ailerons. They are controlling a technological system. Through the engineers use of the control devices they will fly the model airplane for testing purposes. They are the controlling element; they make the decisions to control engine speed and altitude. The major point is that all the requirements for a controlled system are in effect.

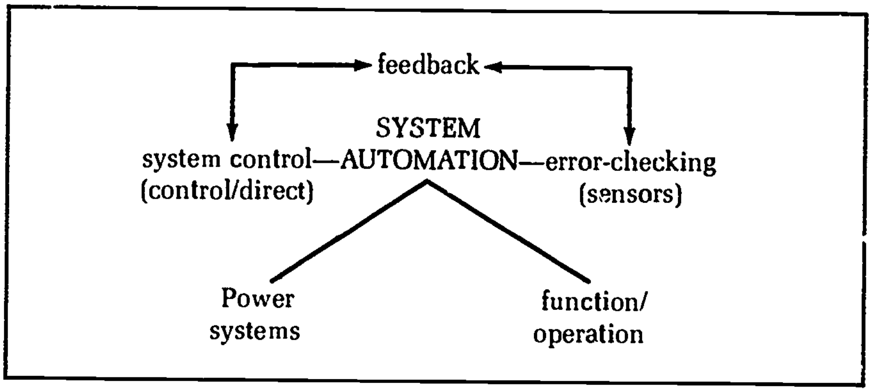


FIGURE 6
The relationship of control, power information and feedback in an automated system.

Automatic Systems Control Computers

Many automatic systems use some form of computer to control them. You might say that computers offer technological systems control. The computer may be located in an automobile or airplane to control their technical systems.

In each of these examples, the input to the controlling computer is accomplished by sensors. These sensors are one of several methods of computer input. A second method of controlling a computer is by a programmed set of instructions, which we commonly called a computer program. A computer program provides a computer with a set of machine instructions and data that will allow it to control a technological system. A computer-controlled traffic system is a good example of a computer controlling a complex technological system.

For example, a traffic light at a road intersection can be controlled by a computer for optimum traffic flow. The computer monitors the flow (rate or number of vehicles), the interval between the cars, and compares it to the different

COURTESY— NASA LANGLEY—OFFICE OF PUBLIC AFFAIRS

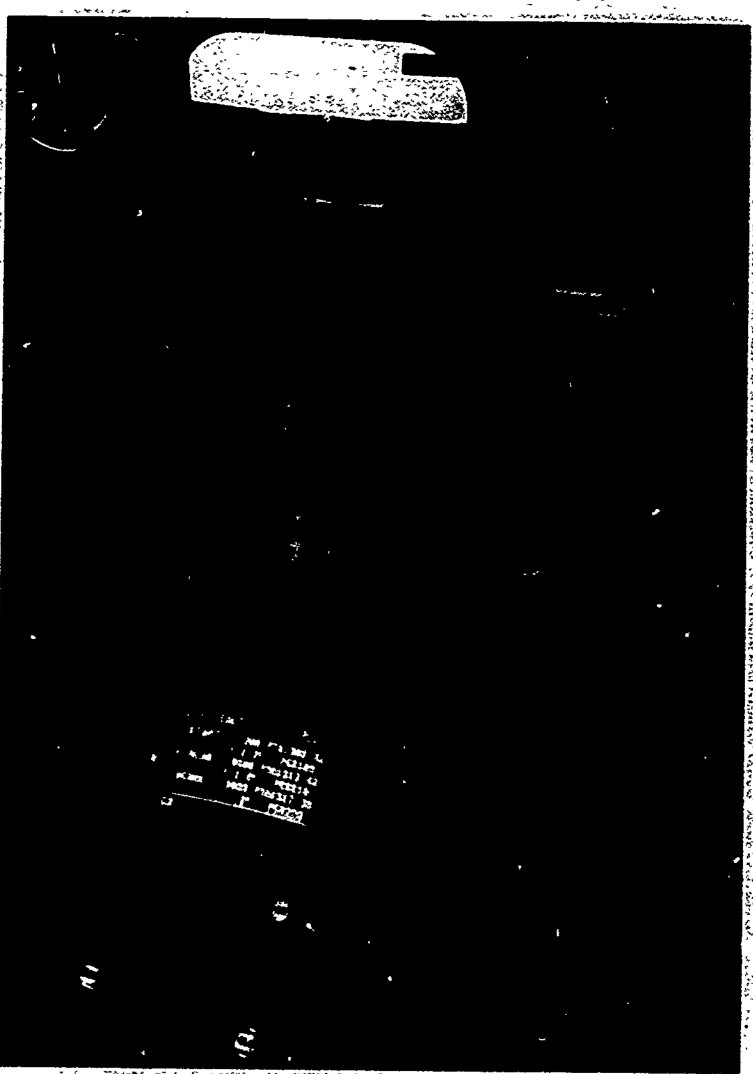


PHOTO 3
Flight Simulator

entrances of the intersection. The traffic control computer then switches the signal lights to accommodate the heaviest flow of traffic. Thus, the computer makes decisions based on input from sensors that sense the prevailing traffic patterns and makes adjustments accordingly.

Artificial Intelligence (AI) or Expert Systems (ES) are computer programming areas that are currently receiving considerable attention.

Expert Systems is a branch of computer science that deals with the development of large databases of information that provides a human-to-machine interface based upon the data base. ES programs "mimic" the human brain through a complex set of logical computer instructions and a database. Typical ES programs include Prologue, LISP, and others.

These programs contain lists of rules and facts that are compared to a persons, or sensors, input. The computer will search the database for facts according to the rules contained in the program and provide some form of output. The output may be to control a technical system or provide a physician with the name of an illness and appropriate treatment.

The significance of Artificial Intelligence or Expert Systems is the program's capability to make decisions based on a variety of facts or conditions rather than accepting very specific instructions in an exact format.

The future of AI and ES are exciting in that these new computer programs will anticipate the needs of an operator rather than require the constant monitoring and input from an operator.

Human Factors

In working with the control of technical systems, a unique branch of psychology has emerged that is called ergonomics or human factors. The human factors engineer is concerned with working in four levels of technology in the human-machine scheme. The four levels are:

- The person supplies the power to the system and controls it.
- The power of a machine is supplied by another source and the operator controls the machine.
- The machine or system supplies the power and information needed to run the system, but the operator or person controls it.
- The highest level of technology, where the power, control. and information is supplied by the system and a human only monitors the system.

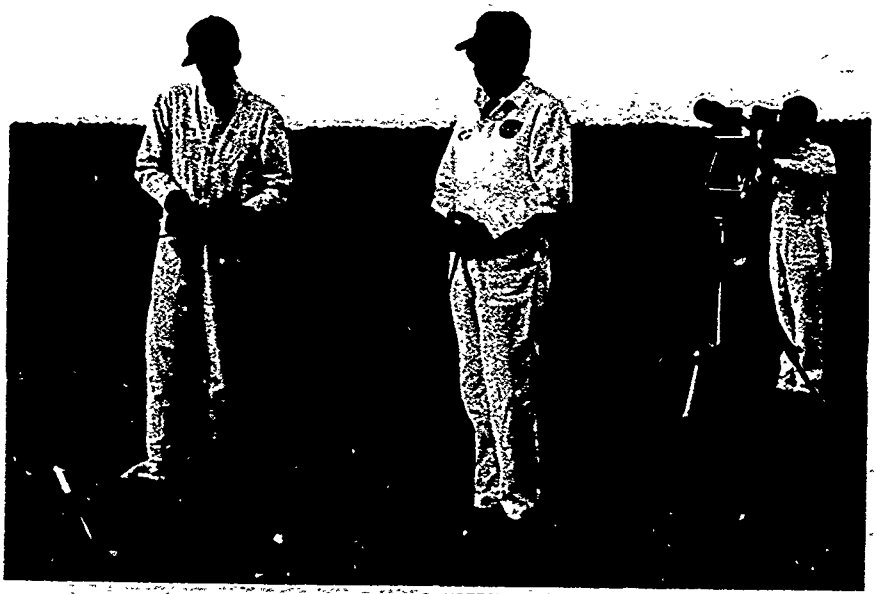


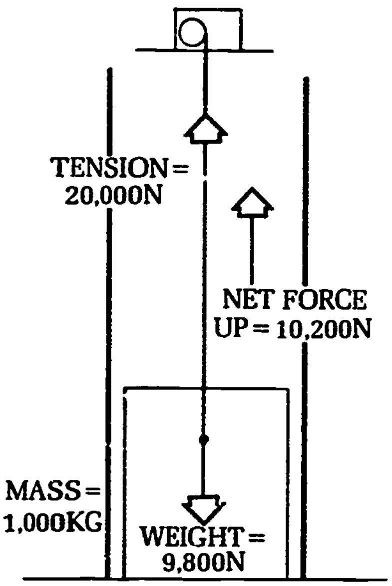
PHOTO 4 COURTESY—NASA LANGLEY—OFFICE OF PUBLIC AFFAIRS

A model aircraft remotely controlled by NASA scientists.

Examples of the different levels of technology would include

- A person using a wrench to tighten a nut and bolt. (The person supplies both the power and the control.)
- A person using a radial arm saw (The saw supplies the power while the operator controls it.)
- A newpaper printing press (The press supplies the power and information, ink requirements, paper speed. cutting and folding while a press operator controls it.)
- A passenger aircraft where the autopilot can supply the power, control, and information while the pilot monitors the operation.

While it may appear that the fourth level, the highest, may be the only one demonstrating technological control, they all are technological systems and demonstrate the input, control, and transmission of power. Human factors plays an important role in the human control of technological systems. Human factors or ergonomics can be best summarized by asking the question, "What is the best way for humans to interact with a machine?"



F = Force
a = acceleration
W = Weight
M = Mass
g = Gravity (9.8 meters/sec²)
N = Newtons
Where: $w = Mg = (1{,}000\text{kg})(9.8\text{M/sec}^2)$
$w = 9{,}800$ Newtons
$F = F_2MAX - W = 20{,}000\text{N} - 9{,}800\text{N}$
$f = 10{,}200$ Newtons
$$a = \frac{F}{M} = \frac{10{,}200\text{N}}{1{,}000\text{Kg}} = \frac{10.2\text{M}}{\text{sec}^2}$$

FIGURE 7
Sample elevator problem illustrating maximum acceleration.

Constructional Activity

The study and construction of a working model elevator illustrates the concept of controlling a technological system. Additionally, the study of the design and societal impact of elevators reinforces the areas of human factors and the significance of elevators as transportation systems.

The design problem can be simply to construct a model elevator that will travel at least three floors, stop at each floor exactly, continue to the third or top floor, and return to the first floor and then repeat the cycle.

What are the technical requirements for the system? First, a mechanical structure is needed: the elevator car and shaft. Second, some means is needed to raise and lower the elevator. Third, there is a need for some means to control where the elevator starts and stops, and limits the travel to the top floor. These are the conditions.

Applying problem-solving and critical thinking skills will provide solutions to the problem. What can we construct the elevator shaft and car from? Metal? Wood? Plastic? A combination of all three?

What means can we use to raise and lower the elevator car with? Electric motor? Electric motor with a gear box?

How do we control the direction of travel of the elevator? With gears? Electronic switching?

How do we control where the elevator cars stops relative to a floor level? With mechanical microswitches? Or photosensitive devices and electronic switching?

Each of the above possible solutions to the design problem can be solved with critical thinking and problem-solving skills. Why not have your class divided into competitive design teams to see which team can provide a creative, but workable solution?

Math/Science/ Technology Interface

The sketch that is shown in Figure 7 illustrates a conceptual model of an elevator. The elevator car weighs 1000 kg. with three persons riding in the elevator. What would be the greatest upward acceleration possible under these circumstances? What would be the greatest downward acceleration?

Note—When the elevator is at rest, or moving at a constant speed, the tension on the cable is equal to the weight of elevator car plus its occupants.

Summary

As we have seen, control of technological systems extends to all levels of machines and tools that we use in our daily living. The human interface with controlling directed toward using simple machines and the highest level dealing with automated machines such as the automatic pilot in an airplane. As computers and computer programs become more sophisticated the social issues and concern will be expressed as to how much we actually control our technological destiny or whether the new technologies will be controlling us.

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How Resources are Processed by Technological Systems

A Point of View

As covered in some of the earlier articles in *Resources in Technology*, the generally accepted primary technological systems are production, communication and transportation. Resources are processed by our extensive and complex production system and the many subsystems they incorporate. The production system, while being the major processing component of our technological systems, does require inputs from the other two primary systems in order to function effectively.

The processing of the required raw materials for the manufacture of a new civilian commuter aircraft, for example, obviously involves many elements of our society's various technical systems and subsystems. Little could be coordinated or accomplished without the vast resources of our communications system. The raw materials could not be moved from extraction sites to processing facilities for fabrication into the aircraft's many structural components without our transportation system. The interrelationship of the technical systems involved would be in evidence throughout the production process.

It is that relationship which enables our technological society to continue to function. Without it and all that it involves, we would still be just a stone's throw from our caves.

PHOTO 1
Cutaway view of a jet engine.

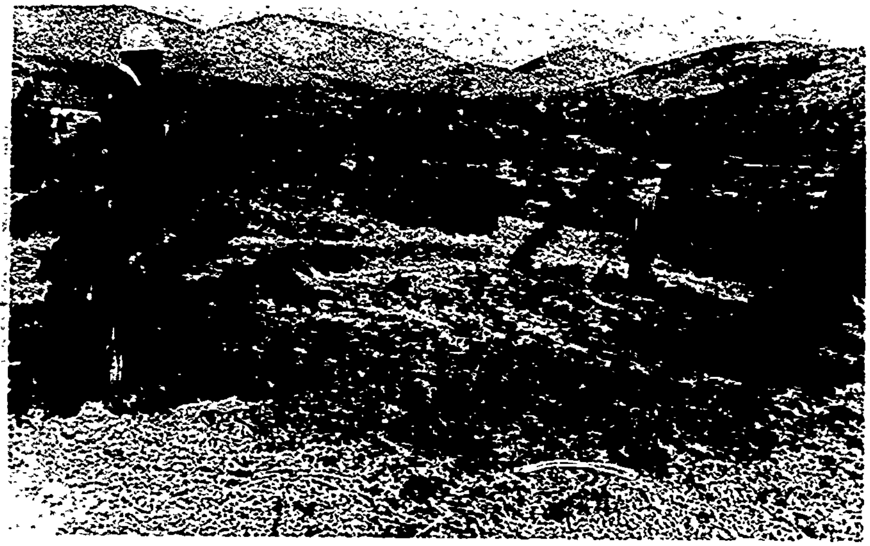

PHOTO 2
Land, trees and air are some of our most valuable resources.

Contemporary Analysis

Materials are those from which finished products can be made. Although the term refers chiefly to natural resources, some raw materials come from synthetic chemicals. Land, timber, water, air, fibers (both artificial and natural), and minerals of various kinds constitute what is generally known as resources (DeVore, p. 293, 1980). Some experts include fish and wildlife as well among our natural resources.

Each of these must be processed in some fashion by our technical systems. Because of the diverse nature of resources, each must, of necessity, be processed in an individual manner. It is beyond the scope of *Resources in Technology* to go into each individual process. We shall instead examine some representative resources and their processing. Many elements in the processing of resources through to finished products are generally common among them.

For production to occur, certain inputs must be present. These are the resource itself, technology, capital, management and labor. These elements (inputs) work together to produce goods (outputs).

In the face of the requirements for revised and more refined methods to increase the productivity of our technological processes, another technology has emerged as a separate, but related entity: Process Control. The concept of process control has been recognized for a long time and in reality has always been with us. Natural process control is an operation that regulates internal functions important to a living organism (Johnson, p.2, 1982). Some examples of it are body temperature, blood pressure and body fluid rates.

Artificial process control emerged once humans recognized the requirement for regulating some of the external physical parameters in their environment to sustain life. Early examples of process control include the regulation of fire for cooking, heating, lighting and smelting.

Actual process control, as a recognized technology, came into being when humans learned to adopt automatic regulatory procedures to produce goods more effectively and efficiently. It is now used in industrial applications to control such things as temperature, flow, level, force, humidity and intensity.

Process control, technology's primary function, is to maintain variables at or near some predetermined value. It provides or indicates some required corrective action to maintain the variables involved within certain limits.

Four elements of process control are common to all its applications.

Process—First is the process itself. The flow of a molten metal from a container, the container itself, and the liquid molten metal together constitute a process.

Management—Second, measurement within the process is another element of process control. Among the features of the process in the first example that may require it are temperature, flow rate and volume.

Evaluation—The third common element is evaluation or the controller. Evaluation may be performed by a human controller, computer, or electronic or pneumatic signal processing. Because of its rapid decision-making capabilities, the computer is easily adapted to this

PHOTO 3
A critical assembly process.

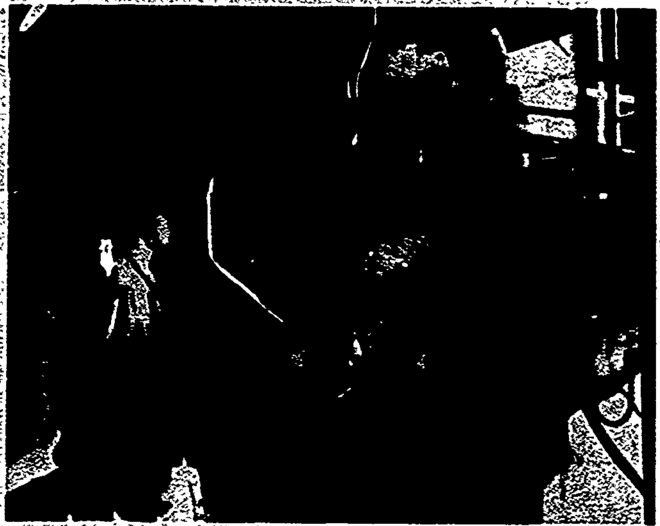

PHOTO 4
A worker monitoring a control system.

element of process control.

Device—The final common element is the device that provides the required changes to maintain the variable at the desired value. This is the final control element. The required chan‹ s are effected by the control element based on inputs from the evaluation element. Changes may be implemented by valve operation, the application of more or less heat, the addition of more material, or any of several other inputs.

Why not have your technology education class try to identify the locations and functions of the four process control elements in the following tv o examples? In some cases, the elemeuts might be controlled automatically, while in others human control might be present.

Specifically, processing is the changing of materials into something useful. The mining component of our production system presents a good example of processing at work. To be even more specific, let's look at the production of aluminum. It is only after a series of processes that the metal appears as we know it.

The ore is found near the surface in many parts of the world and readily extractable. Bauxite ore is usually mined using power shovels and draglines.

Using the Bayer process, the ore is ground to a uniform size, rinsed with water and heated. The heating removes as much of the free water as possible. Following this drying process, the ground bauxite is treated chemically with sodium hydroxide (caustic soda) in huge digesters. The sodium hydroxide dissolves the alumina within the ore to form a concentrated solution of sodium aluminate.

The sodium aluminate liquor, as it is called, is then "seeded" with hydrated alumina crystals in tall precipitater towers. Other crystals in the solution are attracted to these "seeds" which help form heavy groups which then settle out.

Next, the settled crystals are washed and heated to over 2000°F. to remove all the water. The final result of this process is a white alumina powder. At this point, the powder is a firmly bonded chemical compound of alumina and oxygen.

Using another process, the new compound is moved to a smelter or pot room where it is transformed from a powder into the glistening, molten metal: aluminum. This is an involved process, but technology in this area has improved steadily. More and more operations are now being done automatically under computer control.

Other minerals use processing techniques appropriate to their unique chemical compositions. As each of these techniques is implemented, communication must be maintained and the required transportation functions performed. Each of the primary technical systems of production, communication and transportation, plays an important role in resource processing.

To use a further illustrative example of processing, one quite removed from mineral resources, let's consider how another natural resource is processed. Refined processing techniques have drastically increased the uses our society derives from forest products. Once trees were primarily important for their lumber which was used for general manufacture, ship construction and fuel.

With the advent of new technologies and processes, our forests not only continue to supply the basic material for home construction and other common uses, but may also be utilized in the production of countless other products. Among them are many chemical products such as lacquer, cellophane, explosives and animal feeds.

In the processing involved in the production of plywood, for example, wood undergoes many separate, but related

PHOTO 5
An auger machine which increases the recovery of coal by 40%.

processes. Depending on the exact type of plywood desired, differing processes are used. Here again, as in all other process operations, the primary technologies of production, communication and transportation must interface.

After a tree is selected and felled, it must be transported to a sawmill and its arrival must be coordinated (communicated) so that processing may begin. Transporting may be by water, overland, or both.

Once at the sawmill, the tree becomes lumber through a series of processes that can include debarking, sawing, trimming and planing. In the case of plywood, other operations may be used to produce the large, thin sheets of veneer required for its production. These veneers may be produced by three different processes: sawing, slicing, or rotary cutting. Following that, a gluing process called lay-up is employed. Then the large plywood sheets are placed in giant hydraulic presses and dried.

Each of these processes is closely monitored using process control technology. Operations in the forest products industry, as in almost all others, are being automated more and more. The ubiquitous computer is now a commonly found tool.

Many of the processes in Chart 1 are used in more than one field. All, however, combine certain aspects of the three primary technologies: production, communication and transportation.

METAL WORKING	PETROLEUM	CONSTRUCTION	PETROCHEMISTRY
Shearing	Distilling	Layout	Degassing
Abrading	Adsorption	Cutting	Polymerization
Shaping	Absorption	Planing	Pelletizing
Drilling	Flexicoking	Filing	Centrifuging
Milling	Reforming	Fastening	Drying
Turning	Cracking	Finishing	Injecting
	Distilling		
	Absorption		

CHART 1
Some Processes Used in Selected Industries

PHOTO 6
After large trees are felled, the timber must be sectioned into manageable sizes for skidding, loading and transporting.

PHOTO 7
Large trucks are usually used to transport lumber to mill sites.

Socio/Cultural Impacts

It is difficult to imagine just where our society would be or what shape it would be in without the benefits of resource processing. Certainly, our lifestyle would be quite different and our standard of living would be considerably lower. The regulation and control of processes through process control technology has enabled us to even further refine and improve the products of our countless processes.

Two developments occurring as a direct result of improved processing are more and more automation and mechanization. Much more qualitative and quantitative production is now possible. Our gross national product continues to grow. On the negative side, though, the increased implementation of automation and mechanization has had some detrimental side effects.

Machines are now doing more work with less manpower thus displacing some workers. Complex production processes are very often more effectively monitored by computer networks than by individual groups of workers.

Another result of improved processes has been the emergence of the continuous-flow production line. Using this technique, product assembly and various other processes can often be accomplished much more efficiently and economically. The result has been even more goods produced for consumption. On the negative side, the dehumanization of some production processes has often resulted in employee alienation.

Worker dissatisfaction, hostile attitudes and a lack of employee commitment are often evident in automated and mechanized settings. Many employees, no longer feeling challenged, seem to take little pride in their work.

Some scholars believe that ours is a technologically directed society. That is to say, technology provides the direction humans will take rather than them having the freedom to make choices as to their technological destinies. This not uncommon belief is called technological determinism, a nearly self-explanatory term.

Improved processes promote improved

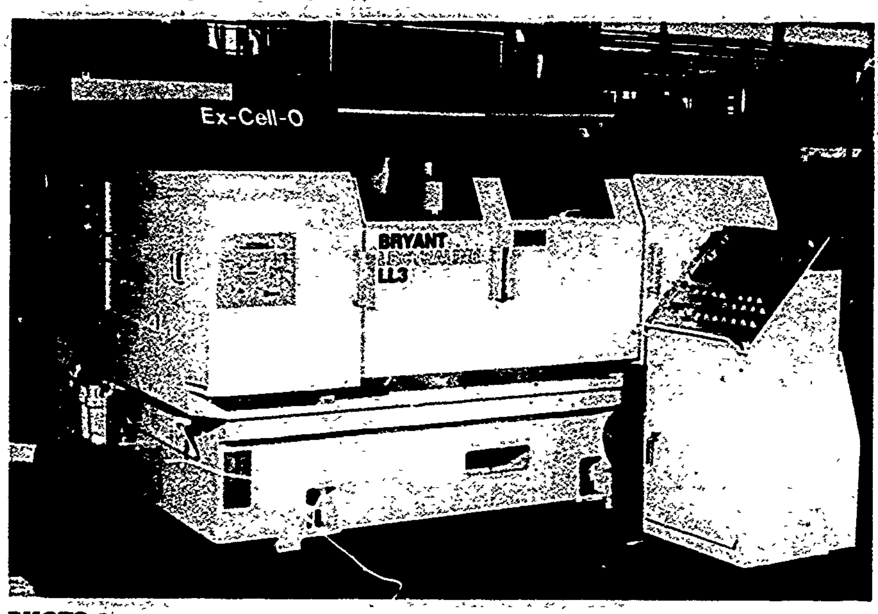

PHOTO 8
A grinding machine with a numerically controlled computer.

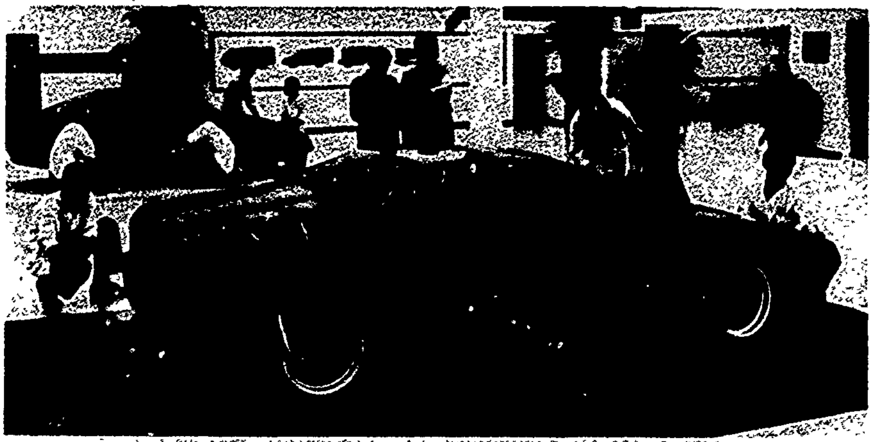

PHOTO 9
New processes enable our society to produce more new and complex goods each year.

technology which in turn promotes improved processes. As long as humans can direct their efforts in the positive directions opened by technology and avoid the negative ones, the dogma of technological determinism will not flourish.

New processes designed to concentrate on the development of newer materials and processes and on human aspirations, values and motivations are already emerging to improve our future (Pytlik, p.138, 1978). As our society prepares to enter the twenty-first century, our production processes, directed by us, can help by providing the goods to make the transition one that is favorable to all.

Constructional Activity

Almost any hands-on activity your technology education class might perform will be an exercise utilizing several types of processes. As a constructional activity, you might have your class construct some small wood project of their choice. In doing so, some of the processes involved might be cutting, boring, shaping, fastening and finishing. Your class's particular projects may employ other processes as well, depending on project complexity. Have your students list the processes they think will be used during the construction of their projects. Upon completion, see if they liscovered any other processes were required.

As an alternative constructional activity, have some of your students work with acrylics. They could form simple projects such as a letter holder, bookend or a set of coasters. Some of the required processes would be cutting, heating, forming, shaping and smoothing. Again, the point would be made that many different processes go into the completion of a final product.

Your lab may aiready be set up to mass produce a certain product. See whether or not your students really understand what individual processes are used. Do they consider the total operation just one big process? Are they able to identify the separate processes they use daily in producing your end product?

Whatever your constructional activities, processes will be an integral part of the production. Without processes, you will have no production.

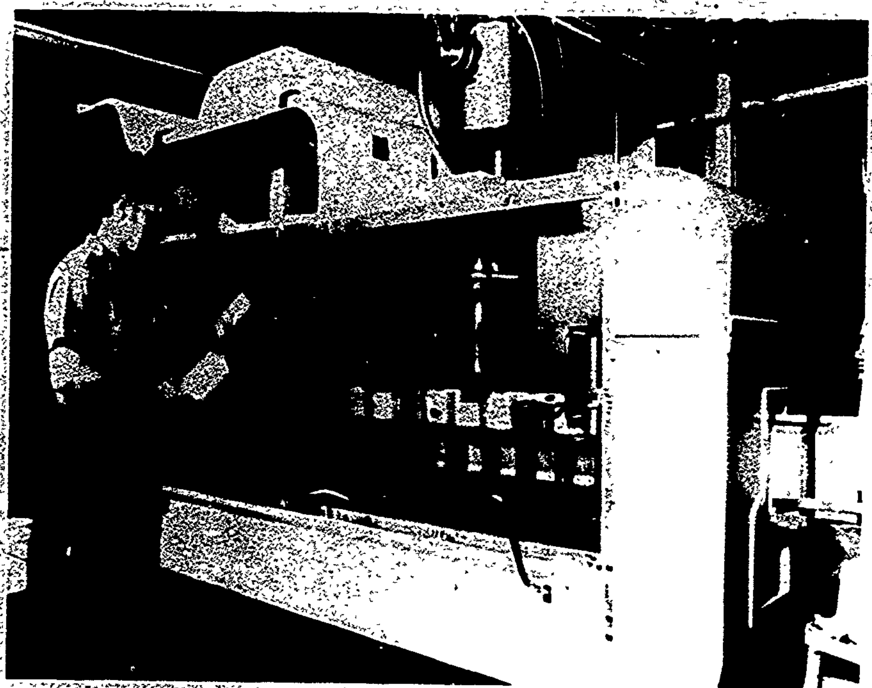

PHOTO 10
A milk packaging machine that is able to package large quantities of milk with little human control.

Math/Science/Technology/ Interface

Mathematics is the language of technology. Precise technical communications among individuals actively engaged in the various technical disciplines on local, national and international levels can be assured only if all use the same well defined set of units of measurement. The metric system of units provides for such communications and has been adopted by most technologically based societies today. In the United States, however, much technical work is still done using the English system of units. Because of that, it is often necessary to perform transformations between the two systems.

In process control technology, a particular set of units called the International System (SI) has been developed to insure the accurate and consistent transfer of data. SI units are based on defined units for eight physical properties. The eight properties are:

1. Length
2. Mass
3. Time
4. Electric current
5. Temperature
6. Luminance
7. Plane angle
8. Solid angle

All other units in the SI (i.e. farads, coulombs, Pascals, etc.) can be derived from this basic set.

Bearing in mind the need for precise communication, let's look at a simple example. Have your students change six feet into meters. We know that a meter is 39.37" long. Using basic mathematics, the problem would be expressed as:

$12\ \text{in/ft} \times 6\ \text{ft} \times 39.37\text{in/m} = 1.829$ meters

An important point to be considered in dealing with mathematics in technology is the significance of calculations. A technician must be careful not to obtain a result that has more significance than the numbers employed in the calculation itself. To illustrate this, look at this example:

A transducer has a specified transfer function of 23.1mV/°C for temperature measurement. The measured voltage is 410mV. What is the temperature (T)? Using the information given, we can easily arrive at the following equation:

$T = (410\text{mV})/(23.1\text{mV/°C})$

$T = 17.748917°\text{C}$

The solution was found using an eight-digit calculator. The two values in the original problem were significant only to three places. Therefore, the result can only be significant to three places. Thus:

$T = 17.7°\text{C}$

Much more complicated data can be communicated using the language of technology: mathematics. The interface of math, science and technology is a prerequisite for the continued development of civilization as we know it.

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PHOTO 11
A new laser machining system.

PHOTO 12
A large component of a complex processing system.

Summary

The processing of our resources by our technological systems is an integral part of our society. Using refined and more effective processing techniques, we reap the benefits of a very high standard of living and a tremendous gross national product.

Process control technology is in large measure responsible for many of the improved products we can obtain today. The positive effects our processing technology provides for us are somewhat offset by certain negative factors which also can result. Two of those factors are the dehumanization of the workplace and displaced workers. The highest conceivable standard of living can someday be achieved through the final development and perfection of processes which make available unlimited necessities and luxuries in the most cost-effective manner (Bolz, p. 1-03, 1977).

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Photo 2 courtesy of the U.S. Bureau of Reclamation.

Photos 3 and 4 courtesy of Allis-Chalmers.

Photo 5 courtesy of the U.S. Department of Energy.

Photos 6 and 7 courtesy of the USDA Forest Service.

Photo 9 courtesy of Chrysler Corporation.

Problem-Solving Tools

Computers and Computer Systems

To look at problem-solving in our technological systems of production, communication, and transportation, we will examine computer driven systems as a subsystem because they exemplify the overlap and interdependence that often exist among systems of technology. Computer systems play a central role in modern technology.

The complex nature of industrialized nations such as the USA, Japan, and West Germany must, forever more, use sophisticated tools for problem-solving. Computers and microprocessors come in varied forms ranging from the rather simple (by today's standards) microprocessor in your wrist watch, to low cost game computers, processes controllers for manufacturing equipment, to microcomputers, minicomputers, mainframe computers, all the way up to supercomputers. They have become forever integrated into our existence.

Even in fun and recreation we rely on computer technology. Walt Disney World's advanced computer center in the Magic Kingdom controls countless

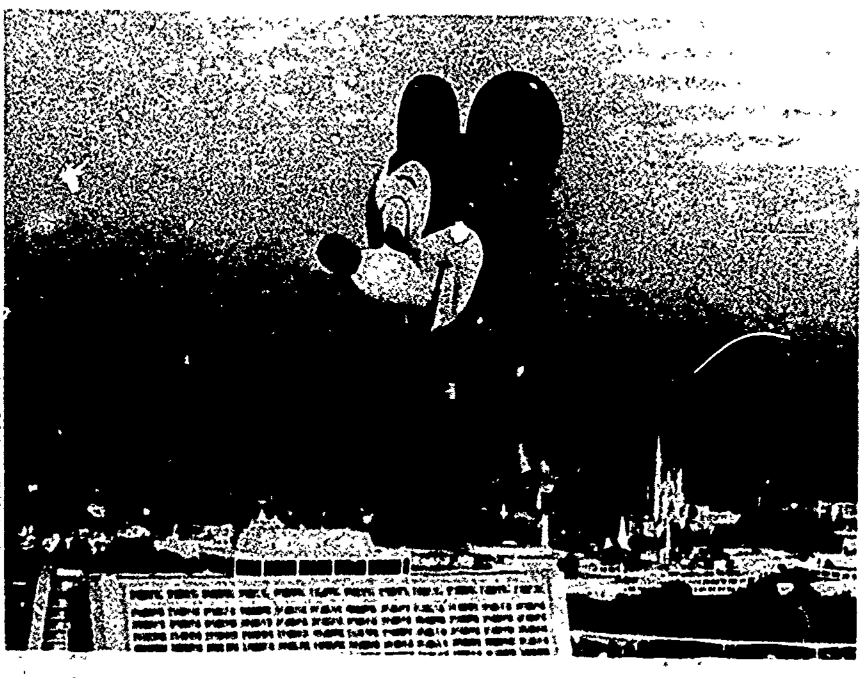

FIGURE 1
The Digital Animation Control System at Walt Disney World provides computer control over Epcot Center and the Magic Kingdom. Computer systems monitor animation support, Dynamic Economic Energy Dispatch System, supervisory control and data acquisition, and general purpose ride control. © Walt Disney Co.,1986.

DIGITAL WATCH	ANALOG WATCH
Full functioning computer	Machine
Power Source is. . . . A battery with electrical energy	A coiled spring—you provide the energy
Regulates Time by. . . . A quartz crystal is set to vibrate 32,768 times a second by the battery	A balance wheel regulated by gears to reduce the swing period to one second.
The mechanism is. . . . Driven electrically by a series of circuits on a silicon chip containing almost 5,000 transistors	Driven by the power of a lever
The time is displayed by . . . Millions of microscopic liquid crystals	Hands as a part of the machine

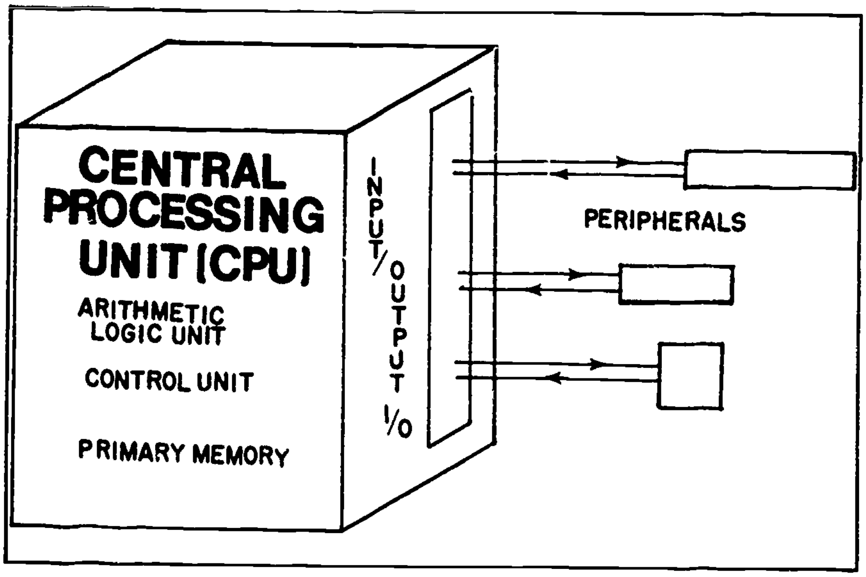

FIGURE 2A
Components of a digital computer.

services including transportation systems and communications systems; it sends voice and gesture commands to hundreds of "Audio-Animatronics" figures, opens theater doors, operates lights and curtains, and monitors subsystems such as security, fire protection, and power (Figure 1).

A CPU (central processing unit) with a control unit and arithmetic logic unit plus memory and input/output (i/o) ports to connect to peripheral devices comprise the basic hardware components of a digital computer whether they be microcomputers or mainframe computers (Figure 2).

These digital computers have about the same capabilities but with higher power as computers having greater speed and more memory. Microcomputers, often referred to as personal computers (PC), because usually only one person at a time uses one, do not have the speed, memory, nor ability to support multiple users as do more expensive minicomputers. As you move up to mainframe then supercomputers you find increased speed, memory, and ability to support more users.

The remarkable and rapid development of personal or microcomputer computers brings with it predictions that by early 1990's each engineer will have her/his own PC (Figure 3). This prediction seems believable when we see how the software (application programs) continues to become more powerful as well as easier to learn and use (user friendly).

FIGURE 2B
Mainframe computers such as this large one currently and in the foreseeable future will do most of our ' scale data proc g. Conti..ued improvements with integrated circuitry will bring about even greater computing capability.

To use these application programs, one does not require programming experience; instead they learn to use particular programs such as a word processing program for writing letters, reports, etc. Many models of this type of program were originally developed for larger computers and have been reprogrammed to run on PCs.

Ongoing development of specialized programs for problem-solving in engineering, science, business, and management for technological systems and subsystems should lead to PCs becoming nearly as popular and widely used as today's hand held calculators. Their number in classrooms from elementary school through college will continue to grow. As people become accustomed to their convenience at school and on the job more and more will purchase them for home use thus spurring on greater competition among computer manufacturers and even more powerful PCs at very reasonable prices.

FIGURE 3

Microcomputers or PCs today have data processing power equal to or greater than mainframe computers less than 20 years ago. Their power will continue to grow as their size stays about the same. This will place tremendous computation ability along with many application programs at the finger tips of almost anyone desiring it.

Computer Systems

A computer system includes hardware (computer and peripherals devices connected to the i/o ports) and software. Examples of computer systems include CAD (computer aided design) systems, computer control systems for regulating operation of an oil refineries, and a CAM (computer aided manufacturing) systems.

A typical CAD system, often labeled an engineering workstation, consists of the CPU, secondary storage, input devices, graphics terminals, and output devices (Figure 4) with specialty software. Input devices include mouses, joy sticks, light pens, and digitizer pens. Output devices include dot matrix, laser, ink jet or daisy wheel printers; pen or photohead plotters; microfilm and other photographic devices for making 35 mm color slides and instant prints.

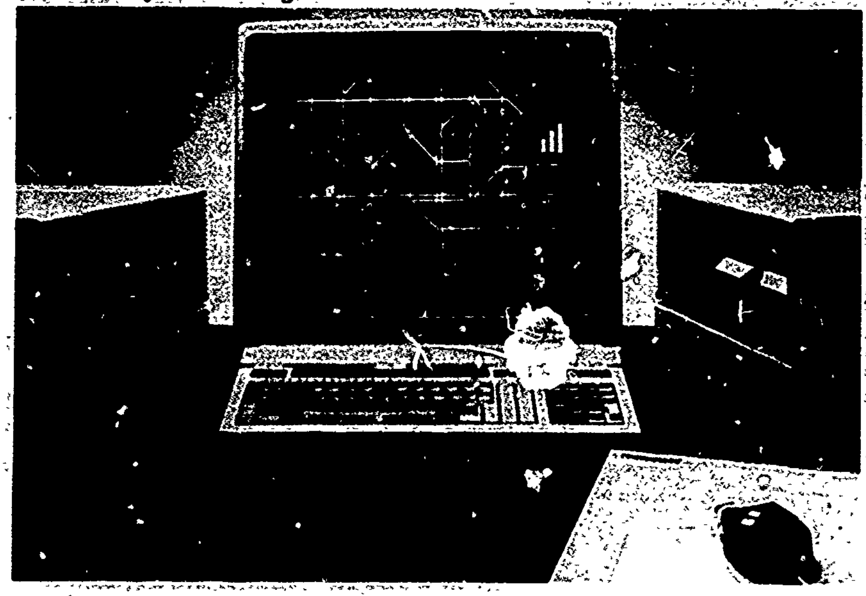

FIGURE 4

CAD systems are one of the fastest growing computer systems. PC based CAD systems have enough design/drafting capabilities for many industrial design jobs. Their power continues to grow. Ability to network PCs with mini and mainframes provides a great amount of computer availability to even the smallest firms.

The designer uses the input devices similar to the way one would draw on paper but has considerably more ability to generate graphical and alphanumeric images with the electronic devices. Modifications of work is quite easy compared to the manual method.

Linking computers and computer systems together into network systems allows for the expansion of individual systems and very powerful and efficient communications. The term local area network (LAN) describes the linking of computers within an office, building, or plant. Coaxial cable as used with cable television and optical fibers may serve as the LAN link.

Networking also links computer system on a regional, national or global scale using microwaves and orbiting satellites. To name a few, worldwide networks serve international corporations, the armed forces, weather services, and telecommunications agencies such as phone companies.

Networking allows the sharing of information for problem-solving at the speed of sound or light. The data and images that a computer system generates are reproduced within inches of the computer or sent by network anywhere on earth or even to outer space; this includes alphanumeric data and complex color pictures.

Let us examine some examples of computer driven systems for problem-solving.

Problem-Solving in Production

Production systems consist of construction, manufacturing, and processing subsystems which divide into a number of subcomponents and support technologies including extraction, transformation, marketing, service, and recovery. Computer systems serve all aspects of production.

Manufacturing has experienced phenomenal changes recently due to the introduction of computer systems to production. Traditionally, a product of manufacturing goes through a product cycle as depicted in Figure 5. The designer and drafter creates the concept with pencil and paper on the drawing board; modelmakers or machinists craft a model; testing, refining and retesting by technicians, technologists and engineers yield a prototype which undergoes still more testing for refinements as a part of the design process; eventually the product comes out of the manufacturing stage.

The stages prior to production of the final product are often long and costly. Computer systems now allow for computer aided engineering (CAE) that employs such tools as CAD with sophisticated design programs including finite element analysis (FEA). The tools not only shorten but also improve the design process.

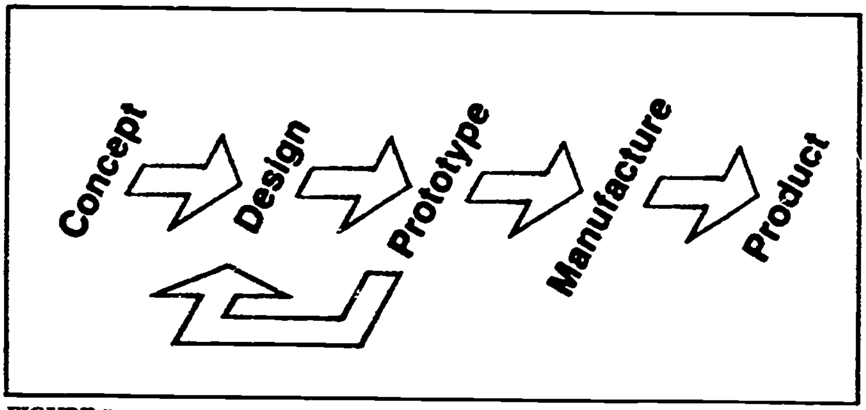

FIGURE 5
Traditional Product Development Cycle.

The FEA found in some CAD programs generate the following:

■ Geometry of a part with its coordinates and algebraic description is modeled by the program as the designer produces it on the computer monitor (Figure 6);

■ Finite element mesh consisting of connecting lines (wireframe) that outlines and subdivides the part (Figure 7);

■ The lines or finite elements serve as vectors or paths onto which various conditions such as applied force, temperature, and pressure are imposed on the model;

■ The model data is then processed by the FEA program which makes hundreds of calculations to predict behavior to the designated conditions within and between the design elements.

Figure 8 shows a stress distribution on the air filter (Figure 6) designed around duPont's Delrin engineering plastic. The FEA program predicted the stress distribution indicated by color changes (only shown in shades of gray in Figure 8) that corresponds to increased levels of stress. In this case a red line (arrow tip) predicted the filter would rupture at 600 lbs. per square inch (4137 kilopascals). Testing of the actual part proved the FEA prediction correct.

Designing this filter in the traditional manner would have added an estimated six months to the process. The initial design for the filter would have been created, tooling made to mold production quantities of each filter design using various plastics to test their suitability; then model filters subjected to a battery of tests. By using a CAD system with a powerful design program, much of the evaluation was done by simulation in which the part was evaluated using mathematical models developed by the CAD program programmers.

In Figure 6, a Polaroid instant print generated by the computer, the filter is shown in three dimension with shading. Powerful CAD systems can produce solid models of parts once the basic size and

FIGURE 6
CAD system generated image and polaroid print of air filter.

shapes are inputted by the designer. If you have ever drawn an isometric or oblique drawing of a spherical part even as simple as the filter then you understand the difficulty and time consuming effort required.

Sophisticated CAD programs can do these tasks in seconds and even PC-based (less sophisticated) systems can do similar tasks but require more processing time. Much of the model building and testing and design in the product development cycle was eliminated and thereby saved valuable time for the company thus allowing them to keep ahead of their competition.

Solids modeling, mentioned above, contrast with wire-frame molding in the manner CAD systems generate 3-D images. Wire-frame breaks apart into elements (Figure 7) and does not have the capability to show parts as a solid three dimensional object even though the picture appears three dimensional. With the wire-frame, all lines show instead of front lines and surfaces hiding those behind them.

Analysis of wireframe models must deal with two dimensions (of either length and width or width and depth or height and width) just as one deals with a multiview orthographic drawing. Analysis of area is possible with two dimensional models but the data is not present for volume or three dimensional analysis. Solids modeling produces an image like Figures 7 and 8 without the need to remove hidden lines and surfaces. Wireframe CAD programs might have the capability to remove hidden lines but the data base on the object in the computer is still two dimensional.

The above example of a computer system using CAD workstations covers only a portion of the computer system's capabilities for problem-solving in production technological systems. Computer aided manufacturing (CAM) builds on the CAD database to further automate production.

Problem-Solving in Technology

Communication technology systems includes the subsystems of:

- Technical graphics
- Graphics communications
- Electronic communications
- Static communication devices

Further subdivision of the subsystems incorporates designing, transmitting and receiving technologies which support the total of communication technology.

Also bear in mind what we said above about the overlap and interdependence of our major technological systems. Much of communication technology directly supports production technology as is evident in the discussion on CAD systems which represents integration of components from technical graphics, graphic communications, and electronic communications. We will continue to show how computer systems directly aid in problem-solving in communication technology.

In the brief discussion above about computer networks, you gained some insight on electronics communications. So many entities of our society are tied together by electronic communications networks that we can literally communicate computer data anywhere. The most extensive system of computer networks is through telephone lines (Figure 9).

FIGURE 7
Wireframe separates the filter into more than 1,000 finite elements. Computer applies boundary conditions to each for FEA.

FIGURE 8
Stress distribution was predicted on computer models, color changes (shades of gray in this black and white print) correspond to increased levels of stress. Arrow points to where red line appeared indication probable failure of the filter using an ABS. Substituting ABS with Delrin acetal plastic provided sufficient strength for the required service conditions.

Most of us have had first hand experience with "plastic money" which is an example of problem-solving with communication technology. The credit card with digital information stored on iron oxide, polyester magnetic film on the back of the plastic card allows access to credit information on individuals all around the world. In fact, the same information could be transmitted to and from space stations. Telephone lines connect banks with retail outlets (local shoe store), service centers (auto garage) and central credit agencies (Retail Merchants Association).

To determine whether or not an individual has sufficient credit to purchase a given product or service, the merchant or service center need only connect to the appropriate credit card center, run the card through a digital reader that sends the account number to the computer of the credit card center, where the computer processes the data and displays the amount of credit remaining on that individual's account. To the casual observer credit verification with plastic money seems simple enough, but that simplified process represents an unbelievable amount of problem-solving from communications systems. And we have only seen the beginning.

Very large scale integration (VLSI) has advanced to such a point that VLSI chips are now small enough to implant into plastic credit cards. These microprocessor chips can store huge amounts of information including data on credit, health, security access, telephone numbers, almost any conceivable data. This data can be read in a manner similar to the way the magnetic strip on the current credit card is accessed. The source of energy to power the microprocessor in the card is silicon solar cell. The card can also serve as a calculator with a liquid crystal display that provides information at touches of the key pad.

Problem-Solving in Transportation

Transportation technology consists of subsystems of terrestrial, marine, atmospheric and space which function with vehicle and support system technologies. The desire to get there faster, with more, maximum comfort and fuel efficiency will always keep people busy with problem-solving in transportation. Computer systems are also meeting the challenge in this area.

Space transportation gets much of our attention especially in light of the tragedy of the Challenger destruction. Many people fail to realize that the Space Shuttle program is still a R&D effort with high risk. We are a long way from the time when space travel becomes as routine as atmospheric, terrestrial, and marine travel.

Throughout the development of space travel computer systems have been an indispensable problem-solving tool. The extraordinary venture of transporting humans to and from the surface of the moon was not possible without heavy reliance on computer systems.

For example, the entire flight was simulated on a computer. This means every aspect of the launch; speed of spacecraft travel; relationships among the earth, moon, and vehicle; amount of fuel; vehicle, passenger, and cargo weight; plus many many more variables (sets of figures such as speed, weight and volume) had to be reduced to mathematical data and fed into equations to determine how the various factors would interact.

The highly competitive auto and truck industry employs computers for problem-solving in many areas ranging from use of CAD systems and aerodynamic analysis, computer simulation of operation (much like the moon flight) and installation of computers to control engine and powertrain functions.

Aircraft of all kinds undergo extensive analysis prior to the flight of the first prototype. Figure 10 shows a scale model helicopter being prepared by an engineer at NASA's Langley Research Center for wind tunnel testing. The test shown in the picture involves a laser velocimeter which will help feed data into a computer system for analysis of helicopter rotor performance. The laser system allows readings to be taken of complex air flows in difficult to get to places not possible with standard wire and tube instrumentation.

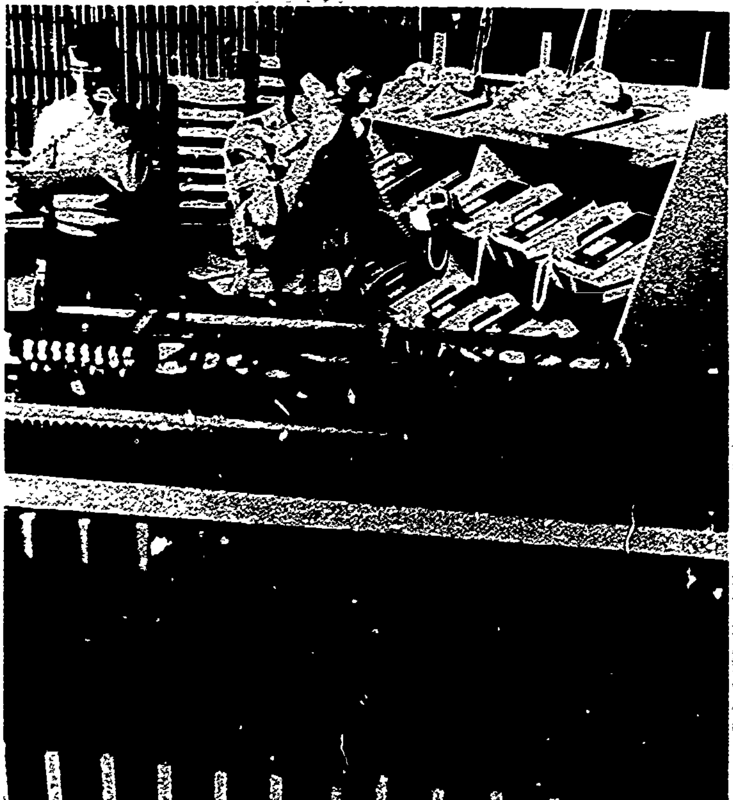

FIGURE 9
Networking computer systems together provides automatic high speed switching of telephone communications around the world.

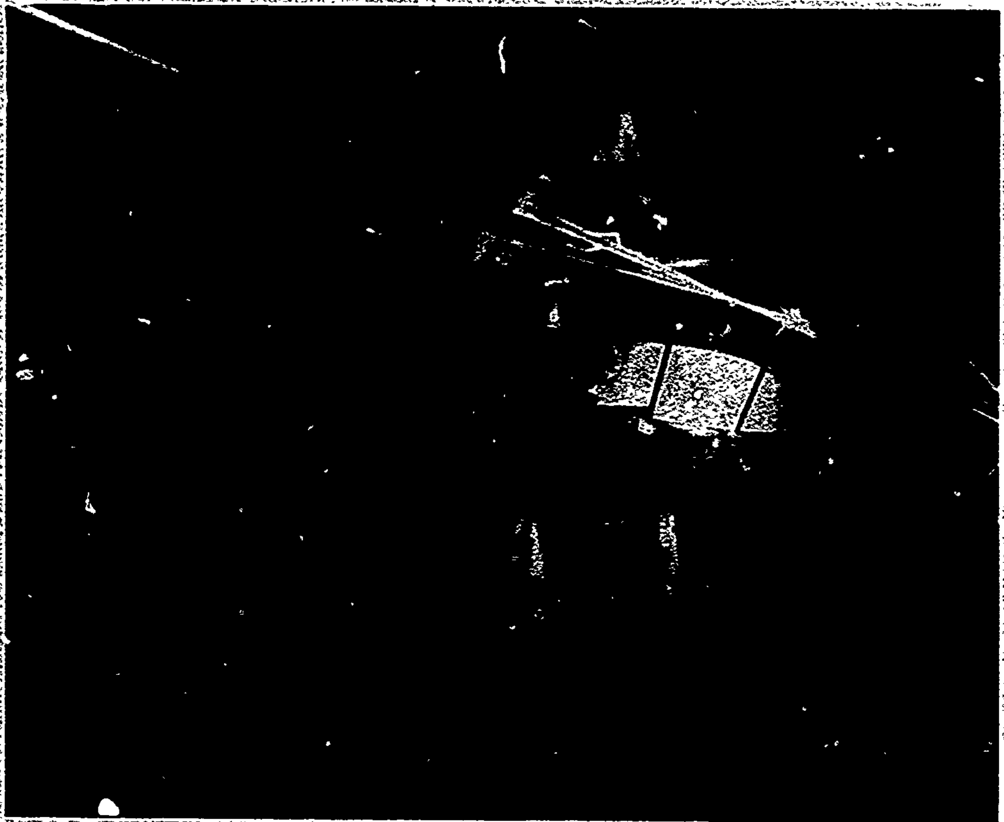

FIGURE 10
Computer systems link up with other high technology for problem-solving in all major technologies. Here an engineer works in a NASA windtunnel that integrates lasers with computer systems.

Instructional Activity

Select a picture or observe a situation such as Figure 11. Analyze the photo in terms of technological systems and their problem-solving opportunities. For example, we see a monorail train system (transportation technology) which required extensive problem-solving from design, to construction (production technology), and now with control and maintenance. Can you name where computer systems acted as tools to solve these problems?

Also note the picture taking activity (communication technology), the water system, and an educational exhibition building in the background. What problem-solving opportunities come to mind regarding those elements?

A key to this activity is the reference to opportunities for problem-solving. This means opportunities for careers. Computer systems and automation are having profound consequences on jobs. People are rapidly being replaced by computer controlled machines to do physical labor. Problem-solving requires human abilities even when artificial intelligence (AI) is involved.

FIGURE 11
How many applications of computer system problem-solving might have operated on what is seen in the picture?

Communication/Technology Interface

Typically in these "Resources in Technology" instructional modules you are presented with a math/science/technology interface segment. Here we chose to highlight the importance of communication skills.

Some people have a mistaken idea about technical jobs. They feel that engineers, technicians, and crafts people need only have a strong background in math, science, applied technology and appropriate manual skills to be successful in their technical specialty. But without a grasp of communications fundamentals, one is unlikely to advance very far.

In the first place, reading skills becomes more important as technology continues to make our world more complex. We must be able to read many types of material from operation and maintenance manuals to reports of experiments and development procedures.

Next, technical people must be able to communicate their ideas both orally and in writing. With microcomputers that have word processing programs becoming so available, many engineers, scientists, and technicians find they must learn keyboarding and word processing skills so they can develop their own reports without support of a typist.

Try this: Use library resources to aid in the above Instructional Activity on computer systems for technological problem-solving. Concentrate on periodicals such as *The Technology Teacher's* "Resources in Technology", *High Technology*, and *Popular Science*. If possible use a microcomputer to type a technical report then make an oral report of the project to your class. Try to involve your math, science and English teachers to insure that those subjects have been given appropriate attention.

Student Quiz

1. Name two predictions about computer systems as problem-solving tools.
One PC for every engineer by early 1990's, more powerful and quite affordable PCs, more PCs in home and classroom and PCs nearly as available as today's handheld calculators.
2. List the hardware components of a computer.
CPU, arithmetic logic unit, control unit and i/os.
3. What is the purpose of simulation on computer systems?
Mathematical duplication of the variables to determine how a designed product or system will react to sets of conditions. It reduces the amount of model building, testing, and design recycling.
4. Name one example of computer systems for problem-solving introduction, communication and transportation technology other than described in this module.
May wish to use of a photo like Figure 11. Many examples possible.

Possible Student Outcomes

- Recall some predictions regarding computer systems as future problem-solving tools.
- Explain the difference in a computer and a computer system.
- Name the main components of a computer and of a CAD system.
- Define and cite examples of the following terms: CPU, simulation, solids modeling, wire-frame modeling, finite element analysis, hardware software, user friendly, CAD, CAM, CAE and i/o devices.
- Give an example of how computer systems serve as problem-solving tools in each of the major technological systems.
- Do library research and write a report on a current application of computer systems solving problems in a technological system.

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Debski, D. (1986, Fall). Prototyping on your computer. *Engineering Design.* pp.14-15.

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Acknowledgements

Figure 1 courtesy Walt Disney World.
Figure 2b, 3 and 9 courtesy AT&T.
Figure 5—8 courtesy David Debski and E.I. duPont de Nemours.
Figure 11 courtesy NASA Langley Research Center.

Technology and You Impacts, Choices and Decisions

Impacts of Technology

When we read about technological developments, often we get mixed emotions. Futurists offer both promise and gloom of the consequences of trends in the ever evolving technology. Laser development, for example, continues to bring us instruments to improve our existence whether as replacements for the traditional surgical scalpel or for improved telephone systems in which optical fibers replace copper wires. But we also read about laser space weapons, "Star Wars" technology that could move the horror of nuclear weapons into space and bring us closer to the doomsday of nuclear war. Fertilizers and pesticides designed to make the land more productive in order to help feed more people may also contribute to the pollution of ground water, rivers and other waterways.

There are numerous critical issues of the future ranging from how we can avoid World War III; what to do about the rapid population increase; how to insure adequate food, shelter and energy is available to meet the needs of civilization; what measures to take to insure a safe environment free of air, water and noise and other forms of pollution; how to provide for adequate health care to the aged who have increased life expectancy.

Technology will definitely play an important role. Hopefully, people of your generation will be able to wisely manage technology to make it work for betterment of life. For example, futurists look to space colonization and cultivation of deserts as potential for expanded resources (Figures 1 and 2).

FIGURE 1
A cultivated desert as envisioned in Epcot Center.

To manage technology one needs to understand it. This means to possess an education which includes mathematics, science and various aspects of technology which one can learn in technology education courses. Even for those people who do not go into technical fields, it is imperative that they have technological literacy to be intelligent citizens. Accountants, store clerks, history teachers, farmers or anyone else must make choices, as consumers, voters or politicians, which affect the impact of technology. The current debates about our future in space serves as a good example. Some state SDI (Strategic Defense Initiative) can make the world safe from a nuclear war. Others say that SDI will do what other weapon systems have done: continue the acceleration of more and deadlier weapons. The latter group wants space to be free of weapons and used only to help solve problems for humanity. The National Aerospace Plane (Figure 3) could serve either purpose: it could carry weapons into space and be used to transport components for a manned space station to allow research into new materials, improved medicine and better access to solar energy.

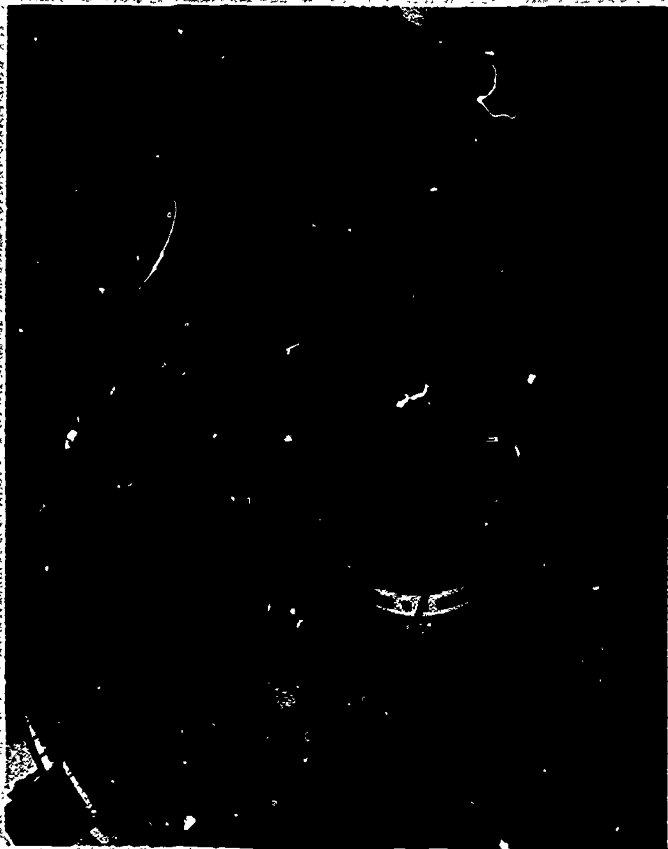


FIGURE 2
A vision of a space colony as seen in Epcot Center's "Horizons."

Some argue that before we spend great amount of money to develop space technology that we should look to the oceans for their potential to provide natural resources. After all, with the total surface area of the earth about 500 million square kilometers with over 350 million square kilometers or about 70% of the surface covered by water, isn't it important to fully understand the potential impact of marine technology? In the oceans there are tremendous reserves of minerals that are scarce on the land surface. For example, nodules (balls of metal created from metal ions joining) of high grade ore, such as manganese, nickel, copper and cobalt, lie on the sea bottom and only need to be picked up for refining. However the nodules lie at great depths and require sophisticated marine technology to reach them.

Marine technology, including the study of plant and animal life (Figure 4) is costly. However should we finance such important technology? Should space technology funding be reduced? Should we continue to spend huge amounts on weapons for destruction rather than on technology to improve conditions on earth and also look to the stars?

Politicians, guided by voters, will make the choices. However, to understand the debate and make wise decisions, citizens must be able to read about technical issues and understand the increasingly complex nature of the technological systems that have been described in numerous earlier Resource in Technology chapters.

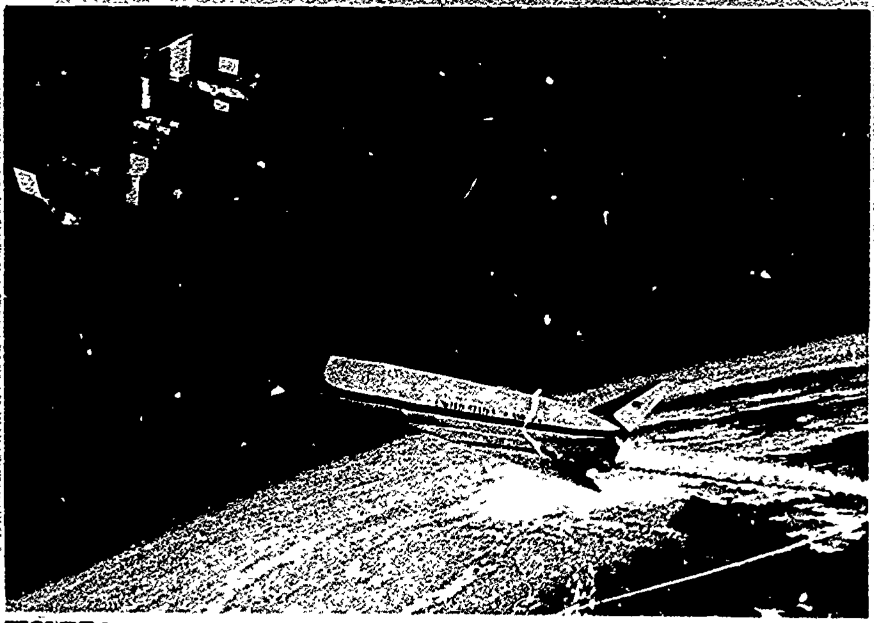


FIGURE 3
The Aerospace Plane (as depicted by an artist) will serve as space launch vehicle and hypersonic cruise vehicle.

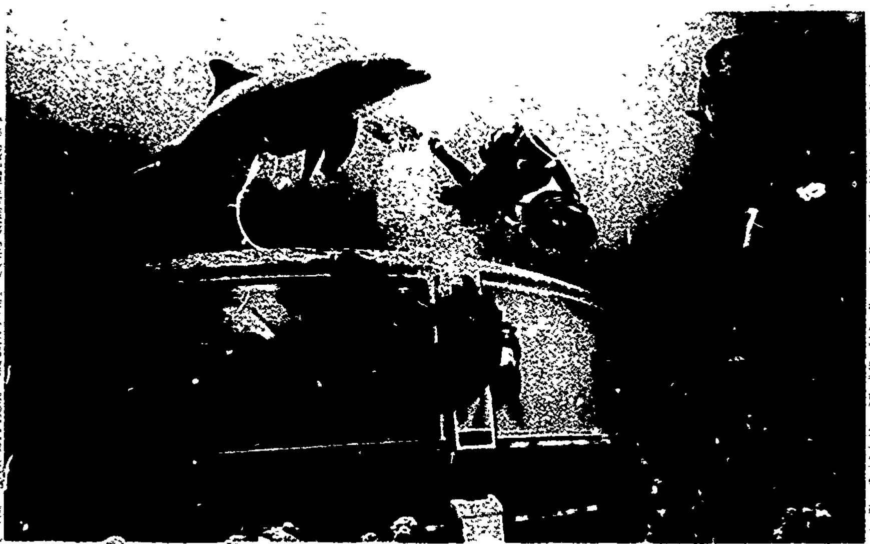


FIGURE 4
The "Living Seas" attraction at Epcot Center allows visitors to observe some 8,000 marine creature and see marine technology in action.

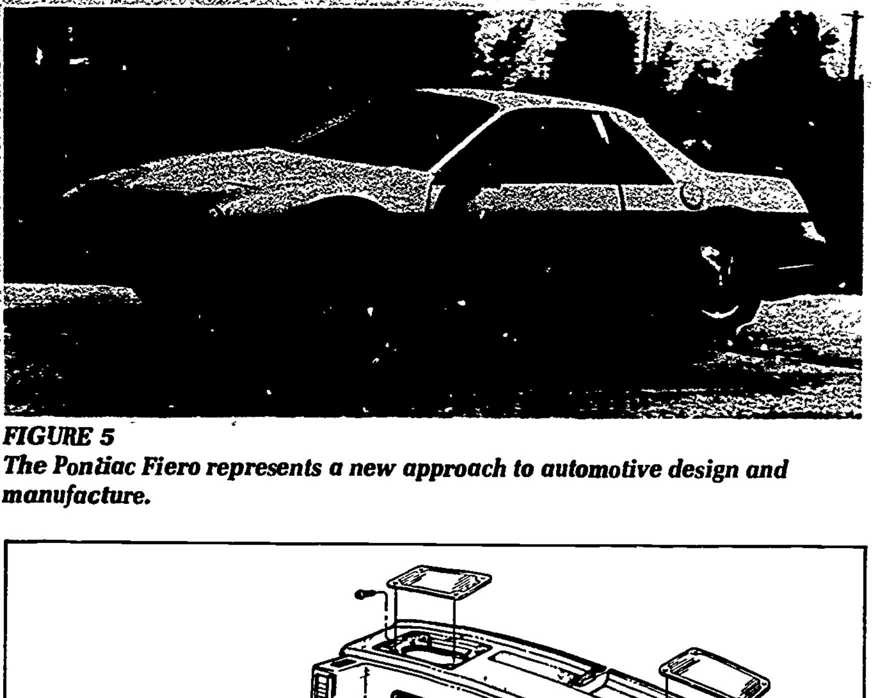


FIGURE 5
The Pontiac Fiero represents a new approach to automotive design and manufacture.

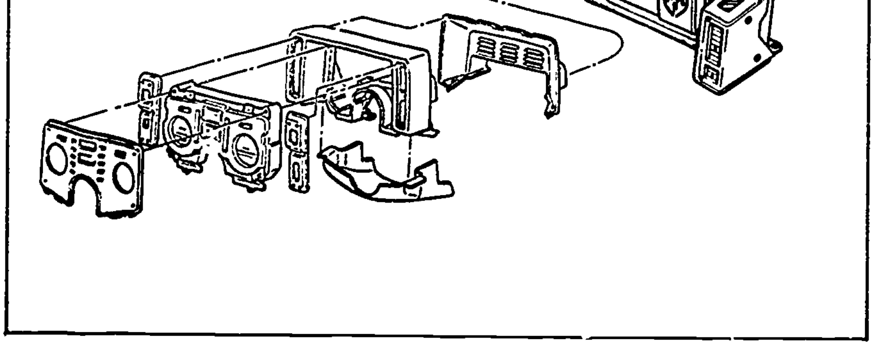


FIGURE 6
Modular units enable improved automated assembly procedures.

Impacts on Careers

The rapid technological change will have profound impacts on the nature of work in the future. All predictions indicate many jobs today that require mostly manual skills will be drastically reduced. Already we see the effects. Factory jobs related to television manufacture have left the United States with all television sets being built in countries such as Taiwan or Mexico where labor costs are low. Many American auto workers have lost their jobs because the Japanese have imported higher quality, lower cost cars. U.S. automakers have begun to design cars differently (Figure 5) so they can be built with less human labor and more automation. A car made with fewer parts (Figure 6) can be assembled by robots instead of humans.

The most unskilled human worker can pick up a screw and drive it into place, but a robot finds that very difficult. Therefore automobiles are being designed with the fewest possible screws, nuts, washers, etc. *Design for Automation* sets up new design guidelines to insure that robots and automated equipment can be best utilized. Already new products such as typewriters, refrigerators, and entertainment devices are reflecting such design changes and many more will come.

What does this mean for jobs and careers?

Information from the U.S Department of Labor's Bureau of Labor and Statistics cited in the *Occupational Outlook Handbook* and its quarterly journal provide in-depth predictions about jobs. Most knowledgeable specialists on jobs and careers see an increase in low paying service jobs such as fast food servers, nursing home aides, or recreation workers—the required educational level to fill these jobs is low, but so are the rewards. Increases are also expected in jobs requiring a sound technical background that couples with certain manual skills such as mechanical engineering technicians and technologists who will pay a major role in manufacturing. On the other hand, assembly line workers will be in less demand. The reason for these job shifts can be understood when one understands the AMRF project of the National Bureau of Standards (NSB).

Figure 7 is a floor plan of the AMRF (Automated Manufacturing Research Facility) which is being used to develop improved methods of manufacturing with machine tools. The AMRF seeks to automate all phases of design and manufacturing with a high degree of flexibility to allow production of small lots of products at a low cost. This concept, known as flexible and integrated manufacturing systems (see Resources in Technology 3), employs many new technologies such as CAD, CAM, robotics, automated materials handling and warehousing, plus many high tech sensing systems using lasers and electronics with sound, pressure, and heat to allow ongoing inspection and monitoring of product quality throughout the manufacturing cycle. Reliable systems of measurement are crucial to automated manufacture of quality products (Figure 8). Note the industrial robots in the AMRF are similar to the one in Figure 9 but not like the personal robots in Figure 10. Robot #5 depicted in the movie "Short Circuit" looks more like the mechanisms being developed to make personal robots that might do household and office building chores.

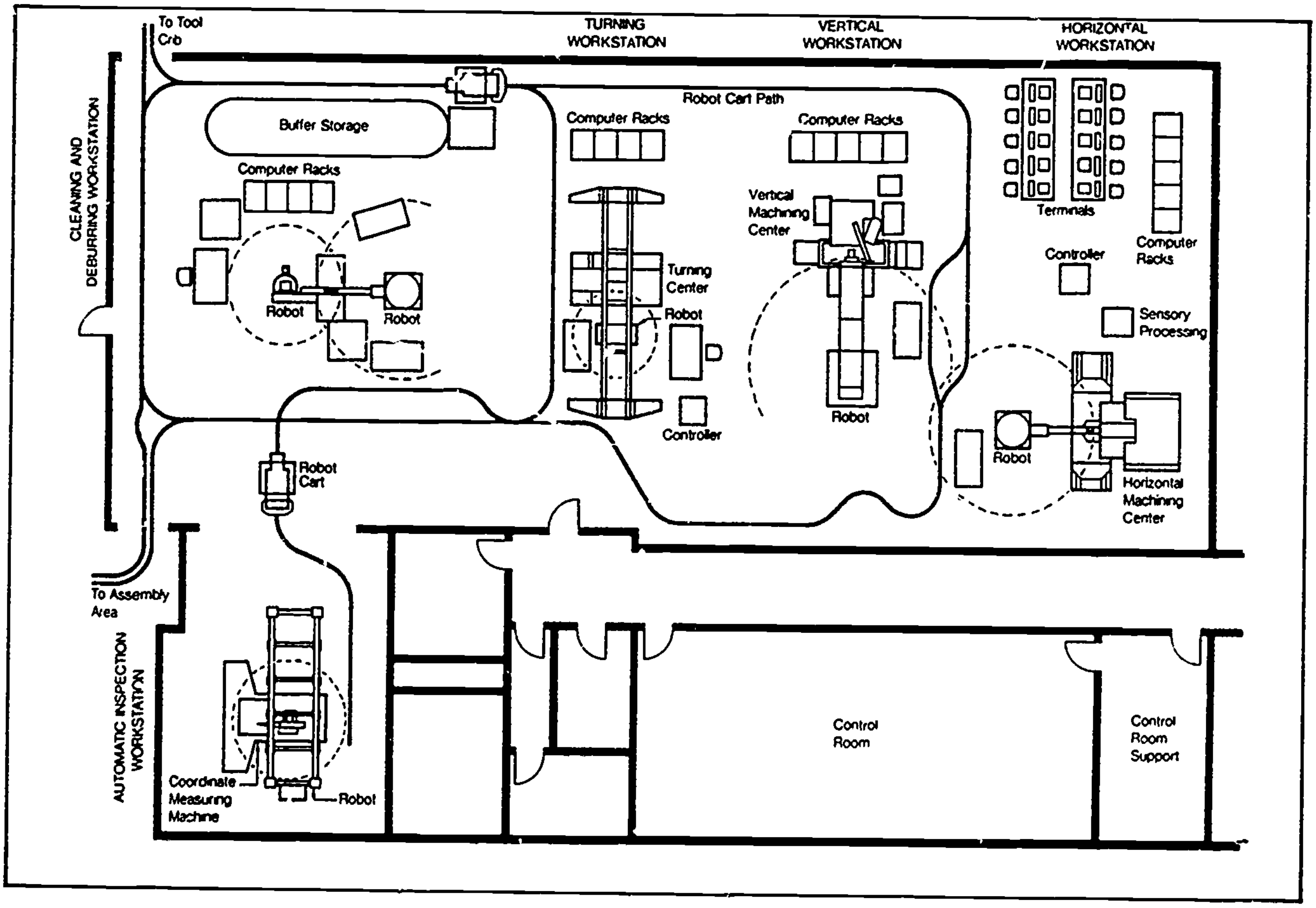
Industrial robots are still very primitive but they can perform dangerous, dull, repetitive jobs with high reliability. Development of personal robots is also in the early stages, but both of these technologies will continue to advance.

The point to understand here is that this nation must move to high tech manufacturing systems that require less use of muscle power and more use of brain power. We must continue to develop new technology for improved products and systems that will insure the United States jobs in manufacturing in order to maintain our standard of living. The future jobs will require people to design, control and maintain automated manufacturing systems, this means fewer jobs in most manufacturing plants, but perhaps more plants for producing more products; and therefore, more jobs. The manufacturing jobs will require sound technical backgrounds, and should be more interesting and rewarding than assembly line jobs. There will also be increased demand for service jobs that employ technically competent individuals who can troubleshoot and maintain systems and products.

Because of the good rewards and greater acceptance of women in technical jobs there will be a broader distribution of women in position traditionally held by men and likewise of men in jobs usually held by women. This should provide for more equality.

FIGURE 7

The NBS's Automated Manufacturing Research Facility is a "test-bed" to experiment with new standards and study new methods of measurement and quality control for automated factories.



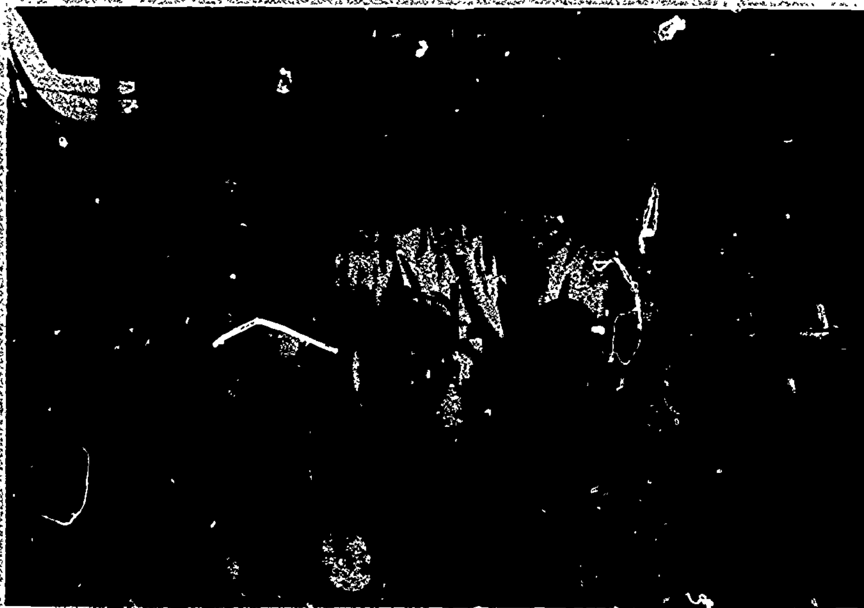


FIGURE 8
Lasers serve as precise tools to measure physical and chemical values in production systems.

FIGURE 9
Industrial robots can do dangerous, dull and repetitive work better than humans. However, complex tasks such as assembly requires smarter robots and products designed for automation.

FIGURE 10
Personal robots are in their infancy, SMRT-1 at Epcot Center was designed to play guessing games by decoding "yes" and "no" answers through a voice recognition box.

Impact of Computers and AI

Computer driven systems have become, for evermore, a major aspect of our way of life (See Resources in Technology" April 1987). The microcomputer (Figure 11) will become even more powerful as certain technologies advance. Biochips, the integrated circuits made of carbon-based, organic molecules will use technology that can be compared to working with the cells within living organisms (see "Micromicromicromicromicro Chips" *Popular Science*, December 1986). Breakthrough in molecular electronics have led to predictions of super-fast computer memories based on biochips. Such chips could give us circuit density 100,000 times that of present day silicon chips, while the organic chips would be thousands of times faster using hundreds of thousands of times less energy for power. Microcomputers will soon account for a majority of the CAD workstations, whereas today, the majority of CAD systems are mini and mainframe computers. Reports of CAD systems slashing off 50% of design time and 33% of product testing time makes such systems very appealing even to the smallest plant or machine shop.

Fifth generation computers with parallel processors, optical computers and laser disk technology are evolving ideas that will increase the power of all computers.

Artificial intelligence (AI) is the technology involving development of computers (hardware) and computer programs (software) that can be used for more human-like problem solving. The central goal is to have computers that learn from experience as humans do, to understand language, and reason for problem solving.

Take, for example, a personal robot that might be purchased to vacuum the rooms in a house. When the robot comes upon obstacles such as walls, trash cans, a desk or other fixed devices, it would store the location of object and the next time be able to quickly move through the building avoiding objects as it vacuumed. Such applications are far away.

The emphasis is now more on expert systems software which will enable engineers, scientists, physicians or other technical workers to solve problems with the aid of computers that are loaded with programs designed to reach conclusions the most efficient way possible.

For the fully automated manufacturing factory to exist it must be a computer integrated manufacturing system (CIMS) and some feel that AI and expert systems must be employed. New program languages of LISP and PROLOG will replace BASIC, FORTRAN COBOL and others so engineers can communicate in plain English to ask questions of the computer for problem-solving such as getting assistance in designing the flow of materials through a production line or interpreting design engineering notes so manufacturing techniques can process the product design.

FIGURE 11
Continual increases in power alone with decreases in the cost of microcomputers will have a tremendous impact on problem-solving abilities for technological systems.

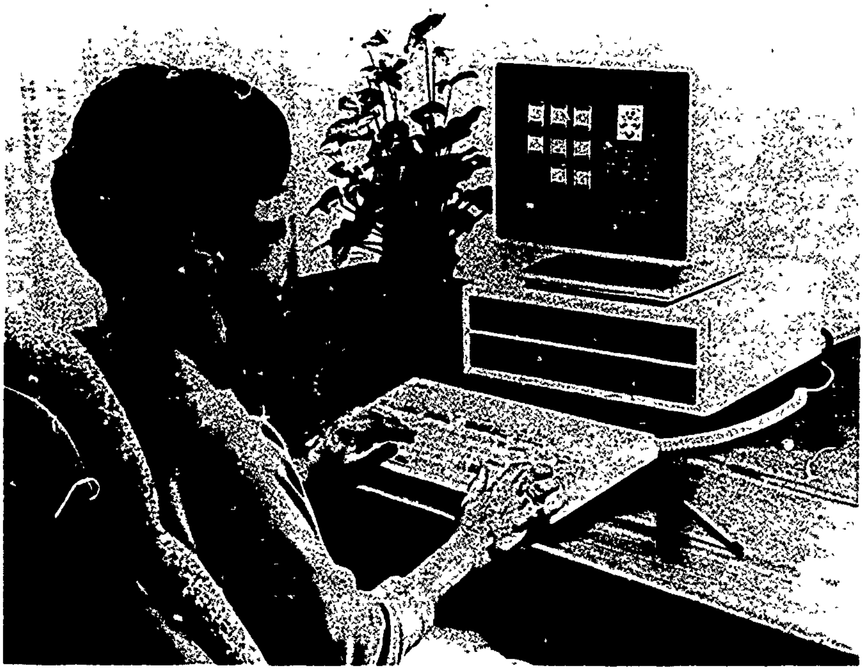


TABLE 1
Positions available to graduates of mechanical design technology—manufacturing technology

Production Line Supervisor	Field Engineer
Robotics Technologist	Computer Programmer
NC Machine Programmer	Mechanical Designer
Manufacturing Engineer	CNC Programer
Metallurgical Technologist	Production Planner
Materials Handling Manager	Test Technologist
Research Assistant	Tool Designer
Plant Layout Designer	Technical Writer
Quality Control Inspector	Cost Estimator
Meteorologist	Methods Analyst
Structural Designer	Piping Designer
Machinery Designer	Systems Analyst
Computer Hardware Designer	Automotive Stylist
Nondestructive Test Inspector	Die Designer
Materials Engineering Technologist	

Your Choices and Decisions

The above discussion provides a look at the impact of emerging technology. You must evaluate the choices that the new technology will present then make decisions on how you wish to plan your life and career so that you can fit into the future in a position tha' desirable to you. Those people who do not recognize the need to carefully plan and keep abreast of new developments may find that the future does not serve them in the manner that they expected.

There are few guarantees about the future, but people who gain a good education in technical fields are assuring their ability to adapt to change. Change is one of the guarantees. Tomorrow will be different from today.

Many new jobs are opening on the technological team because of new technology. For a deeper study into careers in technology, use the "Resources in Technology" module on "Careers in Technology", *The Technology Teacher*, September/October 1985.

Mechanical Design and Manufacturing Engineering

Technology can serve as an example to see how new education programs have developed to meet the need for job preparation for the future. Table 1 is a listing of the types of jobs that one might secure from pursuing a two-year or four-year degree in Mechanical Design and Manufacturing Technology. There are similar opportunities in fields related to construction technology, electronics technology and the medical fields.

Many people, even high school guidance counselors, do not realize that a person interested in working with their hands can go into college programs in which they can earn a B.S. degree and work in the field of mechanical engineering as technologists. Such college programs build on high school experiences like mechanical drawing, manufacturing, or materials and processes technology. They provide the students with the necessary further education in communications, science, mathematics, and other liberal arts studies, but focus on developing technical competency involving use of computers, machine tools, robotics, CAD, measuring instruments, and control systems just to name a few.

When a person has completed a B.S. program like Mechanical Design or Manufacturing Technology, they have a valuable education with many, many options. Their strong technical foundation allows them to continue to learn as technology continues to change. Consider the Walt Disney Epcot attraction, "Journey into Imagination" with its new "Captain EO" 3-D film (Figure 12). All the props, computerized special effects, cameras, recording equipment and even the theater used to show the film required many technical people to put it together. Disney "imagineers" must have a knowledge of electromechanical systems. Some use CAD workstations to design the animated props and characters. Most equipment used in making the film or the attraction is a product of manufacturing systems that employ technicians and technologists with, perhaps, college degrees in Mechanic sign Technology and Manufacturing . ch-nology.

The above example of Epcot provides but one possible case of how Mechanical Design/Manufacturing Technology can give you the type of education necessary to support a small aspect of the entertainment industry. Think about the numerous and wide ranging fields that require similar technical people such as the following industries: computer, automotive, large appliance, nuclear power, furniture, textile, shipbuilding, aerospace, home entertainment equipment and petroleum.

When planning your high school course of studies, it is important to recognize what is required to enter certain careers. Do not let some setbacks stop you from pursuing a path that interests you; there are often several routes that can be followed to the various career fields.

FIGURE 12
Hooter the Green Elephant from the "Captain EO" film at Epcot Center. How many jobs related to just this one attraction required the knowledge and skills of mechanical design and manufacturing technologists.

Instructional Activity

With the information provided above you are in a position to begin exploring career possibilities that interest you. Most libraries have a fairly good selection of reference materials on career planning. Guidance offices also may have books and filmstrips related to various career fields. To organize your exploration of career interest do the following:

- Develop a list of three or so technologist jobs that require a specific type of education, such as those listed above for mechanical design/manufacturing technology.
- Read about the jobs in such reference books as *Occupational Outlook Handbook*. Explore the nature of the work, prediction for employment for these jobs, salary ranges, and type of education necessary to qualify.
- Discuss these interests with guidance counselors, teachers, parents and people in these fields.
- Study college catalogs to see what colleges and universities offer degrees leading to your areas of interest and meet with their representatives when they visit your school.

This approach is a beginning of an organized methodology to career planning. Once you have begun to collect information about a career, you can develop a career path that should lead you into a rewarding career.

Student Quiz

1. Name and describe three technological developments that will greatly impact on humanity and manufacturing in the future.
Laser instruments/weapons, space exploration, marine technology, increased automation, increased power of computers for many activities such as CAD and CIMS, AI and expert systems
2. What is necessary to manage technology so it will have beneficial impacts on humanity?
Intelligent citizens who understand technology in order to insure that wise choices are made regarding new developments.
3. Name the members of the technological team and describe the nature of their work and education.
Technician, craftspeople, scientist, engineer, and technologist—see details in module
4. Name four jobs in mechanical design/manufacturing technology that one could qualify for with a four-year technology degree.
See listing in Table 1

Possible Student Outcomes

- Name at least three dramatic impacts that technology will have on humanity.
- Describe what is required to manage technology so that it properly serves humanity.
- Explain the differences in technicians, engineers, craftspeople, and technologists in terms of the nature of work and education.
- Determine some career choices available because of evolving technology.
- Use resources to study about careers of interest.
- Decide on a career that interests you and develop a plan to lead you into that career.

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Figures 1, 2, 3, 4, 10 and 12 courtesy of Walt Disney World.

Figure 3 courtesy of NASA Langley Research Center.

Figures 5 and 6 courtesy of Pontiac Motors.

Figure 7 courtesy of National Bureau of Standards, Center for Manufacturing Engineering.

Figure 8, 9, and 11 courtesy of AT&T Bell Laboratories.

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