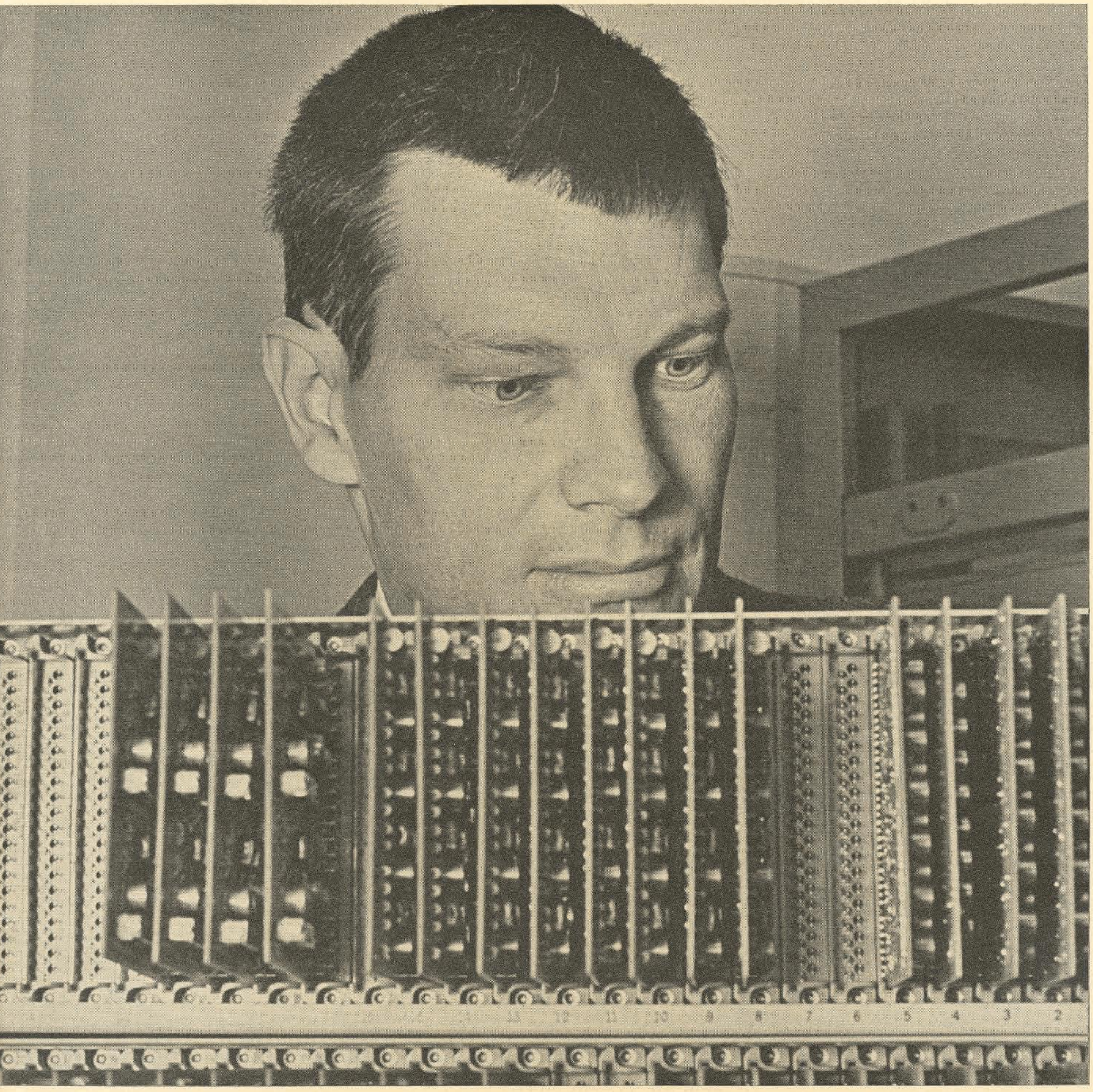
APRIL 1967

ENGINEERING AND SCIENCE



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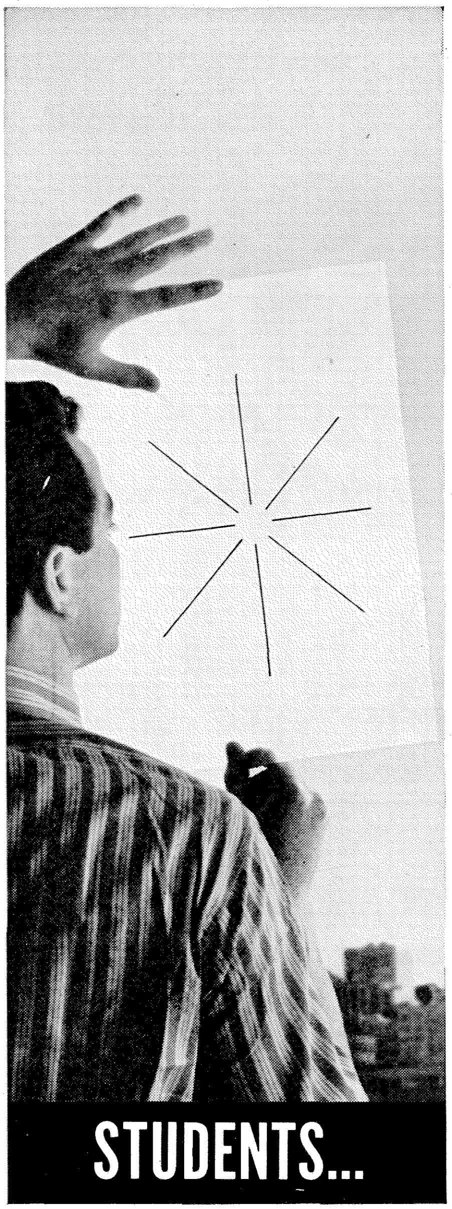

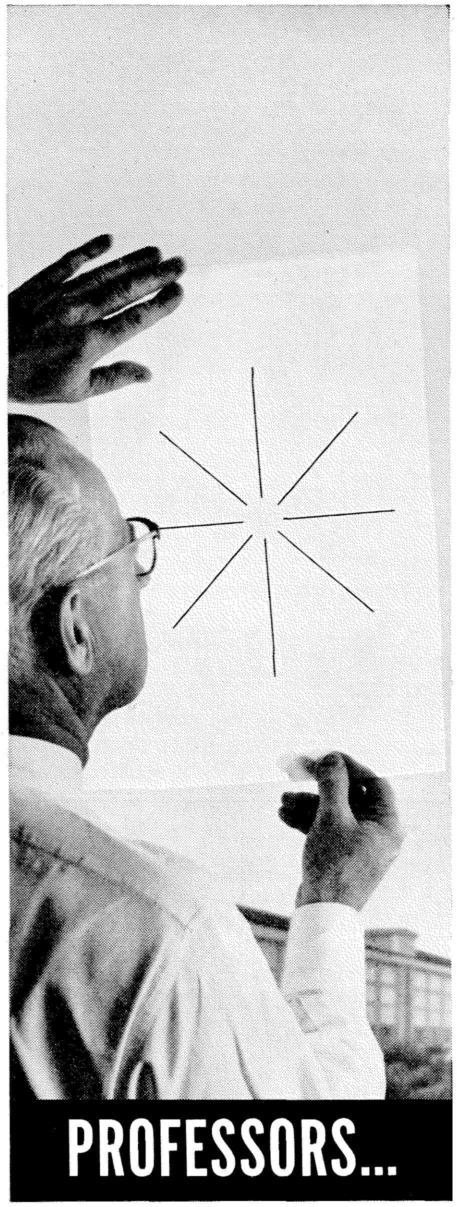

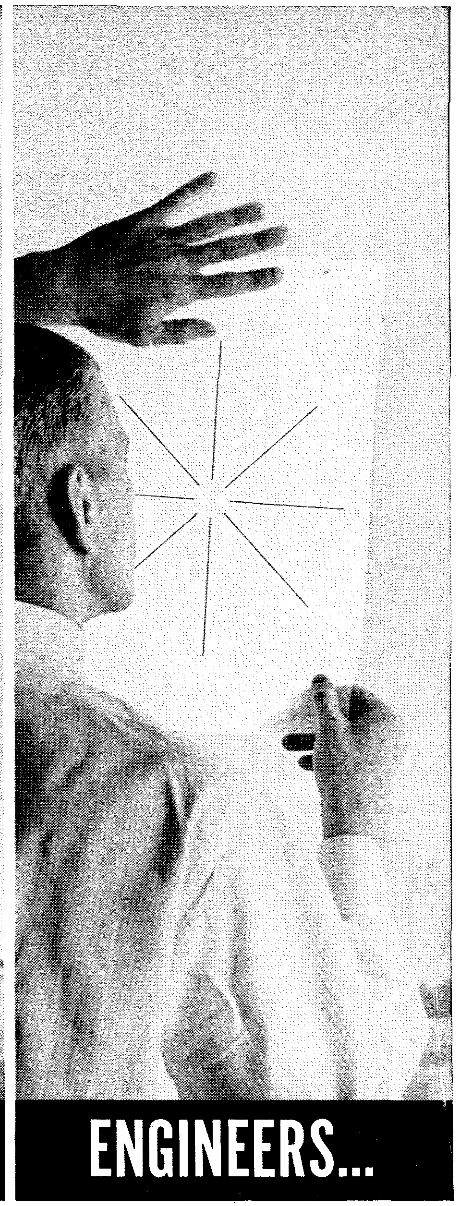

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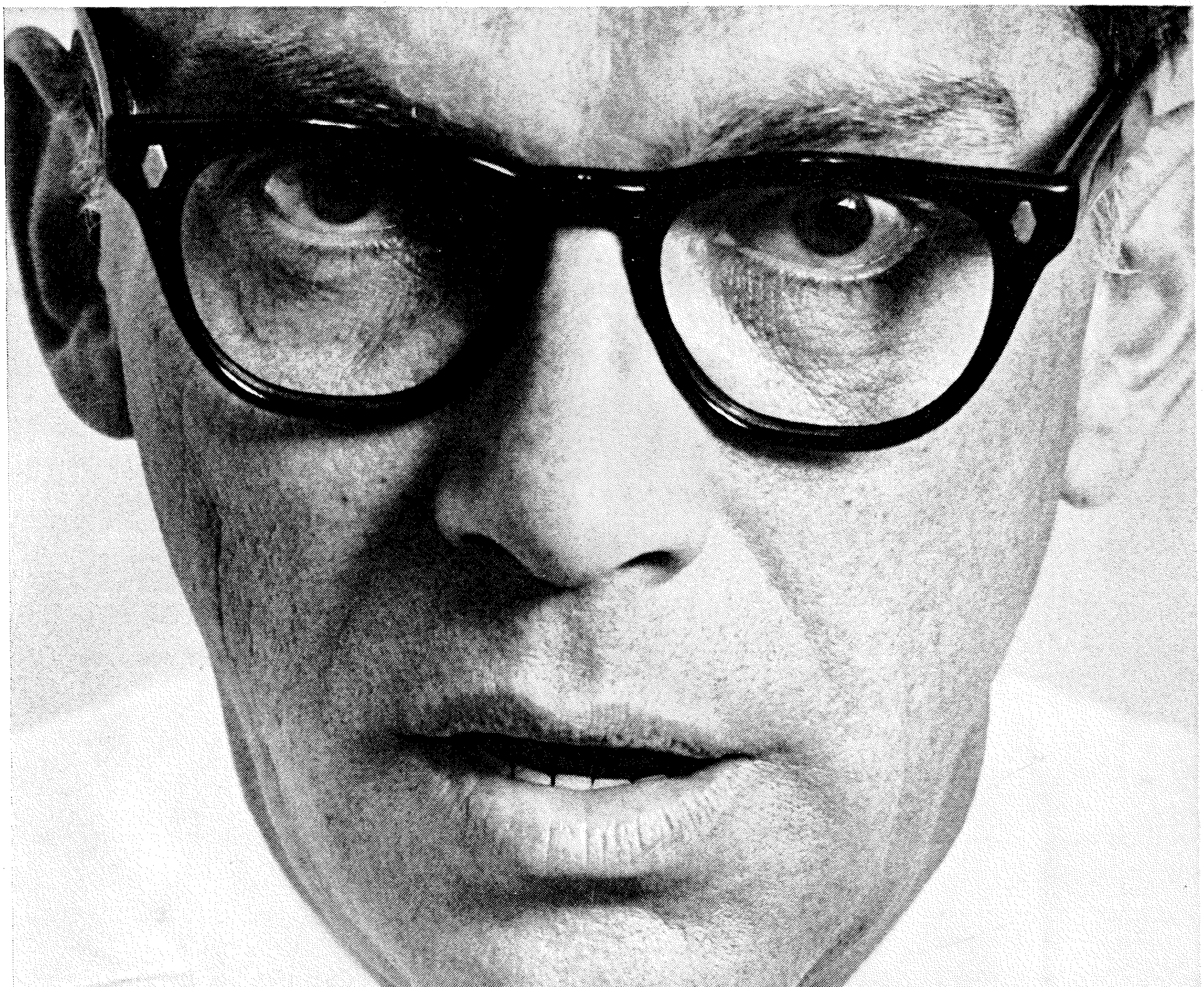

ENGINEERING AND SCIENCE

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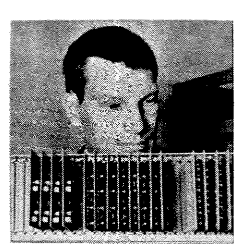

COVER

Edwin Dennison, staff member of the Mount Wilson and Palomar Observatories and head of its three-year-old astro-electronics laboratory, inspects the new data acquisition system being prepared for the 200-inch telescope at Palomar. This system is one step of the lab's continuing program of modernization of the astronomical equipment. Dr. Dennison describes the program's progess in "Electronics and the New Astronomy" on pages 9-12.

MECHANICS

Edward A. Fox, *Rensselaer Polytechnic Institute*—A coherent treatment of particle, rigid body, and continuum mechanics with an emphasis on kinematics—particularly, kinematics of deformation. Attributing the undergraduate's difficulty with mechanics to an inadequate knowledge of kinematics and a general lack of understanding of the kinematics of deformation, the author discusses finite displacements and strains as the key to comprehension of the entire subject. *431 pages; $12.50.*

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G. C. Jain, *Rice University*—Just published for the student of electrical engineering, this text is a practical introduction to the basic physical principles underlying the behavior of the materials he will use. Solid state physics and such topics as thermal, electric, and magnetic properties of matter are emphasized. Quantum mechanics and statistical physics are discussed in an easily understood manner; fundamental ideas are introduced by simple examples; and the proofs of basic formulas are presented clearly without loss of rigor. Tested problems with proven answers are provided in each chapter. *377 pages; $12.95.*

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DIFFERENTIAL GEOMETRY

Louis Auslander, *The City University of New York*—This treatment of differential geometry of surfaces combines both the modern and classical approaches to give the student a better insight into the subject. The first three chapters deal with the algebraic and analytic prerequisites for the remainder of the book. Chapter III is unusual in that it treats Matrix Lie groups rather than Lie groups, thus giving the student the advantage of the flavor of the general results without unnecessary abstraction. Chapters IV and V treat the local theory of surfaces, first from the modern approach, and then from the classical approach. The concluding chapters introduce the student to the theory of manifolds by means of the presentation of such subjects as non-euclidian geometry. A noteworthy feature of the text is the treatment of exercises; beginning with Chapter II, they are integrated into the text to help the student think out the material for himself. *275 pages; $10.95.*

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Allen A. Goldstein, *University of Washington*—This text is concerned with the ideas involved in developing constructions for solving the closely related problems of finding (1) roots of systems of equations and operative equations in a given region, and (2) the extremal problems of minimizing or maximizing functions defined on subsets of finite and infinite dimensional spaces. The book aims not necessarily to furnish practical algorithms for solving problems, but to provide the tools for studying algorithms connected with the problems mentioned above. Notable features include special topics in theoretical numerical analysis and exercises constructed so that they may be answered with a computer. *175 pages; $9.25.*

INTRODUCTION TO LINEAR ALGEBRA

Peter Kahn, *Cornell University*—This text develops the basic concepts of linear algebra from a relatively sophisticated point of view, which it endeavors to motivate, justify, and explain. For example, the concepts of vector-space isomorphism and inner product space are motivated in detail before the precise definitions are given. Emphasis is given to the development of the students' mathematical insight and problem-solving capacity as the book proceeds from the specific to the general, the concrete to the abstract, the geometric to the algebraic. Other noteworthy features include portions devoted to intuitive motivation; complete treatment of the set-theoretical prerequisites for understanding linear algebra; and many provocative, non-routine exercises. *Coming in May.*

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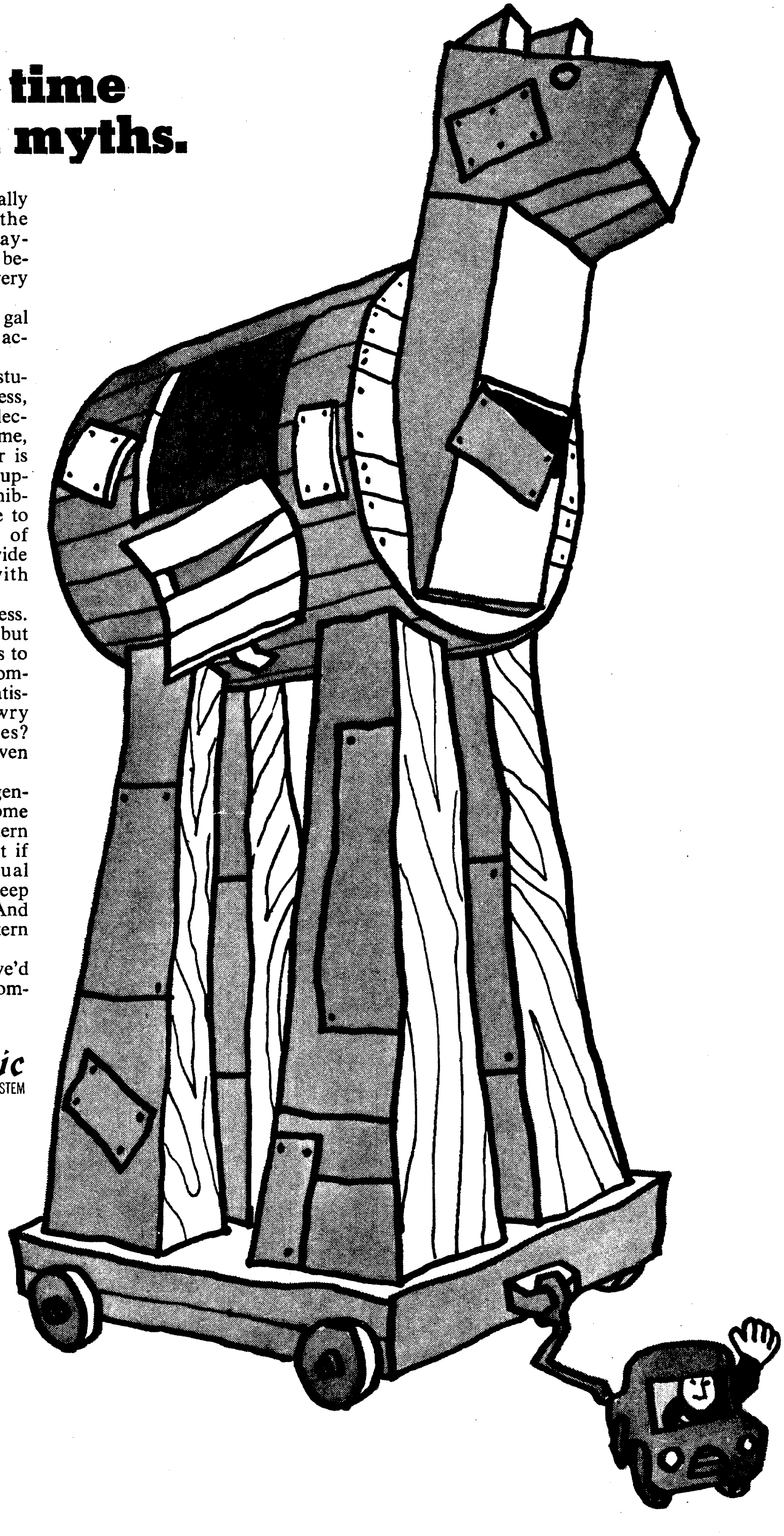


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April 1967, Vol. XXX, No. 7

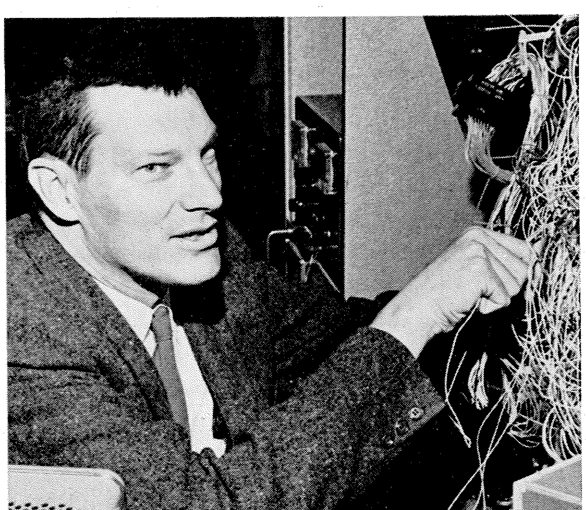
ELECTRONICS AND THE NEW ASTRONOMY

by Edwin W. Dennison

In 1964 a panel concerned with astronomical facilities prepared a report for the National Academy of Sciences covering a ten-year program for ground-based astronomy. This report emphasized the shortage of ground-based optical facilities and projected the increasing inadequacy of observing resources. It also pointed out the urgency of improving the operating effectiveness of the telescopes in existence.

For the past three years the Mount Wilson and Palomar Observatories Astro-Electronics Laboratory has undertaken an electronic instrumentation program to achieve these goals. We began with a summary of some aspects of the relationship between optical ground-based astronomy and space astronomy. These two sources of information about extraterrestrial objects can supplement each other only if the ground-based telescopes are equipped to operate at the most advanced levels of technology. If we turn to space astronomy for data which we are not able to get from ground-based telescopes only because we have failed to develop new techniques, we are in an economically indefensible position and will have subjected our space experiments to a somewhat greater possibility of failure. By testing new techniques on the ground-based telescopes we gain experience from which we can further develop space experiments and hardware.

In June 1964 Ira S. Bowen, at that time director of the Mount Wilson and Palomar Observatories, analyzed the relationship between telescope apertures, exposure times, auxiliary instruments, and the efficiency of any given telescope for meas-



Edwin W. Dennison is a staff member of the Mount Wilson and Palomar Observatories and head of the Observatories Astro-Electronics Laboratory on the Caltech campus. The laboratory came into being in September 1963 in recognition of the need to advance the techniques and equipment used at the observatories and to develop new equipment. Dr. Dennison and his staff design, build, install, and maintain all the electronic equipment used in connection with the Mount Wilson and Palomar telescopes.

Support for this work comes from the Carnegie Institution of Washington, Caltech, the National Science Foundation, NASA, the Advanced Research and Planning Agency, and the U.S. Navy.

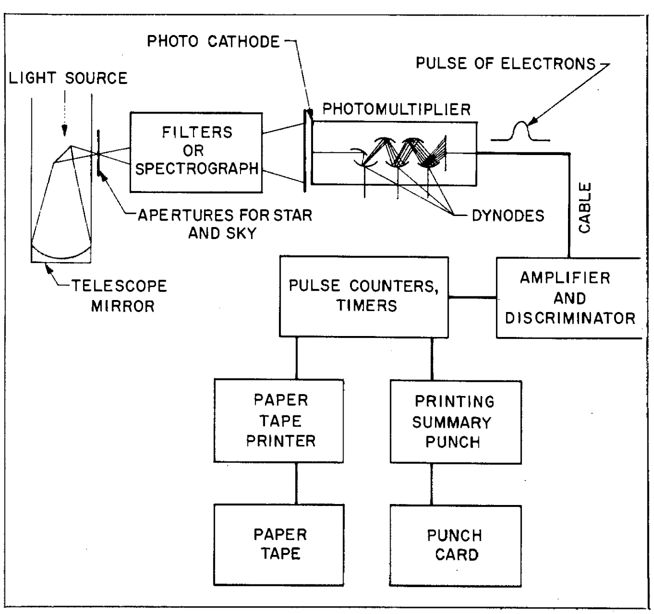
"Electronics and the New Astronomy" has been adapted from a talk given by Dr. Dennison at a conference on The New Astronomy and Its Technology, sponsored by Caltech's Office for Industrial Associates on February 9.

uring faint objects or spectral lines. Although he dealt primarily with the problems of determining the direction that future telescope builders should take in selecting telescope apertures, it is interesting to note that his results state that observing time and telescope light-collecting area are interchangeable. In other words, a telescope with a collecting area twice as large as another can make the same observations with the same degree of accuracy in half the time. This is the primary reason for building large telescopes. However, for any telescope with an aperture larger than about 16 inches, there is very little gain in angular resolution—the ability to distinguish between two points in space. Dr. Bowen concludes that when all factors are considered, a 200-inch aperture is optimum.

An auxiliary instrument that speeds up the operation of a large telescope is equivalent to an increase in the effective aperture. Since the value of the 200-inch telescope is almost $10,000,000, any device that increases operating efficiency by 10 percent can be considered to be worth almost a million dollars. Clearly, these devices are an economical way of increasing the power of large telescopes.

One of the first experimental projects our astroelectronics lab initiated along this line was the modernization of the photon-counting techniques used with the 200-inch telescope.

In a photon-counting system (see diagram below), for every four or five photons that strike the photo cathode, one photoelectron is emitted. This electron is accelerated through a series of dynode amplifiers and is multiplied by nearly a million. These electrons emerge from the photomultiplier as a single electrical pulse, the duration of



Block diagram of a typical pulse-counting photometer and data system used with large telescopes.

which is about ten nanoseconds (a nanosecond is a billionth of a second). An amplifier increases the pulse amplitude by about 2,000, and a discriminator rejects low amplitude noise and interference pulses. The pulses are then counted by an electronic counter. From the beginning of this cycle—the single photoelectron to the pulse counter—the over-all amplification is two billion.

New high-speed amplifiers

The original system we built was somewhat primitive and had a time resolution (the ability to distinguish between two pulses) of only one microsecond, or approximately one hundred times longer than the duration of the pulses coming from the photomultiplier. Eventually we were able to get high-speed pulse amplifiers that have a time resolution of about ten nanoseconds. These new pulse amplifiers and discriminators have another great advantage. By virtue of their compactness, they are less subject to interference from TV stations on Mount Wilson and from telescope control relays.

The high-speed systems are not needed for counting photons from most of the extraterrestrial objects astronomers are now studying. Many of these images have pulse counts as low as only 10 to 100 counts per second as compared to counts of up to three billion for very bright stars. However, the high-speed systems are necessary for calibrating the photometers by measuring the brightness of standard stars (up to three million counts per second).

The first data system we built for the 200-inch, which is still in service, uses a reversing counter. This system has two apertures, one covering the star plus a certain amount of sky background, the other, adjacent to it, covering an equivalent amount of sky background only. A mechanical "chopper" switches back and forth between the two apertures at a rate of 15 cycles a second, permitting the light input from each to be recorded alternately. When we are looking at the star-plus-sky background, we can make the counter count in a plus direction; when we are looking at the sky background alone, the counter will count in a negative direction. The accumulated count represents the difference between the two, or the count due to the star alone.

In the improvement of our entire photometer system, the next logical step was to go to a two photomultiplier system. This system has been constructed but has not yet been used. It has two photomultipliers, each looking through one of the two apertures. One looks at the star-plus-sky background; the other looks at the sky background alone. A small mirror, activated by a stepping motor, moves back and forth between the two and reverses the role of the two photomultipliers so that the first photomultiplier looks at the sky background, the second at the star-plus-sky. This addition of the second multiplier immediately doubles our observing capability but requires that we have the two reversing counters to operate the system.

The next degree of sophistication in the advancement of our instruments is a 33-channel spectrophotometer—an instrument still in the design and development stage. It will contain 33 photomultipliers operating simultaneously. The optical part of the device is similar to the single photomultiplier system, with two apertures and a chopper. Because of the large size of the system and its cost, it is more economical to use 66 unidirectional counters rather than 33 reversing counters. The system records all the data, and the computers take the difference between pairs of counters.

The unidirectional counter method provides us with an additional useful piece of information—the sum count—which helps establish the expected accuracy of our data. Repeated observations indicate that the accuracy of the data we get from all of our pulse-counting systems is almost equal to the accuracy predicted by statistical theory.

A pulse-counting photometer

For the 100-inch telescope at Mount Wilson we have developed a pulse-counting photometer to work with the coudé spectrograph. It contains two reversing counters, similar to the unit at Palomar, but the counters are set up for the primary purpose of measuring the ratio of light intensities.

The principle is quite straightforward. One counter is connected to a photomultiplier which monitors the background or continuum part of a stellar spectrum. The other photomultiplier is exposed, through a slit, to one point on a spectral line. When the total count in the monitor counter reaches a preset number, the scan channel count is recorded and the scan slit moves on to the next point.

This means that despite the variations in sky transparency, thin clouds, seeing fluctuations, or guiding errors, we are able to make accurate photometric measurements.

If we reverse the role of these two counters and count to the preset number for the scanning aperture, we can always ensure that we are making our measurements with constant accuracy. In other words, we spend more time collecting data in the center of a deep absorption line than we do at a point in the continuum. In this case, the count that comes from the monitor, or reference counter, must be inverted to get the ratio of these two numbers.

This 100-inch system was designed for work on the coudé spectrograph, but it was also designed to be a general purpose device. It has been used for broad-band photometry and for photometric measurements with a spectrum scanner. And we have used it with some of the infrared detectors. In this case we take the output from the infrared detector and connect it to a voltage-to-frequency converter so that we get a series of pulses. The number of pulses per second is proportional to the input signal, and we can treat this signal, as far as the counters are concerned, in exactly the same way we would treat the pulses coming from a photomultiplier.

Two sets of records

On all of these nighttime data collecting systems we use a paper tape printer to record the information onto a tape and, operating simultaneously, a printing summary punch to record the same information on IBM cards. The tape is essential because the observer needs to be able to see his results at the time he is getting them and to be able to go back two or three observations to compare new data with observations made earlier. The summary punch is valuable because the cards can be read directly into the computer with no hand manipulations.

We have also worked on the 150-foot solar tower at Mount Wilson where we are concerned with measuring the magnetic field on the sun itself. There we use a two-axis servo system in which the image of the sun follows the motion of a large ring. Two photocells, with a pair of apertures for each, generate the electrical signal for the servo system. The ring "holds" the sun accurately in its center, and, as the ring is moved in a raster pattern by means of a digital control, it is possible to scan the image of the sun over the slit of the spectrograph. The light emerging from the spectrograph falls on two photomultipliers, and their output is amplified by DC amplifiers. Because the light level is so high, there is no advantage in using pulse amplifiers.

With analogue computer techniques we generate electrical signals from which we can derive the longitudinal magnetic field, the radial velocity, and the intensity for the area of the sun which falls into the spectrograph slit. Then, using voltage-to-frequency converters and reversing counters to generate digital data, we record these data on magnetic tape in a computer-compatible format. The tapes are brought to Caltech for processing by the 7094 computer. These solar magnetograph observations result in graphical plots consisting of lines of equal magnetic field on the sun—isogauss lines.

We are developing several techniques for using automatic data reduction equipment to analyze photographic plates and convert the data into a usable form for the computer. First, we have put a digitizer on our Grant measuring engine to aid in the process of getting light measurements into the computer. Second, we are putting a two-axis digitizer on the iris stellar photometer. The iris photometer will also have a servo system so that the iris can be closed down around the star image automatically. Use of this system allows the star image on photographic plates to be converted into computer format directly and, because it is almost completely automated, greatly reduces the element of human error.

Third, we will construct a two-dimensional automatic scanning microphotometer. Its function is to scan images on photographic plates, take the output in an automatic digital form, and send these data to the computer, which converts this information into isophote lines.

The developments described so far have been designed to do specific jobs for specific instruments, like the 200-inch telescope. However, there is a class of items on which we have been working that are designed to be used for all telescopes and for all forms of observing.

Among these, designed but not yet in operation, are precision digital encoders, precision clocks, and possibly on-line computers, all of which will enable us to set our telescopes more accurately. The encoders have a resolution of approximately one second of an arc, and the clocks are accurate to one-tenth of a second of time. With these we can specify the coordinates (latitude and longitude) of the objects to be observed and can set the telescope automatically to within ten seconds of an arc of the apparent position.

Fainter stars

We also have plans, but as yet no hardware, to improve the operating efficiency of the telescope by using closed circuit television image intensifiers to help the observer locate his object and also to enable him to see stars that are fainter than those he can see in the eyepiece with his unaided eye. Experience indicates that a TV system with an image orthicon camera tube used in a storage mode should enable us to see stars that are very nearly at the photographic limit of the telescope.

Our modernization program has resulted in tangible and substantial gains. By using the automatic data recording equipment with the pulse-counting amplifiers, astronomers are able to observe twice as many stars in a specific period of time as they were able to observe with the older DC amplifier and the strip chart recorders.

By using the pulse-counting data system, an observer can get the same accuracy and confidence level in a ten-second integration as he was able to get in one minute of recording with a strip chart recorder. When the two photomultiplier tube photometer is used, the observer gets an additional factor of two in operating efficiency. Great gains have also been made by use of the computer to reduce data. The photometric data that we are getting from Palomar can now be reduced to a usable form in a matter of minutes compared with the several weeks previously required.

Another computer-use gain has been in the making of isogauss maps from the solar magnetograph observations. In a few minutes of computer time and something like 40 minutes of automatic plotting time, we are able to make isogauss maps which previously required a month or more to make. Because of the long time required in the past, few of these reductions were ever made. Now one or two per day are turned out in a routine manner.

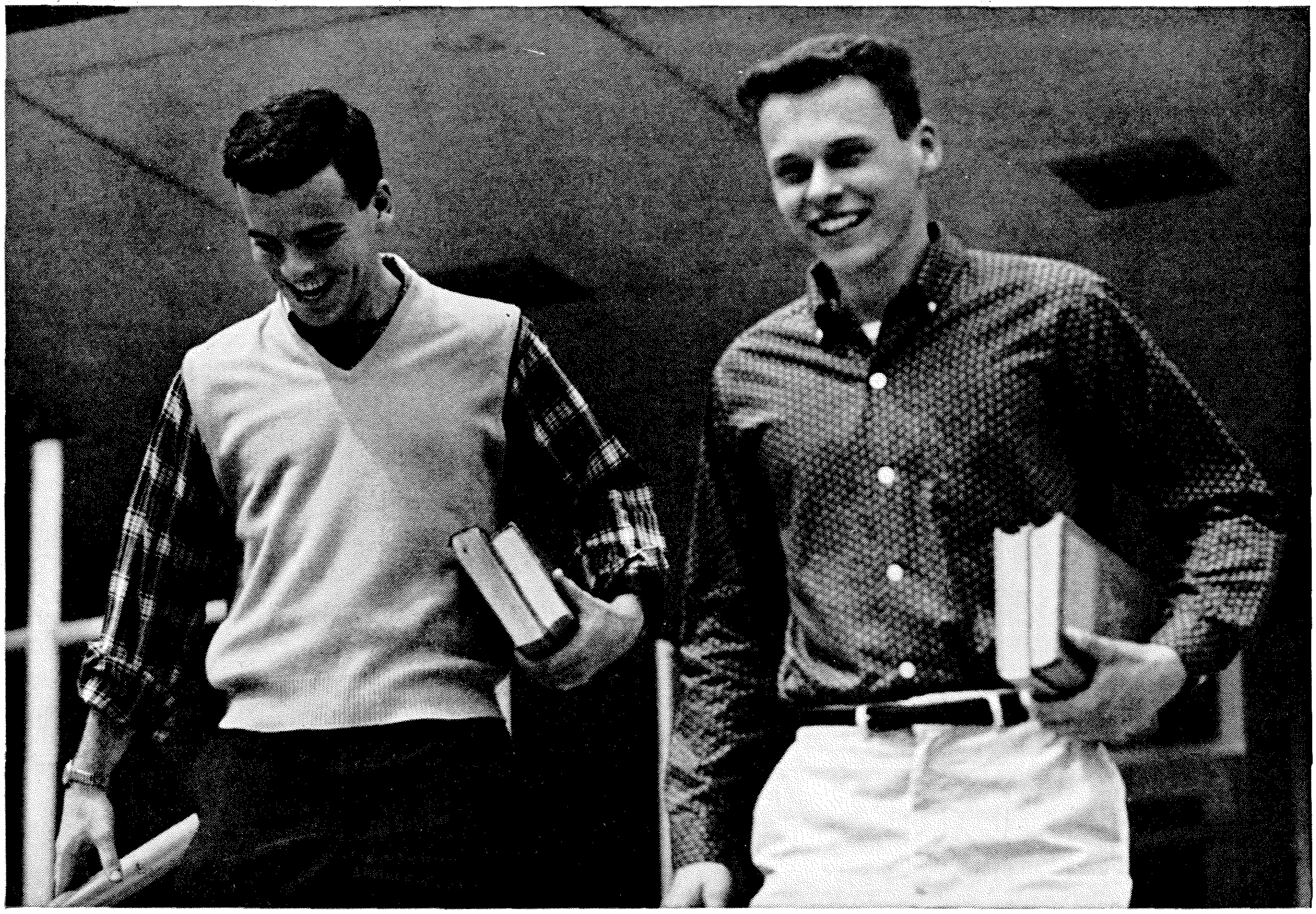
The human factor

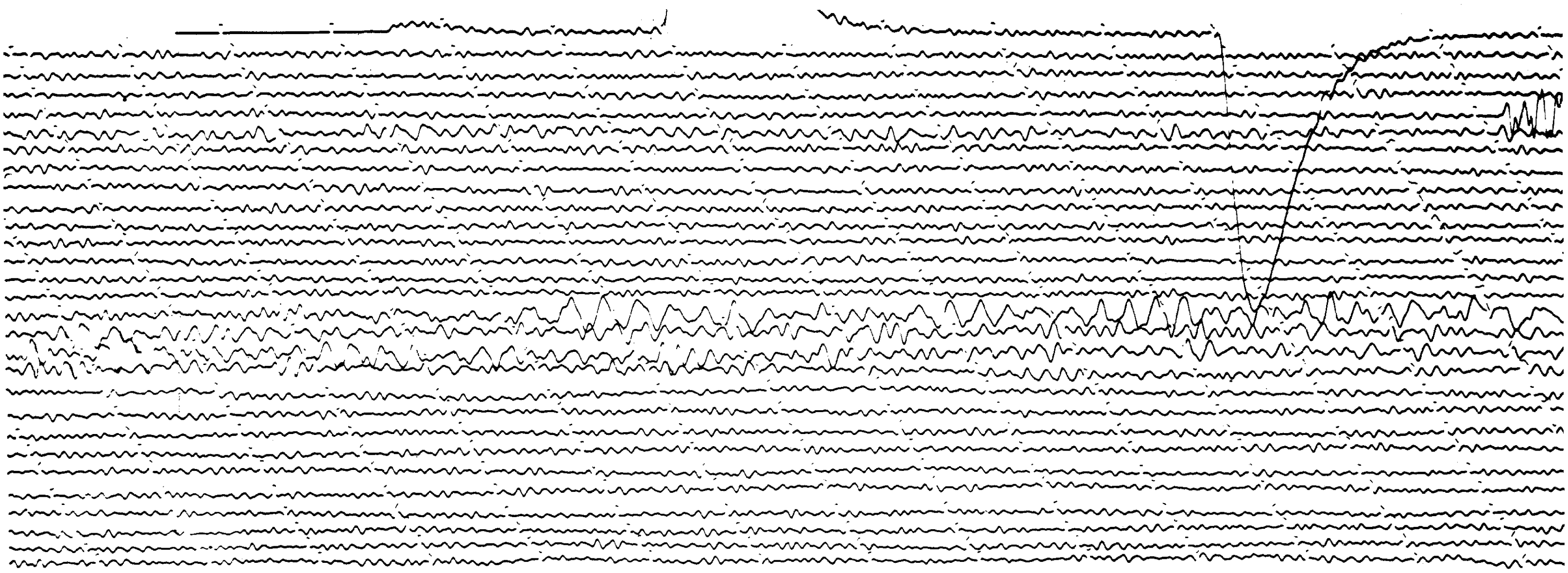
So far this report has dealt only with the instruments themselves. But the human factor—the relationship of the observer to his equipment—has also been more effectively refined. The equipment has been maintained and checked out before each observing run by the same laboratory personnel as those involved in its construction and design. This ensures a very sensitive feedback to the design stages of new instruments and minimizes the chances of our repeating mistakes.

Further, we have followed the principle that the systems we are designing should do exactly what the observer wishes. At all times he must be able to monitor and control his data system, but he must never be a part of the data collection chain. In that way the element of human fallibility is reduced.

For the future there is a great need for a two-dimensional photometric measuring technique which will have the sensitivity and linear characteristics of the photomultiplier system. This device will have an all-electronic, numerical output suitable for computer handling and will transmit the data directly from the telescope to the computer to eliminate the necessity for having to use a photographic plate as an intermediate data storage device between the telescope and the computer.

Beyond this are many potential techniques which could further enhance ground-based astronomy. We at the astro-electronics laboratory will not be able to foresee them all, so we must rely on others to help us, to inform us of the techniques that have been developed in industry and other laboratories, and to share their ideas with us.





EARTHQUAKES OR EXPLOSIONS?

by Graham Berry

A Caltech-Columbia research team finds consistent differences in the seismic wave patterns of earthquakes and underground nuclear blasts.

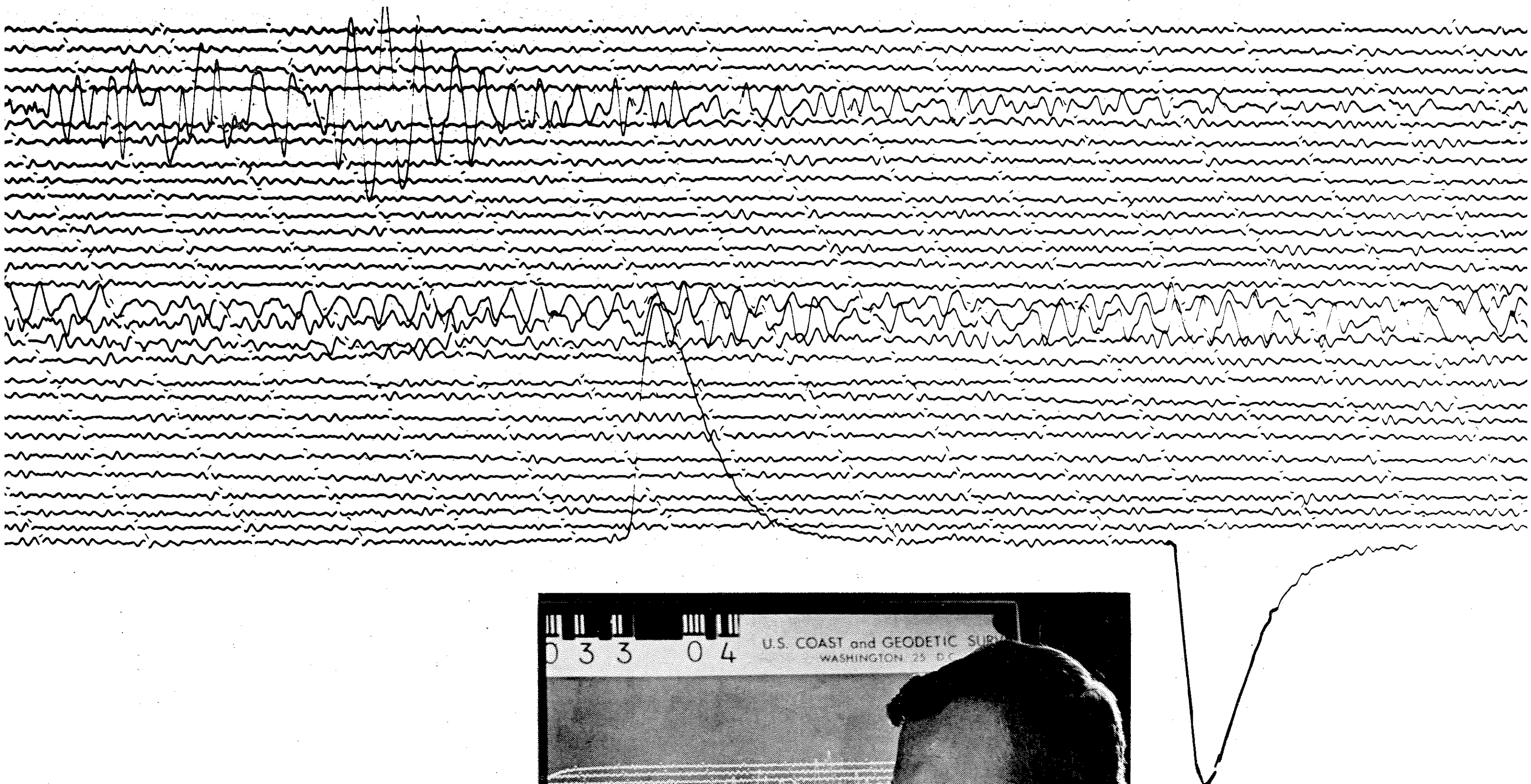
A seismological technique which helps to distinguish between seismic waves generated by underground nuclear explosions and those generated by earthquakes has been developed by a research team of Caltech's Seismological Laboratory and Columbia University's Lamont Geological Observatory.

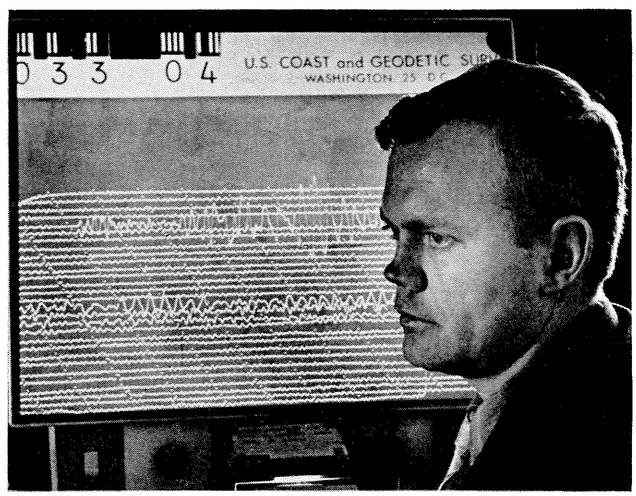
The development of this technique involved analysis and comparison of the seismic records of many small-to-moderate earthquakes and several underground nuclear explosions in a search for consistent differences that would distinguish the seismic records of earthquakes from those of nuclear tests.

Working on the project with James Brune, Caltech associate professor of geophysics, were Chi-Yu King, formerly a research fellow in geophysics at Caltech, now at UCLA; Robert C. Liebermann, a Caltech graduate of 1964, now a graduate student at Columbia; and Columbia researchers Alvaro Espinosa, Jack Oliver, and Paul Pomeroy.

In studies of records of nuclear tests made in Nevada and Alaska, and of earthquakes in Japan, Alaska, and Canada, the Caltech-Columbia researchers found a consistent difference between the seismic waves of the earthquakes and the tests—a difference in the amplitude ratio of the long seismic waves to the short ones. When an earthquake or explosion occurs, long seismic waves (about 70 kilometers from crest to crest) travel *over* the surface of the earth at about 3.5 kilometers per second, and short waves (about 8 kilometers from crest to crest) pass *through* the earth at nearly 8 kilometers per second. The two types of waves are called surface waves and body waves respectively. The researchers found that for earthquakes and tests having body waves of about the same magnitude, the surface waves generated by the underground explosions were usually much smaller in amplitude than the surface waves generated by the earthquakes.

The amplitude is influenced by the size of the energy source and the velocity with which the energy is released. Earthquakes release their energy from a large volume of rock by rupturing along a





James Brune, associate professor of geophysics.

fault for perhaps several miles with a velocity of about three kilometers per second. These effects increase the relative amplitude of the long-period waves. In an explosion the rapid release of energy from a confined region produces relatively high amplitude, short-period body waves, and lower amplitude surface waves.

As a pattern emerged from the studies, the scientists decided to make detailed studies of seismic waves from explosions and earthquakes occurring in the same area in order to confirm the result. In this way they would screen out the possibility of any seismic pattern differences that might be attributed to differences in geological formations at the test sites and in the earthquake areas.

One of the areas selected for the detailed study was the region around Amchitka Island in the Aleutians, the site of the underground nuclear test Long Shot, which was detonated on October 29, 1965. Twenty-nine earthquakes that occurred in the same area in the period between March 1963 and October 1965 were also studied in detail.

Long Shot generated body waves of magnitude (logarithm to the base 10 of amplitude) 6.1, and surface waves of only magnitude 3.9. An earthquake that produced body waves of magnitude 6.1 would be expected to have surface waves of magnitude 5.7, i.e., about 60 times greater than observed for the explosion. In contrast, most of the 29 earthquakes (with body-wave magnitudes ranging from 7.0 to 4.5) generated surface waves with amplitudes very near those expected.

The research was supported by the Advanced Research Projects Agency, the Air Force Office of Scientific Research, the U.S. Army Research Office, and the American Chemical Society.

This proposed diagnostic aid for distinguishing between explosions and earthquakes might be important in working out an effective detection system considered necessary before the signers of the Nuclear Test Ban Treaty can discuss broadening the pact to include underground tests.

THE UNITED STATES, THE SOVIET UNION, AND CHINA: PERSPECTIVES IN NUCLEAR POWER

by Albert R. Hibbs

As China begins to develop into a big power strategically, what does she intend to do? To try to answer this question is an impossible task. One attitude, however, was expressed by former Chinese foreign minister Chen Yi, when asked about the possibility of war with the United States.

"For 17 years we have been waiting for the imperialists to come and attack us. My hair has turned grey waiting. Perhaps I will not have the good fortune to see the Yankee invasion of China, but my son will be able to see it and will fight it."

When asked about nuclear war, he answered:

"The sooner the better. China is hated by both the reactionaries and the revisionists. We have to run the risk. Perhaps one day they will destroy Peking with their bombs. We estimate that hundreds of millions of people will be sacrificed. We will fight for maybe 30 more years."

In contrast, the official statement of the government following each of China's five atomic tests:

"We are deeply convinced that a nuclear war can be prevented, provided that all the peace loving peoples and countries work together and persevere in this struggle. As in the past, the Chinese people and government will continue to carry on an unswerving struggle together with other peace loving people and countries for the noble aim of completely prohibiting and thoroughly destroying nuclear weapons." The news agency usually follows such a statement with the promise that China will never be the first to use nuclear weapons.

These two types of statements come from China at regular intervals. Although on the surface they appear to be contradictory, are they really? I think that upon close examination they are not. One idea is that nuclear war is inevitable; the other is that China will never be the first to attack. Combining the two ideas, it becomes clear that China *would* consider provoking a nuclear war, in which case some other power would be the first to use nuclear weapons. China could then retaliate.

Is China's long range plan to provoke nuclear war once she has the strength to retaliate? Despite all her statements, is China really that hostile?

In 1962 China took a brief excursion over the northern border of India. Then, after beating the Indian troops rather badly, the Chinese withdrew to a line they claimed was the proper border between the two countries. There was very little to stop them from invading, yet they didn't.

Despite the fact that they have been associated with a series of trouble-making incidents in south Asia, Africa, and even South America, they have never taken any direct military action in these countries. Maybe it's because they are not yet strong enough. Or maybe it is that direct military action is not the policy.

It is an opinion often voiced that the possession of nuclear weapons on the part of the Chinese will act to decrease their feelings of insecurity in the world and, in turn, their hostility. They feel, at present, that they are a second-rate nation, and they want to be a first-rate nation—thus they act hostile and aggressive. As soon as they have weapons and are established strategically as a big power, they will no longer need to act in this manner.

Keeping these things in mind, how will the rest of the world react as the Chinese begin to develop their strategic potential with nuclear weapons and long-range missiles? More countries than just the United States and the Soviet Union are likely to respond. The most significant response is likely to come from those countries that are near enough to be threatened even by China's earlier missiles and which, at the same time, have the technological capability to develop weapons of their own. High on the list of such countries are India and Japan, and next, Pakistan and Australia.

The governments of all these countries have expressed their determination not to build nuclear weapons, but this expression was made before China had bombs or missiles and, in some cases, is showing the initial signs of changing.

Outspoken individuals in India who are concerned with this problem are calling into question India's reliance on the United States for atomic defense. The opinion is expressed that America's willingness to defend India will continue so long as China is too weak to harm the U.S. directly, and, once this situation changes, then the U.S. will be much more reluctant to spring to India's defense against China. Along with this opinion are statements concerning the difficulties with Pakistan.

It is argued that the only thing that would deter Pakistan from unleashing a war on India would be the capacity of India to inflict unacceptable damage on Pakistan in a short period of time. A similar argument is advanced with regard to China, against which, it is stated, an overwhelming deterrent force is not necessary—only one big enough to severely damage China's war-making potential.

This argument is one with which we are familiar. It has been used in the public statements of the Soviet Union, France, and China to justify their own strategic nuclear forces, vis-a-vis their particular adversaries with substantially larger forces.

Indian spokesmen in favor of nuclear weapons recognize that both the Soviet Union and the U.S. are pressing India very hard to accept the non-proliferation concepts embodied in the currently proposed treaty. Their response is summed up by the research director of the Indian Council of World Affairs, Sisir Gupta:

> There is no doubt that a good strategic case can be made for an Indian nuclear program. If we cannot do it, either because we do not have the skill or the resources or the capacity to defy our benefactors who are now engaged in a drive to save the world from proliferation, it is another thing. But to say that it will have no use is positively offensive to common sense.

So far, the majority opinion in India seems to be on the other side. It is recognized that China is a growing strategic threat, but a nuclear deterrent is not seen as the proper answer. Again, reference is made to Pakistan, but now in a somewhat different way. Instead of the opinion that the possession of nuclear weapons by India would deter Pakistan, it is suggested by Girilal Jain, assistant editor of *The Times of India* that:

> The Indian possession of nuclear weapons of any description will unhinge Pakistan completely. If there is any Indian decision which will make Pakistan a willing Chinese satellite and thus make a reality of our fears of being encircled, it will be the one to make the bomb.

Those opposed to the bomb also feel that it would really not help in any sort of deterrent role. The type of aggression which India fears is likened to that which took place in Korea or is now going on in Vietnam, and in neither case has the United

Albert R. Hibbs, JPL senior staff scientist.

States or China used nuclear weapons. From this point of view the Indian development of the bomb is seen as a destabilizing force rather than a stabilizing one. China would be more inclined to act against India, and Pakistan to ally herself with China. This means that there is very little reason to develop a weapon and many reasons against it.

It is very difficult to make a judgment between these two viewpoints. Both rest on attempts to predict how India's possession of a bomb would affect the policies of her two military adversaries, Pakistan and China. We know from our own experience how difficult such a prediction can be. We must recognize the value of one line of argument already mentioned; that is, that the U.S. possession of nuclear weapons did not deter the North Koreans nor their Chinese and Soviet allies.

We can also look back to the days in 1957 and 1958 when the Soviets possessed an ICBM, and we did not. For many years we had convinced ourselves that if such a situation were ever to occur, the Soviet Union would face us with strategic blackmail. I recall a vivid presentation of that opinion by one of the Air Force generals responsible for our own ICBM development program. It was early in 1957, before the Russians had successfully tested their first ICBM, but after they had already deployed a number of shorter-range missiles around Europe, and at a time when we knew that they were working as hard as we were on the long-range version. The general said that he had one recurring nightmare—that someday the Soviet Union would warn all shipping out of some region in the Pacific Ocean for a particular day and on that day our radars would track a long-range missile flying from Siberia down across the Pacific. At the end of its flight there would a hydrogen explosion. Then, according to the general's dream, the next day Premier Khrushchev would invite the President to a conference. As the general put it, he and all of his team were working night and day to make sure that such a situation would never occur.

As a matter of fact, a portion of the dream came true. The Soviet Union did test a long-range missile and announce it to the world. But that seemed to be the end of it. There was no demonstration of a combination rocket flight and nuclear test, no call to a conference, or any other blatant blackmail move.

A little further back in history, such blackmail did take place. In 1956 England, France, and Israel combined in an attack on Egypt across the Sinai Peninsula to the Suez Canal. Both the Soviet Union and the U.S. put pressure on these three countries to stop the attack and, in fact, to pull out.

The pressure exerted by the U.S. was of a more traditional diplomatic nature, but the Soviet Union threatened them with attack by nuclear rockets. It is hard to say how important that threat was. There is some reason to believe that the decision had already been made to pull out and cease hostilities before the Soviet threat was made. But this example does stand out as the only international crisis in which a country possessing strategic nuclear power threatened to use it against another country to force a particular course of events. There has been no equivalent situation in the subsequent 20 years. The possession of strategic forces seems to have been more cause for restraint on the part of the Soviets and the U.S. than an excuse for truculence. Will China behave differently?

The other neighbor of China that has the capability of developing nuclear weapons is Japan. Like India, Japan has a long established official policy against the development of nuclear weapons. But recent Chinese accomplishments are, quite naturally, forcing a re-examination of this policy. To a large extent this policy is based on the conviction that the United States will come to Japan's aid if she is threatened by China. Just as some Indians are doubting this concept, so are some Japanese. Others in Japan have pointed out that it will become most critical when China has developed the capability to attack the United States directly.

In Japan's case, there is another problem that somewhat complicates the picture. She looks on the Soviet Union *and* China as potential enemies.

Spokesmen in both India and Japan have made a point of each other's getting nuclear weapons. If India were to begin to develop weapons, this would strengthen the case for Japan to do so, and vice versa. To a large extent, this is based on the almost emotional, but nonetheless realistic, idea that nuclear weapons establish a nation as a big power whose opinion must necessarily be taken into account in the course of global affairs.

The debates in India and Japan have been considerably heightened recently because of the talks in Geneva over the proposed non-proliferation treaty. These two countries are now being asked to join with others in signing away their right ever to develop nuclear weapons. A few years ago these two countries were in the forefront of those who were pressing for exactly this type of treaty, but now there is a quiet but definite change of mood. So long as non-proliferation was simply a theoretical idea, the opponents in any particular country would not be too worried about it and would not feel compelled to go far in opposing it. However, the closer it comes to becoming a realistic possibility, the more the opponents feel the need to speak out.

It is interesting to note one characteristic of the debates in both these countries. Even those who oppose nuclear weapons development do not suggest that China will become more friendly as the years go by. Debaters on both sides look upon China as a steadily growing military threat, and the debate centers around how best to respond.

Both Australia and Pakistan have military alliances with the United States, and both are inclined to believe that we will come to their aid. This is particularly true of Australia, which at times seems almost too relaxed in its conviction that the U.S. will help. Partly because of such convictions, partly because of the cost, and partly because the Australians look upon Indonesia as a much more serious military threat than China, there is less debate in Australia about "going nuclear" than there is in India or Japan.

As for Pakistan, it is questionable whether they really possess the technology and the resources to undertake nuclear development on any sort of sensible time schedule.

This brings us finally to the two major nuclear powers, the Soviet Union and the U.S. Both have reason to feel threatened by Chinese developments, and yet both already feel threatend by each other. What responses are open to these two countries, and what would be the outcome if one course or another were followed?

Both countries have repeatedly asserted their determination not to attack the other one first and that their nuclear weapons are deterrents, with essentially a defensive function. But the "defense only" policy, if it is continued, places certain limitations on what can be done with regard to China. For example, it may be militarily possible to destroy the Chinese nuclear capability right now. In fact, the destruction might be carried out using nonnuclear weapons only—by bombarding key nuclear installations. The location of such sites is apparently well known. Nevertheless, although this has been mentioned, neither we nor the Soviet Union has shown any inclination to undertake such a mission.

If there were great enough provocation, an attack on Chinese nuclear facilities might take place. But the Chinese are undoubtedly aware of this, and it is not likely that they would provide the provocation. Therefore, the operating policies which we must look forward to are those which take into account the steady growth of Chinese strategic power.

There are two technical responses which we and the Soviet Union can make. The first is to increase the numbers of our own nuclear weapons in order to deter China. The second is to develop antiballistic missile forces which can defend us against Chinese attack. Let us see what these courses of action would involve.

A summary of the strategic forces of the United States, according to the Institute for Strategic Studies' periodical, lists the U.S. as having a Minuteman force of 1,054 missiles by mid-1967, together with 54 Titans. Along with this, there are 37 nuclear submarines, each with 16 Polaris Missiles, making a total of 592 Polaris Missiles. In addition the U.S. has a total of 680 strategic bombers. According to the Institute, there are no antimissile defensive forces at present but, instead, antiaircraft forces plus a missile defense warning system.

So far this strategic force has been constructed as a deterrent against the Soviet Union. What will be necessary once the Chinese get into the race? Is it reasonable to suppose, for example, that an equivalent number of missiles will have to be constructed to deter the Chinese? Or are the current forces enough to deter the capabilities of both China and the Soviet Union at once? It is unlikely that the second alternative will be considered adequate by defense planners. It has already been suggested that one reason for the development of an antiballistic missile defense system is to counter potential Chinese missiles, which are looked upon as easier to defend against than the Soviet Union's. However, the capabilities of Chinese missiles will certainly develop with time. There is no reason to look forward forever to small or primitive missiles coming from China. There is the possibility, however, that as the years go by the technology of antiballistic missiles will also increase steadily, so that they will continue to be a match for the Chinese force.

One approach which is likely to be suggested is a buildup of both offensive and defensive systems as a counter to a growing Chinese threat.

What sort of a threat are we defending against now? According to the I.S.S., the Soviet Union has around 300 ICBM's. There is a submarine fleet equipped with short-range missiles (between 300 and 500 miles) totaling about 50 missiles in all, and approximately 1,000 strategic aircraft.

Suppose then the Chinese develop a few hundred strategic missiles basically equivalent to the present Soviet capability. Would this imply a necessity for the U.S. to double its current strategic missile strength or to create an equivalent combination of missiles and antimissile systems which would, in some sense, give an additional deterrent force comparable to that which we now feel we have against the Soviet Union? This would seem a necessity if we assume that the Soviet Union and China would present a threat essentially double that which is now presented by the Soviet Union alone.

Of course the Soviet Union could take the same point of view toward China and build up its strategic force by some percentage. Its deterrent philosophy appears to be that a smaller number of larger missiles can hold off the U.S. So perhaps the Soviet Union would be content with adding only a hundred missiles to its arsenal.

Judging from the current public statements of strategic planners, the Soviets are already developing antimissile systems, and they might add more to their presently planned inventory to take account of the Chinese threat. But now a new quantity enters the picture from their point of view, that is, the increased American force, which the Soviets would be bound to notice. It would seem logical that the Soviet Union would find it necessary to double its offensive and defensive forces to counteract the doubling on the part of the U.S. The U.S., in turn, would feel still more threatened by the Soviet Union, etc. In other words, when a third strategic power enters the picture—a power that is a potential threat to both the current major adversaries—the situation becomes highly unstable. In this situation, there would be great pressures on both the Soviet Union and the U.S. to come to an agreement with each other which would prevent the necessity of matching each other's forces while they were both attempting to deter China.

One conclusion that we might reach from this line of argument is that if we elect to use the technique of strategic deterrents to counter the Chinese threat, we will be forced into some sort of military agreement with the Soviet Union.

Are there any signs at present of this taking place? Actually, there are two. Both the Soviet Union and the U.S. have joined forces in pressuring the rest of the world to agree to the non-proliferation treaty. Although both sides recognize that China would undoubtedly not take part in any such agreement, at least it might prevent other entries into the field.

The second sign is much less distinct. Recently the United States has invited the Soviet Union to join in an agreement which would limit, or even prevent, the development of ballistic missile defensive systems. So far the Soviets have not seemed overly inclined to go along with this idea, but they seem willing to at least discuss it.

Perhaps it is not realistic to believe that this idea will be accepted in the form proposed by the U.S.—that both nations agree to hold the number of missiles they have at present without expansion and to avoid the development of any defensive forces. It might be more worthwhile to look at this as the opening ground for a series of discussions between the two countries as to how to deal with the Chinese threat. One could speculate on a number of different agreements, such as one to deploy antimissile systems only in those locations where they would be defensive against flights from China, or an agreement to limit offensive missiles to those which are deployed and which have ranges useful against

China only. For the Soviet Union, this would imply missiles of a thousand-mile range or so, deployed in their western regions. For the U.S., it would imply the deployment of Polaris submarines in the western Pacific only. Alternatively, both countries might agree to concentrate on antimissile systems in the next round of strategic development, creating and deploying such systems in a way clearly a defense against China rather than each other.

Although such agreements are conceivable in theory, they have a ring of unreality about them. It might be more likely to suppose that the two countries will gradually work their way into a precarious but steadily strengthening agreement of nonaggression—tacit at first but eventually formal.

Throughout all of this theorizing, we have presumed that China would stay hostile to both sides, and that the only check on her could be an opposing strategic force. It is this assumption which is, perhaps, the most worthwhile to explore, but which is at the same time the most difficult to assess. Is there anything which the United States and the Soviet Union, either together or separately, can do over the next decade to ameliorate the hostile attitude of the Chinese Communists? I will not attempt to answer the question, but simply to emphasize its importance.

Beyond that we have the problem of the potential proliferation of nuclear weapons on a still broader scale. If India and Japan, for example, were to initiate the development of nuclear weapons, how would that affect our own strategic position? Currently they are our friends, so we might feel inclined to encourage them to go into the nuclear business. The counter argument is that every new center of nuclear power poses new problems for the world at large. But perhaps this idealistic philosophy should be re-examined. It may be that in view of the growing Chinese threat we should encourage Japan and India to build up their own strategic systems to partially relieve ourselves of the necessity to counter China alone while we still feel somewhat threatened by the Soviet Union. We might at least consider dropping our attitude of discouragement and standing off from the discussion entirely. Of course, we would then be accepting one side of the argument which is already being made in both these countries—namely, that their possession of a nuclear force is their best defense. At the same time, we would be tacitly contradicting the other side, which claims that the development of nuclear forces in these countries would provoke China still further.

In discussing the relationships between the Soviet Union and the U.S., we came to the conclusion that whatever we could do to ameliorate the hostility of China would be to the best interests of ourselves and the Soviets. It would be consistent with this attempt, then, to continue to discourage the development of nuclear weapons by China's neighbors, particularly when they are aligned with us.

To summarize, first, there is every reason to believe that within the next 10 to 15 years the Chinese Communists will be able to develop a significant nuclear strategic force capable of directly threatening the U.S. Second, as long as present political interactions remain the same, if the U.S. were to counter this Chinese threat by developing a stronger strategic force on our side, the Soviet Union would undoubtedly be inspired to do likewise, making our situation still worse and forcing us into a still larger nuclear program, which would, in turn, affect the Soviet Union, and so on. Third, it is likely that both the Soviet Union and the U.S. have already recognized this potential and are in the process of feeling out ways to avoid it by coming into some sort of an arrangement with each other regarding the strength, characteristics, and disposition of their nuclear forces. There is the idea that the U.S. and Soviet Union could agree to direct all future strategic developments *only* against China.

Fourth, considering that any complete trust between the Soviet Union and the United States is unlikely for many years to come and in view of the apparent impracticality of both sides defending simultaneously against each other *and* China, there are reasons for attempting to learn how to get along with the Chinese Communists and encouraging them to cut down on their level of hostility. Fifth, consistent with this last approach is the proposition to prohibit the further proliferation of nuclear weapons, since the countries which would be most likely to be next on the list are friendly to us and potentially provocative to China.

Summarizing all of these lines of thought, we may well conclude that the entry of China into the strategic arena will force major realignments among the current strategic powers, as well as a re-evaluation of the proper role for strategic nuclear forces to play in world affairs. We must realize that the next generation of strategic planners is likely to look back upon the situation we call the balance of terror as "the good old days."

As senior staff scientist at Caltech's Jet Propulsion Laboratory, Albert R. Hibbs is involved in advanced technical studies for the space program and in special studies of space technology for the U.S. Arms Control and Disarmament Agency. As a member of the Caltech faculty, he gives special lectures for the division of the humanities and social sciences. "The United States, the Soviet Union, and China: Perspectives in Nuclear Power" has been adapted from one of his lectures given at Caltech on March 7.

RESEARCH NOTES

A NEW DIMENSION—QUASARS

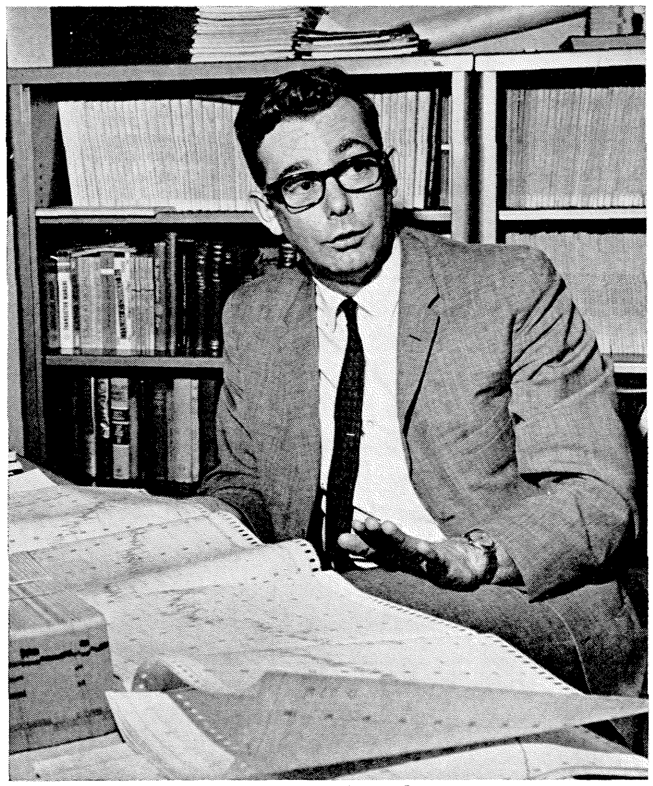
New evidence gathered by Caltech astronomers indicates that the size of the nuclei of quasars is much smaller than earlier studies showed—perhaps only one-hundredth the diameter that was previously estimated.

The new calculation is part of a tentative picture of quasars that is gradually emerging. Quasars, which are the brightest and probably the most distant known objects in the universe, are believed to consist of an immensely bright nucleus surrounded by an envelope of hot, luminous gas, perhaps in cloud form, that is at least 100 times larger than the nucleus itself.

The revised estimate of the diameter of the nucleus is based on observations by J. Beverley Oke, staff member of the Mount Wilson and Palomar Observatories and professor of astronomy at Caltech. He noted marked fluctuations of light, within 24-hour periods, on quasars 3C-279 and 3C-446. Because the velocity of light is finite, if a fluctuation occurs in a period as short as one day, then the source cannot be much more than a few "light days" in diameter. A light day is 16 billion miles, or the distance light travels in one day at the speed of 186,000 miles a second.

Dr. Oke estimates that, although the nucleus of each of the two quasars, 3C-279 and 3C-446, has a diameter only one-millionth as large as the diameter of a galaxy of a billion stars, that nucleus may be 100 times brighter than such a galaxy. How so small an object can produce so much light is still a mystery.

Dr. Oke made his discovery while conducting a survey of quasars whose light is known to fluctuate during intervals of months or years. He determined that 3C-279 increased or decreased in brightness by 25 percent within 24-hour intervals and that 3C-446 grew dimmer for several days at the rate of 10 percent per day. Last year Allan Sandage, staff member of the Mount Wilson and Palomar Observatories, discovered an increase in the brightness of 3C-446 of 20-fold. 3C-279 has changed in brightness six- to seven-fold over the past two years.



Astronomer J. Beverley Oke

Dr. Oke also found that whereas the nuclei of 3C-279 and 3C-446 varied markedly in brightness there was no corresponding variation in the light from the glowing clouds of hot, tenuous gas that envelop them. The enveloping clouds must, therefore, be much larger than the nucleus. Dr. Oke estimates the temperature of the clouds to be about 40,000° F. and their total mass to be at least one hundred thousand to a million suns. Photographing a quasar through a big telescope will not give a picture of the nucleus and its cloud halo. Optically, the objects appear as faint point images. Detailed observations are spectroscopic, and, in his survey, Dr. Oke uses a photoelectric spectrum scanner with the 200-inch Palomar telescope. The scanner, which he developed, measures light intensity very precisely and counts photons—the smallest units of light—one by one.

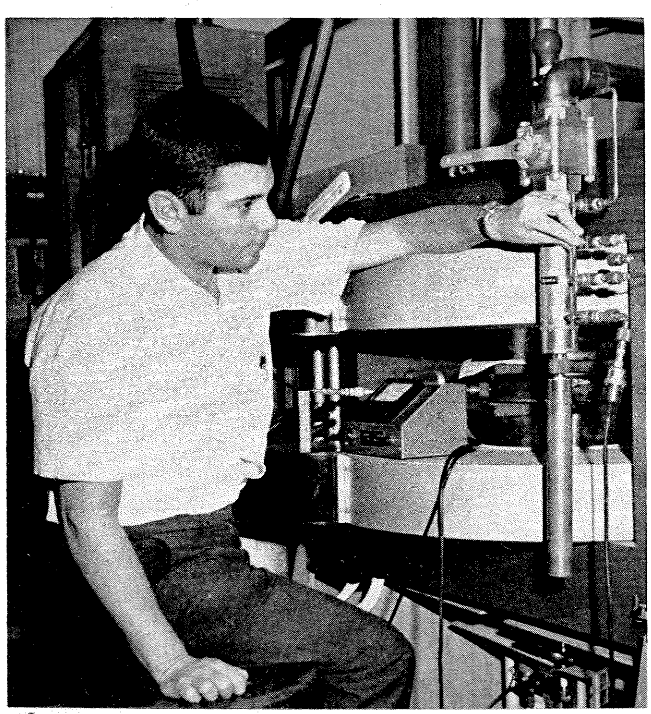
Dr. Oke's survey of quasars may help astronomers determine the size and shape of the universe and give them new insight about its early history.

A NEW POSITION—SHOCK WAVES

A major problem that has hampered experimenters in high-speed shock wave research—the inability to produce a shock wave in an electromagnetic shock tube that would travel *in front of* the current sheet used to drive it—has been explained by a Caltech graduate student in aeronautics, Alan Hoffman.

The electromagnetic shock tube has been in use in the laboratory for more than ten years. To produce a shock wave in the tube, several capacitors are discharged. These capacitors deliver an enormous amount of electricity for a very short time (hundreds of thousands of amperes for a few millionths of a second) through a conductor surrounded by a half-inch-diameter insulator located in the middle of a 10-inch-diameter cylinder containing a gas. The electrical discharge forms a current sheet around the outside of the insulator and expands outward into the tube at a speed of about 10,000 miles per hour. Researchers had expected this sheet of electrons to push the gas ahead of it and form a shock wave. Caltech experimenters found that the wave stayed within the current sheet. When they tried to remedy the situation by increasing the speed at which the sheet was driven, the shock wave formed at the rear.

"It was as if the shock wave was being dragged along," Hoffman says. "We needed to get the wave in front of the current sheet so that we could study the hot, ionized gas that forms between the two."



Alan Hoffman, Caltech graduate student in aeronautics, uses the Inverse Pinch electromagnetic shock tube to solve a puzzling problem involved in the creation of high-speed shock waves.

The shock tube used in the recent Caltech research, an Inverse Pinch, was designed and built in 1962 by Hans W. Liepmann, Caltech professor of aeronautics, and his students. Although it has been used successfully for some aspects of shock wave experiments, the problem of why the wave never *preceded* the current was, until Hoffman's recent work, never quite clear.

An analysis of the problem, which led to the solution, was made possible by the simplicity of the Inverse Pinch. Other types of electromagnetic shock tubes did not permit engineers to recognize that the problem even existed because they did not use pressure probes to locate the shock position within the current sheet. The Inverse Pinch gives a stable, reproducible, relatively thin, constant-speed current sheet—all necessary conditions for working out the position problems of the waves.

Hoffman devised a computer program to simulate the behavior of the laggard shock waves and then demonstrated that a wave could be pushed in front of the current sheet if a light gas—hydrogen—was used and if the starting speed of the current sheet was slowed to about 20,000 miles per hour. Earlier experimenters had tried to solve the problem by speeding up the rate to as high as 50,000 miles an hour. This approach had served only to complicate the problem. By driving a gas with a force field moving at supersonic speed, the Mach number—the ratio of the speed of the current sheet to the speed of sound traveling through that particular gas—is increased. However, when a gas with a higher Mach number was used, the shock wave formed further toward the rear of the current sheet.

Hoffman, by using hydrogen gas which has a high speed of sound and, therefore, a low Mach number and by driving it with a low starting speed, was able to get the shock wave started at the front of the current sheet before increasing the speed to the necessary proportions to produce the supersonic waves. Now waves can be produced that will travel at more than 100 times the speed of sound and that will move in the very front of the sheet.

The new development offers a better way to study shock waves at much higher speeds and will be helpful in the study of problems relating to the reentry of aircraft, the collision of solar wind with the earth's magnetic fields, the use of ionized gases for rocket propulsion, and plasma physics.

Perhaps one of the most significant implications of Hoffman's work is that the solution of the dragging shock waves problem indicates that fluid mechanics principles can sometimes be used to solve puzzling problems in the field of plasma physics.

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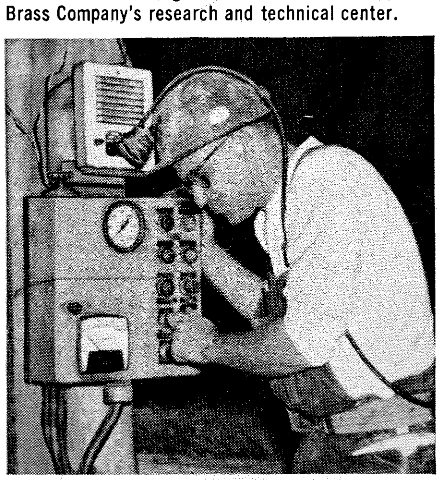
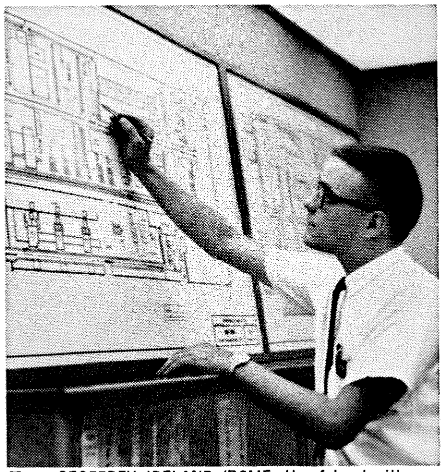
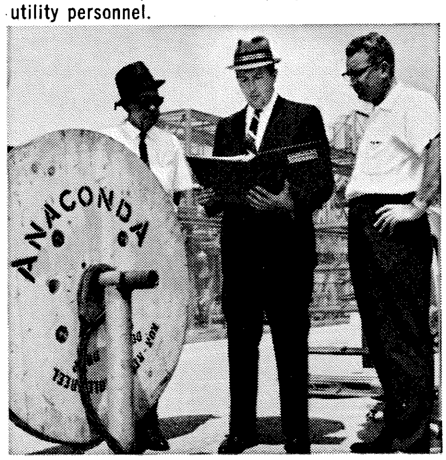
Top: LUIS LOZANO (BS Met. E., Brooklyn Poly. '61) is research metallurgist at Anaconda American Brass Company's research and technical center.





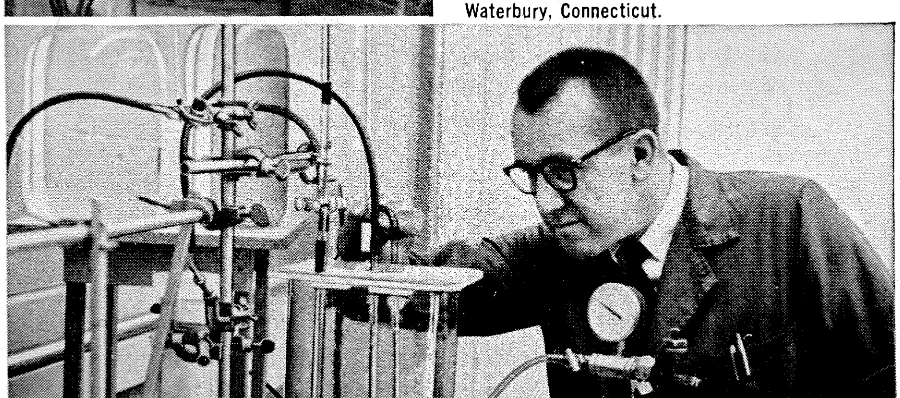
Top: GEOFFREY IRELAND (BSME, U. of Louisville '63) is assistant plant engineer at Louisville works of Anaconda Aluminum Company.

Below: ROBERT SWIRBUL (BS Bus. Ad., U. of Tampa '58), center, district manager of Dallas sales office of Anaconda Wire and Cable Company, reviews cable specifications with power utility personnel.

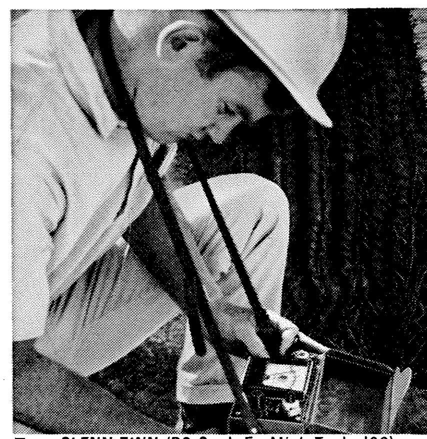


Left: PETRUS DUTOIT (BS Mining Engrg., Montana Tech., '56), mining engineer, at the controls of a raise boring machine in the Mountain Con mine. This mine has the latest in underground mining equipment.

Below: LAWRENCE KENAUSIS (BS Chem., Holy Cross '53; MS Chem., Boston College '55; PhD Chem., U. of Penn. '61) is senior research metallurgist at Anaconda research and technical center in Waterbury, Connecticut.

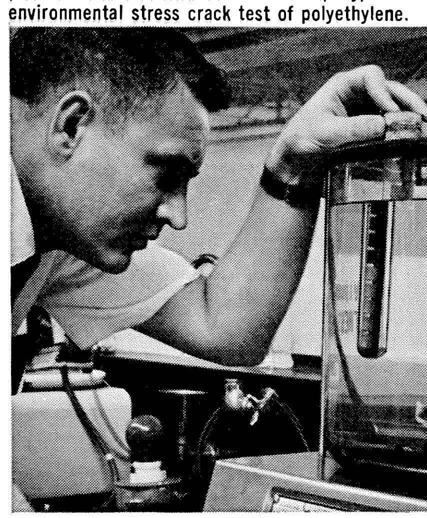


Top: JUDITH HIHNALA (BS Bact., Montana State '63) studies bacterial leaching of copper and zinc ore and concentrates in extractive metallurgical research laboratory.



Top: GLENN ZINN (BS Geol. E., Mich Tech. '66), geophysicist with the geophysical department's southwest office in Tucson, Arizona, is studying toward a master's degree in geophysics at University of Arizona.

Below: FRANKLIN ANDREWS (BS Math., Northern Ill. U. '62), manager—quality assurance at Sycamore plant of Anaconda Wire and Cable Company, checks environmental stress crack test of polyethylene.



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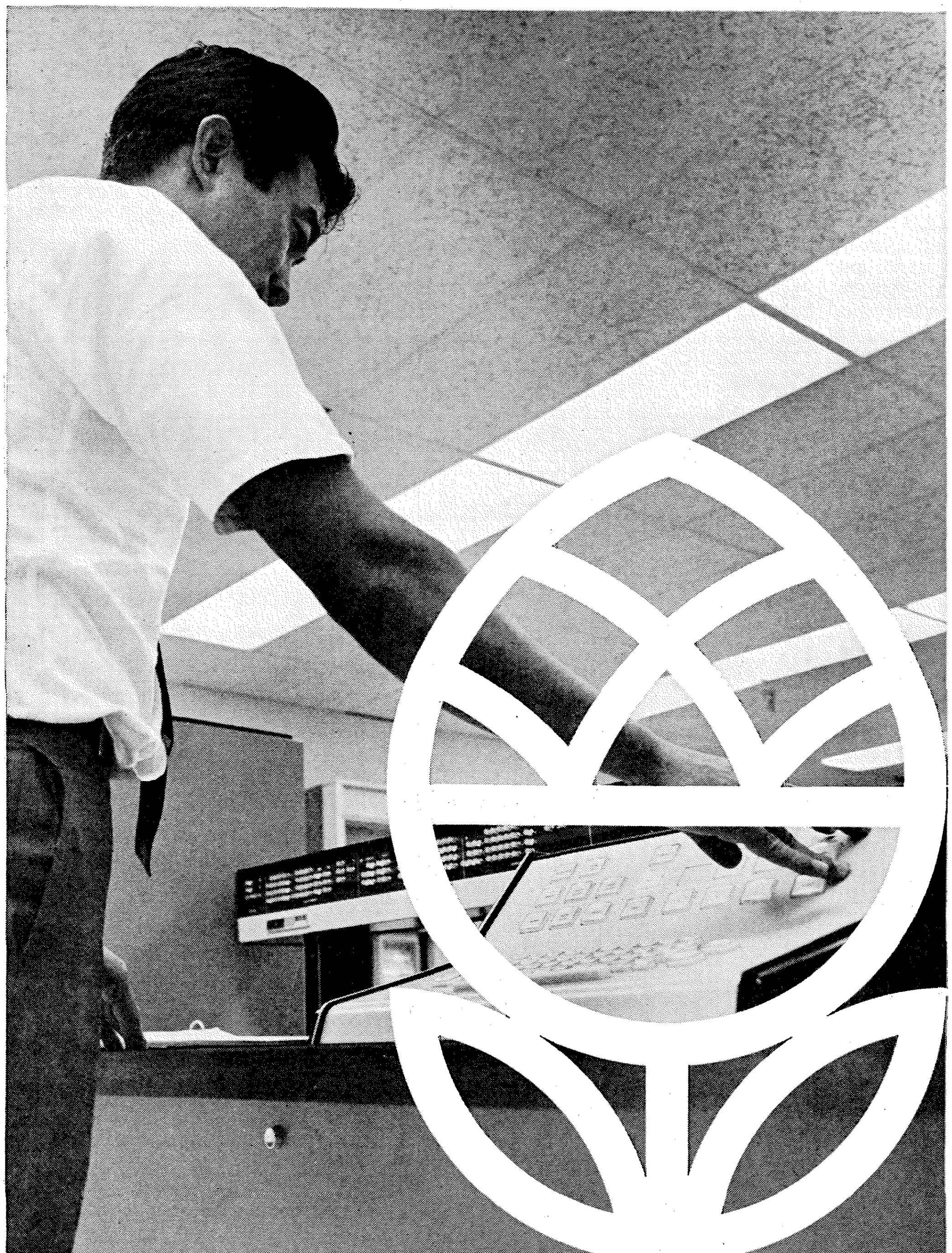

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To coordinate and contribute to advanced memory research. Should be knowledgeable in nanosecond pulse techniques and high-speed applications of magnetics, such as cores or films for digital computer memories. Requires both analytical and experimental ability and covers the full spectrum of activities: elements, circuitry, systems. Work includes batch-fabricated film memories, advanced plated magnetic film memories and integrated circuit memories.

Mechanisms Specialist
Experienced in applied mechanics problems and in the analysis and advanced design of complex mechanisms. Should be equally skilled in mathematical analysis and laboratory measurements.

For more information and Division brochure, write Tom E. Lyon, Technical Placement, at the address below.

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PERSONALS

1927

O. F. RITZMANN died of a heart attack at his home in Fox Chapel, Pa., on February 26. He was 65. Ritzmann had retired last December from the Gulf Oil Corp. and Gulf Research and Development Co., where he was a geophysicist and patent engineer. He is survived by his wife, three daughters, a son, and eight grandchildren.

1933

HARALD OMSTED, MS, structural engineer, retired in June 1966 from the Los Angeles City Schools. After spending three months in his native Norway, he is now working temporarily as a consultant for the Los Angeles Schools.

1948

JOHN O. RASMUSSEN JR, senior staff member of the Lawrence Radiation Laboratory and professor at the University of California, Berkeley, is one of five U.S. nuclear scientists to receive the Ernest Orlando Lawrence Memorial Award for 1967. The award is presented by the U.S. Atomic Energy Commission for recent contributions in the field of atomic energy. Rasmussen was cited for his "outstanding contributions to the better understanding of nuclear structure by his imaginative experimental and theoretical studies."

1949

CECIL E. SPRUILL, MS, died on January 31 in Dallas, Texas, after a brief illness. He had been a research engineer with the Ling-Temco-Vought Corp. in Dallas since 1953.

1958

MICHEL EBERTIN, MS, is the new supervisor of metal oxide semiconductor technology in the advanced engineering department of Autonetics—a division of North American Aviation, Inc. in Anaheim, Calif. Ebertin was formerly a specialist in research in the same department, and will continue his work in the development of micro-electronic techniques for large-scale integration.

1959

GERHARD J. KLOSE, MS '60, PhD '66, writes that he is an engineer with Electro-Optical Systems in Pasadena.

1963

KARVEL K. THORNBER, MS '64, PhD '66, was married April 1 to Nora Josephson in Palo Alto, Calif. Miss Josephson is the second woman to complete the requirements for a PhD in physics from Caltech and will receive her degree in June. Thornber is a research fellow at the Stanford University electronics laboratory.

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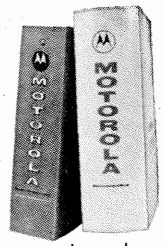

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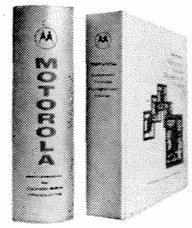
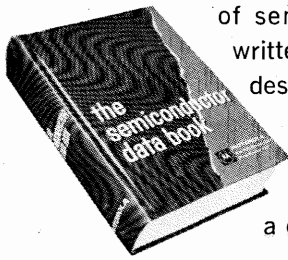
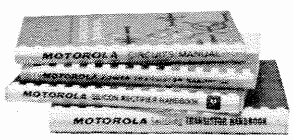
You won't find these books on any best seller list. In fact, you won't find too many people in the whole country who will even want to read them.



They're part of the continually growing library of Motorola manuals explaining the design and application intricacies of the fast changing world of semiconductors. They're written for a very specific audience—design engineers—and written with the knowledge that new advances will soon pace many out-of-date. To keep current is a challenge. Motorola welcomes it.



Today, semiconductor components and integrated circuitry are part and parcel of the modern engineer's way of doing things. Barely 10 years ago, most were items for theoreticians' drawing boards.



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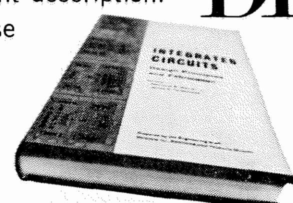
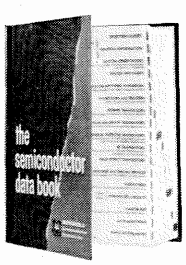


Motorola's technical publications are written for the benefit of any company's engineers. University teachers and students, too.



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