Review

SPRING 1972

OAK RIDGE NATIONAL LABORATORY

A Mood for Change

THE COVER: Discussions among concerned staff members are going on all over the Laboratory, and this issue's lead article is something of a distillate of six months of such give-and-take. Bob Livingston's office of Program Planning and Analysis gives an account of itself, beginning on the opposite page.

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OAK RIDGE NATIONAL LABORATORY

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OAK RIDGE NATIONAL LABORATORY
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A Mood for Change

Program Planning at ORNL

By the PLANNING GROUP

IT'S HARD TO SAY exactly when it all began and perhaps even more difficult to pin down the point in time when the force of the winds of change began to move up the scale from gentle breeze to hurricane. But few at the Laboratory would deny that the storm is now raging; the signs are everywhere evident: changing role of the AEC as new responsibilities in nonnuclear energy and environmental effects are assumed; creation of the Environmental Protection Agency; public debate on national energy policy and technology assessment; reduced federal funds for research and development. At the Laboratory, these external effects have already caused and will continue to bring about major changes in programs, technical staff composition, and staff organization. The Planning Group was created, in part, to assist the Laboratory management in understanding how best to adapt to new demands and opportunities as they arise.

There is no need to dwell on the creation of the Planning Group, since the event is too recent to be of historical interest and too old to be newsworthy. But we must mention Dave Rose, the first and original ORNL long-range planner, who said he felt at times "like a man with a canoe paddle trying to change the course of an ocean liner." His legacy speaks for itself, as we are often reminded when we walk past the NSF-ORNL Environmental Project trailers. When Dave was in charge of the Planning Group, he was the only full-time member of it. Periodically he would invite various people at the Laboratory to join him for a limited period of time and work on one or two specific problems. After Dave returned to MIT the staff of the Planning Group was enlarged to three full-time members, of which two were to be on nominal one-year assignments, and the official name of the group was changed from "Long-Range Planning" to the catch-all "Program Planning and Analysis." With enthusiastic words of encouragement from management, the three of us who are at present involved on a full-time basis joined the Planning Group in the summer of 1971. In the beginning some of us felt like the character in the tired cartoon sitting in front of a clean desk and asking his colleague, "Now that we're organized, what do we do next?" This feeling did not last long, and we soon found ourselves involved in more things than we could handle comfortably.

The Operation

We respond primarily to three motivating forces. The first stems from central management,

Oak Ridge National Laboratory has a long tradition of exploring ways in which science can be put to work to solve society's problems. (See articles by Weinberg and Liverman in the Winter 68 *Review*.) The early days of environmental concern saw the establishment of the ORNL Office of Long-Range Planning, directed by Dave Rose, whose description of the National Environmental Laboratory concept (Spring 70) will also be recalled by *Review* readers. Re-entitled Program Planning and Analysis when its direction was transferred to R. S. Livingston last year, the office has continued in its attempt to define the role of a vast Federal research institution in terms of the ways in which it is able to address the needs of the nation. A small group of young scientists, concerned with the Laboratory's options for direction, expressed a desire last summer to see an article in the *Review* based on their discussions of the subject. After a number of false starts, this article resulted, written principally by Frank Plasil, who wrote the absorbing story of his escape from East Pakistan in the Fall 71 issue. Plasil called upon Livingston and Cal Burwell for assistance, and the three of them have put together an account of how the Planning Group is working, along with some history of its beginnings. Bob Livingston, who received a Ph.D. degree from the University of California for work performed there under E. O. Lawrence, joined the Manhattan Project in 1942, coming to Oak Ridge in 1943. He served as director of the Electronuclear Division from its beginning in 1951 until its absorption into the Physics Division last year. As director of Program Planning, he has chosen to work with a rotating staff of full- and part-time loanees from other Laboratory divisions. Plasil and Burwell are on loan full time for one year from Physics and Reactor Divisions, respectively. Cal Burwell joined the Desalination Project from Los Alamos Scientific Laboratory in 1965. He earned a B.S. degree in chemical engineering at Purdue and a master's degree in nuclear engineering from the University of New Mexico. Frank Plasil, Czechoslovakian-born nuclear chemist, received his undergraduate education at the University of London, his doctorate at Lawrence Radiation Laboratory. The three authors are shown here in one of their frequent planning sessions in Livingston's office in 4500N.

who asked us to look into a variety of problems. These range from planning studies to staff work. The second motivating force originates in the Planning Group itself. All of us have strong feelings about things that should be done and about innovations that should be instituted. The opportunity to work on them is an important fringe benefit of our new jobs. The third motivating force is perhaps the most exciting and also the most rewarding. It consists of the ideas and suggestions from staff members. We realized early in the game that what we needed was easy communication with Laboratory staff at all levels. We set about in a systematic way to create the necessary channels. We met with division directors, with project directors, with small groups from several divisions, and with an ad hoc group of some of the younger ORNL staff members. Our interaction with this ad hoc group is stimulating and productive and forms the theme for this article. Perhaps nowhere in the Laboratory is the mood for change more strongly felt and more forcefully vocalized than by these concerned staff members.

The "Under 35s"

The group was formed at the invitation of the Planning Group, but it quickly acquired a character of its own. The selection of the members was random and arbitrary. The one guiding principle was that the members had to be relatively young, active, and interested in the welfare of the Laboratory. A few prospective members were identified by the Planning Group, and they, in turn, selected the others. It wasn't until a few months after the original group of about a dozen was formed that any effort was made to be "representative," and additional members were added until every research division was included. The group searched for a name but never really solved the problem. "Monday Luncheon Group" is tolerated only because any other title seemed too formal. For a period of time they were known as the "Nothing Now" group. To some, they are still known as the "Young Turks," but this label is undesirable, not only because of its threatening aspect but also because it led some to label an analogous older group the "Old Turkeys."

Some of the adjectives appropriate to early meetings of the group are "spirited," "volatile," "effervescent," "aggressive." A flood of frustrations and bottled-up feelings poured out in unstructured fashion. The group discovered that life was very different from division to division, and notes were compared. Soon the need for information became obvious, and the group, in addition to meeting periodically with us, met separately with several members of management. Patterns emerged, leading to more questions. Why are the policies so different from division to division? Why is change, any change, so difficult to achieve? What (or who) are the roadblocks? Why is communication so inadequate? Why do so many feel like mushrooms? (An old joke: "First they keep us in the dark, then they pour the manure over us, then they 'can' us.") Who in fact runs things? The AEC? Central management? Division directors?

After several sessions an attempt at a systematic approach was made. A list of 53 ideas for innovations and changes at ORNL was drawn up. Suggestions from all sources were discussed and included. The ideas were then rated by the group, and a second list evolved in which the items were ordered according to their score. This exercise does not claim to be either exhaustive or scientific, and many of the ideas on the list were not new and did not originate with the group. It does, however, give some idea of the relative importance attached by the younger staff to the various suggestions, and it provides a framework within which to discuss proposed changes. The subjects of primary concern could be divided into four broad categories: personnel policies, program policies, management style, and communication. We shall consider them one at a time, and the order in which we do so has no significance.

Personnel

The longest list of important items fell into the *personnel policies* category, with emphasis on personnel renewal rather than on personnel benefits. The two suggestions in this category that received highest priority were the proposal to establish a comprehensive sabbatical program, and the suggestion that an in-house educational program be instituted. The first of these suggestions is one of the legacies from the early days of Long-Range Planning, when Sheldon Datz helped to prepare the original proposal on a sabbatical policy. One of our first actions was to follow up this effort. With the Personnel Division we developed a plan for Leaves for Professional Development, and this plan is now under consideration.

Activity on an in-house educational program is meanwhile in high gear. Early this year, both in response to encouragement from central management and because of our own interest in this matter, we started to design an educational plan. The style in which we set about this task illustrates two methods frequently used by the Planning Group. One is to invite full-time participants to join the group for a few months in order to get a specific job done. In this case we borrowed Hal Schmitt from the Physics Division to head up the in-house educational effort. The other method is the use of an advisory committee made up of members from various divisions.

So far, two educational programs are being planned. One involves the full-time participation of a relatively small group of staff members. They will spend on the order of one year learning about environment and ecology problems so that they will be well qualified to apply their own particular talents in these growing fields. The second educational program will involve staff participation on a broad level. Courses will be offered to the staff ranging from highly specialized subjects to curricula that would result in general exposure to a new field.

Two other items are on the list relating to the educational program. One is the suggestion that a program of internal sabbaticals be established; i.e., staff members would join groups at ORNL in fields other than their own so that they could acquire new expertise. The other is the request that internal mobility be enhanced and that reassignments be made attractive. The full-time educational program may be a step toward these objectives. As the plan is now conceived, the participants in the full-time program would spend perhaps half of their time working with groups active in the new field of their choice. This would, in a way, be similar to an internal sabbatical.

Furthermore, since the main goal of the full-time educational program is to prepare individuals for research activity in new and growing fields at ORNL, then it should certainly stimulate mobility and make it attractive. That, at any rate, is the idea.

Another item under *personnel policy* is the need for uniformly applied personnel appraisal and development methods. The Monday Luncheon Group thought that such methods should include periodic discussions between employee and supervisor, reviewing progress and defining goals. Many of the young people felt that they have the right to know what their supervisor thinks of their performance. The Personnel Division is at present working on a personnel evaluation plan with the advice of a committee made up largely of members of ORNL supervisory staff. The committee also includes a member of the Planning Group. It is expected that the appraisal system will have a significant positive impact on the development of Laboratory staff capabilities.

The final two suggestions that can be classed as personnel matters are concerned with the influx of new staff members into the Laboratory. The need for young talent is dramatized by the results of a recent study of about twenty research and development institutions, including all the national laboratories, which showed that ORNL has the highest average staff age. (Bell Telephone Laboratories has the lowest.) The two suggestions are: to strengthen the current Ph.D. recruiting program, and to strengthen postdoctoral programs. As far as Ph.D. recruiting is concerned, this has been an active year. So much follow-up work accumulated from the resultant recruiting trips that the Planning Group persuaded Dan Robbins to spend several months on a full-time basis coordinating the program. Dan is currently on loan to the Planning Group from the Reactor Chemistry Division and works with the Personnel Division on this assignment. Concerning the improvement of postdoctoral programs, not much action has, as yet, taken place. Recently R. D. Birkhoff, from the Health Physics Division, expressed to us his strong belief that ORNL must have a better postdoctoral policy so that we can better compete with universities. He has agreed to help us generate a proposal to strengthen postdoctoral programs.

Lab Directions

The next category of items from the list of priorities is that of *program policies*. During the time that the list of innovations was being drawn up by the young people, we were devoting a considerable amount of thought to program planning. After all, in the eyes of many, a planning group should spend most of its time planning for future research activities and studying ways in which to attract new projects. We discussed the ideas at great length with the Monday Luncheon Group. The three suggestions considered to be the most important were:

— Identify radically new fields of basic research in which ORNL should be involved.

— Make strong efforts to terminate research in nonproductive fields.

— Focus Laboratory activities on an expanded energy program, including nonnuclear energy.

It is hard to argue with such general and obviously desirable goals. The problem is, How can we start to work toward them? One of the major projects of the Planning Group is the formation of a "Basic Physical Sciences Assessment Council" (BAPSAC). The membership of 30 is broadly representative. All research divisions are included, and while most of the members are bench research scientists, a few division directors and associate directors are also included. The first two items above should be covered by the BAPSAC study, but the charge to the council is even broader than that. The final product of BAPSAC should be a report on the present status and on the future of basic physical research at ORNL. We hope that it will include recommendations regarding future directions and regarding possible supporting organizational changes. To be successful, BAPSAC will have to be alive to current budgetary restrictions; its recommendations will have to reflect a realistic appraisal of the funding situation.

With strong encouragement from Alvin Weinberg, the Planning Group is also working on ways the Laboratory might expand its nonnuclear energy research. The motivation for this activity is a recent change in the AEC enabling legislation that now authorizes the Commission to conduct activities for itself or for others that it deems appropriate to the development of energy as broadly defined. ORNL is attempting to find out how seriously the AEC is taking this legislative prodding. We set up an Energy Council to guide the Laboratory's response, and several proposals were recently submitted to the AEC in the field of nonnuclear energy. These included research and development on more efficient turbine power cycles, hydrogen systems, improved materials for high-temperature batteries and cryogenic power transmission cables, improved power station cooling towers and heat rejection systems, and power station siting. Already the AEC has responded by asking the Laboratory to head up a team of experts to outline an approach to the development of synthetic fuels (e.g., hydrogen) to replace dwindling U.S. supplies of oil and natural gas. The AEC has also requested additional funding to conduct research on cooling towers, cryogenic power transmission, and high-temperature batteries. We believe that the Laboratory will receive some degree of financial support in one or more of these areas.

Communication

The next broad category of proposed innovations is that of improved *communications.* The young staff members feel that little opportunity has been available for their opinions to be heard in management circles, and that no mechanism has existed by which management could informally respond to questions from the staff. Two highly valued proposals, periodic staff briefings by management with question and answer period, and an informal monthly newsletter with letters to the editor, have been implemented. Meetings that include a question and answer period are being arranged with the help of Ernie Silver, and members of the Monday Luncheon Group are serving as assistant editors for the Newsletter. Most reactions to these have been positive.

The final item under *communication* is concerned with problems at the divisional level. The suggestion is to require division managements to establish staff feedback channels, such as divisional meetings, in order to discuss division and Laboratory policies. The debate on this subject highlighted a recurring theme: the nonuniformity of management style from division to division. Some divisions do a good job of keeping their staff informed, while others keep their staff, like the mushrooms, in the dark. No systematic effort is at present being made to remedy the situation. The problem is, however, receiving attention, and in response to the new thirst for communication, several divisions have recently held their first staff meeting in several years.

Finally we come to the *management style* category. This is the area where one expects differences of opinion to exist between managers and their staffs. After the list of innovations was rated by the nonmanagement group, we circulated it to central management, division directors, and project directors and asked them to rate the same items. We were delighted to find agreement between the two groups on most items under *personnel policies*, *program directions*, and *communication.* However, the majority of the management group did not react favorably to the three suggestions proposing changes in management methods that were assigned high priority by the young staff group. The first of these was that systematic staff consultation take place before

A questionnaire, asking for evaluation of the following ideas as possible innovations at ORNL, went out to about 50 staff members and to an equal number of Laboratory managers. The response formed the basis for some of the Planning Group's activities.

COMMUNICATION

—Monthly newsletter, informal, with letters to the editor
—Periodic staff briefings by top management with question and answer period
—Include background information on official memoranda
—Publicize the Planning Group as a place to send suggestions
—Require division management to establish staff feedback channels, e.g., divisional meetings to discuss division and laboratory policies
—Place the managers' handbook (book of rules) in the library
—Redefine or change the role of information meetings
—Redefine or change the State of the Laboratory talk
—Improve and/or evaluate the Nuclear Division News
—Improve and/or evaluate the ORNL Annual Report
—Improve and/or evaluate the ORNL Annual Review
—Circulate or make available the Monthly Report of ORNL
—Establish a catalogue of all services and available equipment, and publicize the existence of such a catalogue
—Upgrade catalogue of personnel to include up-to-date list of technical specialties

MANAGEMENT RENEWAL

—Identify individuals with management talent, and expose them to top management problems on a rotating basis
—Systematic staff consultation prior to making management changes at division levels
—Fixed term appointments for division directors
—Provide management training for present division managers
—Establish long range planning groups in most (or all) divisions
—Establish an "ombudsman"
—Strengthen the offices of associate directors

PERSONNEL RENEWAL

—Establish comprehensive sabbatical and exchange programs
—Strengthen postdoctoral programs
—Provide appropriate access to salary information on a uniform basis for all divisions
—Institute comprehensive schemes of periodic individual evaluations and let each individual know where he stands
—Strengthen comprehensive recruiting methods, such as the current Ph.D. recruiting program
—Improve vacation policy
—Improve retirement policy
—Improve savings policy
—Institute internal sabbaticals as an opportunity for retraining
—Develop methods of greater internal mobility. Make reassignments attractive

PROGRAM RENEWAL

—Identify radically new fields of basic research in which ORNL should be involved
—Make strong efforts to terminate research in nonproductive fields
—Redirect basic research toward greater relevance to ORNL missions
—Develop a list of criteria by which to rate basic research at ORNL
—Develop an official statement of primary goals and missions of ORNL
—Focus Laboratory activities on an expanded energy program, including nonnuclear energy

EDUCATION AND INTERACTION WITH OTHER ADMINISTRATIVE UNITS

—Study and evaluate the ORNL-UCND relationship
—Study and evaluate the ORNL-AEC relationship
—Study methods by which the Laboratory could change administratively from an AEC laboratory to a truly National Laboratory
—Study methods by which ties with universities can be strengthened
—Institute more graduate practice schools, such as the MIT practice school
—Find ways to attract more graduate students
—Establish more formal outside users groups, such as the UNISOR group
—Start a massive in-house educational program to reestablish lost skills and to provide new expertise (e.g., Bell Labs system)

OUTSIDE IMAGE

—Require rehearsal talks for ORNL speakers who plan to lecture elsewhere on ORNL programs
—Involve junior staff members in ORNL-Washington interactions
—Provide internships at ORNL for science writers
—Increase efforts to publish in journals which have a general readership
—Study ways to improve communication with nontechnical audiences
—Improve ORNL press-release methods
—Mention AEC in official letterhead and/or delete UCND byline from publications
—Establish a distinguished lecture series

management changes are made at the divisional level. In our opinion, it is hard to argue that consultation is a bad idea, provided that it is made clear that it is only an advisory technique and that decision-making remains in the hands of central management. Perhaps those who did not approve of this item had in mind some kind of an election process, such as is sometimes used when university department heads are appointed. While such popularity contests may not be a good idea, one can imagine that responsible consultation could produce fruitful feedback without any sacrifice of the prerogatives of strong and dynamic management.

The young people felt that division directors should have the benefit of some management training. We are aware of two reasons why this idea was not thought to be good by most of management. One that has been stated seems to be based on the belief that management skill is closer to an aptitude than to a technique or a science. That is, one either has the knack or one does not, and learning more about it will not help much. The other may be that previous attempts at management training may not have been of very high quality, and that it would be difficult to design an adequate program to do the job. We hope some day to come up with one.

The final management question is perhaps the most controversial one. The young staff members believe that appointments of division directors should be on a fixed-term basis. When a new division director is appointed, they think it should be for a finite period of, for example, five years. At the end of that time, the division director could be reappointed for another term, but, at that point, the option would be available to central management to make a change gracefully. We were not surprised that the manager group was not enthusiastic about this plan. Needless to say, the suggestion was intended to apply only to new appointments, and not to present division directors.

We have discussed our activities in the context of the priorities of young staff members. For the sake of completeness, we would like to mention one project we are working on that falls outside this framework. We have been involved in an effort to systematize and establish mechanisms to handle the "work for others," which now constitutes about 20% of the ORNL budget. We participate in a review committee which takes a look at proposals for governmental agencies other than the AEC, and which also considers new ideas presented to them in the form of brief statements, before a lot of work is invested in generating full-fledged proposals. We are currently considering the possibility of organizing small task forces in the Planning Group whose purpose would be, on occasion, to provide in-depth peer review of new proposals, and in some cases to study particular suggestions in the light of possible ORNL involvement. In case of a favorable decision, the task force could then help in preparing the formal proposal and mobilizing the necessary manpower.

There are other projects under consideration, but this article is not intended to be an exhaustive catalogue of our efforts. What we hope is that it has conveyed the flavor of Planning Group activities and the mood for change on which many of our activities are based. We have described our efforts in the framework of our interaction with a specific group primarily for illustrative purposes, which is not to say that all of the ideas discussed here originated in that group. We are continuously on the lookout for new channels of communication with all of the staff. Recently, for example, another advisory group, made up of older staff members than the Monday Luncheon Group, has started to meet. It is our wish to be active and responsive, and to get things done. We need your ideas and your help. Please do not hesitate to volunteer either or both.

AMW COMMENTS

We hear much these days about balancing the risks against the benefits of modern technology. Obviously such calculations must be highly uncertain and subjective. One perhaps should not even speak of "balancing" risks and benefits, as though each can be measured and weighed, and as though some supernatural scale is available for performing the balancing act. The best one can really do is elucidate, rather than quantify, the issues. In the process, one must present all *of the risks and* all *of the benefits: the balance is then struck by the working of political machinery.*

I think the essence of the matter is contained in the word "all." As I look at the hassles that surround our new technologies — SSTs, nuclear reactors, pesticides — it seems to me that at least some of those involved are reluctant to lay all of the cards on the table. The technologists can be accused in some cases of ignoring, or not properly addressing themselves to, the risks; the antitechnologists, of not conceding all of the benefits.

There is an interesting symmetry in the situation. Both benefits and risks can be divided into public and private. To take nuclear power as an example (though the example can be extended to many of the new technologies), the public benefits of nuclear power are cheaper and cleaner electricity for society, the possibility of forestalling Malthusian catastrophe, at least temporarily, through utilization of an infinite and ubiquitous source of energy, the conservation of fossil hydrocarbons for future generations to use in chemical industry, and so on. The private *benefits of nuclear power might include higher profits for the purveyors of reactor systems or for utilities (though so far nuclear power has generally lost rather than made money for those involved with it), or the fulfillment of the aspirations of the technologists whose lives (and livelihoods) center around nuclear energy.*

As for risks, these too can be divided into public and private: public risks would include the routine release of very small amounts of radioactivity, the extremely small, but not zero, possibility of an accident that might harm the public, the danger of transporting and disposing of radioactive wastes, the possibility of clandestine sequestering of fissile material for making bombs. Finally, as for private risks, I would mention the embarrassment and possible financial ruin of any company or institution whose reactor malfunctions so seriously as to harm the public. I believe we have not really thought much about the enormous private problem that really serious malfunction of a reactor would present for those associated with the reactor — the great pressure to shut down all reactors of that type, the huge litigation, the enormous financial burden such a catastrophe would place on the company responsible for the ill-fated device. I say this despite the existence of Price-Anderson insurance, which protects utilities from much direct liability. The main consequence of a serious accident would be a loss of public confidence, and this would shake the nuclear industry to its foundations.

I have used the example of nuclear power, but the general idea applies for most other new technologies. A few months ago I addressed a meeting of agricultural experts. They welcomed me as a brother: the criticisms leveled at nuclear energy resonate strongly with analogous criticism of agricultural chemicals. To the agricultural experts the public benefits far outweigh the public risks; and at least those people with whom I spoke at the meeting were sensitive to the private, personal risk (of lawsuit, of loss of job) that they would suffer if their pesticide were taken off the market because it was too toxic.

Let me return to the present controversy between the technologists and the anti-technologists. The anti-technologists (who nowadays seem to wear the mantle of righteousness) mainly dwell on the public risks and the private benefits of technology. To their way of thinking, nuclear reactors are dangerous to the public, and they are being pushed mainly to benefit those who are personally involved in their development or who profit financially from their operation. The technologist looks at the matter from a symmetrical standpoint: nuclear reactors are a great public boon, and they are being pushed despite the private, personal risk that they impose on those connected with the industry.

The situation can be summarized in a symmetric matrix:

	Benefit	Risk
Private	A	T
Public	T	A

In the matrix, A stands for anti-technologists, T for technologists. A in the box Private Benefit means that the anit-technologists stress the private benefit of a technology; T in the box Public Benefit means that the technologists stress the public benefit of a technology; and so on. As you see, there is a remarkable symmetry in the arguments of the two sides. Perhaps the most neglected box is the one labeled Private Risk: one almost never hears in the heated public discussions of this private risk. It is what accounts for the conservatism of technologists who actually build things. This conservatism is ingrained into engineers because they realize that their own personal futures depend on avoiding the catastrophe that the anti-technologists are so quick to bring to our attention.

I rather like this symmetrical matrix — it's sort of neat, and it helps keep track of all the cards that are supposed to be put on the table. Will every participant in the Great Debate on Technology be required to state his views on each entry in the matrix before he is allowed to participate in the Debate? Obviously not; that's not how politics works. But I intend to use the matrix in future confrontations with anti-technologists, and I hope thereby to cajole or even coerce my anti-technological colleagues to do as much.

Alvin M. Weinberg

Ron Winters, associate professor of physics at Denison University, chose to enter the Great Lakes Colleges program at ORNL in its second year so he could have access to the Laboratory's linear accelerator for a year. Although he came primarily for his own research, he found himself getting thoroughly sold on the program for young people that he writes about here. Winters is a graduate of King College in Bristol and of Virginia Polytech in Blacksburg, where he received the doctorate in physics in 1966. The enthusiasm he evinces here for the Great Lakes students indicates he may give the program another whirl.

Those Great Lakes Kids!

By RON WINTERS

IT HAS ALWAYS BEEN one of the axioms of the liberal arts experience that the ideal learning situation is one of cloistered devolvement from the current sociological and political problems of society. While this axiom has never been realized in practice, there has arisen the somewhat provincial notion that formal education can take place only on the campus.

In the sciences, with the need for coordinating courses with laboratory time as well as other requisite courses, this has implied a regimented approach to learning. Unfortunately, in many people's minds, this academic regimentation came to be identified with the discipline of the so-called "scientific method," an approach apparently devoid of the need for creativity or imagination, but requiring only the application of disciplined logic to "solve" any problem. Such a concept raises doubts that the study of science belongs in a liberal arts curriculum. The first step in the attempt to right this wrong notion about science and scientists was the recognition that communication of the excitement and breadth of research can come from letting the students work in the laboratories with research scientists. That is, the liberal arts colleges must begin to respond to the need for every developing intellect to experience first-hand the unique atmosphere associated with any center of

Wilson Palmer, physics major at Earlham College, learns the working of a target chamber at ORIC from his supervisor, Clyde Fulmer.

Jane Bos, biology major from Hope College in Holland, Michigan, in Robin Wallace's laboratory, studying the effects of progesterone on oocyte maturation.

creativity, whether in the arts or the sciences.

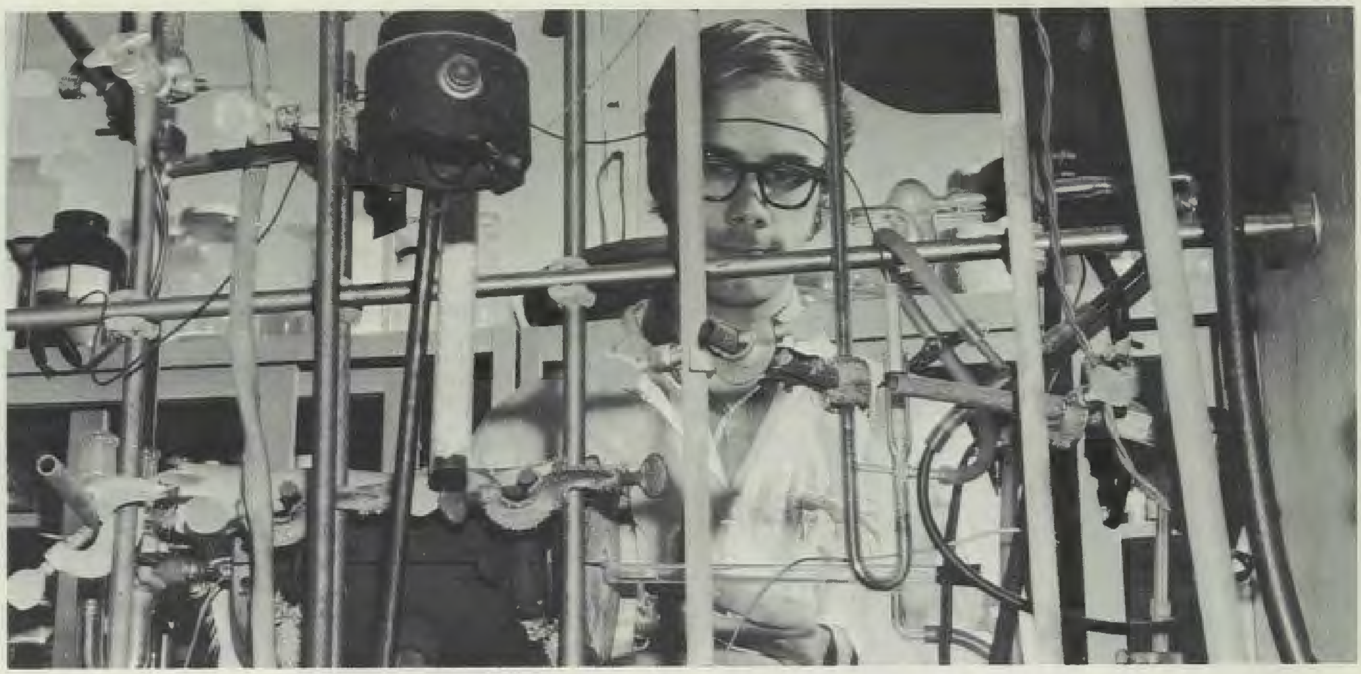
The process of introspection has been particularly intense in the private liberal arts colleges for it is at such schools that the cry for educational relevancy to modern problems contrasts most sharply with the traditional concepts of study of man and his culture. And in our liberal arts colleges, it is the science departments that are bearing a large share of the burden of proof of "relevancy." This candid criticism, by both students and colleagues, may be what has led the science faculty at many schools to take the lead in reshaping their curricula and major-study programs. The departments of physics, chemistry, and biology of the twelve member colleges of the Great Lakes Colleges Association (GLCA) in cooperation with Union Carbide Corporation and ORNL in 1970 started a program which is unique in concept but suggestive of the new ideas being incorporated into the curricula of many of our liberal arts colleges.

This program, the GLCA-ORNL Science Semester, allows selected GLCA students majoring in either physics, biology, or chemistry to spend the fall term of their junior or senior year at ORNL. During this term, the student works a normal laboratory schedule under the supervision of an ORNL scientist. In this way he is exposed to some of the problems and allowed to experience some of the excitement and frustration of research as he learns the science. The first class, 22 strong, demonstrated the success of the program in the fall of 1970. In September of 1971, accordingly, 16 more descended on the Laboratory to begin their Science Semester.

The Program

In addition to working a normal laboratory schedule, the student is enrolled in a general interest seminar held two mornings a week and in an academic course in his major field.

The course also meets twice a week, in the evening, and is taught by faculty members of the GLCA colleges. This past fall, the faculty members resident in Oak Ridge were Dennis Gaswick, professor of chemistry at Albion College; biology professor Al Wohlpart of Kenyon College; and I. I teach physics at Denison University. Our courses were in "Kinetics and Mechanisms of Chemical Reactions" (Gaswick), "Biochemistry" (Wohlpart), and I taught "Nuclear Modeling." These courses



Frank Shirley, DePauw University, is glimpsed through a dry combustion apparatus, with which he is determining the radioactivity of carbon-14 for V. F. Raaen, Chemistry Division.

are designed to help satisfy the major-field requirements for graduation, and to provide formal study in areas encountered in the students' research.

The first two weeks of the seminar are conducted by Larry Akers and the staff of the Special Training Division of ORAU. It is not until after this period of intensive laboratory and lecture introduction to basic laboratory radiological techniques that the student begins work in his research area. This is to prepare the student for his research experience by introducing him to laboratory techniques and equipment which may not have been available on campus. Then the seminar continues throughout the semester as a series of talks given by ORNL scientists. These are intended to present the breadth of the scientific research programs at the laboratory. A few examples of the topics and speakers for this past semester are:

"Reactor Power Sources," Herman Postma

"The Role of ORNL," Alvin Weinberg

"Effects of Reactor Heat on the Environment," Charles Coutant

"Science and Man," Jack Gibbons

The faculty-directed seminar, the courses, and the student research activities are so scheduled as to constitute a full academic program that can accommodate either to semester or quarter academic calendars. Upon completion of a program satisfactory to the resident GLCA faculty at Oak Ridge, the student is awarded a semester (or quarter) of academic credit.

The assignment process is coordinated by Lewis Nelson, director of the Office of Education and University Relations. A staff member from each division, designated as "dean," matches up each student assigned to his division with the appropriate researcher. The extremely favorable response, from both student and supervisor, attests to the acuity and insight the deans bring to the task of assigning these students to their supervisors.

The enthusiasm of the students in the GLCA-ORNL Science Semester Program is a direct result of the time, energy, and personal concern each supervisor has invested in the student and his research. The most serious criticism of the program this year seemed to be that there "is not enough time." This remark came from Tae-Bong Paik, a Korean physics major from Albion College, and the program's only alien, working with Ray Booth. He made the observation at the end of a day which began with a seminar at 8:00 AM and ended with a 90-minute lecture at 9:30 that evening. These and

Ben Fieselmann of Earlham watches a machine smoke a cigarette in Mike Guerin's Analytical Chemistry laboratory.

Andy St. James of Denison works with Jack Harvey on total cross sections with the Oak Ridge Linear Accelerator.

last year's students are offering a strong case for the proposition that today's college students do not wish to drift through school; that, on the contrary, they welcome challenges and the hard work of solving difficult problems. The ORNL research supervisors gave them such challenges.

To show the extent to which students were able to involve themselves in their research projects, I'd like to describe the research of one student selected from each division or project and inject the comments of the research supervisor.

Biology: Wen Kuang Yang, Pete Walburg, and Mike Hanna, who supervised John Metcalf of DePauw, invited John back for the month of January to continue their work on the detection and characterization of the myeloma protein produced by the plasma cell tumor in germ-free mice. Through their combined efforts, John was able to return to the laboratory as a paid consultant on the research project.

> "We are very impressed with John; the research project on which he worked involved three different research laboratories and he proved to be more than capable of coordinating and learning the various ideas and research techniques." (Yang)

Physics: Clyde Fulmer, who supervised Wilson Palmer of Earlham College, has submitted for presentation at the Washington, D.C., meeting of the American Physical Society, a paper discussing the work in helion bombardment of ^{56}Fe in which Wilson participated at the Oak Ridge Isochronous Cyclotron.

> "It was an interesting and satisfying experience working with an undergraduate physics major, particularly one from a liberal arts college. I think Mr. Palmer's experience at ORNL will have a decided effect on his career choice." (Fulmer)

Chemistry: Al Meyer and Del Manning, who supervised John Hammond of Denison University, report that a paper describing their work with John will soon be submitted either to the *Journal of High Temperature Science* or to the *Journal of Electroanalytical Chemistry.*

> "This was the first undergraduate with whom I have worked and I was impressed with his ability to carry out his research. He was a very conscientious and hard worker." (Manning)

Environmental Sciences: Robert Van Hook supervised Sue Steubs of DePauw in a part of a research project designed to estimate the amount of radioactivity man might ingest along with his foods. This project involves study of each step in the food chain from soil to plant to animal to man. Miss Steubs measured the concentration factors of ^{137}Cs, ^{60}Co, ^{125}Sb, and ^{106}Ru. Japanese millet was grown in White Oak Lake bed soil containing these radioisotopes and then fed to herbivorous insects. The ratios of activity in insect to soil and

Dave Ahlgren, from DePauw, uses a mass spectrometer to determine the composition of cuprous chloride·ammonium chloride·carbon monoxide for Larry Landau's isotope separation program in the Chemistry Division.

insect to grass were then determined. These ratios serve to indicate whether at any stage bioaccumulation or biomagnification occurs.

> "Sue did an excellent job, particularly in light of the fact that her undergraduate training was in chemistry, and her work in our group was primarily physiological ecology." (Van Hook)

Instrumentation and Controls: Ray Booth, supervising the work of Tae-Bong Paik, introduced him to the use of the hybrid computer to simulate the concentration of tritium in fish. Tae-Bong was responsible for writing the computer code developing various models of the fish-lake system. This research project is an excellent example of a problem cutting across the bounds of several academic disciplines since one objective of the simulation was to reproduce data acquired by Dr. Jerry Elwood of the Environmental Sciences Division.

Booth indicates that a paper reporting the work with which Tae-Bong was involved will soon be submitted for publication to a journal such as *Health Physics.*

Alice Trickler of Earlham College works with L. H. Smith on tissue cultures for radiation recovery at the cellular level, Biology Division.

The following is a list of students and their research supervisors for the fall 1971:

Student	GLCA College	Supervisor	Division
Dave Ahlgren	DePauw University	Larry Landau	Chemistry
James Allen	Albion College	Bill Sides	I & C
Jane Bos	Hope College	Robin Wallace	Biology
Gordon Bryce	Albion College	Charles Nowlin	I & C
Howard Ducharme	Hope College	Charles Coutant	Ecological Sciences
John Dwyer	DePauw University	C. F. Barnett	Thermonuclear
Ben Fieselmann	Earlham College	Mike Guerin	Analytical Chemistry
John Hammond	Denison University	Al Meyer	Analytical Chemistry
John Metcalf	DePauw University	W. K. Yang	Biology
George Neumann	Earlham College	Charles Scott	MAN
Tae-Bong Paik	Albion College	Ray Booth	I & C
Wilson Palmer	Earlham College	Clyde Fulmer	Physics
Andy St. James	Denison University	J. A. Harvey	Physics
Frank Shirley	DePauw University	V. F. Raaen	Chemistry
Sue Steubs	DePauw University	Robert Van Hook	Ecological Sciences
Alice Trickler	Earlham College	C. C Congdon	Biology

> "His cheerful and enthusiastic approach made it a pleasure to work with Tae. His interest and insights led to challenging and productive discussions." (Booth)

MAN Program: Charles D. Scott and John Mrochek supervised the work of George Neumann of Earlham College. George's work was primarily directed toward the isolation, purification, and identification of certain biochemical compounds in body fluids. The ultimate goal of this work is to establish biochemical indicators of diseased states or abnormal body functions, such as schizophrenia, cancer, and inborn metabolic disorders.

> "I am an enthusiastic advocate of getting undergraduates involved in *real* problems early in their academic careers rather than isolating the student from those real problems. The work that George did here indicates that students will work enthusiastically on difficult problems as long as the problems seem important." (Scott)

Thermonuclear: C. F. Barnett supervised the work of John Dwyer of DePauw University. John was involved in the development of an energy-sensitive neutron detector necessary to the ORMAK project. Barnett has invited John to return to ORNL this summer to continue work on the project.

> "John was an outstanding college student and should become an outstanding physicist. The GLCA program is great. It benefits both the Laboratory and the students." (Barnett)

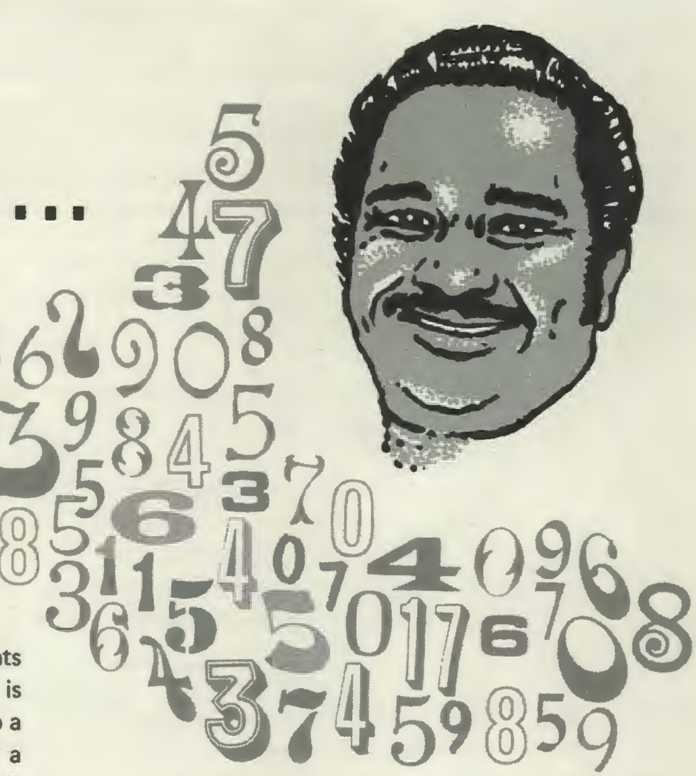
These remarks are typical of the Laboratory's response to the GLCA students. Everyone has seemed more than willing to spend time and energy on the program.

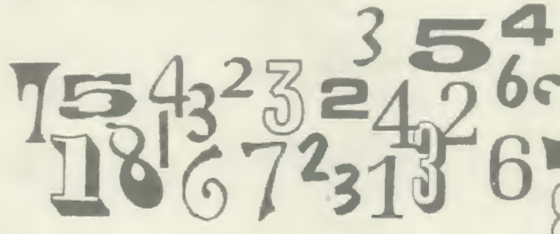
As for the students, the worth of the program to them went beyond the research or classroom activities. It is hard to put a value on the experience of discussing with Physics Division Director Joe Fowler the role of imagination in science, after listening to him speculate on the phenomena one might expect if nuclei were doughnut shaped; or to gauge the impact of the discussion the students had with ORNL Director Weinberg about the role he envisions this Laboratory playing in our society's future.

Learning must in part be dialogue between intellects that have contemplated like and unlike notions. Such exchanges of thought took place at ORNL last fall. These were important steps for the students toward intellectual liberation, which of course is the essence of a liberal arts education.

Take A Number.....

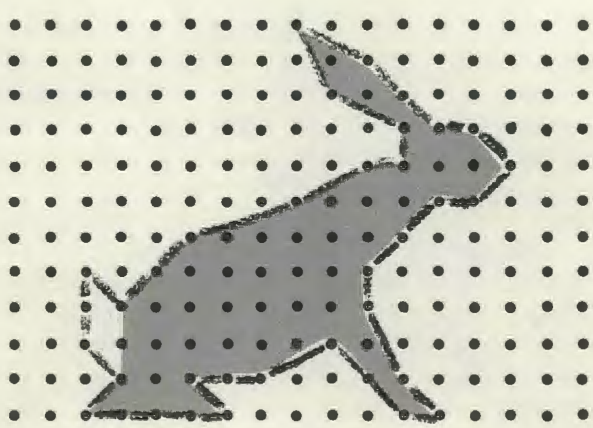
BY V. R. R. UPPULURI





Lattice Points and Polygonal Area

By lattice points in the plane one means the points with integral coefficients. By a simple polygon is meant a polygon that is topologically equivalent to a circle. It is interesting to note that the area of a simple polygon whose vertices are lattice points is equal to the number of interior lattice points plus half the number of lattice points on the boundary minus one.



For instance the area of the simple polygon drawn in the figure is equal to $31 + (36/2) - 1 = 48$ square units. What can one say about the corresponding result in three dimensions?

Divisibility by 11

It is well known that an integer is divisible by 3 if and only if the sum of all the digits in the integer is divisible by 3. For instance, 1493 is not divisible by 3 since $1 + 4 + 9 + 3 = 17$ is not divisible by 3. Along the same lines one can decide whether an integer is divisible by 11 or not by adding the digits in the odd and even locations. Let S_o denote the total of the digits in odd locations and S_e denote the total of the digits in the even locations. If $10S_o + S_e$ is divisible by 11, then the given integer is divisible by 11. For instance: (*a*) Take 1342. $S_o = 5$, $S_e = 5$, and $10S_o + S_e = 55$ is divisible by 11, and hence 1342 is divisible by 11. (*b*) Take 902. $S_o = 11$, $S_e = 0$, and $10S_o + S_e = 110$ is divisible by 11, and hence 902 is divisible by 11. (*c*) Take 11111. $S_o = 3$, $S_e = 2$, and $10S_o + S_e = 32$ is *not* divisible by 11, and hence 11111 is not divisible by 11. We also note that the given number is divisible by 11 even if $S_o + 10S_e$ is divisible by 11. So in the rule of thumb it does not matter even if one forgets whether 10 multiplies the sum of the digits in the even or odd locations.

BOOKS

By ERIC HIRST

World Dynamics, by Jay W. Forrester, Wright-Allen Press, Inc., Cambridge, Mass., 1971. 142 pages, $9.75.

HOW WILL WE AVERT what, to many, appears to be the inevitable crisis as the world's population rises rapidly to an intolerable level? At what point will various forces — pollution, lack of food, overcrowding, depletion of natural resources — cause a catastrophic decline in population? Can this Malthusian crisis be averted with massive birth-control programs? Or can modern technology and increased capital expenditures combine to increase the world's food supply and raise material standards of living? Perhaps a drastic reduction in the rate of pollution generation would be sufficient to avoid disaster.

Jay Forrester provides an interesting approach to the questions posed above, a simple computer program which solves a system of 45 equations. The solution provides several variables as a function of time, given from the year 1900 to 2100 in this book. The important point is that all the equations are connected to, and dependent on, each other. Mathematicians call such systems "coupled"; engineers say that such systems exhibit "multiple feedback loops." Perhaps the best description of the equations in this world model is that everything is connected to everything else. For example, material standard of living is represented in the model as a function of capital investment, which in turn depends on the usage rate of natural resources, the fraction of natural resources remaining, the fraction of capital devoted to food production, the birth and death rates, and so on. Carried to its logical extension, each variable can be seen to depend on every other variable.

This world model is built around five basic factors, or variables: population, capital investment, natural resources, pollution, and the fraction of capital devoted to agriculture. Within the computer model, the 45 equations evaluate numerous secondary variables, which in turn determine the state, or level, of these five primary variables as functions of time.

Quality of life is perhaps the most important secondary variable in this system since it is used as a measure of the performance of the world system. It is derived from other variables representing material standard of living, crowding, food supply, and pollution. These variables in turn depend on each other and a host of other secondary variables.

Forrester uses his model to develop various scenarios for the world's future. These mathematical projections suggest several interesting features concerning the dynamics of the world system. A continuation of current trends might so deplete the supply of natural resources that population would decline markedly in about fifty years. Attempts to reduce the rate of use of natural resources would allow population and capital investment to grow until a pollution crisis begins in 2030. This increase in pollution kills 75% of the world population within 20 years. If the effects of both resource depletion and pollution are removed from the system, world population is ultimately stabilized at almost 10 billion in 2200 by crowding. If the effects of crowding are also removed from the system, then the Malthusian spectre of food shortage ultimately halts population growth by about 2300.

These computer projections show that the dynamic behavior of complex social systems is often counter-intuitive in that solutions which are effective in the short run may have unsuspected adverse long-term effects. Thus, "an attempt to relieve one set of symptoms may only create a new mode of behavior that also has unpleasant consequences."

How then can we avoid these world problems? Or is mankind doomed to certain catastrophe? According to the world model, a combination of various policies (each of which alone won't work) may avert a population disaster and maintain an adequate quality of life. One suggestion involves *simultaneous* controls in natural resources usage rate, pollution generation, capital investment, food production, and birthrate. The results of these combined policies are a slight drop in world population relative to 1970 and a slight improvement in the quality of life.

Just how believable is the world model, and the solutions it offers? First, the model formulated in this book is far too aggregative to be really useful. No distinction is made between underdeveloped countries and industrialized nations. Also, Forrester does not use real world data — facts and numbers — in deriving his model. Each of the components in the model is intuitive and very approximate: what Forrester and his colleagues thought reasonable. I confess that, in most cases, I found his logic compelling. But we could both be wrong. After all, we both live in the most affluent country in the world, and work in academic-research environments. Data exist that could have been used in formulating and evaluating the components of the world model. The failure to use such data constitutes, for me, the most serious weakness of Forrester's world model.

Several assumptions within the components are rather dubious. Understanding these assumptions is crucially important because the computer results depend entirely on these assumptions. Therefore, conclusions based on this world model must be carefully interpreted in light of these assumptions.

As an example, consider the relationship between pollution and capital investment. According to the world model, pollution increases as capital investment grows. Forrester points out that this is incorrect if "high levels of capital investment imply capital devoted to pollution control," but no attempt is made to modify the simple pollution/capital-investment submodel used.

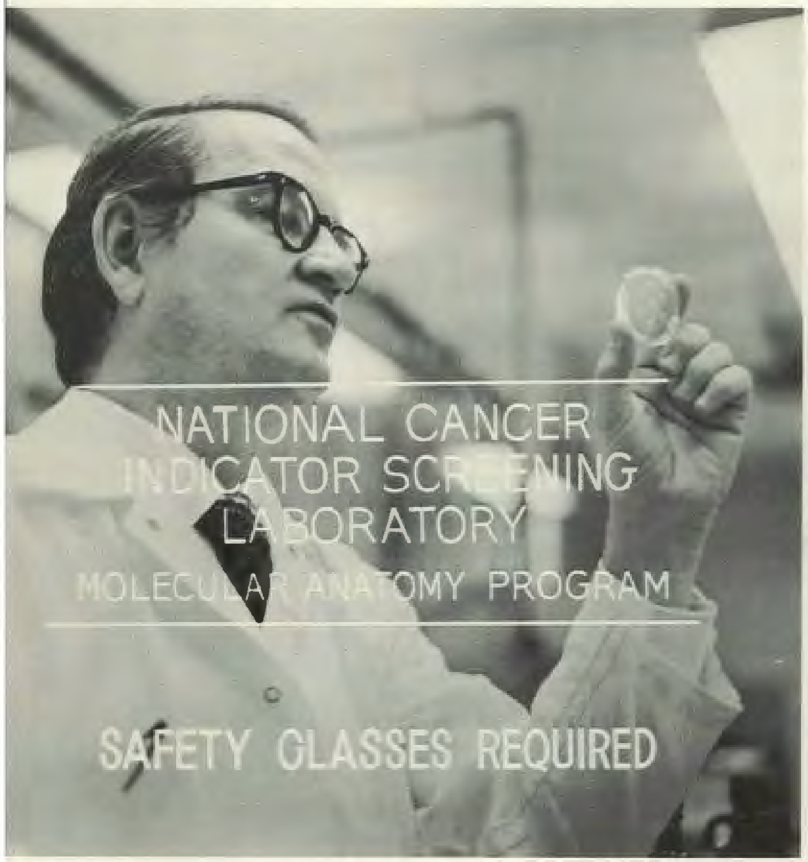
Why is this so important? After all, the pollution/capital-investment relationship is only one of many within this model. Later in the book, Forrester shows how the world system might respond to increased capital investment. According to his model, a 20% increase in the rate of capital investment in 1970 precipitates an enormous pollution crisis by 2040. This increase in pollution causes population to decline from more than 5 billion in 2010 to 1 billion in 2060.

Would this really happen if capital investment were increased? The answer depends on how that capital is used. Devoted to pollution control equipment, it would probably cause pollution levels to decline, rather than rise as predicted by the model, and the pollution crisis would be averted.

Consider another example of the relationship between system assumptions and system results. Forrester's model predicts a pollution catastrophe if the usage rate of natural resources is cut and no other measures are taken. This seems unlikely if a reduction in resource usage implies a more efficient use of natural resources, such as by recycling. However, the world model cannot respond in any other manner, since it only relates pollution generation to population and capital investment, but not to the usage rate of natural resources.

Because of these shortcomings, which are freely admitted by Forrester, the world model cannot be used as a policy tool. In fact, uncritical acceptance of the computer results without a thorough understanding of the model's details is potentially dangerous. On the other hand, the world model is a bold, imaginative, and very useful piece of research. While the model suggested in World Dynamics is incomplete, it provides a valuable framework on which to build more accurate and detailed models of the world. Such work is progressing at MIT under Dennis Meadows, a colleague of Forrester's.

But don't wait for Meadows's model; world models will, it is hoped, always be under development. Read Forrester's book, study his model and the underlying assumptions, look at his computer projections in the light of these assumptions, and try to understand the ways in which various public policies might affect the long-term well-being of mankind.



Norman G. Anderson may be pardoned if he looks upon himself as the Vesalius of the living cell. As creator of ORNL's MAN (for Molecular ANatomy) Program, he cherishes the ultimate goal of complete analysis of the human cell. He hopes to attain this with the biochemical and biophysical tools he has developed for dissecting and studying the cell's components. Both are in use in clinics and laboratories, performing high-resolution analyses and separations at the macromolecular level. One result is Zonimmune, a new influenza vaccine so free of impurities that it can be administered to anyone without fear of side effects. The GeMSAEC, a fast analyzer, is capable of providing simultaneous analysis of up to 90 samples of biological material, complete with on-line computer data reduction. It is this machine, as well as several new analytical systems, that Anderson uses in the fetal antigen studies discussed here. Anderson has been at ORNL ever since he received his Ph.D. in cell physiology at Duke University in 1952. He has gained international renown with his ingenious inventions, and has recently returned from Munich, where, as 1972 recipient of the German Institute of Clinical Chemistry's Biochemical Analysis Prize, he delivered the address at the Institute's annual meeting. He spoke about the GeMSAEC fast analyzer systems.

Screening for Cancer

By NORMAN ANDERSON

SO MANY TESTS for cancer and cures have been proposed in the past that it is almost a reflex to discount new ones. In many cases such tests claim to detect nearly all cancers at an early stage; the result is a widespread belief that a test is not useful unless it lives up to such claims. Not a small fraction of the effort of the National Cancer Institute has gone into the investigation of these tests, which in most instances have turned out to have limited use or none at all.

Recently, however, a new view has appeared, based in part on the assumption that there might never be a single successful early cancer detection test and that instead a carefully constructed battery of tests should be devised which would be evaluated statistically in a large-scale study and would be continually revised and enlarged on the basis of experience. The battery of tests would be run in large regional laboratories on samples submitted by private physicians, schools, employers, or other organizations. As will be shown, there is no doubt that this would contribute significantly to the detection of cancer and is probably the most worthwhile immediate-action program that could be instituted under the proposed new increase in the national cancer effort.

Cathy McDowell loads serum samples into a ring that will be used in the GeMSAEC.

Why are we so optimistic about the development of significant new tests? Recently tests have been developed that have extremely low or zero rates of false positives, although they are positive in only a few types of cancer. These tests now fall in a pattern that suggests more will be discovered. Cancer is, in its detailed biochemistry, a multiplicity of diseases, and even tumors of one organ that are microscopically very similar may be biochemically quite different. This realization underlies the belief that a battery of tests will be required and that the development of such a battery will need not only continual development of new tests, but sophisticated automation and computerization as well. These can only be developed in close collaboration with a regional or national screening laboratory where very large numbers of samples are handled daily and where large numbers of frozen samples from known sources are available for comparison. In many instances the tests will be for a class of substances ordinarily found only in the earliest stages of human development but which may reappear in cancer.

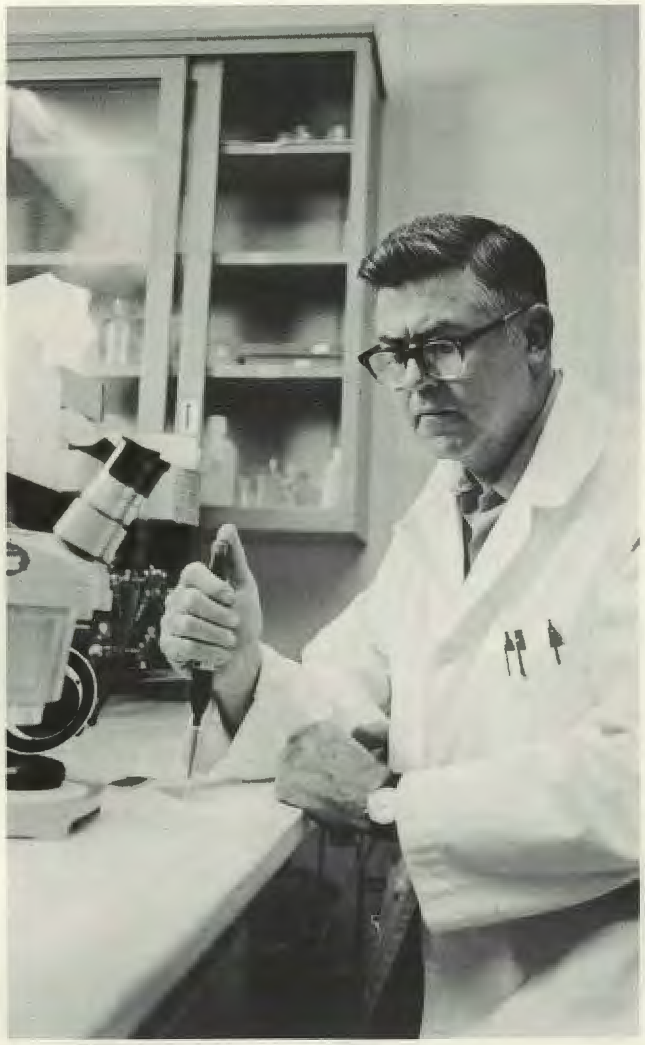
Embryonic and Fetal Antigens

New macromolecules, not present in the tissue of origin, are often found in cancer cells. One of the basic problems has been to discover the origin of these distinguishing molecules. Three major sources have been proposed.

The first is that they are the products of mutations, which in turn may be due to radiation or mutagenic chemicals. The test of this concept is the presence of amino acid substitutions in normal cell proteins such as have been demonstrated in hemoglobin, for example. So far this test has not been made.

Tom Tiffany places the transfer disk that Cathy has loaded into the Fast Analyzer for actual analysis of the enzyme activity.

Jim Attrill applies test sera and antibody to a special plate designed to identify specific antigens that might be present in serum. The technique, developed by and named for Ouchterlony, offers a simple, direct screening method for large-scale operation.



The second suggested source is virus infection, which brings new genetic information into a cell and may result in the production of a new gene product in the form of a new protein. An enormous amount of work has been done on oncogenic or cancer-producing viruses, and a tentative conclusion may now be drawn. There is almost no epidemiological data supporting the view that cancer is due to an infection agent. A few localized cases, or "clusters," have been observed, but many if not most of these can be explained on purely statistical grounds. Most of the experimental work has been on highly inbred strains of animals and does not apply to "wild" or outbred populations, which include men. This is not to say that the contributions of virology may not be important in the future but rather to point out that not a single classification, diagnosis, or treatment of a human cancer patient has been changed or improved thus far as a result of virological approach to the problem; nor has any cancer been prevented.

A third source of "new" proteins in cancer cells is the reexpression of proteins which normally occur at some other time or place in the organism. To see how this could occur and what is implied, it is necessary to review briefly certain aspects of human development. Each of the billions of nucleated human cells contains, as far as can be discovered, the same set of information in the form of 46 chromosomes. Each chromosome in turn carries a large number of genes. When a human egg is fertilized, a very rigid schedule or program of selective gene expression starts, which is different for different cell lines. Thus the very early embryo may contain cells which look alike microscopically but will give rise to quite different tissues and organs. The end result will be, of course, fully differentiated adult cells. However, many intermediate cell types will occur during embryogenesis; these will form the growing and changing structures of early life. In the embryo an enormous amount of activity occurs, with cells very rapidly dividing, migrating to new sites, changing character on contact with other differentiating cells, and gradually forming the most complex system yet found in the universe. The nervous system, more intricate than any computer, wires itself with precision. The optic nerves grow from the developing eye back into the brain and attach themselves in the proper projection areas as precisely as if done by a machine. The wondrous thing about all this is that many of the organs, such as the heart, function during all but the very earliest stages of development. Blood is being pumped as the chambers and valves form — there is no "downtime" for modification.

All this is done by the mediation of macromolecular synthesis, and we know of no other way in which the genes can schedule human development except by starting or stopping the synthesis of new nucleic acids, proteins, or polysaccharides.

Even the most casual reflection will suggest that tens of thousands of different molecular species having special catalytic properties or combining to form unique structures must exist to account for what we observe. Nowhere does so much remain to be learned.

A *very* large number of different proteins are thus made transiently during development. Studying these has been extremely difficult because early embryos are very small, the phase- or stage-specific substances may be present in only small amounts, and it is difficult to develop assays for their activity. Many of these substances have to do with rapid cell division and with the dissociation, movement, and reassociation of cells. It is evident that the normal cell genome contains all the information necessary to make a very wide spectrum of different cells. *It is also evident that if normal proteins mediating properties of different cells were brought together in an abnormal array, a malignant cell might result.* The differentiation mechanism apparently has certain built-in selection rules forbidding the coexistence of certain sets of proteins. Should the mechanism break down, forbidden groupings could occur. These ideas form the basis for the theory that the so-called "tumor-specific" antigens or enzymes may actually be normal at some other time and place in development.

The literature of pathology contains many references to the morphological similarity between embryonic and cancer cells. Until relatively recently, however, the search for similarities was not extended to the embryonic level. Several lines of evidence suggest that the pathways of differentiation leading to adult cells are partly reversible and, in fact, that such dedifferentiation is preprogrammed as a response to injury. When a wound occurs, for example, many previously quiescent cells will begin to divide and to move to new positions. When the repair is finished, the more quiescent state of full differentiation is again reached. When injury is continued, however, producing what the cancer pamphlets call the "sore that does not heal," some of the dedifferentiated cells may regress further; should errors in the differentiation program occur, they may become fixed in a dedifferentiated state. If division and growth continue, more errors may accumulate, yielding some aberrant cells which grow even faster. Selection thus favors malignancy. We must now ask the question, do we indeed find embryonic or otherwise normal but misprogrammed proteins in human cancer tissue or in the plasma of cancer patients?

Abelev, working in Moscow, discovered in 1963 that mice bearing primary cancer of the liver have an embryo-specific globulin or alpha fetoprotein (AFP) in their serum. Another Russian worker, Tatarinov, showed in 1966 that a similar protein was also found in the serum of adult humans with primary hepatomas. This work has now been extended and confirmed by many laboratories, with the following conclusions:

— AFP is absent when a liver cancer has originated in a different tissue, i.e., metastasized to the liver.

— The percent of proven cases of primary liver cancer showing AFP varies with geography and ethnic background from approximately 40 to 70%. The occurrence of AFP is an "all or none" phenomenon; it is either there or not. This strongly suggests that two types of liver cancer are being distinguished — a view supported by differences in prognosis between AFP-positive and AFP-negative liver cancer patients.

— AFP is found in embryonal cell carcinoma of the testis, where a reversion to an embryonic cell type also occurs.

— AFP normally is found in the unborn child but disappears before or shortly after birth.

— False positives are not a problem.

A second embryonic antigen was discovered in human cancer of the colon by Gold and associates in Toronto in 1965. Again a high proportion (70%) of the patients, but not all, with proven cancer of the colon show the antigen in their serum. However, among those that do, successful surgery leads to a rapid drop in circulating antigen level, whereas incomplete tumor removal and a bad prognosis are indicated by continued presence of the antigen. At the 1971 Conference and Workshop on Embryonic and Fetal Antigens in Cancer, held at ORNL, evidence for other embryonic antigens in human cancer including leukemia were presented, giving great promise that many additional tests can and will be developed.

In embryonic development there are many instances where contact between cells of different origin produces differentiation along a new line. A form (or isozyme) of alkaline phosphatase peculiar to the placenta has been found to occur in several types of cancer, most frequently after metastases have occurred to the liver or bone. In a series of

590 cancer patients studied by Stolbach and associates, 27 were positive, and all of these had metastases. There were no false positives in 50 normal sera.

There are other serological tests useful in cancer diagnosis, of which I will mention only two. The first detects multiple myeloma, a form of human cancer resulting in an elevated gamma globulin. Its discovery is often one of the most totally unexpected findings in serum analysis. Here the substance tested for is not a fetal or embryonic antigen but a presumably normal protein or protein constituent present in an abnormal amount.

All of the tests thus far mentioned are for high-molecular-weight proteins or glycoproteins. In some cancers abnormal amounts of particular low-molecular-weight compounds occur. An example of this is the excretion of vanilmandelic acid (VMA) by patients with pheochromocytoma, a cancer of the adrenal medulla. VMA, along with a host of other interesting compounds, is found in the urine chromatographs described by Chuck Scott in the Fall 1969 issue of the *Review*.

Cancer Screening

A number of tests now exist which, while individually of restricted usefulness, may be very useful as a group. Since there is every indication that new tests will be found, the group of tests may be expected to be gradually enlarged. Development and evaluation are best done as part of an ongoing program rather than as a series of separate small studies. Naturally, positive results from such screening must be combined with other tests and examinations to determine whether a cancer has indeed been found.

Genetic Screening

Once a screening laboratory has been established, there are many things it can screen for besides cancer. Methods for discovering serum, red cell, or white cell mutant proteins have been worked out in considerable detail; these not only disclose individuals bearing the mutations, but also, widely applied, can serve as an indicator of the natural or background mutation rate in man. With data available on a continuing basis, changes in the rate due to radiation, environmental chemicals, or average age of parents when a child is born might be determined. To do all this, however, requires precision analysis of very large numbers of samples at low cost.

Problems in Automation

In the MAN Program and in other parts of ORNL, including the Analytical Chemistry Division, extensive effort has been put into development of methods of biochemical analysis. Much of this work is aimed directly at attempting to solve some of the problems of the clinical laboratory; it has led to the development of devices such as the GeMSAEC Fast Analyzer, which is largely adapted to measurements of enzyme activities and the amounts of relatively low-molecular-weight compounds. Most of the tests we expect to include in a cancer screen will be based on immunological reactions, many of which are difficult to automate.

At present several approaches are being explored in some detail. These include isopycnometric techniques utilizing very tiny polystyrene beads that have the interesting property of adsorbing antibody molecules from solution and holding them very tightly on the bead surface. This thin film of protein has sufficient mass to change the bead density appreciably, and it will now be found to come to rest at a different level when centrifuged at high speed in a sucrose gradient. Each bead adsorbs about 600 antibody molecules from solution, but the adsorption of less than a tenth of that amount may be accurately measured. If the antigen which combines with the antibodies on the beads is now added, an additional layer is formed on the beads, and they "band" further down the gradient. The antigens used may be protein molecules or viruses, and the amount of material attached to each bead ranges from 10^{-12} to 10^{-16} gram. This method, originated at ORNL, holds promise of solving many difficult problems of antigen detection.

Other techniques are also being explored, including laser excitation of fluorescent antibodies attached to tumor cells, the use of fluorescence depolarization to detect antigen-antibody reactions, and adaptations of the GeMSAEC Fast Analyzer to radioimmunoassays.

It is quite evident that new concepts are emerging which, when combined with new technology, can yield measurable benefits to all of us. However this work is all of one piece, and the whole enterprise is in jeopardy if it does not relate to basic studies on the one hand and identifiable patients on the other. The organization of an experimental screening laboratory as part of the MAN Program fills a vital gap between research and development and the ultimate user of the results.

Frank Bruce, ORNL's associate director for administration, has been with the Laboratory since 1943, shortly after he graduated from Tufts University. Before his assignment to the Director's staff, he was a member of the Chemical Technology Division, specializing in waste disposal and the processing of irradiated fuels. In 1960 he became director of safety and radiation control for the Laboratory, and the following year was named assistant deputy director as well. He has held his present position since 1970, with additional responsibilities for the Personnel Division, Applied Health Physics, the Information Division, and the Industrial Cooperation Program. To him has fallen the task of maintaining the lines of communication between the Laboratory and the city of Oak Ridge: in ORNL's response to the United Fund drive, in the Chamber of Commerce, and in the subject at hand, local industrial growth as it is stimulated by the proximity of a large research institution. He gives here a progress report on ORNL's contribution to the local economy.

SPINOFF INDUSTRY

By FRANK BRUCE

RECENTLY I REMARKED that there are, in the local area, 27 companies that have been started by past or present ORNL employees. The statement was greeted with an incredulity that was not lessened by my naming some of the companies, because the names themselves were unfamiliar to the listeners. This gave rise to the suggestion that I write something about how ORNL has contributed to the local economy by "spawning" new private enterprises. I believe *Review* readers will be surprised at and proud of the impact the Laboratory has had upon this small part of Appalachia.

My vantage point for providing this information evolved over a number of years. It all began when I became associated with the Laboratory's Industrial Cooperation program at its inception in early 1962. This program was set up for the purpose of identifying Laboratory developments that might have potential commercial significance, and offering them to industry for possible commercialization. Under the same policy, the Laboratory also helps industry in such ways as arranging conferrals with staff members, arranging for consultants, and generally trying to be helpful. Close-range interactions are inevitably stronger than long-range ones; and as a result, many of our closest contacts in the industrial cooperation program are with local industry.

In 1965, Leonard McCoig, then president of the Oak Ridge Chamber of Commerce, asked Alvin Weinberg for someone from the Laboratory to work with the city's businessmen in "bridging the gap between town and gown." I got the job and from then until 1970 tried to tell the Oak Ridge business community in its monthly Chamber board meetings what it should know about the scientific happenings at the Laboratory and in the nuclear community at large. As an outgrowth of this, in 1970, Herman Snyder, then president of the Chamber, asked me to chair the Chamber's Industrial Development division. I still hold this office and also am a member of the Board of Directors. My association with the business community has been thoroughly enjoyable, offering many insights which I otherwise would not have had. I draw upon some of these for this article.

Impact

Here are some facts. By last count there were no less than 40 industries in the city of Oak Ridge itself. They employ 960 people. Eighteen of these industries were started by Laboratory employees and provide jobs for 534 people, although not all of them are full time. So you see, "ORNL-based" companies provide over half of the non-governmental employment in the city. It should also be pointed out that these companies are taxable, in contrast to the AEC installations, and therefore their favorable impact on the local economy is greater than the number of their employees might indicate. In addition to Oak Ridge proper, there are nine more companies started by ORNLers close to Oak Ridge.

What kind of companies have derived from the Laboratory? Of the 27, I would describe 17 of them as being technology-based. Twelve of the 17 have a product which came out of ORNL research and development, thus falling in the glamor group of spinoff companies. Of the rest, about half manufacture a product that is unrelated to Laboratory r & d, and the other half perform work of a service nature.

Fourteen divisions of the Laboratory have contributed people who started companies, so no one group seems to have a monopoly on the entrepreneurial instinct. Although the most prolific divisions have been Plant and Equipment and Instrumentation and Controls, the Physics Division spun off the one company, ORTEC, which employs more people than all the rest combined. How these companies evolved and what they are doing is interesting, and may bear a closer look.

As a surveyor in the Health Physics Division, John Brown recognized the need for a commercial source of prenumbered paper pieces for the assay of transferable radioactive contamination. Subsequently he established Acme Distributors to manufacture and sell them. The company is operated by Brown, who is still at the Laboratory, and his wife.

Air-Tec was formed by R. E. Adams of the Reactor Chemistry Division and Edward Parrish of Inspection Engineering. Before leaving the Laboratory, Adams was engaged in the development and evaluation of methods for removing radioiodine and particulates from contaminated air at nuclear installations. Parrish was involved in applying these and other techniques to engineering systems. In 1970, they left ORNL to establish Air-Tec. The company provides such services to the nuclear industry and also engages in consultation on the design and operation of other air cleaning systems.

The Nucleus was started by David Coffey while he was a member of the Thermonuclear Division to fill the need for devices for use in teaching nuclear technology. The Nucleus also produces equipment for the health physics field. In 1968, Coffey resigned from the Laboratory to devote full time to The Nucleus and to a second company, American Magnetics. American Magnetics specializes in the manufacture of high-performance superconducting magnets for use in research. While it is closely associated with The Nucleus, American Magnetics is a separate company.

Architectural Materials Laboratory, Inc., was formed by Neil Case of the Isotopes Division in 1967. Its product, unrelated to ORNL, is moisture-cured polyurethane epoxies and chips for use in making seamless floors.

Atomcraft Company is owned and operated by Don Ward, of the Neutron Physics Division, and his wife. The company produces souvenirs related to atomic energy and sells them, primarily at the American Museum of Atomic Energy.

Chemical Separations is a company whose business centers around continuous ion exchange. While a member of the Laboratory's Chemical Technology Division, Irwin Higgins invented a continuous ion exchange contactor. The AEC did not opt for the patents on the device, so Higgins applied for them himself. Chemical Separations was organized in August 1955, and for nearly three years was operated by Higgins and a few other ORNL staff members during evenings and weekends. In May 1958 the company received an order that required full-time attention, so Higgins took a leave of absence until the following October. By then the volume of business warranted Higgins's leaving the Laboratory in favor of Chemical Separations; it was becoming a full-time venture. The company is still engaged in the manufacture of continuous ion exchange contactors and in the development of processes that use the equipment.

Cumberland View Farms was established by James Kile in the spring of 1955, about six months after he terminated from the Laboratory. While here he worked with the Russells in the Biology Division. Cumberland View Farms raises and sells 12 inbred strains of mice that are used for basic medical research. Approximately 15% of the Farms' sales — about 350,000 mice per year — are local; much of the balance of sales is to the National Cancer Institute. Export sales are also made to Europe, South America, and the Orient.

Elographics. G. S. Hurst, while on leave from the Health Physics Division to the University of Kentucky in 1966, invented a device that uses electrically conducting paper, and suitable circuitry, for converting graphical information to digital. The patents are owned jointly by Hurst and the University of Kentucky. In 1971, Hurst and a few other staff members formed Elographics to develop a commercial model of the instrument and to market it. Elographics recently moved into its first home and at present has three full-time employees. Hurst, who remains at the Laboratory, is its president.

Tennelec and Fairport. The history of Tennelec is tied in with that of several other Oak Ridge companies. In 1951 Edward Fairstein and Frank Porter left the I & C Division to found Fairport, an electronics company. Fairstein's interest in development, as opposed to straight production, led him to split off and establish Tennelec in June 1960. Fairport continues in the manufacture and sales of electronic instruments under Porter. During Tennelec's first year the company was a basement enterprise operated by Fairstein, his wife, and Herman Hurst, who had left the I & C Division a few years before. During the first year, Fairstein also consulted at the Laboratory, preparing the service manuals for the ORNL-developed pulse height analyzers. After a few months with Tennelec, Hurst left to form Infabco, a local company that served as the manufacturing arm of both Tennelec and ORTEC. Eventually Tennelec undertook its own manufacturing, and ORTEC bought out Infabco. Herman Hurst is now manager of production for Elographics.

Tennelec's business is the design and construction of electronic instruments for nuclear research. Its product line has expanded from a single item, a low-noise amplifier, to a catalogue of more than 100 instruments at present. Gross sales are about $1.25 million. Tennelec is now further diversifying into commercial electronics and is surveying the medical electronics field.

Hezz and Henson Stringfield of the Budget and Program Planning Office and the Isotopes Division, respectively, helped their wives in setting up **Film Badge Fabricators, Inc.**, in 1945. The company originally manufactured the ORNL-developed film badge for personnel monitoring. More recently the company has also undertaken the manufacture of shielded carriers for transporting radioactive materials.

Kervonics was founded in 1971 by C. V. Dodd of the Metals and Ceramics Division. The main product of the company is a phase-sensitive eddy current detection instrument, developed by Dodd several years ago at the Laboratory. It is used to identify various kinds of metals. He is still an ORNL employee and expects to turn over the operation of the company to a full-time manager when the volume of business warrants it.

Laboratory Balances and Microscope Services. E. R. Crawford of the P & E Division established his company to provide a precise maintenance and calibration service for balances and microscopes used in research.

ORTEC came about through the realization, by a group of six ORNL staff members in early 1960, that silicon surface barrier detectors should have a promising market in nuclear research. By fall of that year the first commercial detector and associated electronics were ready to market, and so favorable was the customer response that by early 1961 the company could no longer be operated by its founders on a part-time basis. In mid-1961 Tom Yount joined ORTEC as president and general manager, and about a year later John Neiler resigned from the Laboratory's Physics Division to become ORTEC's vice-president and technical director. From the very beginning ORTEC has been a success story, and now it is one of the largest world-wide suppliers of nuclear and x-ray radiation detectors and electronics for particle and quantum energy spectrometry. Based upon ORTEC's nuclear technologies and spinoff from life sciences activities in Oak Ridge, the disciplines served have been expanded through the years to include materials analyses by x-ray spectrometry, biochemistry with acrylamide gel electrophoresis, and electrophysiology with signal conditioning and data acquisition electronics. ORTEC is now the largest private employer in Oak Ridge.

PSR, Inc., was started by Dick Poole of the P & E Division. Several ORNL people participate in its operation: Percy Staats, Bill Colwell, Henry Morgan, and George Werner, among others. The company makes glassware for use in scientific research and has unusual expertise in the repair of lasers.

Reactor Controls was started in mid-1961 by Joseph Gundlach, formerly of the I & C Division. The company is engaged in the development of instrumentation and control equipment, with emphasis on radiation detectors.

Research Consultants, Inc., has two components: OR Analytical Systems and OR Analytical Laboratories. To date, only the former has been active. RCI was started in 1970 by Howard Bedell, formerly of National Spectrographic Laboratories, with the assistance of Edward Spitzer, a former member of the Analytical Chemistry Division. RCI is unique in that it is the first local company formed by a non-Oak Ridger to market an ORNL development. The product in this case is the ORNL electron spectrometer, developed by Thomas Carlson and Manfred Krause of the Physics and Chemistry Divisions, respectively. RCI aspires to supplement the manufacture and sale of the electron spectrometer with an analytical laboratory that would specialize in the application of electron spectrometry to a variety of uses for which the technique is especially suited.

Tennecomp was founded in late 1967 by Ross Burrus and William Gibson, who until then had been physicists in the Neutron Physics Division. Initially it was an 80%-owned subsidiary of Tennelec; however, in 1969 the Tennelec interest was sold. Tennecomp's product line includes nuclear pulse height analysis systems and computer systems for controlling instrumentation. The company has grown rapidly to a staff of more than 20 people, and annual sales of about one million dollars are expected nationally and internationally this year.

Tennessee Technical Translators was established in 1960 by François Kertesz of the Information Division and Stanley J. Rimshaw of the Isotopes Division as a service for translating scientific articles from other languages into English. Its biggest customer is the U.S. Atomic Energy Commission, although work is also performed for local industries and AEC contractor laboratories.

U.S. Nuclear, Inc., which manufactures boron carbide neutron absorbers, was formed in 1970 by a small group of ORNL engineers and technicians. The head of the group was Sam C. Weaver, who left the Laboratory in early 1971 to become president of the company on a full-time basis. U.S. Nuclear, Inc., has grown rapidly and has successfully competed with larger, established companies. It now owns a 12,500-sq-ft facility on Warehouse Road in Oak Ridge that contains its offices, laboratory, and manufacturing area. In its first 12 months of operation, it had sales of $217,332.82 and earned $37,824.00 after taxes.

The company is currently building a 10,000-sq-ft fuel element fabrication facility in the Oak Ridge Consolidated Industrial Park. This will be the first plant to be built in the new park. The fuel elements will be used in test and research reactors. At full production the company anticipates employing approximately 50 people in this plant.

And finally, seven machinists — Paul Galyon, Earl L. Leisure, C. C. Hendrix, C. T. Hall, C. W. Hall, Bob Harris, and D. Harrell — all former P & E Division employees — now have their own machine shops in the Knoxville–Oak Ridge area. One, Bull Run Machine and Welding Company, had the ORNL-developed nuclear instrument modular system as its first product. The company is now manufacturing the ORNL electron spectrometer for Research Consultants, Inc.

Comparisons

How does ORNL compare with other institutions in the number of new companies flowing from it? In several parts of the country, notably the San Francisco Bay area and the Boston area, large numbers of technology-oriented companies have resulted from government-supported r & d parents or from universities. In the San Francisco area, many of them derive from Stanford Research Institute; in the Boston area, from Massachusetts Institute of Technology. A. C. Cooper, of Purdue University, has made a study of the factors involved in such spinoff and has rated a number of

Defense and NASA contractors in the Palo Alto area on the basis of the number of new companies they have given birth to. Cooper uses "spinoff rate" as a figure of merit. He defines spinoff rate as the ratio of the number of companies deriving from a large institution or company to the average number of employees of the parent company. In Cooper's study the decade of the sixties was used, and only companies having at least one full-time professional employee were counted. He did not give credit for spinoffs that were engaged solely in the consulting or computer software business.

Using Cooper's ground rules, I have identified six companies, employing 472 people, that qualify as spinoffs from ORNL during the period between 1960 and 1970. This gives the Laboratory a spinoff rate of 1.3×10^{-3}. Contributing to this rate are: The Nucleus, ORTEC, Reactor Controls, Tennecomp, Tennelec, and American Magnetics. It is interesting that no companies spun off in the years 1962–1966 inclusive; otherwise our production of new companies might have been truly outstanding. However, the trend has reversed: two companies were created in 1970 and three in 1971.

Cooper found that the spinoff rate from small companies is higher than that from large ones. All of the parent companies having less than 500 employees showed an average spinoff rate of 1.7×10^{-2}. Those employing more than 500 rated only 1.7×10^{-3}. Thus ORNL shows up fairly well when classed with institutions of comparable size.

Cooper also determined spinoff rates for specific organizations in the Palo Alto area. ORNL shows up well there, too, except when compared with the faculty and research associates of Stanford University. This, however, is a select group, whereas the spinoff rate for ORNL was calculated on the basis of the entire Laboratory employee count.

Beyond a doubt, ORNL spinoffs have made a substantial contribution to the local and national economy; in particular, by creating jobs for our young people. Yet there are any number of questions we might ask ourselves. Is it sufficient for ORNL, with its excellent staff and fruitful program, to have a spinoff rate which is only average, or should we expect more? Why were there no spinoff companies formed in the 1962–1966 period? Why have there been so few — I know of only one — local companies started by employees of the other Nuclear Division facilities and the private sector? Since the AEC installations are supported with tax money, should the Commission be willing to go further in encouraging spinoff in the interest of enhancing the whole national economy? Perhaps speculation on these and other questions would serve as the basis for a future *Review* article.

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to the editor . . .

We were very interested in John Pinajian's article, "UNISOR: A Look Forward," in the *Review* (Fall 1971). The cooperation described between a Federal agency (the United States Atomic Energy Commission), a state government (that of Tennessee), and universities is significant and admirable, but, we fear, less unique than the author suggested.

The German nuclear research establishment, Die Kernforschungsanlage Jülich, GmbH, is well known in Oak Ridge. . . .KFA has close links with several universities, especially the Technische Hochschulen (technical universities) of Aachen, Bonn, Bochum, Köln, Düsseldorf and Münster. Joint research projects employ both KFA and university facilities and many KFA scientists teach at these institutions. In addition, there are also both scientific and technological cooperations with industries. A widely known example is the In-core Thermionic Reactor, a joint project between Brown Boveri & Cie., Internationale Atomreaktor GmbH, Siemens AG, and KFA Jülich. Thus KFA represents on a rather large scale the same sort of cooperative effort as does UNISOR.

(Signed) Chr. Lehmann,
Institut f. Festkörperforschung, KFA
M. T. Robinson,
Solid State Division, ORNL
(currently at KFA)

LAB ANECDOTE

BLUE GLOWS AND SHIPS' WAKES

Why do we know that the blue glow from a nuclear reactor is indeed Cerenkov radiation? Because Walter Jordan said so, that's why.

P. A. Cerenkov irradiated a flask of water with radium gamma rays in 1934, and observed the faint blue glow. I. M. Frank and I. E. Tamm, three years later, published the theory for which they and Cerenkov received the Nobel Prize in physics: charged particles traveling in water faster than the speed of light in that water leave behind some light, much as a ship in water leaves a wake. In 1938, G. B. Collins and V. G. Reiling at Notre Dame University sent 2-MeV electrons through various materials to prove the theory. (Their paper contains the acknowledgment, "We are indebted to Dr. E. Guth for many helpful suggestions and discussions.")

It was not surprising, then, that in 1944 at least one physicist stared at the irradiated uranium slugs in the canal of the Graphite Reactor and tried to decide between fluorescence and the Cerenkov effect. The light was faint through ten feet of water, so the decision awaited the operation of the LITR, the Low Intensity Training Reactor, at three-quarters of a megawatt. Even at that power the color photograph on the front cover of *Scientific American*, October 1951, required nearly a minute to expose. This photograph, ORNL #7702, hangs in the central entrance of 4500N as the first of three such ORNL reactors.

It was then that Walt Jordan (now an ORNL senior research advisor) borrowed a hand spectroscope from a colleague and saw the continuous spectrum from red to violet; a line spectrum would have required another explanation. Looking through polarized film, he found polarized light at the reactor sides. With a light meter, he found the same light intensity that came from the theoretical calculations. In less than a week he changed from skeptic to believer. And today every schoolchild can echo the statement that the blue glow from the reactor is Cerenkov radiation.

—Herbert Pomerance

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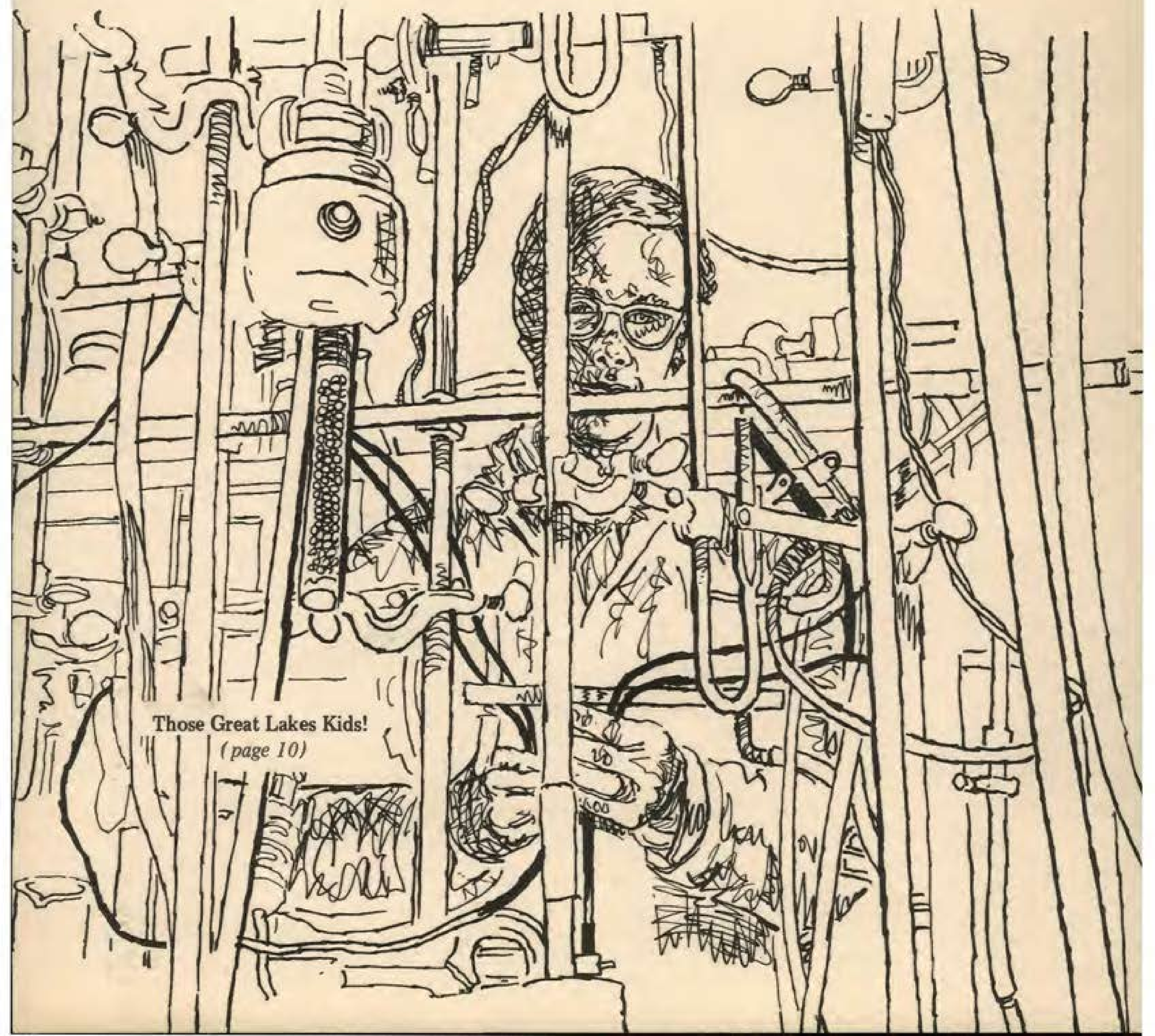

Those Great Lakes Kids!
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