SOUTHWEST CENTER FOR ADVANCED STUDIES

ANNUAL REPORT 1966-1967

FORMERLY GRADUATE RESEARCH CENTER OF THE SOUTHWEST

Southwest Center for Advanced Studies
(Formerly Graduate Research Center of the Southwest)
Annual Report, 1966-1967

Cover Illustration Note

A tall-standing landmark placed on the Center's campus in 1967 by TAGER (The Association for Graduate Education and Research) exemplifies the expansion of graduate education opportunity in the North Central Texas area. Television links between academic institutions and to industry, for graduate teaching, are a current part of the many co-operations in which the Center is involved and has fostered.

But they are only a part. The fuller story of advanced education programs, keyed to basic research in several disciplines, is told in this Annual Report. Mingled with the story of accomplishments, the region's future needs are also assessed.

Contents

Awareness and Rededication 2
Graduate Education —
Its Impact on Regional Economic Progress .. 3
Graduate Education by Television — TAGER .. 4
Achievements in Education — SCAS 5
Campus Development 6
The Body of Research
Atmospheric and Space Sciences 7-9
Geosciences 10-11
Biology 12-15
Materials 16
Mathematics and Mathematical Physics 17
Computer Center 17
Pion Dosimetry 18
Research Partners 18
The Year: Passing of a Beloved Scientist 19
Milestones 19
In Recognition: *Individual, Corporate*
Pledges, Gifts 20
Patrons of Science 20
Financial Report 21
Governors and Trustees 22
Advisory Council 23
Officers and Staff 24

Published at Dallas, Texas, by the Southwest Center for Advanced Studies
An independent, non-profit institution chartered by the State of Texas for purposes of fundamental research and advanced education, in the public interest.
Printed in the United States of America

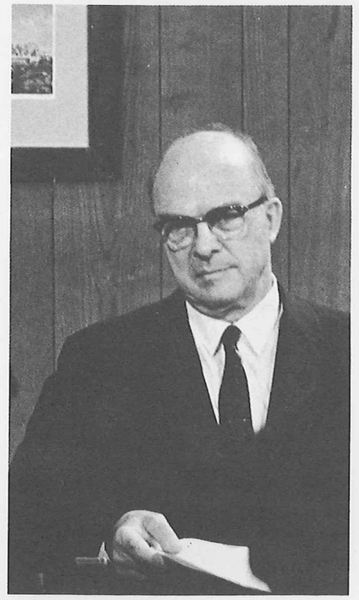
Awareness and Rededication

"An awareness of the basic need for more scientific manpower began to grow in the minds of some university and science-industry leaders in the Southwest a few years ago. University long-range planning has revealed a keen sensitivity to the needs, and the cry of science-industry leadership for its required scientific backup has become more insistent." . . . from "A Community of Scholars," 1963 Publication, the Southwest Center for Advanced Studies, Dallas.

Today, that awareness is, if anything, intensified. The commitment to fulfill the need grows ever stronger while the progress toward its fulfillment is commendable indeed. And, yet, because the technological forces increase almost as exponentially as the numbers of those to be educated, the chasm sometimes seems spanless in spite of the multiplicity of institutions, their strengths, and their unchallengeable dedication to help bridge it.

To fulfill, even approximately, the quantity of our higher educational needs at the quality level required in our immediate environs, there is no magic formula to reveal anew. As in all affairs in which men seek constructive and co-operative achievements, the components for potential success in higher education for our area are complex, but also perhaps fundamentally simple. In order for our diverse institutions, including the Southwest Center for Advanced Studies, to achieve expeditiously and cohesively their mutual goal of brainpower for a future as great in opportunities as complexities, surely we must build not only our private but our state-supported institutions. In both the private and state institutions those responsible must be unrelentingly conscious and strongly committed to achievement through the dual approach.

If it is to be productive, the co-operative spirit between either kind, any two or all the institutions and their people must be extended in direct and candid explorations of the common goal with sincerity of purpose and mutual trust. The goals of our institutions must be realistically balanced as to the whole. In each institution which will help meet the challenge, a clear orientation to the totality of the needs for advanced education and research



Erik Jonsson
(addressing Dallas citizens by television concerning the Goals for Dallas program).

will be the keystone to over-all achievements. The value to the Southwest and indeed the nation can be infinite.

Against such a background and in view of the State legislative call for intensified planning to meet the higher educational needs in the North Texas area, we wish to reaffirm our belief in the ability and commitment of our institutions of higher learning to meet the challenge. It is the intent of the Southwest Center for Advanced Studies to assist in whatever role and ways it can to expedite achievement of the ultimate mutual goals. Within that framework we record the completion of another year of achievement by the distinguished community of scholars who compose the Southwest Center for Advanced Studies and submit the report of their 1966-67 work with the highest commendations of their capabilities, diligence and dedication.

We note with enduring sadness the untimely death of Lloyd Viel Berkner, long-time scientific leader of the Southwest Center for Advanced Studies.

Erik Jonsson
Chairman, Board of Governors

GOALS FOR DALLAS

Higher Education

The Southwest Center for Advanced Studies, with the American Assembly, co-sponsored the program to study and define the common goals of Dallas citizens. Nearly 10,000 citizens participated in discussions and recommended revisions in the draft of goals which was reported in the 1965-66 SCAS Annual Report.

The section of the goals most directly pertinent to SCAS's own activities are reprinted below:

HIGHER EDUCATION
General Goal

Dallas and the North Texas area — possessing the necessary population, economic wealth, human resources and the nucleus of a university-college complex — can and must become one of the great education centers of the nation. We should provide the intellectual atmosphere and programs to meet the higher educational needs of individuals, to expand knowledge through research at all levels, to strengthen our economy and to make our lives more meaningful and satisfying. All programs should be of high quality, with graduate programs reaching to become steeples of excellence.

Specific Goals

Make an heroic effort to develop wide support and understanding for our institutions of higher education, recognizing that further industrial, economic and cultural gains in the region depend increasingly on the ability to educate our citizens and to attract others to Dallas. We must expand private support, insist on significant increases in state support for this area and supplement both with federal funds.

GRADUATE EDUCATION —
Its Impact On Regional Economic Progress

Education is shaping our economic future. It has been thrust on the consciousness of America as the means for our country to mold its future and grow to further greatness. Education provided the tools for our agricultural, industrial, technological and social evolutions. As our knowledge has grown, in pyramidal fashion, so has our need for the several levels and many specialties in our educational system. Change is the order of the day. Better education, and more of it, is needed each generation.

Fifty years ago an eighth grade education was no limiting handicap for most jobs; today, high school is not enough. Fifty years ago only 15 per cent of our youth graduated from high school and today it is 76 per cent. Fifty years ago only 4 per cent of the high school graduates entered college and today more than 50 per cent do. More and more job opportunities require, and social desires demand, college training. Texas college enrollments will double in 10 years. Think of it: in 10 years we must double our college and university capabilities. And as for graduate education — this is the fastest growing. Whereas our academic institutions themselves once employed most of the master's and doctor's degree holders, now government and public service, the military, business and industry are competing for their increasing share. And they pay for and encourage their employees to go back to school, thus swelling the ranks of those with graduate degrees.

Once each educational institution was relatively self-contained, and colleges were best located in small towns responsive to their needs. Today our education system revolves around the centers of population. Each level of education and each institution carries a relationship to the others and the whole must interact with and serve the region. Not the town or city alone, but the region.

Junior colleges are becoming region-oriented. They will influence what is taught at the public school level so that students will flow easily out of high school and into college work. Senior colleges will give way to junior colleges for some part of their freshman and sophomore work and in turn act to improve quality and venture into master's degree programs. Universities will grow to such size that a larger and larger proportion of their offerings will be at the graduate level. Different kinds of graduate in-

Gifford K. Johnson

stitutions will develop — medical universities, technical universities, teaching universities and universities for the social sciences.

Private institutions are under pressure better to define the roles they can and wish to play, for they cannot gain new resources and grow as fast as enrollments are increasing. They can, however, lead the way in quality and excellence, and along those paths they choose to follow. The publicly-supported institutions must continue to assume the largest burden of growth and yet strive for greatness and for productive relationships with private institutions. The ratio of students in private and public colleges and universities has changed from 50-50 (20 years ago) to 35-65 today.

Graduate education is much more expensive than undergraduate and therefore rapid growth in this area is an extra problem. A major source of support is the federal government, both for scholarships and for research grants. A state such as Texas, which has much to do in both quantity and quality, the better to match other areas of the country in graduate education, must consider additional state funds for scholarships and research to develop, attract and hold top students and faculty in our graduate schools, both public and private.

The National Science Foundation has recently announced a study confirming the importance of research. It points out that 21 per cent of all the funds that 711 of our degree granting institutions used came from federal sources for the support of academic science in 1963. As usual, the few obtain the most, for only 15 per cent of the institutions received 96 per cent of the total funds.

There is a direct relationship between federal funds and the production of doctoral degrees in science and engineering and medicine.

There is a distinct trend in industry to draw most of its leaders from those with graduate degrees.

The Southwest Center for Advanced Studies was brought into being to influence and promote doctoral education of high quality in this area. We have recruited a great faculty and, with them, a most substantial body of research, growing to $5 million this year. We have conducted many experiments and collaborative teaching programs with institutions in the area.

Last year we again stated our objectives to emphasize that we were here to help advance graduate education in the region to a level comparable to other leading regions.

In re-examining our objectives and developing our longer range plans, we see:

1. Our regional graduate education requirements in science and technology have only begun to grow and expand.
2. We must help to develop graduate student sources. This can be done by adding to our present summer programs, providing opportunities for undergraduates, with both research participation and study involved. And, by providing updating courses for college teachers.
3. We see a need to produce an ever-changing and broad array of skills at the graduate level, including a broad-gauge, multiple-skilled *scientific philosopher* to meet industry's requirements.
4. We must further develop the largest body of basic research in the region, by attracting eminent faculty through whom such research is obtained, and seek ways to apply that faculty strength and our laboratories in expanding the graduate programs of both private and state-supported institutions.

Gifford K. Johnson

Gifford K. Johnson, President
October 25, 1967

Education's tower became an open tracery of steel in international orange and white during September, 1967.

In classrooms on the campuses of three universities, at the Southwest Center for Advanced Studies, and in the research and development buildings of four industries, graduate students began studies by television.

Nine locations across Dallas, to the far western boundary of Fort Worth, were linked by a closed-circuit, microwave television system constructed by TAGER (The Association for Graduate Education and Research of North Texas). A tenth industrial classroom site 50 miles northeast of Dallas, at Greenville, continued service started early in the year via leased communications lines.

Thirty-seven courses were offered in the first semester, 11 being interchanged among TAGER's institutions; these include a five-day program of seminars by the Center's faculty and visiting scientists. Twenty-six of the courses, principally in advanced engineering subjects, were offered by Southern Methodist University's Institute of Technology.

TAGER had just passed its second anniversary as television teaching began. A seven-member education consortium, TAGER was founded in 1965 to speed development of graduate education in North Texas by combining faculty and other academic resources of its membership. In addition to the Center and Southern Methodist, members are Texas Christian University, the University of Dallas, Bishop College in Dallas, Texas Wesleyan College at Fort Worth, and Austin College at Sherman.

The pilot TV network opened in September extends from TAGER's key station on the Center campus to Southern Methodist, the University of Dallas, and Texas Christian. It also reaches receiving classrooms at Collins Radio Company and Texas Instruments Incorporated in the north Dallas suburban area; the Ling-Temco-Vought research centers in Dallas-Fort Worth suburbs, and at General Dynamics, on the far west side of Fort Worth.

The microwave television system is a powerful co-operative effort to solve the logistics and reduce the costs of graduate education.

TAGER courses started in the fall term included work in mathematics, statistics, physics, atomic and molecular spectra, quantum mechanics, and physiology.

In addition to the seminar program, Center faculty members teach co-operative courses for other TAGER schools. An example is *Selected Topics in Applied Mathematics*. The teacher is Prof. Wolfgang Rindler of the Center's Mathematics and Mathematical Physics Division. The source school is designated as Southern Methodist. Students there, at Texas Instruments, and at General Dynamics, enroll in *Mathematics 123*. For the same course, students at the University of Dallas enroll in *Mathematics 51*.

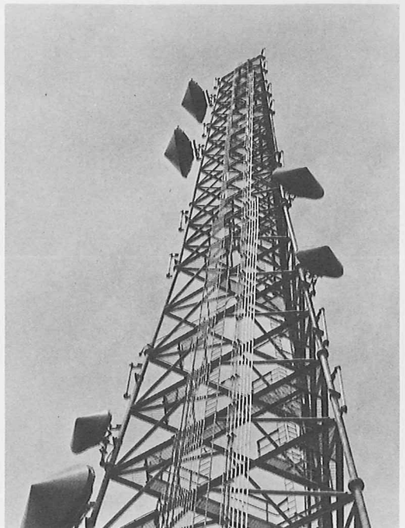
The TAGER network will be extended to Austin, Bishop and Texas Wesleyan Colleges as the spectrum of courses broadens from graduate science and engineering to include undergraduate work and additional disciplines. It will also extend to other industrial sites in North Central Texas, to meet added requests for graduate education opportunity.

TAGER's first President, Robert W. Olson, took office in the summer of 1967. President Olson is "on loan" to TAGER from Texas Instruments, where he is Vice President, Special Projects Office. Mr. Olson is a member of the Texas State Board of Registration for Professional Engineers. He is also a national director of the Industrial Research Institute, a consultant to the Organization for Economic Co-operation and Development, and a member of the Joint U.S.-Brazil Subcommittee on Industrial Research. He has served as Chairman of the Advisory Council of the Engineering Foundation, The University of Texas.

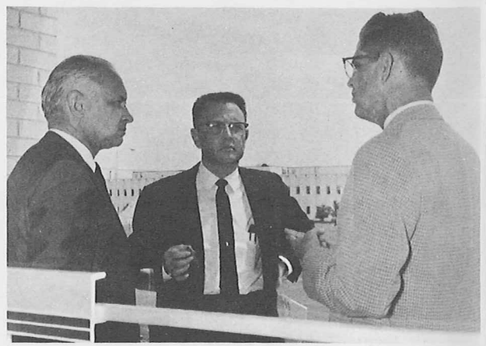
Cecil H. Green, a co-founder of the Center, is Chairman of both TAGER's Board of Governors and Board of Trustees.

Initial planning and executive direction of TAGER, through its first 18 months of operation, were carried out by Dr. Jesse E. Hobson, of Heald, Hobson, and Associates.

The TAGER Planning Committee now responsible for co-ordinating the TV teaching programs is headed by Ross C. Peavey of the Center, as Chairman. Members are Dr. Leigh Secrest and C. Frank Seay, Jr. Dr. Secrest is President of the TCU Research Foundation and Dean of the Graduate School at Texas Christian University; Mr. Seay is Assistant to President Willis M. Tate at Southern Methodist University.



TAGER President Robert W. Olson



Center column — The TAGER-TV antennas rise 250 feet above the Center's campus.

Right — Planning Committee members Peavey, Secrest, and Seay meet at the key station site.

When Space Scientist Charles Y. Johnson began his lecture on *Ion and Neutral Composition of the Atmosphere,* September 13, 1967, the Center recorded its approximate 650th visiting speaker since seminar presentations began in the fall of 1962.

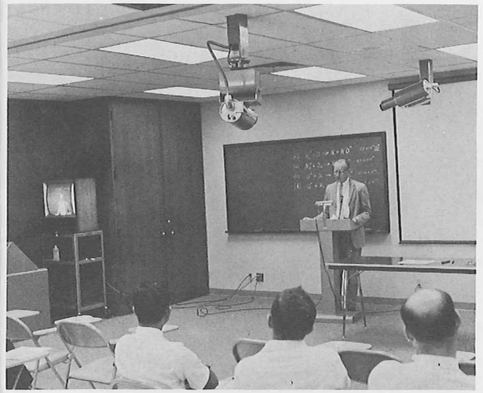
Representing the Naval Research Laboratory at Washington, D.C., Scientist Johnson was also the first visitor to be presented on the TAGER television network.

The substantial numbers of seminar visitors, reaching a total of 143 speakers during the year ended June 30, 1967, represent only one part of the Center's contribution to advanced education.

Faculty and staff also gave 92 seminars during the same year, attended by industrial scientists and faculty and students from regional universities.

In classrooms, the Center's total teaching achievement extended to 34 faculty members, teaching 40 courses at 10 institutions, since the fall of 1963. Thirty-one of the courses in the total history were at graduate level.

Visiting Lecturer Charles Y. Johnson presents the first televised seminar from the Center.



During the year ended June 30, 235 students at seven universities were taught by Center faculty members. The courses totaled 54 semester hours, and drew upon faculty from Atmospheric and Space Sciences, Geosciences, Biology, and Mathematics and Mathematical Physics Divisions, as well as the Computer Center staff.

Teaching at the high school level began in September, 1967, in computer programming and mathematics, for the Richardson, Texas, system.

At the Center, post doctoral education continued for 20 staff members during the year. The post doctoral programs inaugurated in 1962 had brought a total of 47 advanced students to the Center as the year ended.

Dr. John Dowling was appointed on the faculty of Texas Technological College, and Dr. Benjamin Gottlieb was appointed to the Bishop College faculty from the post doctoral group.

Summer student programs again brought more than 65 college undergraduates to the campus during this year, for research participation and special instruction.

A *Short Course in Earth Sciences,* conducted August 7-25, 1967, by members of the Geosciences faculty and visiting lecturers, brought 29 college teachers to the Center. The group literally came from coast-to-coast locations, and represented junior colleges, independent colleges, and several large state universities. The special course was sponsored by the National Science Foundation.

In addition to the teaching activities, the total of scientific publications by Center faculty reached 324 at the close of the year.

Teachers from 29 colleges attended the Short Course in Earth Sciences at the Center in August, 1967.

CAMPUS DEVELOPMENT

Development of the Center's campus continued through the past year with the addition of one auxiliary office building, while two industrial research structures were added in nearby locations.

The Western Company of North America formally opened its Research Division laboratories on March 17, 1967. Western's site is within the 160-acre Technology Park development at the south boundary of the Center's lands.

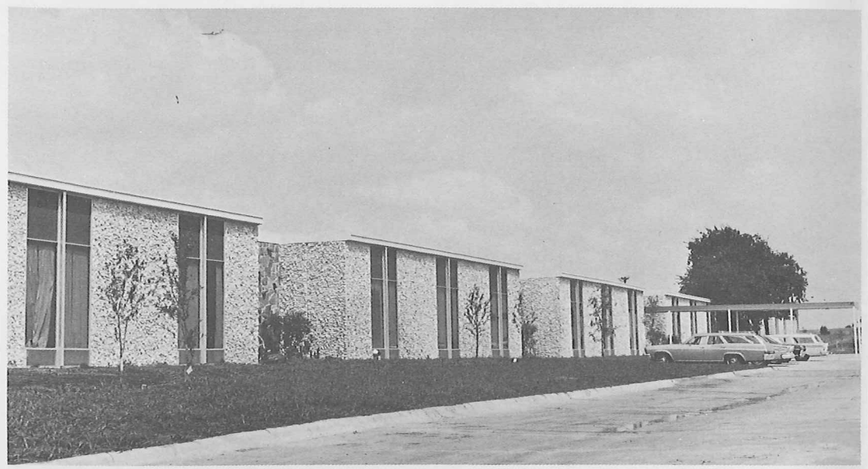
Texas Instruments Incorporated began use of a test range to the northwest of the central campus, on 125 acres acquired in 1963.

The North Office Building was opened in December, 1966, housing the Center's Mathematics and Mathematical Physics faculty and several administrative and supporting service offices.

TAGER (The Association for Graduate Education and Research) built an administrative office and key station building for its television education program during the summer of 1967; a 250-foot tower was also erected, to carry microwave antennas for the three-channel system (See Page 4).

Upper — The Western Company has occupied its 39,000 square foot Research Division laboratories in 160-acre Technology Park.

Lower — Texas Instruments Incorporated has constructed electronic test facilities on a 125-acre campus area.



THE BODY OF RESEARCH

Atmospheric and Space Sciences

Atmospheres and the fields permeating them, from Earth's surface through interplanetary space, are the domain of the space scientist.

Looking at many kinds of radiation in space, as well as dynamics, his research may eventually affect space travel, including commerce; communications by radio, and the forecasting of weather.

During the past year, solar cosmic radiation gained in importance as the Sun's radiation cycle began an upswing that will continue for the next several years, including the period when Apollo flights begin to put men on the Moon.

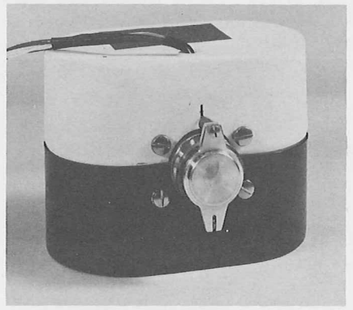
The radiation environment of interplanetary space has been better defined, during the past two years, by analysis of *Pioneer 6* and *Pioneer 7* data, obtained during many cosmic ray increases of solar origin.

These two space vehicles, each carrying the Atmospheric and Space Science Division's cosmic ray experiments among several kinds of instrumentation, are intended to remain in Sun-centered orbits approaching the paths of Venus and Mars.

The small radio voice of *Pioneer 7* has returned data to define the Earth's magnetic envelope as cigar-shaped, 160,000 miles in gross diameter, and streamed by the solar wind to a distance of 3.5 million miles on the lee side of Earth.

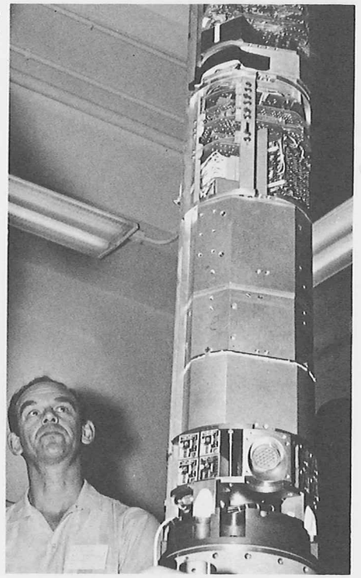
Many other important conclusions have been drawn from the *Pioneer* data. Among them are these few:

Solar cosmic ray propagation processes observed near Earth show a strong dependence on solar longitude. They are most efficient when a parent flare begins about 45 degrees to the west of the Sun's central meridian as viewed from Earth.



This is the sensing element of the Cold Cathode Gauge Experiment, to be placed on the Moon's surface by Astronauts. (See Pages 8-9.) Primary objective of the experiment is to measure the density of the lunar atmosphere and thus provide data for determining atmospheric pressure. Prof. Francis S. Johnson of the Center's Atmospheric and Space Sciences Division is Principal Investigator for this project.

Right — Professor Heikkila and the Modular Auroral Probe assembly (See page 9).



"Western origin" cosmic ray fluxes move rapidly from Sun to Earth, injecting quickly onto a tube of magnetic force that bends toward Earth among other tubes in a spiral field. The cosmic radiation energy in this system does not scatter greatly.

"Eastern origin" fluxes show greatest early intensity on tubes to the evening side of an observer, with a rise following the transport of these tubes to his vicinity.

On occasions, the onset phase and totality of flare effects show irregular time variations in both intensity and paths. This is taken as evidence of inhomogenous filaments of cosmic ray distribution in the interplanetary field, and in turn as an indication of some slow azimuthal distribution of solar cosmic rays. Typical cross sections of the filamentary distributions are a half-million to 5 million miles in diameter.

At late times in flare effects, cosmic radiation shows a persistent anisotropy, or favored directions, which is not field aligned. This implies that solar cosmic radiation tends to remain identified with the tube of force onto which it is first injected; that is, the solar cosmic ray population co-rotates with the Sun, and with the interplanetary magnetic field.

Professors McCracken, Palmeira, and Rao, with Dr. Bukata and Mr. William C. Bartley, have designed and directed the cosmic ray experiments and analytical program.

Dr. Jon G. Ables, Oklahoma State University graduate student, completed his dissertation research in the program during the past summer, and was awarded the Ph.D. at Oklahoma State in July.

In-flight instruments were augmented during the year by the May 24, 1967, launch of an *Interplanetary Monitoring Platform* (IMP-F). This vehicle, in a highly-eccentric polar orbit, carries the Division's cosmic ray detector in and out of Earth's magnetic field. Currently being built are another IMP package, and three additional Pioneer deep-space detectors.

Space detectors generally seek and see the lower cosmic ray energies, in the order of 10-to-350 *million* electron volts.

But cosmic rays coming from the far reaches of our galaxy to reach Earth's upper atmosphere have energies as high as 300 *billion* electron volts and greater. This compares to the 200 billion electron volt design plan for the National Accelerator Facility, now being planned for a midwestern site.

When these energetic rays strike in the upper atmosphere, the reaction creates showers of atomic nuclear particles. Many surface arrivals of energetic particles are observed by the Division's two neutron monitors.

Some of the immediate energetic products are pions, or pi-mesons, which in turn produce *muons* (mu-mesons) and neutrinos. Practically nothing can stop a neutrino, which has no electrical charge. It zips through the Earth and continues into space.

But the charged muon can be captured and seen as a small lightning streak in a magnetic spectrometer or "spark chamber."

FACULTY AND STAFF
July 1, 1967

Atmospheric and Space Sciences

Professor and Head
Francis S. Johnson, Ph.D.

Professors
William B. Hanson, Ph.D.
Walter J. Heikkila
Kenneth G. McCracken, Ph.D.
(On leave)
Gilbert N. Plass, Ph.D.

Associate Professors
Carl B. Collins, Ph.D.
John H. Hoffman, Ph.D.
James E. Midgley, Ph.D.
Thomas N. L. Patterson, Ph.D.

Assistant Professors
R. Richard Hodges, Ph.D.
Worth B. Hurt, Ph.D.
Ricardo Palmeira, Ph.D.

Research Scientists
Jon G. Ables, Ph.D. Candidate
(Degree awarded, July, 1967, by Oklahoma State University)
William D. Bunting, M.Sc.
James S. Donaldson, M.S.
Thomas W. Flowerday, M.S.
Ronald Giroux, B.S.
Philip T. Gronstal, M.S.
William R. Sheldon, Ph.D.
J. B. Smith, B.S.
Jens Tarstrup, M.S.
Brian A. Tinsley, Ph.D.
(Appointed Assistant Professor, effective August, 1967)

Engineers
Richard L. Bickel, M.S.
James M. Carroll, B.S.
James C. Corwin
Nick Eaker, B.S.
Edward C. Lee, B.S.
Billy W. LeFan, B.S.
Charles R. Lippincott, M.S.
Joseph F. Metrailer, M.S.
Richard H. Morgan, B.S.
William J. Odom, B.S.
Felipe Selva, B.S.
Donald R. Stang, M.S.
Teddy Thomas, B.S.
Karl R. Tipple, M.S.
Richard G. Van Tyne, B.S.
Willie W. Wright, M.S.
Jack M. Younse, B.S.
Donald R. Zuccaro

Adjunct Associate Professor
Alexander A. J. Hoffman, Ph.D.
(Texas Christian University)

Visiting Assistant Professors
George W. Kattawar, Ph.D.
(North Texas State University)
U. Ramachandra Rao, Ph.D.
(Physical Research Laboratory, Ahmedabad, India)

Post Doctoral Research Associates
Frank R. Allum, Ph.D.
Robert P. Bukata, Ph.D.
Supriya Santani, Ph.D.
W. Hugh Wright, Ph.D.

Visiting Scientists
Forrest D. Colegrove, Ph.D.
(Texas Instruments)
Benjamin Gottlieb, Ph.D.
(Bishop College)
Arthur W. Green, M.S.
(Texas Instruments)
James E. Hughes, M.S.
(Austin College)
Ann Palm, Ph.D.
(University of California, Berkeley)

A joint program with Texas A&M was initiated during the past year, involving the construction of a "rocking chair" spectrometer with a pair of eight-ton saturated iron magnets. The amount of bending in muon spark trails by the magnetic field gives the clue to particle energy, and in turn to the original cosmic ray direction and energy. Spark chambers are situated above and below the magnets.

Dr. Sheldon of the Division and Prof. Nelson M. Duller of Texas A&M University's Physics department are the Principal Investigators in the high-energy cosmic ray program. The spectrometer is being built on the A&M campus, and portions of the program are being performed by three doctoral degree candidates as dissertation research.

Design of an underground cosmic ray telescope is being done at the Center. Data from this companion experiment, involving high zenith angles, will be matched with that of the spectrometer in further refinement of the muon energy-range relation. Telescope sites 3,000 feet beneath the French-Italian border and 17,000 feet up in the Bolivian Andes will provide the comparative data.

The rocking chair aspect of the large spectrometer comes from its mounting on semi-circular I-beams that permit rotation to all zenith angles.

On the Earth's surface at Dallas, small pulsations in the magnetic and electrical fields slow down at local nighttime; the waves have longer periods, up to 150 seconds, and are at lower frequencies, on geomagnetically "quiet" nights.

The observation has been made by Adjunct Associate Professor Hoffman of Texas Christian University and Visiting Scientist Green of Texas Instruments Incorporated, in experiments running since early 1965.

The micropulsations were sensed by mu-metal cored coils and earth-current electrode systems, and the data converted to power spectra. Selection of quiet days was with the aid of daily magnetograms from the Environmental Science Services Administration (ESSA) Standard Magnetic Observatory, at the Dallas Geomagnetic Center. Both the standard observatory and the micropulsation experiments are located at the DGC site, on the Center's campus.

A source mechanism for generation and propagation of magnetohydrodynamic (MHD) waves, which cause the small pulsations, has been suggested by the research observations. The theory leads both to lower-frequency nighttime micropulsations in the PC-3 and PC-4 categories, and allows for so-called *pearl* events (at 0.3 to 3.0 cycles per second, and rather rare).

A current sheet, or strip, may form an elliptical wave guide or duct along an Earth magnetic field line, with abrupt terminations at the base of the ionosphere. MHD waves, originating as the solar wind buffets the magnetosphere of the Earth, could be reflected and produce standing wave resonances within such a duct. Half-wave lengths of waves having periods from 20 to 100 seconds would fit on known lengths of field lines.

Because of the lee-side shape of Earth's magnetosphere, some field lines may be considerably longer at local nighttime, and thus produce the longer-period micropulsations.

In addition to diurnal changes, the theory also calls for an increase in PC-3 and PC-4 periods at higher latitudes. This is being tested by analysis of data obtained from Soviet observatories, located about 20 degrees higher in latitude, matched in time to Dallas data.

When Astronauts arrive at Earth's oldest satellite, the Moon, they will leave a cold cathode ionization gauge to measure the lunar atmosphere's pressure. The gauge will also show the loss rate, or dispersal, of contaminants left in the landing area by Astronauts and their Lunar Excursion Module.

Professor Johnson is Principal Investigator for this project. To be operated continuously for a year, the cold cathode gauge will transmit data to the Manned Spacecraft Center at Houston through a central Apollo Lunar Surface Experiment Package (ALSEP) telemetry station.

The experiment, shaded from the Sun during lunar daylight and heated in nighttime, must withstand a 500-degree temperature range centered at Fahrenheit zero. The cold cathode ion gauge, supplied by the National Research Corporation, will be in a sealed vacuum package as its travel begins, to avoid contamination in transit and during deployment at some 60 feet from other ALSEP experiments. The seal will be broken and the equipment activated by Earth-originated command some two days after the Astronauts have left the lunar surface.

The abundance of hydrogen in the Earth's corona appears to have seasonal variation, maximum in the fall and minimum in the spring. This conclusion has been drawn by Dr. Tinsley on the basis of two years of observations of Balmer-alpha radiation in the night airglow. Observations were made by grille spectrometer instrumentation at a New Mexican mountain location near the period of solar minimum. A marked increase of helium emissions (at 10830 Angstroms) during the morning and evening twilight was also noted in the winter of 1966-67.

If no large nighttime source of ionization is available to the F_2 region of the ionosphere, it is essential that persistent equatorial winds exist at night at these approximate 300 kilometer heights. Without such winds, the nighttime concentration of electrons would be several orders of magnitude smaller than observed. The inference for dynamo winds as a factor in daily variations of F_2 electron concentration has been made from preliminary results of calculations by Professor Hanson.

Professor Hanson (center) makes final inspection of the Javelin rocket-borne ionospheric probe prior to shipping the instrument for the June, 1967, flight.

A new explanation for the rapid falloff with altitude of neutral sodium atoms, observed above 92 kilometers by airglow experiments, has been suggested by Professor Hanson and Mr. Donaldson. The mechanism relies on an east-west neutral wind to lower the positive sodium ions to that region, where they are destroyed, presumably in a reaction with ozone.

Iron particles in the lower ionosphere, coming from meteor destruction, presumably have scattering effects on radio waves. A study to understand these properties, especially those of forward scattering, is being made by Professor Hodges. From this understanding it will be possible to examine the influence of large iron-particle concentrations, such as may be present in meteoric dust clouds, on radio-wave dispersions in the ionosphere.

Data reduction from the mass spectrometer in the *Explorer 31* satellite, which was launched piggyback with *Alouette II*, the Canadian topside ionospheric sounder, in late 1965, has been transferred to the Center. Explorer 31 carried several instruments to measure the various properties of the ionosphere. Included was a small magnetic mass spectrometer, to measure the relative abundances of ions, The instrument was constructed at the U. S. Naval Research Laboratory. The Principal Investigator, Professor Hoffman, has since joined our faculty.

Rocket probes to the Upper-F region of the ionosphere began with a Wallop's Island, Virginia, launch of a Javelin rocket package on June 21, 1967. The series of firings will be from sites and at times chosen to match overpasses of *Alouette II* and *Explorer 22*. Ion traps and an ion spectrometer are carried in the Javelin packages. The flights are intended to show vertical profiles of the ionosphere as the satellites view it from topside.

The Division has also provided ion mass spectrometers and planar traps to be flown on the *Orbiting Geophysical Observatory* (OGO-F) Satellite. Professor Hanson is Principal Investigator for both the Javelin flights and the similar OGO-F experiment program.

Rocket investigations of auroral zone and polar cap phenomena are being carried out by Professor Heikkila, from the Churchill Research Range in Canada. The *Modular Auroral Probe* (MAP) payload design is unique, allowing for quick-change, plug-in experiment combinations. It also is designed to be recoverable, by parachute.

This makes it especially attractive for graduate student use. The student needs only to build his experiment package, rather than a complete system including power units. If his experiment fails, there is the chance to repair and fly again. Two graduate students, Mr. James R. Sharber and students, James R. Sharber and John David Cunningham, both of Texas A&M University, have prepared a particle detector unit to fit, the MAP system.

Professor Heikkila is Chairman of Polar Cap investigations for COSPAR, the United Nations Committee on Space Research. Through COSPAR, international co-operation in polar area observation will be sought and summary information developed and circulated.

Professor Hanson serves on the Ionospheres and Radio Physics Subcommittee of NASA's Space Science Steering Committee, and is also a member of the Geophysical Research Satellite Definition Group, aiding in the definition of scientific objectives for the 1970's.

Professor Johnson is a member of NASA's Lunar and Planetary Missions Board, the Group for Lunar Exploration Planning of the Manned Spacecraft Center and the MSC Apollo Meteorological Advisory Group; he has also been a member of the Planetary Atmospheres Subcommittee of the Space Science Steering Committee, Chairman of the Lunar Atmosphere Measurements Team, and a member of the Voyager Capsule Advisory Group.

Professor Johnson is also a member of the Space Science Board, National Academy of Sciences.

During the past year, Professor Johnson was named an adviser in science and engineering to the Environmental Science Services Administration (ESSA).

FACULTY AND STAFF
July 1, 1967

Geosciences
Professor and Head
Anton L. Hales, Ph.D.
Professors
John W. Graham, Ph.D.
Mark Landisman, Ph.D.
Consulting Professor
Eugene T. Herrin, Ph.D.
(Southern Methodist University)
Associate Professor
Charles E. Helsley, Ph.D.
Assistant Professors
Martin Halpern, Ph.D.
Ian D. MacGregor, Ph.D.
(Appointed Associate Professor, Effective September, 1967)
Dean C. Presnall, Ph.D.
John S. Reitzel, Ph.D.
Glen H. Riley, Ph.D.
Post Doctoral Research Associates
James L. Carter, Ph.D.
Jack Dowling, Ph.D.
Adam Dziewonski, Ph.D.
Visiting Scientist
Philip Horton, Ph.D.
(Phillips University)
Research Scientists
Selwyn Bloch, B.Sc.
Ju-Chin Chen, Ph.D.
Rodleigh W. E. Green, B.Sc.
William I. Manton, M.Sc.
(Appointed Assistant Professor, Effective August, 1967)
Engineers
Donald Bacon
John A. Keiller

THE BODY OF RESEARCH

Geosciences Division

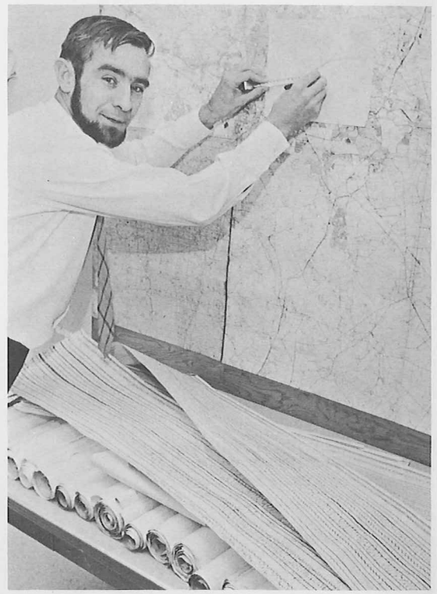
One of the early results of the study of the dispersion of surface waves was the confirmation of the existence of the Gutenberg low-velocity layer in the Earth's upper mantle. Since that time, much has been learned of the structure of the upper mantle from studies of the relation between group and phase velocities of surface waves and the periods of the waves.

During the past year in the Geosciences Division, Professor Landisman, with Dr. Dziewonski and graduate students Robert P. Massé and Brian J. Mitchell, has developed new methods for finding and displaying the group velocity-period relation. Mr. Bloch and Professor Hales have similarly studied a variety of procedures for the determination of phase velocity to period.

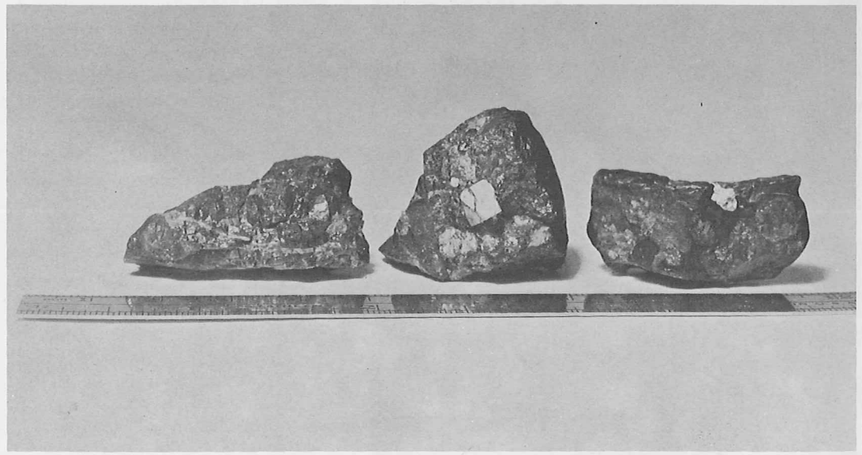
These new techniques are being applied in studies of surface waves from such widely scattered areas of the surface of the Earth as Australia, Central Africa, North America, and Europe. With the new knowledge of upper mantle structure which comes from these studies we hope to understand better the processes which have shaped the Earth we see today.

Body wave studies, too, have played their part in the attempt to understand the structure of the upper mantle, and especially the regional differences in that structure. Dr. Hugh A. Doyle, Research Scientist, and Professor Hales have extended the study of the regional differences in travel time, begun by Dr. John Cleary and Professor Hales, to S waves. It turns out that the upper mantle S velocity variations are three to four times larger than the P velocity variations; so much larger, in fact, that the only likely explanation of them is that there are layers in which partial melting has occurred at depths of the order of 100 kilometers below the surface.

Mr. Green and Professor Hales have shown too that the differences in travel times of the waves from Lake Superior to the central United States and those from Nevada to the same region, produced by large man-made explosions, imply that the velocity in the low velocity layer already known in the Nevada area is even lower than had been thought.



Right — Travel time records from Lake Superior and Nevada to the central regions are studied by Research Scientist Green.



Proof of Earth-mantle origin for kimberlite inclusions is shown by the presence of diamonds in three eclogite samples.

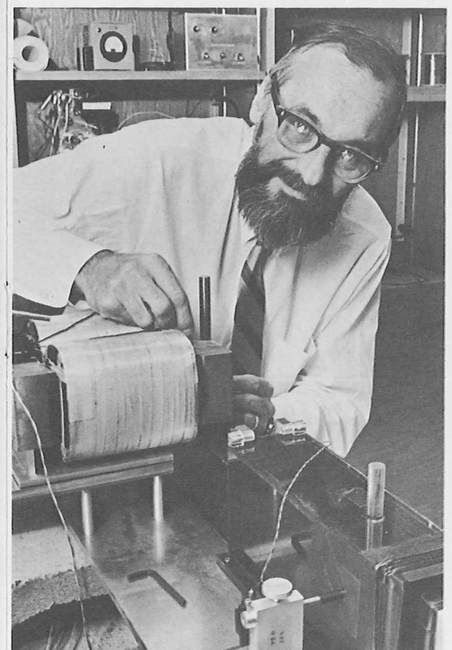
The samples were donated to the late Dr. Brian T. C. Davis, former Geosciences faculty member, by Mr. R. C. Versluis, a prospector from Barkely West, South Africa, for investigation of the genesis of the diamonds and the enclosing eclogite.

Another method of looking for high temperature zones in the upper mantle is to study the magnetic fields induced in the Earth by magnetic storms in the ionosphere and other disturbances of the magnetic field. Professor Reitzel and Prof. D. Ian Gough built equipment for this purpose and were able, from a reconnaissance into the Rocky Mountains in 1966, to show that in Colorado there is a similar magnetic anomaly to that already found by other workers in Texas.

Professor Helsley, with graduate students Henry R. Spall and Amos Nur, has collected more material for paleomagnetic measurements directed at finding out where the continents were in relation to one another many millions of years ago. Professor Graham's studies of the deformation history of rocks have been stimulated by the development of another technique, measurement of the dielectric anisotropy, for this purpose.

Dr. Carter and Professor MacGregor have made X-ray and optical measurements on the suite of inclusions from the African kimberlite pipes. There is clear evidence from the mineral assemblages that these samples come from the mantle. One of the more spectacular proofs lies in the occurrence of diamonds in three of the eclogite inclusions. Photographs of the diamonds *in situ* are shown here. This study has stimulated the development by Dr. Carter of a model of upper mantle composition based on his analyses of inclusions in basalt flows at the surface, and high-temperature pressure experimental work in the laboratory by Professor MacGregor.

Professor Graham has developed new techniques for study of the deformation history of rocks.



Measurements of the ages of Antarctic Peninsula and South American rocks have been made by Professor Halpern, and those of rocks from the Black Hills and Australia by Professor Riley. Mr. Manton has continued the study of the origin of igneous rocks, making further measurements on samples from Africa and the northwestern United States.

The search for an explanation for the enhanced brightness of the backscattered light from the Moon's surface at zero phase angle has been pursued, but so far no really convincing solution to the problem has been found. In view of the difficulty in making models at the wavelengths of visible light, Dr. Horton and one of his students have begun a study of scattering at radar wavelengths.

There are many Earth areas in which sediments have been laid down to a depth of 10 kilometers or more. It has long been recognized that it is difficult to conceive of a mechanism by which such great thicknesses exist in shallow water; that is, on the continental shelf, simply because, even allowing for isostatic effects, the sea soon is filled up.

Summer student Jim Rhoads of Austin College prepares magnetic variometers for a Colorado field experiment.

It is possible that the sediments were deposited in the deep seas, beyond the continental margin. It is, in theory, possible to discriminate between the two modes of deposition by determining the thickness of the crust below the Gulf Coast sediments. To this end, Professors Hales and Helsley conducted a seismic refraction experiment along a line south and north of High Island, Texas. The experiment was carried out with the co-operation of the U. S. Coast and Geodetic Survey. Observations were made on land and at sea.

Analyses of observations made in the Caribbean, the Pacific and off the East Coast of the United States have been continued this year by Professor Helsley and Dr. Dowling.

The second of a series of American Association of Petroleum Geologists geological highway maps, produced by a committee under the chairmanship of Dr. Philip Oetking was completed during the year. The map covered the four states of Utah, Colorado, Arizona and New Mexico.

LEFT — Professors Helsley and MacGregor have been named Principal Investigators for future NASA studies of lunar surface material to be returned from first manned landings on the Moon.

FACULTY AND STAFF

July 1, 1967

Biology Division

Professor and Head
Carsten Bresch, D.R.N.
Professors
Royston C. Clowes, D.Sc.
Walter Harm, Ph.D.
Daniel L. Harris, Ph.D.
John Jagger, Ph.D.
Claud S. Rupert, Ph.D.
Consulting Professor
Charles A. Thomas, Ph.D.
(The Johns Hopkins University)
Visiting Professor
Harold L. K. Whitehouse, Ph.D.
Associate Professors
Hans Bremer, Ph.D.
Rudolf L. Hausmann, M.D.
Wolfram Heumann, Ph.D.
Dimitrij Lang, Ph.D.
Yvonne Lanni, M.D.
Harold Werbin, Ph.D.
Assistant Professors
Ronald Bauerle, Ph.D.
Hermann G. Bujard, Ph.D.
Myer L. Coval, Ph.D.
Herbert Gutz, Ph.D.
Klaus Haefner, Ph.D.
Klaus Heckmann, Ph.D.
Winfrid G. D. Krone, Ph.D.
Michael Patrick, Ph.D.
Philip Witonsky, Ph.D.
Research Fellow
Hideo Hirokawa, Ph.D.
Research Scientists
Ira Felkner, Ph.D.
Juergen Wiemann, Ph.D.
(Technical Executive Officer)
Post Doctoral Research Associates
Horst Brunschede, M.D.
Rufus S. Day, Ph.D.
Beatriz Gomez, Ph.D.
Helga Harm, Ph.D.
Adelaide McFarren, Ph.D.
Hildegard Michalke, Ph.D.
Wolfgang Michalke, Ph.D.
Karl Mueller, Ph.D.
Christine Smith, Ph.D.
Derald Smith, Ph.D.
Hiraku Takebe, Ph.D.

THE BODY OF RESEARCH

Biology Division

Most of the studies conducted in the Biology Division during the past year fall into the category of molecular genetics. They are in one way or another related to or directed at determining the detailed structure and functioning of the heredity-controlling DNA molecule and how the cell implements its instructions (gene action).

With the electron microscope, Professor Lang has recorded the size and shape of DNA under the influence of environmental changes; for example, the effect of drugs such as actinomycin. In water, DNA swells up more than any other known molecule, and this makes studies of its physical properties very difficult. Nevertheless, Professor Lang has recently succeeded in determining the diffusion coefficient of DNA at extremely low concentrations, where the molecules behave independently of one another.

Professor Bujard is studying the DNA of bovine papilloma virus, using the ultracentrifuge and the electron microscope. The DNA of this virus forms a closed ring and shows a twisted superstructure. Professor Bujard found that the twists of this superstructure are right-handed. In collaboration with Professor Clowes, he also has investigated the physical nature of bacterial drug-resistance factors, believed to be small molecules of DNA. These factors are responsible for the development of resistance by bacteria to common antibiotics, a development causing great concern in the field of preventive medicine. The widely-known "hospital Staph" is an example of a bacterium which we could formerly destroy easily with antibiotics, but which now eludes all attempts to control it.

Professor Harris has investigated the physical nature of enzymes responsible for splitting high-energy phosphate bonds, a process that provides much of the chemical energy of the cell. Recent work on the effect of pH on the kinetic constants of the enzyme reaction has revealed the probable existence of a group of protons within the enzyme; these act to draw electrons away from the phosphate group upon which the enzyme is acting. These studies are leading toward a detailed understanding of the structure and function of the active site of an enzyme.

It is known that the first step in gene action is the transfer of the "message" (sequence of nucleotides) from a small segment of the DNA molecule to another molecule called *messenger RNA* which grows along the DNA chain, thus acquiring a nucleotide sequence complementary to that of the DNA. The messenger RNA then carries the information to the sites of protein synthesis.

Protein synthesis is the central "operating process" in cells, because proteins make up much of the cell structure and also constitute the enzymes which produce the rest of the cell structure and which carry out, within the framework of this structure, all the biochemical functions of the cell.

Professor Bremer is studying the manner in which messenger RNA is synthesized on the DNA molecule. He has found that in a living system, a typical RNA is manufactured at the rate of 25 nucleotides per second, which provides some notion of the high rate of information transfer that occurs in living cells. *In vitro* (outside the cell), RNA molecules can also be made to grow on DNA molecules. Under these conditions, however, they grow only intermittently, with stops as long as several seconds. Professor Bremer is currently attempting to understand why the RNA molecules grow differently inside and outside the cell.

Professor Witonsky, who recently joined our division, is investigating the nature of the enzyme, RNA polymerase, which produces this messenger RNA. Although there has been little evidence to support the idea, it has been generally believed that the RNA polymerase separates the strands of the normally two-stranded DNA molecules and then proceeds to make messenger RNA along one of these strands. Professor Witonsky has conducted temperature studies which indicate that this separation of DNA strands, or melting, does in fact occur.

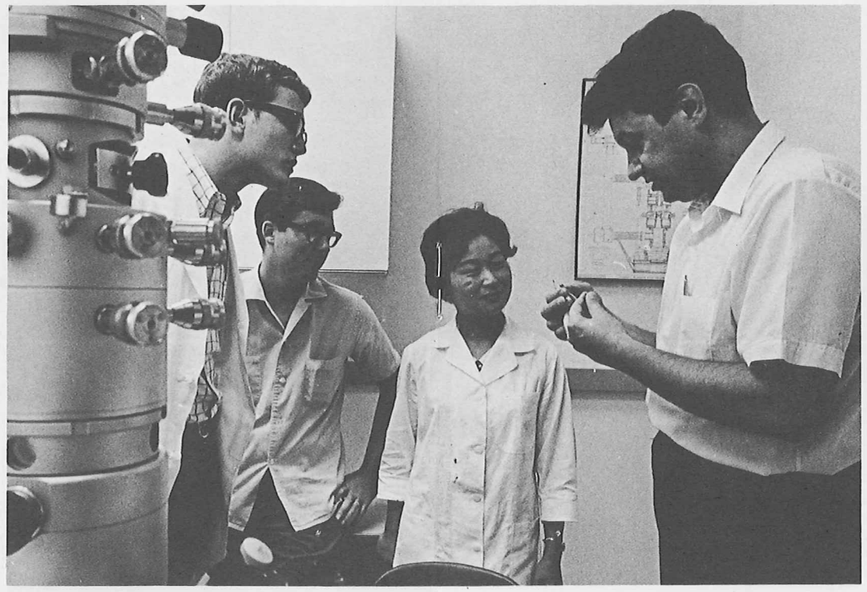
Related work, carried out at a more genetic level, is that of Professor Bauerle, who is investigating the structural elements and their interactions in the small part of DNA (the operon) that produces a single messenger RNA. An operon contains several genes, whose message is transcribed into the messenger RNA only after the action of a switch or "operator" at the beginning end of the operon. By genetic techniques, Professor Bauerle is examining the behavior of these components of the operon.

Professor Clowes has studied the action of small molecules of DNA, or plasmids, that sometimes attach to the large molecules of DNA (chromosomes) and sometimes act independently as small units. These factors may determine the sexuality of bacteria, the production of proteins that are lethal for other bacteria, or resistance to a broad spectrum of antibiotics, and they can be infectiously transferred between certain bacterial strains. His work suggests that there is only one active factor per nucleus, and this factor is attached to a specific site on the cell membrane. If other factors are present at the same time, they are generally repressed by the active factor.

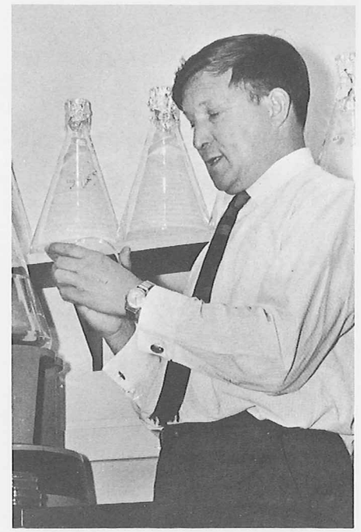
Molecules of DNA can interact to produce new combinations of genes that in turn give rise to modified cells and organisms. This is called *genetic recombination,* a phenomenon responsible for the progeny of sexual organisms being only partly similar to the parents. It is a very fundamental and powerful attribute of the genetic material of living systems.

We are most fortunate to have on our campus, for six months, Visiting Professor Whitehouse from the University of Cambridge, who is studying theoretical models of genetic recombination. By analysis of a broad spectrum of experimental findings, Professor Whitehouse has arrived at a model having the following characteristics: (a) there are fixed primary breakage points in the DNA and these are located at the ends, not in the middle, of genes; (b) these breakage points are always at one particular end of the gene, and (c) the initial step in recombination, which requires one of the DNA strands to open up, is not breakage of a strand but rather failure to close a gap in the strand that existed after a previous DNA replication.

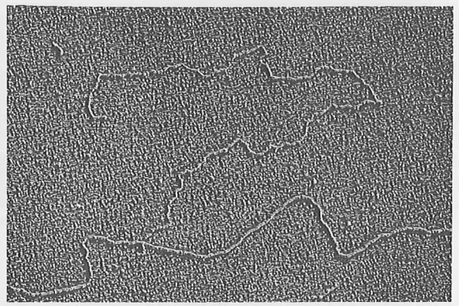
DNA can be isolated from one type of cell and then made to "infect" another type of cell. In so doing, this "transforming" DNA transmits some of the characters (genes) of the old cell into the newly infected cell. Dr. Hirokawa has been able to infect bacterial cells with an artificial hybrid DNA, in which one strand comes from one organism and the other strand from another organism. Such an infected bacterium upon multiplication gives rise to a mixture of colonies, some containing characteristics of one of the infecting DNA strands and some characteristics of the other strand. This shows that both strands of the infecting DNA become integrated into the chromosome of the host cell. This integration is a form of genetic recombination. In collaboration with Dr. Felkner, Hirokawa has isolated a mutant bacterium which takes up DNA with good efficiency but shows very poor transformation, which is to say that its genetic recombination is very inefficient. Studies with this organism promise to reveal some characteristics of the process of recombination.



Professor Lang explains operation of the electron microscope to students.



Professor Clowes' research includes studies of the action of DNA plasmids.



Single-stranded DNA (top) in electron micrograph can be distinguished from double-stranded DNA (bottom) by presence of more "kinks" and less contrast.

Professor Lanni joined the Biology Division late in the year. Since then she has had a fellowship to attend a three-week course in Naples, on the subject of DNA-RNA hybridization. Professor Lanni is interested in all aspects of the infection of a bacterium by a bacteriophage. Her work has elucidated some of the early steps in transfer of phage DNA into the host cell and has indicated which genes are transferred early and which are transferred later.

Professor Heumann has studied a curious form of sexuality, in certain types of soil bacteria, called "star formation." Such bacteria congregate in groups that resemble stars and then, in some unknown manner, exchange genetic material. Professor Heumann believes that star formation may be considered a repair mechanism for radiation damage, because star formers are much more resistant to irradiation by sunlight. This repair appears to be a type of genetic recombination, in which the good parts of the chromosomes of various cells are linked together and the bad parts (those affected by the radiation) are eliminated.

Professor Bresch is investigating reduction division, or meiosis, the process by which the ordinary (somatic) cells of the body, which possess a double set of chromosomes, are converted into the sexual cells (sperm or egg) which have only a single copy of each chromosome. Meiosis is a fundamental mechanism in biology, and one which permits extensive genetic recombination.

Professor Bresch studies this phenomenon in yeast, one of the simplest forms of life exhibiting meiosis. He has now been able to isolate mutants defective in various steps of meiosis, and has thus completed the first essential move toward an understanding of the biochemistry of meiosis.

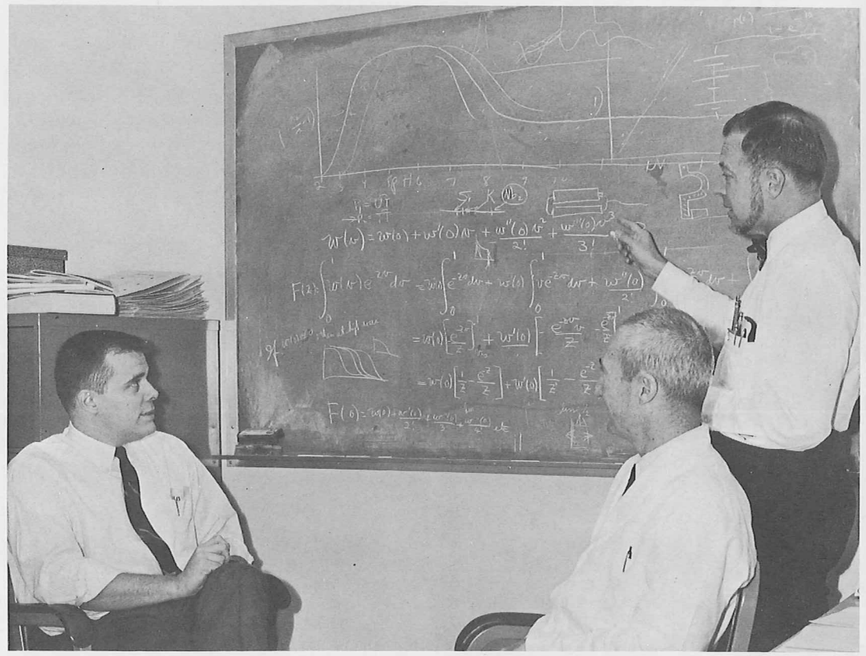
Related studies in yeast are conducted by Professor Gutz, who recently discovered an effect he calls "twin meiosis", a phenomenon in which two cells from different diploid strains of yeast can mate and then produce two separate meioses. He is attempting to understand the physiological conditions which permit twin meiosis. Professor Gutz is also studying the phenomenon of "gene conversion," in which he finds behavior which cannot be explained by current models of recombination.

Professor Heckmann is working in the genetics of protozoa. He is particularly interested in the structural differentiation of the surface of these cells. It is known that the arrangement of surface organelles is dictated by pre-existing orientations, and that some differentiation of the surface structure may be induced by the presence of other structures.

Professor Heckmann's work indicates that these patterns of differentiation are subject to long-range control by nuclear genes, and he now looks forward to studies of the interplay of genetic and non-genetic factors in these processes. This type of study, namely the manner in which genes express themselves during the life cycle of the cell, is of great importance and is likely to become the central type of biological problem to be attacked in future decades. Its relation to the theoretical problem of cancer and of other differentiation abnormalities is obvious.

Professor Krone is attempting to understand the congenital disease of humans called "mongolism", in which children are born with very low mentality and impaired cell biochemistry. This defect is caused by the presence of an extra chromosome in the cells of the victim. Professor Krone is comparing the activity of certain enzymes in skin cells of monogoloid humans with those of normal humans, in an effort to determine why one chromosome more than the normal 46 should have such drastic effects. He has recently broadened his study to include action of the weak carcinogen, thioacetamide. These studies may provide insight into the mechanism by which carcinogens operate.

Professors Patrick, Werbin, and Rupert confer on a question in photobiology.



One of our largest groups is studying the biological effects of ultraviolet radiation (UV photobiology) at the microbial and chemical level. The subject is of interest for a variety of reasons, one of them being the central role played by energetic untraviolet radiation (far UV) in the origin and evolution of life on Earth. Far UV affects the genetic material (DNA) of the cell. One of the major photoproducts is a "thymine dimer", a lesion that effectively produces a "spot weld" in the DNA, which can lead either to death of the cell or to its mutation into an abnormal cell. Professor Rupert and Professor Patrick are attempting to identify intermediates in the formation of thymine dimers and are also studying other photoproducts produced by far UV.

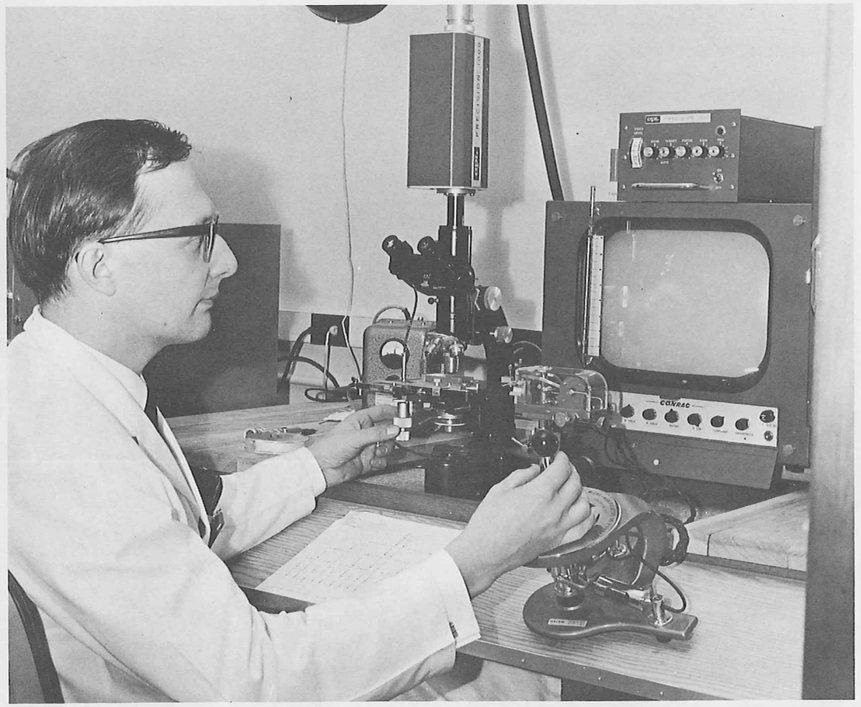
A major reason for interest in far UV photobiology lies in the fact that damage produced can be repaired to a remarkable extent by the cells themselves. These repair phenomena include spontaneous processes, or dark repair, as well as repair stimulated by visible and near-visible light (photoreactivation). The dark repair system is believed to have much in common with the process of genetic recombination.

Professor Rupert has developed a mathematical model, based on UV studies of bacterial transformation, of how genetic recombination might effect the repair of UV damage. Professor Harm has recently found that dark repair in bacteria falls into two classes, one of which is closely related to the recombination system while the other appears to be more distantly related. He has found that a very low intensity of UV radiation allows much more complete repair. This finding is undoubtedly of ecological importance and also contributes to our understanding of mechanisms. Professor Patrick has recently found evidence that inactivation of DNA by nitrous acid shows dark repair, another evidence that dark repair can work on other damages than those caused by ultraviolet.

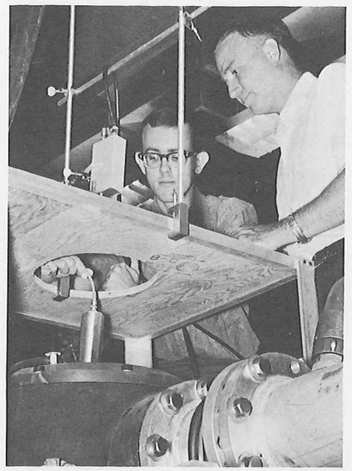
Photoreactivation usually uses an enzyme which, when activated by visible light, can repair far-UV damage such as thymine dimers. The first such enzyme was found in bacteria about a decade ago by Professor Rupert. An apparently similar enzyme has now been found for the first time in a plant tissue (an alga) by Professor Werbin, who is continuing studies on its characterization. Professor Jagger has recently obtained evidence suggesting that photoreactivation at certain wavelengths, around 3130 Angstroms, may be a direct reversal of the far-UV damage, not requiring an enzyme. This possibility is being investigated on a biochemical level by Professor Patrick.

Near UV, less energetic ultraviolet that is present in sunlight, appears to act on the quinones, substances intimately involved in the biochemical energetics of the cell. A typical quinone is Vitamin K, a factor required for blood clotting. Professor Werbin, with the collaboration of Professor Jagger, is studying the chemistry of quinone photoproducts. One of the important photoproducts appears to be a quinone dimer, somewhat analogous in structure to the thymine dimer.

Some very fundamental and painstaking work in radiation biology is being conducted by Professor Haefner. After treatment with either UV or X-rays, individual cells placed in a growth medium divide over and over again. Using micromanipulation techniques, Professor Haefner separates the tiny (about one-thousandth of a millimeter diameter) bacterial progeny cells and observes which ones live and which ones die. This pattern of survival (lethal sectoring) can tell us much about how radiation kills cells. Professor Haefner's work has already eliminated several theoretical possibilities. One of those remaining is that at least part of the lethal sectoring might be caused by a delayed repair of radiation damage occurring in later generations.



Professor Haefner demonstrates micromanipulation techniques with electronic scanning equipment, used to separate bacterial cells.



Professor Crawford and Steve Curry, graduate student, of Southern Methodist were first university users of the High Magnetic Field Facility. Mr. Curry is inserting a lithium-drifted silicon radiation detector and radiation source in the bore of the magnet, to determine effects on the detector.

FACULTY AND STAFF

July 1, 1967

Materials Research Division
High Magnetic Field Facility

Acting Head
C. Girvin Harkins, Ph.D.
Adjunct Professors
Sybrand Broersma, Ph.D.
(Oklahoma University)
Dayton D. Eden, Ph.D.
(Ling-Temco-Vought, Inc.)
Norman G. Einspruch, Ph.D.
(Texas Instruments Incorporated)
J. R. Sybert, Ph.D.
(North Texas State University)
Groves C. Wetsel, Ph.D.
(Southern Methodist University)
Visiting Investigators
Prof. George W. Crawford
(Southern Methodist University)
Prof. Lloyd E. Gourley
Prof. Mary F. Gourley
(Austin College)
Prof. H. J. Mackey
(North Texas State University)
Prof. Jack Yahia
(Oklahoma State University)
Research Scientist
Gerald J. Smith, B.A.
Research Assistant
Stanley E. Monroe, B.A.

THE BODY OF RESEARCH

Materials Research Division

Magnetic fields of 90,000 gauss were generated at the Center's High Magnetic Field Facility on July 13, 1967.

The successful production of such fields places the Center in the first four magnet laboratories of the nation, ranked by capability to generate continuous strong fields in useful volume.

The laboratory is the only one of such size and capability west of the Mississippi.

The three large-bore electromagnets available at our facility were constructed and tested in January, 1967, at the National Magnet Laboratory, Massachusetts Institute of Technology, and were received at the Center in March.

Large motor-generator units, capable of supplying some two million watts of power for the magnets, were first tested in June. The dual-generator system is that formerly used by the M.I.T. magnet laboratory, and was transferred to the Center in 1966 as a gift from M.I.T.

Construction of the facility, which was begun under the direction of Prof. Lauriston C. Marshall, was completed under Professor Harkins' supervision as Professor Marshall reached his retirement during the year.

Professor Harkins is also conducting the Center's research in magnetic effects, with interest centered on complexion compounds and thin films.

The High Magnetic Field Facility, as the primary laboratory of the Materials Research Division, offers opportunity for research in very basic properties of materials. The behavior of electrons in metals, as application of a strong magnetic field changes energy relationships, is an example.

In addition, materials may be made more "perfect" by removing thermal imperfections; using magnetic field and cryogenic techniques together, materials can be subjected to the lowest temperatures, only a few microdegrees above absolute zero.

The combined techniques offer a unique opportunity for research in physics, chemistry, biology, and associated engineering problems.

Under a 1967 grant by the Advanced Research Projects Agency, the Center has made the facility available to several Principal Investigators from Texas and Oklahoma universities, as well as to their graduate students.

Development of high-pressure and high-temperature laboratories are future additions to the regional facilities, to expand the Materials Research Division's service to both universities and industry.

Future planning for the Division also includes the establishment of a materials preparation group, to provide ultra-pure materials samples for basic research, and to develop experimental devices.

Professor Harkins reports on the High Magnetic Field Facility's capabilities as industrial visitors spend a day at the Center.

THE BODY OF RESEARCH

Mathematics and Mathematical Physics Division

The third in a series of international Texas Symposia on Relativistic Astrophysics, all organized jointly by the Mathematics and Mathematical Physics Division and corresponding groups at The University of Texas and Belfer Graduate School, Yeshiva University, was held in January, 1967, at New York City.

There were more than 650 registered participants from 25 countries. Some of the highlights involved contributions of Prof. I. S. Shklovsky and Prof. V. L. Ginzburg, both of the U.S.S.R., on X-ray and gamma ray astronomy; their contributions had an important influence on research in the United States in subsequent months.

Professor Robinson is an editor of the symposium proceedings, which are in preparation as this report is published.

The next symposium in the series will be held in Dallas, as was the first. It is scheduled for December 16-20, 1968.

Professor Rindler, during the year, worked with a group at the Massachusetts Institute of Technology on problems of computer-assisted learning.

The ever-growing size of college classes will eventually make inevitable the use of large electronic "brains" for simultaneous tutoring of up to 1,000 students. The most revolutionary method consists of a more-or-less free computer-student conversation by use of electronic typewriters.

Professor Rindler takes the roll for the first class taught by a Center faculty member on the TAGER television network, September 5, 1967.

A beginning has been made in the programming, and the first field of study chosen was relativity theory.

Professor Rindler also worked out a parallel between Kruskal space and the uniformly-accelerated frame of special relativity, to throw new light on some of the topological complexities of the former.

Professor Ozsvath elucidated the geometry and kinematics of finite rotating universes.

Professor Cahen, assisted by graduate student Jaqueline Sengier, worked on further applications of his bivector Cartan formalism. He obtained the complete solution to the problem of classifying vacuum solutions admitting a simple geodesic Debever congruence. Numerous exact solutions and theorems concerning other situations were also obtained in his study.

Professor Cahen also worked on Lie algebras and, among other things, studied an essential extension of the Poincaré group. Professor Bichteler's work in algebra included a result showing existence of a global spin structure for a gravitational field if, and only if, the second Stiefel-Whitney class of the spacetime vanishes.

Professor Bichteler also solved the local Cauchy problem for the relativistic Bolzmann equation, and prepared a comparative dictionary of the various equivalent mathematical formalisms used in relativity, such as spinors, tensors, bivectors, and forms.

Dr. Elliott Krefetz applied the so-called post-Newtonian approximation of general relativity to the classical question of the three-body problem, and also to the internal constitution of the stars.

FACULTY AND STAFF

July 1, 1967

Mathematics and Mathematical Physics

Professor and Head
Ivor Robinson, B.A. (Cantab.)
Professors
Yuval Ne'eman, Ph.D.
(On leave)
Istvan Ozsvath, Ph.D.
Wolfgang Rindler, Ph.D.
Visiting Professors
Roy Kerr, Ph.D. (The University of Texas)
Alfred Schild (The University of Texas)
Andrzej Trautman (University of Warsaw)
Associate Professor
Michel Cahen, Ph.D.
Post Doctoral Research Associates
Klaus Bichteler, Ph.D.
(Appointed Assistant Professor, effective July, 1967)
Elliott Krefetz, Ph.D.

Computer Center

New and continuing education activities, plus both hardware and software improvements, were recorded in our Computer Center during the past year.

A six-weeks course in Computer Management, developed in connection with the Data Processing Management Association, was held for 18 managerial people from industry. The Computer Science Course for Bishop College was continued during the spring term; 14 college and university students, from six schools, took part in the summer program here.

Preliminary planning to develop a graduate level Computer Science curriculum is underway with other TAGER institutions. The program is intended to share both faculty and facilities.

An added 131,000 bytes of core storage, for a total of 262,000 bytes, was a major equipment expansion of the year. Also added to the basic 360/50 system were a data acquisition terminal, an 1100 line-per-minute printer, and a second selector channel.

With software additions, including WATFOR, a FORTRAN language compiler for student programs, total system improvements resulted in a four-to-one through-put gain during the year.

Major equipment placed on order for delivery between now and late 1969 will increase the hardware availability to one millon bytes of large core storage and a 360/65 system.

STAFF

July 1, 1967

Computer Center

Director
Jack S. Donaldson, M.S.
Administrator
John R. Carpenter
Systems Programming Manager
Carl M. Peters, B.A.
Scientific Programming Manager
Charles R. Shelton
Operations Manager
Bob J. Capers
Librarian
Kay Kimsey

THE BODY OF RESEARCH

Pion Dosimetry Project

Prospects for a "meson factory" at Los Alamos, N. Mex., brightened early in 1967 when President Lyndon B. Johnson asked Congress for $50.3 million to build the facility.

At the Center, this news pointed up Prof. Chaim Richman's special project in Pion Dosimetry.

The negative pi-meson, produced in an accelerator, may prove useful for treatment of human cancer. The pi-meson is called "pion," for short.

Professor Richman began to look into the use of pions for cancer therapy about six years ago. He joined the Center faculty in 1962.

He saw the possibility of using pion beams to produce highly-localized radiation. That is, to use a fast-moving particle from the atom's nucleus; aim it at tumor cells by careful selection of its energy, and produce a reaction like a sky-rocket's star-burst within the target area.

The goal: To do the most damage to the tumor cells, and the least damage to healthy tissue, both nearby and in the radiation path.

The principle has been well-demonstrated by Professor Richman's experiments, using pion beams from the Berkeley 184-inch cyclotron. Bean roots, and mice with implanted cancer cells have been the targets.

But there has been no pion source powerful enough for use in human therapy. One million pions per second have been produced for the mouse experiments. Human treatment needs a machine that can produce hundreds of millions.

The "meson factory" at Los Alamos will meet this requirement. It will be a linear proton accelerator (LINAC) that can hurl the heart of the atom down a half-mile-long tube into a target from which pions bend off in a pencil-like beam.

The pion is a part of the atomic nucleus. It is generally regarded as the "glue" that binds together protons and neutrons in the nuclear cluster. The basic particles are bound by some of the strongest forces known; mesons are a part of this force, although their exact role is not clear.

Professor Richman describes his own efforts as one program of many aimed at better treatment for tumor and cancer. His research, in physics, should not be regarded as "the great cure," he comments.

A long list of biological experiments are now necessary, and are being planned, to work out the effectiveness of the pion radiation in destroying tumor cells and preserving healthy tissue.

The LINAC at Los Alamos will not be completed until about 1971.

FACULTY AND STAFF

July 1, 1967

Pion Dosimetry

Professor
Chaim Richman, Ph.D.
Assistant Professor
M. R. Raju, D.Sc.
Post Doctoral Research Associate
Nabil Amer, Ph.D.

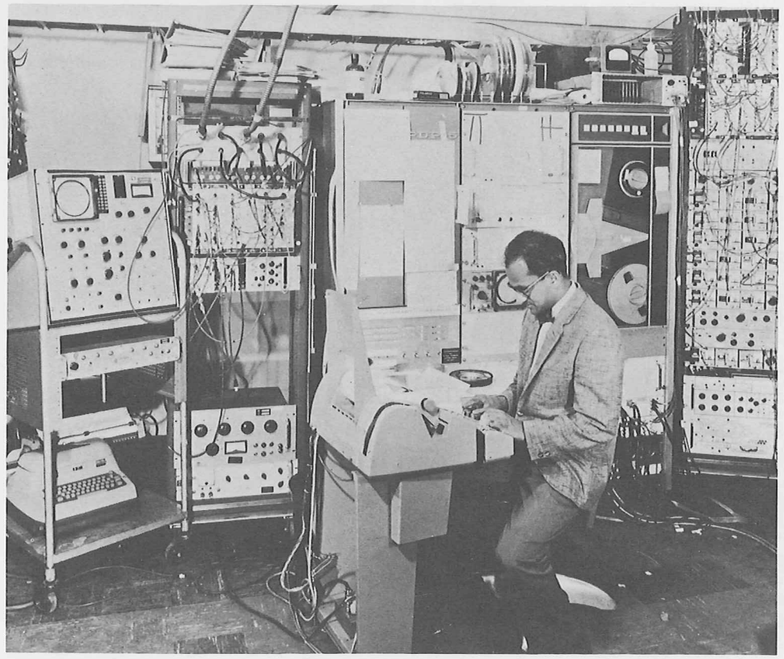
PARTNERS IN RESEARCH

More than four-fifths of the basic research at the Southwest Center for Advanced Studies is supported by grants and contracts. We are pleased to acknowledge these research partnerships in the listing published below.

During the year ended June 30, 1967, 77 research projects were funded, in whole or in part, by the following agencies:

- Advanced Research Projects Agency
- Air Force Cambridge Research Laboratories
- Air Force Office of Scientific Research
- American Cancer Society
- American Chemical Society
- Atomic Energy Commission
- National Aeronautics and Space Administration
- National Institutes of Health
- National Science Foundation
- Office of Naval Research
- U. S. Army Research Office (Durham)

These instruments provide the dosimetry data in pion experiments conducted by Center faculty at the University of California, Berkeley. Professor Raju is pictured at the recording system.



The Year: Passing of a Beloved Scientist

Lloyd Viel Berkner, an Incorporator, the first President and a Member of the Board of Governors of the Southwest Center for Advanced Studies, died in Washington, D. C., June 4, 1967. He had been stricken the previous day, while serving as a member of the Council of the National Academy of Sciences, in which he held the office of Treasurer.

The following resolution is published by the Board of Governors, with desire to record their deep sorrow at the death of their esteemed associate:

"RESOLVED that the Board of Governors of the Southwest Center for Advanced Studies hereby gives expression of its heartfelt sorrow and deep sense of loss in the death of Lloyd V. Berkner, beloved colleague, a scientist of worldwide reputation, a stalwart pioneer, a strong and courageous leader, and a true and loyal friend. Dr. Berkner has left to each individual his words:

" 'Underlying the process of discovery there is required the mastery of a whole mountain of detailed knowledge. This requires long and bitterly hard work. But this is not enough. It requires the spark of that unusual intellect that through insatiable curiosity can reassociate ideas in new ways, can find new insights.'

"Dr. Berkner indeed gave witness to that which he spoke. To the world, he said: 'To those who cannot identify today's scientific research with human welfare of tomorrow, I would say look more deeply so that you can appreciate its full breadth and penetration. Do not be too impatient for the elaboration and synthesis of those new and great ideas that provide the basic capital on which a rising society subsists.'

"Sorely shall we miss his august person among us, and his undaunted fortitude in building the Southwest Center for Advanced Studies as the foundation of an eminent community of scholars. Ever with us are his name, goals and achievements, as we move forward on the road he paved."

Dr. Lloyd V. Berkner receives the Distinguished Public Service Medal from NASA Administrator James Webb.

Milestones and Achievements

During the year covered by this Report, the following events were recorded:

Lloyd V. Berkner received NASA's Distinguished Public Service Medal, at Washington, October 7, 1966.

The Center became a full member of Gulf Universities Research Corporation, an educational-research consortium of 16 universities and centers from Texas to Florida. Prof. Anton L. Hales was elected a Director.

The North Office Building was added to campus structures, and put into use in December, 1966.

Prof. Francis S. Johnson was named an adviser in science and engineering to the Environmental Science Services Administration, and was also chosen to serve on NASA's Planetary Missions Board.

The Center aided in organization of the 1967 Texas Conference on Relativistics Astrophysics, held in New York City January 23-27. Prof. Ivor Robinson served as an organizer to continue the series of international meetings begun in Dallas in late 1963. Next in the series is scheduled in 1968.

Prof. Walter Harm, Assoc. Prof. Dimitrij Lang, and Asst. Prof. Ronald H. Bauerle received Research Career Development Awards from the National Institutes of Health. Purpose of the grants is to increase career opportunities for scientists "of superior potential and capability in the health-related sciences."

The corporate name of the Center became *Southwest Center for Advanced Studies*, replacing the name *Graduate Research Center of the Southwest*, on January 1, 1967.

The Western Company opened its research laboratories, in the Center's Technology Park, March 17, 1967.

Lloyd V. Berkner received the Bowie Medal, highest award of the American Geophysical Union, at Washington, April 19, 1967.

Seventeen papers were given by faculty and staff of the Geosciences Division at the national meeting of the American Geophysical Union. Prof. Anton L. Hales, Prof. Mark Landisman and Asst. Prof. Glen H. Riley were session chairmen.

Guests at Petroleum Day hear results of research in petrology in a visit to the Geosciences Division.

In Recognition: Individual, Corporate Pledges and Gifts Aid Center

During the year 1966-67, the Center continued and expanded upon its programs to broaden the base of private financial support. Inaugurated in the year were special days at the Center for executives and research leaders from the petroleum industry, as well as groups from insurance and banking businesses.

A total of 300 private donors gave $1,201,165 to advance the Center in the period July 1, 1966, through June 30, 1967. This total amount, in pledges, gifts and grants, was slightly higher than similar totals for each of the two preceding years; $955,739 was received in the year ending June 30, 1966, and $933,277 in the year ending June 30, 1965.

The Center's Resources Committee is headed by Stanley Marcus.

In special recognition to those families and individuals who gave strongest support to the Center in its founding years, the informal association *Patrons of Science* was inaugurated late in 1966.

New memberships are open to friends of the Center who pledge their intent to make contributions of $10,000 or more over a 10-year period.

The Hon. John B. Connally, Governor of Texas, citing the founding members for their contributions to the causes of graduate education and basic research, said: *"You have created something here that will live beyond your time. You have launched an institution that I predict will have a profound influence on education across the nation."*

The membership of *Patrons of Science,* as of July 1, 1967, was as follows:

Patrons of Science

Mr. and Mrs. Fred J. Agnich
Mr. and Mrs. Harry W. Bass
Mr. and Mrs. Clay P. Bedford
Mrs. Lloyd V. Berkner
Mrs. Elizabeth Stemmons Bishop
Mr. and Mrs. James H. Bond
Mr. and Mrs. Roland S. Bond
Dr. and Mrs. Malcolm K. Brachman
Col. and Mrs. D. Harold Byrd
Mr. and Mrs. Sanders H. Campbell
Mr. and Mrs. W. W. Caruth, Jr.
Mr. and Mrs. William P. Clements, Jr.
Mr. and Mrs. Eugene Constantin, Jr.
Mr. and Mrs. Trammell F. Crow
Mr. and Mrs. A. Earl Cullum, Jr.
Mr. and Mrs. Robert S. Folsom
Mr. and Mrs. Douglas W. Forbes
Mr. and Mrs. T. Carr Forrest
Mr. and Mrs. Burton Gilliland
Mr. and Mrs. Cecil H. Green
Mr. and Mrs. P. E. Haggerty
Mr. and Mrs. Jake L. Hamon
Mr. and Mrs. Earl F. Hayes
Dr. and Mrs. William B. Heroy, Sr.
Mr. and Mrs. A. G. Hill
Mr. and Mrs. J. S. Hudnall
Mr. and Mrs. W. Herbert Hunt
Mr. and Mrs. Henry S. Jacobus
Mrs. John Leddy Jones
Mr. and Mrs. Erik Jonsson
Mr. and Mrs. Edmund J. Kahn
Mr. and Mrs. James J. Ling
Mr. and Mrs. Lewis W. MacNaughton
Mr. and Mrs. Stanley Marcus
Mr. and Mrs. Frederick M. Mayer
Mr. and Mrs. Eugene McDermott
Mr. and Mrs. Algur H. Meadows
Mr. and Mrs. Charles A. Meyer
Mr. and Mrs. C. W. Murchison
Mr. and Mrs. C. W. Murchison, Jr.
Mr. and Mrs. John D. Murchison
Mr. and Mrs. John J. Redfern, Jr.
Mr. and Mrs. Elgin B. Robertson
Mr. and Mrs. Winthrop Rockefeller
Mr. and Mrs. Loyd B. Sands
Mr. and Mrs. Julius Schepps
Mr. and Mrs. Frank A. Schultz, Jr.
Mr. and Mrs. Morris G. Spencer
Mr. and Mrs. John M. Stemmons
Mr. and Mrs. L. Storey Stemmons
Mr. and Mrs. Howard T. Tellepsen
Mr. and Mrs. Jack C. Vaughn
Mr. and Mrs. Joseph Zeppa

In Memoriam

The Center mourns the deaths of four *Patrons of Science* within the past year:

Dr. Lloyd V. Berkner, June 4, 1967
Mr. Karl Hoblitzelle, March 9, 1967
Mrs. Grady H. Vaughn, Jr., April 18, 1967
Mr. Grady H. Vaughn, Jr., August 9, 1967

Key Corporate Donors Cited for Contributions

Key corporate and business donors to the Center during its founding years were also recognized by publication during the year.

The following firms, each of which has given $25,000 or more, were cited by W. W. Overton, Jr., Chairman of the Center's National Resources Committee, in the announcement:

Bell Aerospace Corporation
Collins Radio Company
Dallas Clearing House
Dallas Life Officers Association
Dallas Market Center
Dallas Morning News/Stations WFAA
Dallas Power & Light Company
Dallas Times Herald
Dresser Industries, Incorporated
Ford Motor Company
General American Oil Company of Texas
Geotech — A Teledyne Company
Industrial Properties
International Business Machines Corp.
Ling-Temco-Vought, Inc.
Lone Star Gas Company
Mobil Oil Corporation
Neiman-Marcus Company
Pollock Paper Company
Sanger-Harris Department Stores
Sears, Roebuck and Company
Southland Life Insurance Company
Southwestern Bell Telephone Company
Southwestern Life Insurance Company
Texaco Incorporated
Texas Industries, Incorporated
Texas Instruments Incorporated
Texas Power & Light Company

FINANCIAL REPORT

Research

Continued growth in sponsored research and faculty and staff is illustrated in the following table. The faculty and staff increased from 342 to 382 during the past year. The principal areas of this growth were in the Biology Division, the Computer Center and in the Atmospheric and Space Sciences Division.

	Sponsored Research	*Center Supported Research**	*Faculty and Staff***
April-June, 1962	$ 28,059	$	19
July, 1962-June, 1963	615,835	101,804	100
July, 1963-June, 1964	1,893,286	446,756	184
July, 1964-June, 1965	2,662,718	575,575	277
July, 1965-June, 1966	3,551,146	727,490	342
July, 1966-June, 1967	5,267,855	633,872	382

**Including overhead at same rate as recovered in sponsored research.*
***Excludes summer students.*

Operations Summary

The Center's operating expenditures and income used in operations during the year ending June 30, 1967, are compared with the year ending June 30, 1966:

	Year Ending June 30, 1967	*Year Ending June 30, 1966*
Operating Expenditures		
Research and educational activities	$4,836,951	$3,462,412
Administration, interest expense, etc.[a]	2,059,238	2,076,874
Total Operating Expenditures	$6,896,189	$5,539,286
Income Used		
Sponsored research grants and contracts	$5,267,855	$3,551,146
Private gifts[b]	1,063,496	955,739
Rent and miscellaneous income	91,063	72,553
Proceeds from sale of securities and from "Gifts in Kind"[c]	473,775	959,848
Total Income Used in Operations	$6,896,189	$5,539,286

[a]Excludes depreciation of $363,663 for year ending June 30, 1967, and of $307,929 for year ending June 30, 1966.
[b]Includes $307,829 used for health or health-related activities. Excludes $137,669 not available for operations.
[c]Additional securities were sold to make payments of $3,184,775 on loan principals.

Facilities

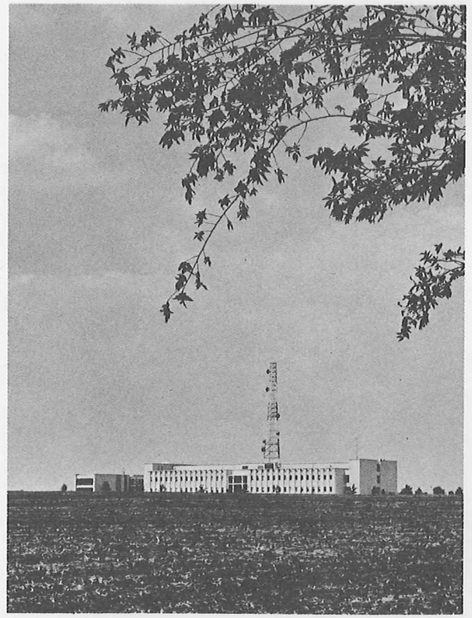
During the year, the Center invested $399,561 in plant and equipment. The total investment in facilities at June 30, 1967, was:

Property, Plant and Equipment at Cost	
Founders Building	$2,695,566
North Office Building	85,972
Site Improvements	469,738
Dallas Magnetic Observatory	49,015
Materials Research Laboratory	258,537
Equipment	1,462,184
Land	3,735,611
Construction in Progress	135,686
	$8,892,309

Members of the Board of Governors

Southwest Center for Advanced Studies
July 1, 1967

Erik JONSSON, Chairman of the Board of Governors
Mayor of the City of Dallas
Honorary Chairman of the Board,
Texas Instruments Incorporated, Dallas
A. Earl CULLUM, Jr., Chairman of the Advisory Council
A. Earl Cullum, Jr., and Associates, Dallas
Cecil H. GREEN, Chairman of the Board, TAGER
Director, Texas Instruments Incorporated, Dallas
Gifford K. JOHNSON, President,
Southwest Center for Advanced Studies
Eugene McDERMOTT, Director,
Texas Instruments Incorporated, Dallas
C. A. TATUM, Jr., President,
Texas Utilities Company, Dallas



Trustees Emeriti

Dr. M. T. HARRINGTON, Co-ordinator of Programs,
Office of International Programs,
The Texas A&M University System,
College Station, Texas
Dr. Oliver S. WILLHAM, President Emeritus,
Oklahoma State University, Stillwater, Oklahoma

Trustees Ex Officio

Ralph N. STOHL, Vice President for Administration,
Southwest Center for Advanced Studies
James S. TRIOLO, Vice President for Development and
Information, Southwest Center for Advanced Studies

Regular Members of the Board of Trustees

Dr. Detlov BRONK, President,
The Rockefeller University, New York, New York
Arthur A. COLLINS, President,
Collins Radio Company, Dallas
Dr. Carey CRONEIS, Chancellor,
Rice University, Houston, Texas
Dr. George L. CROSS, President,
University of Oklahoma, Norman, Oklahoma
A. Earl CULLUM, Jr.
A. Earl Cullum, Jr., and Associates, Dallas
Robert B. CULLUM, Chairman of the Board,
Tom Thumb Stores, Inc., Dallas
Harvey GAYLORD, President,
Bell Aerospace Corporation, Washington, D. C.
Cecil H. GREEN, Chairman of the Board, TAGER
Director, Texas Instruments Incorporated, Dallas
Gifford K. JOHNSON, President,
Southwest Center for Advanced Studies
Erik JONSSON
Mayor of the City of Dallas
Honorary Chairman of the Board,
Texas Instruments Incorporated, Dallas
Dr. Robert B. KAMM, President,
Oklahoma State University, Stillwater, Oklahoma
Murray KYGER, Chairman of the Board,
First National Bank of Fort Worth, Fort Worth, Texas
James J. LING, Chairman of the Board and Chief
Executive Officer, Ling-Temco-Vought, Inc., Dallas
Dr. Herbert E. LONGENECKER, President,
Tulane University, New Orleans, Louisiana
Lewis W. MacNAUGHTON, Chairman of the Board,
DeGolyer and MacNaughton, Dallas
Stanley MARCUS, President,
Neiman-Marcus Company, Dallas
Eugene McDERMOTT, Director
Texas Instruments Incorporated, Dallas
Dean A. McGEE, Chairman,
Kerr-McGee Oil Industries, Inc., Oklahoma City,
Oklahoma
Dr. Joseph C. MORRIS, Vice President,
Tulane University, New Orleans, Louisiana
Dr. John D. MOSELEY, President,
Austin College, Sherman, Texas
Dr. James MOUDY, Chancellor,
Texas Christian University, Fort Worth, Texas
Dr. David W. MULLINS, President,
University of Arkansas, Fayetteville, Arkansas
Dr. Grover E. MURRAY, President,
Texas Technological College, Lubbock, Texas
W. W. OVERTON, Jr., Chairman of the Board,
Texas Bank & Trust Company, Dallas,
Dr. Harry H. RANSOM, Chancellor,
The University of Texas, Austin, Texas
The Hon. Winthrop ROCKEFELLER, Governor,
The State of Arkansas, Little Rock, Arkansas
General Earl RUDDER, President,
Texas A&M University, College Station, Texas
Dr. Frederick SEITZ, President,
National Academy of Sciences, Washington, D. C.
Allan SHIVERS
Austin, Texas
Dr. Julius A. STRATTON, Chairman of the Board,
Ford Foundation, New York, New York
Dr. Willis M. TATE, President,
Southern Methodist University, Dallas
C. A. TATUM, Jr., President,
Texas Utilities Company, Dallas
Dr. Frederick E. TERMAN, President,
Foundation for Science and Engineering,
Southern Methodist University, Dallas
Provost Emeritus, Stanford University
Dan C. WILLIAMS, President,
Southland Life Insurance Company, Dallas

ADVISORY COUNCIL

Southwest Center for Advanced Studies
July 1, 1967

A. Earl CULLUM, Jr., Chairman of the
Advisory Council
A. Earl Cullum, Jr., and Associates, Dallas
James W. ASTON, Chairman of the Board,
Republic National Bank of Dallas
Harry W. BASS,
H. W. Bass & Sons, Inc., Dallas
Perry BASS, Fort Worth, Texas
Clay P. BEDFORD, President
Kaiser Aerospace & Electronics,
Oakland, California
Lewis H. BOND, President,
The Fort Worth National Bank,
Fort Worth, Texas
Roland S. BOND, Jr., President,
Bond Operating Company, Dallas
Dr. Malcolm K. BRACHMAN,
Northwest Oil Company, Dallas
Col. Charles F. BURLEY (Ret.),
Chairman and Vice President,
LT Industries, Inc., Garland, Texas
Col. D. H. BYRD, Dallas
Ben H. CARPENTER, Chairman of the
Board, Southland Life Insurance Company,
Dallas
E. O. CARTWRIGHT, President,
The Cartwright Company, Dallas
W. W. CARUTH, III,
Caruth Building Service, Dallas
James F. CHAMBERS, Jr.,
Chief Executive Officer,
The Dallas Times Herald, Dallas
William P. CLEMENTS, Jr.,
Southeastern Drilling, Inc., Dallas
Dr. Donald COWAN, President,
University of Dallas, Irving, Texas
Jerome K. CROSSMAN,
Attorney at Law, Dallas
Trammell CROW, Dallas
Dr. Milton K. CURRY, Jr., President,
Bishop College, Dallas
A. I. DAVIES, Vice President,
Sears, Roebuck & Company, Dallas
Frank W. DAVIS, President,
General Dynamics/Fort Worth
E. M. (Ted) DEALEY, Publisher,
The Dallas Morning News, Dallas
Joe M. DEALEY, President,
The Dallas Morning News, Dallas
Andrew DeSHONG,
Vice President & General Manager,
Dallas Chamber of Commerce, Dallas
H. H. (Hal) DEWAR, Partner,
Dewar, Robertson & Pancoast,
San Antonio, Texas
J. Harold DUNN, Chairman,
The Shamrock Oil & Gas Corporation,
Amarillo, Texas
Beeman FISHER, Chairman
Texas Electric Service Company,
Fort Worth, Texas
Dr. R. G. FOLSOM, President,
Rensselaer Polytechnic Institute,
Troy, New York
T. Carr FORREST, Chairman,
Forrest and Cotton, Inc.,
Dallas, Texas
J. D. FRANCIS, Chairman of the Board
Mercantile National Bank at Dallas
E. B. GERMANY, Partner,
E. B. Germany & Sons, Dallas
R. A. GOODSON, President
Southwestern Bell Telephone Company,
St. Louis, Missouri
Dr. John A. GUINN, President,
Texas Woman's University,
Denton, Texas
P. E. HAGGERTY, Chairman of the Board,
Texas Instruments Incorporated, Dallas
Dr. William B. HEROY, Sr., Dallas
Mrs. Oveta Culp HOBBY,
Editor and President,*The Houston Post,*
Houston, Texas
Van Alen HOLLOMON,
General Counsel and Treasurer,
Interstate Circuit, Inc., Dallas
W. Herbert HUNT, Vice President,
Hunt Oil Company, Dallas
Claiborne H. JOHNSON,
Tobin Realty Company, Dallas
J. L. LATIMER,
Petroleum Consultant, Dallas
John LAWRENCE,
Chairman of the Board and President,
Dresser Industries, Inc., Dallas
Herman W. LAY, Chairman,
PepsiCo., Inc., Dallas
W. L. LINDHOLM, President,
Chesapeake & Potomac Telephone
Companies, Washington, D. C.
The Honorable Eugene M. LOCKE,
Deputy Ambassador to Viet Nam,
Embassy of the United States of America,
Saigon, Viet Nam
W. W. LYNCH, President
Texas Power & Light Company, Dallas
G. L. MacGREGOR, Chairman of the Board,
Texas Utilities Company, Dallas
Edward R. MAHER, President,
Ed Maher, Inc., Dallas
Henry Neil MALLON,
Chairman of Executive Committee,
Dresser Industries, Inc., Dallas
Edward MARCUS, Executive Vice President,
Neiman-Marcus Company, Dallas
Dr. J. C. MATTHEWS, President,
North Texas State University,
Denton, Texas
Frederick M. MAYER, President,
Continental Emsco Company, Dallas
Avery MAYS, President,
Avery Mays Construction Company, Dallas
Dr. Abner McCALL, President,
Baylor University, Waco, Texas
Robert McCULLOCH,
Chairman of Executive Committee,
Ling-Temco-Vought, Inc., Dallas
Robert M. McKINNEY, Editor,
Santa Fe New Mexican,
Santa Fe, New Mexico
A. H. MEADOWS, Chairman of the Board,
General American Oil Company of Texas,
Dallas
John J. MORRISON, Director,
Gulf States Utilities Company,
Beaumont, Texas
Clint W. MURCHISON, Jr., Partner,
Murchison Brothers, Dallas
John D. MURCHISON, Partner,
Murchison Brothers, Dallas
PETER O'DONNELL, JR., Investments, Dallas
Lester T. POTTER, President,
Lone Star Gas Company, Dallas
John J. REDFERN, Jr., President,
Redfern Development Corporation,
Midland, Texas
Elgin B. ROBERTSON,
Chairman of the Board,
Elgin B. Robertson, Inc., Dallas
Ralph B. ROGERS, Chairman,
Texas Industries, Inc., Dallas
Frank A. SCHULTZ,
Geologist and Oil Consultant, Dallas
Sherrod E. SKINNER, Chairman,
Board of Trustees, Aerospace Corporation,
Detroit, Michigan
E. C. SMITH, Vice President-Texas,
Southwestern Bell Telephone Company,
Dallas
Dr. Law SONE, President,
Texas Wesleyan College, Fort Worth, Texas
Morris G. SPENCER,
The Quadrangle, Dallas
Lee D. STARR,
Special Assistant to the President,
Allied Stores, Inc., New York
Dr. Marshall T. STEEL, President,
Hendrix College, Conway, Arkansas
John M. STEMMONS,
Industrial Properties Corporation, Dallas
W. Dawson STERLING, President,
Southwestern Life Insurance Company,
Dallas
Robert H. STEWART, III,
Chairman of the Board,
First National Bank in Dallas
Charles P. STOREY, Partner
Storey, Armstrong and Steger, Dallas
W. B. STRANGE, Jr., Branch Manager,
Goodbody and Company, Dallas
J. T. SUGGS, Chairman of the Board,
Missouri Pacific Railroad Company,
The Texas and Pacific Railway Company,
Dallas
Henry Gardiner SYMONDS,
Chairman of the Board,
Tenneco, Inc., Houston, Texas
Dr. Maurice L. TAINTER, Chairman,
Sterling Research Board,
Sterling Drugs, Inc., New York
Travis T. WALLACE, Chairman,
Great American Reserve Insurance
Company, Dallas
C. W. WHITTENBURG, Publisher,
Amarillo Globe Times,
Amarillo, Texas
Watson W. WISE,
Owner, W. W. Wise Drilling, Inc.,
Tyler, Texas
Ben H. WOOTEN, Chairman of the Board,
Dallas Federal Savings and Loan
Association, Dallas
Joseph ZEPPA, President,
Delta Drilling, Tyler, Texas

Southwest Center for Advanced Studies
July 1, 1967

OFFICERS

Erik Jonsson, Chairman of the Board of Governors
Gifford K. Johnson, President
Ralph N. Stohl, Vice President for Administration; Corporate Secretary and Treasurer
James S. Triolo, Vice President for Development and Information
Patricia Jackson, Assistant Corporate Secretary
Sol Goodell, Assistant Corporate Secretary

ACADEMIC HEADS

Prof. Francis S. Johnson, Director, Earth and Planetary Sciences Laboratory; Acting Head, Atmospheric and Space Sciences Division
Prof. Anton L. Hales, Head, Geosciences Division
Prof. Ivor Robinson, Head, Mathematics and Mathematical Physics Division
Prof. Carsten Bresch, Head, Biology Division, Molecular Sciences Laboratory
Asst. Prof. C. Girvin Harkins, Acting Head, Materials Research Division

STAFF
(Administrative)

David W. Canham, Research Support Co-ordinator
Jack S. Donaldson, Director, Computer Center
Leo J. Eveleth, Personnel Officer
Stewart C. Fallis, Special Assistant to the President
Richard T. Lipscomb, Development Programs
Alfred T. Mitchell, Information Services
Kenneth Murray, Executive Officer, Geosciences Division
Roswell C. Peavy, Assistant to the President
David C. Pfeiffer, Director, Campus Facilities
D. C. Rebok, Controller
John S. Robottom, Contracts and Grants Administrator
Mrs. Jeanne M. Thweatt, Executive Officer, Biology Division
John W. Vanderford, Executive Officer, Atmospheric and Space Sciences and Mathematics and Mathematical Physics Divisions

Annual Report, 1966-67. Southwest Center for Advanced Studies
Produced by the Information Office, Alfred T. Mitchell, Director.

Design and Layout: By Horace Herron, Dallas. **Photographic Credits:** Photograph of President Gifford K. Johnson by Rick Lipscomb. Pages 10, 11: Photographs of Rodleigh W. E. Green, John W. Graham and James Rhoads by Clint Grant, *Dallas Morning News*. Page 13: Photograph of Dimitrij Lang and student group by Shel Hershorn, Dallas. Page 18: Photograph of M. R. Raju by Lawrence Radiation Laboratory, University of California. Page 19: Photograph of Lloyd V. Berkner and James Webb by *Associated Press*. Other photography by Mitchell.
Lithography: By Bennett Printing Company, Dallas.