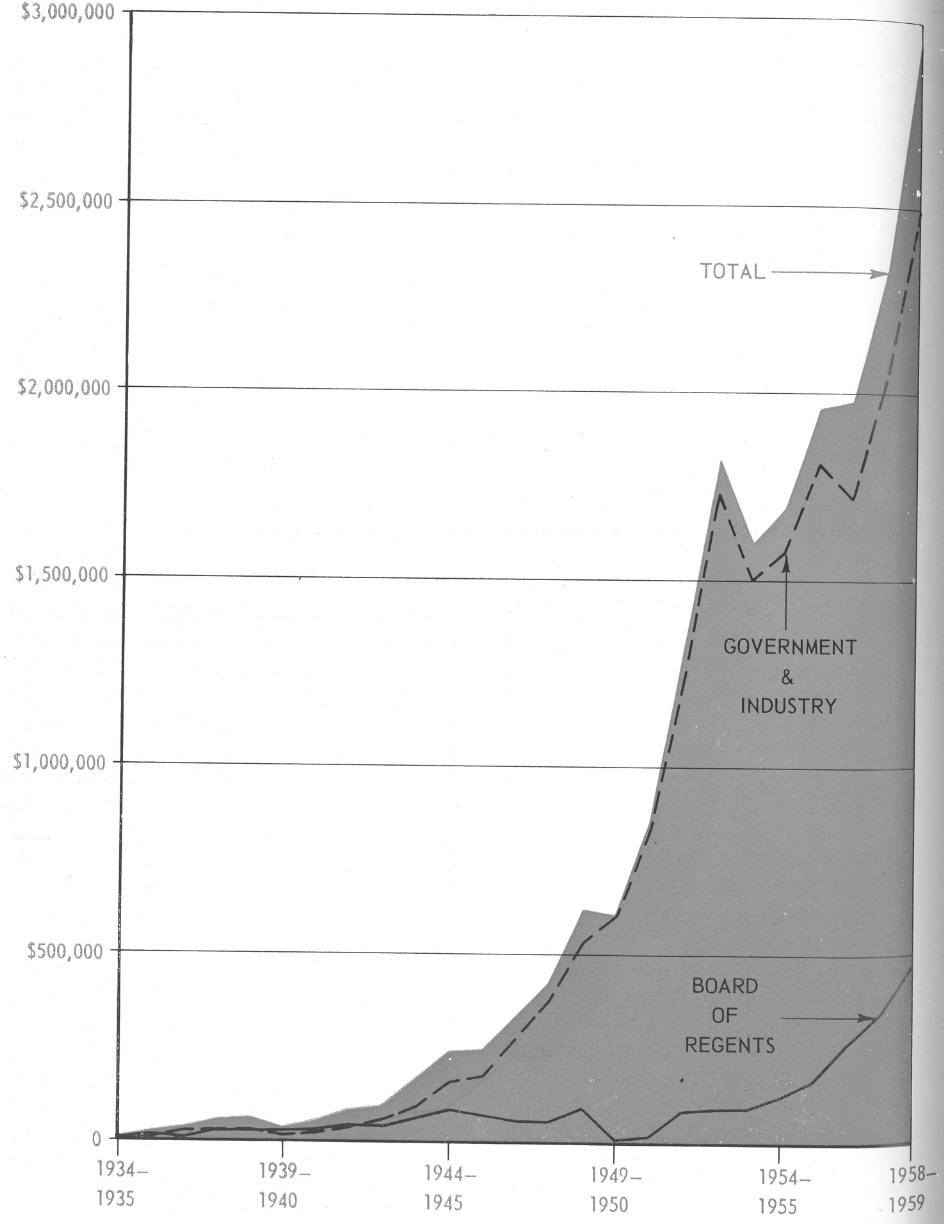

The Station's Income by Source Over Its 25-Year History

DECEMBER, 1959

The Research Engineer

Published by the Georgia Tech Engineering Experiment Station

FIREFLIES IN SPACE

The Research Engineer

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the station

the staff

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the cover

The cover photograph was made by Tech Research Engineer John Erasmus during experiment Bravo of Project Firefly. Erasmus was stationed at Biloxi, from which the Bravo burst appeared to occur just between the Moon and Venus (the two white spots—both are overexposed because exposure was made for the cloud). Immeditely winds up to 300 mph began to carry away and disperse the cloud. The photo was made by a K-24 camera about five minutes after burst and shows the effects of the winds on the cloud, which had appeared almost spherical at burst. The color added to the photo is an approximation to the visible pink caused by Bravo's sodium-cesium mixture. Tech's principal Firefly investigator, Dr. Howard Edwards, explains the purpose of this research in the article beginning on page 4.

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The President's Page

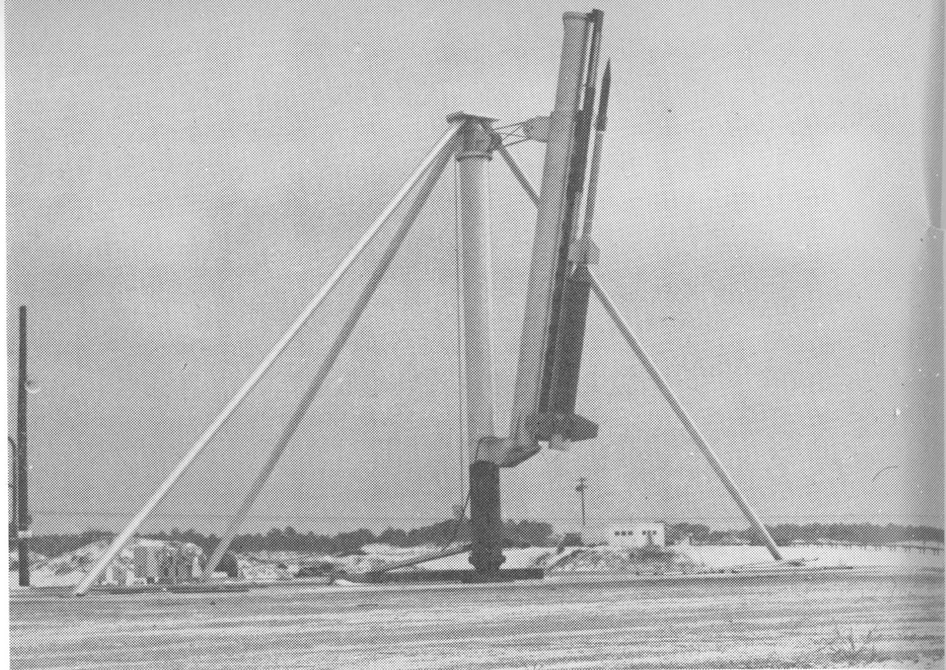
WHAT MIGHT BE CONSIDERED the growing impatience of the Twentieth Century is having its impact on graduate education. Some years ago, at least before World War II, the time lapse between a scientific discovery and its engineering application was not a matter of widespread concern. But, for a number of good reasons, it is now.

One of the natural results of this pressure to move more swiftly from experiment to production is that engineers are becoming more involved in research. The knowledge and methods of ten or even five years ago are often proving inadequate to cope with today's prodigious advances in research and development. Increasing demand is being placed on engineers to witness, interpret, and make use of discoveries in science as they occur.

The engineers most likely to meet this impatient demand are those who, through advanced study and research, have established and maintained rapport with the mercurial frontiers of their fields. This is not an easy achievement now, and it is becoming tougher. Probably the most reliable approach to the problem is through a program of formal graduate study and research.

"Graduate study," however, must not be a static concept either. At Georgia Tech and a number of other institutions, graduate study is reinforced by strong research programs that represent built-in treasuries of frontiers. The presence of these frontiers and the men who explore them have invigorating effects on the quality of graduate instruction and the value of the problems selected for theses. Active faculty and student participation in these explorations helps insure that the graduate program as a whole will continue to produce men who know what research is and who can put this knowledge to effective use.

E. D. Harrison
President



U. S. Air Force

Poised on launch pad at Santa Rosa Island, Florida, is one of the Nike-Cajun research rockets. Overall length is about 25 feet.

Typical apparatus for optical studies of Firefly bursts is this old searchlight yoke, fitted with nine automatic cameras.

Marshall Cooksey

PROJECT FIREFLY

by Howard D. Edwards,
Research Associate Professor of Physics

NATURE HAS A HABIT of making it difficult for scientists to find out her innermost secrets. The upper reaches of our atmosphere are no exception and even with the coming of powerful rockets in 1946 and satellites in 1958, the unknowns far exceed the knowns in this frontier of knowledge.

Since February, 1959 Georgia Tech scientists have been participating in a large Air Force sponsored project, Project Firefly, in an attempt to gain more knowledge on the atmosphere between heights of 85 and 130 kilometers (50 and 80 miles). Heights up to 130 km may seem insignificant in these days of orbiting satellites and planned space flights. However, a great deal more needs to be known about the first hundred miles of our atmosphere before space travelers can get a money-back guarantee on their round trip tickets.

In conducting upper atmosphere experiments there are at least two major uses of the rockets and missiles. These may be described as follows:

(1) The missile is used as a flying laboratory and carries all or most of the scientific apparatus. Results are then either telemetered to ground receiving stations or recorded on film or tape for ultimate nose cone recovery.

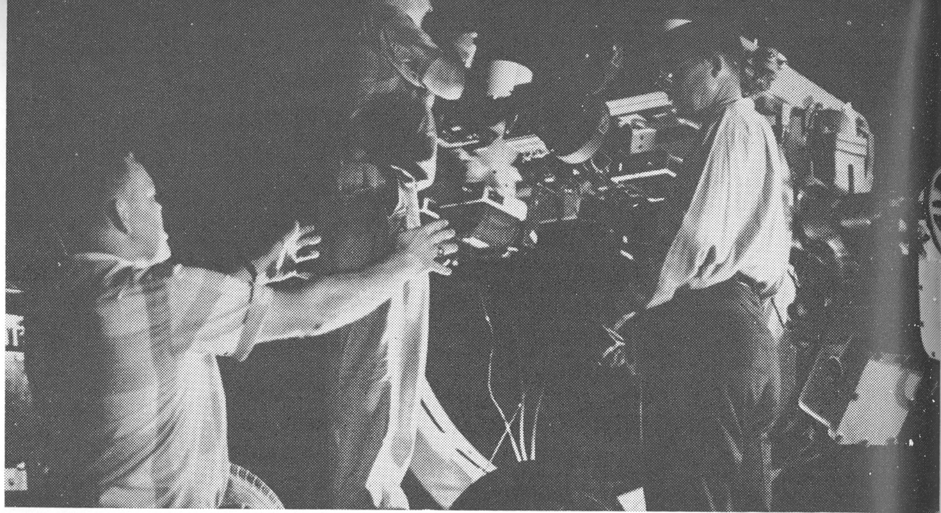
(2) The missile is used as a flying probe with a minimum of instrumentation on board and with a majority of the scientific equipment set up at ground receiving stations.

Project Firefly is an example of the latter method of scientific exploration. The rocket nose cone or payload is made up of a steel cylinder containing several chemicals and a simple timer to close a circuit from a battery. The complicated and expensive equipment is installed at ground stations and hence is not damaged or destroyed during the rocket flight.

Scientists have known for a long time that some atoms have the ability to absorb radiation and then re-radiate the same frequency that has been absorbed. This phenomenon, called resonance radiation, has served as the primary observing technique for the optical measurements taken during Project Firefly. One of the most common atoms capable of producing resonance radiation is sodium. The sodium atom has two strong emission lines at wavelengths of 5890 A and 5896 A (angstroms) which are capable of a very intense resonance reaction. Hence, it is perhaps natural that sodium was the initial chemical chosen for upper atmosphere contamination experiments. The first successful experiment was conducted in 1955. Since that time sodium has been used extensively by U. S. scientists in their upper atmosphere research programs and by the Russians on some of their moon and space shots.

Several other atoms are capable of producing resonance radiation. Some of these are potassium, cesium, calcium, lithium, and barium.

In the 1959 Firefly series the rockets were flown during morning twilight conditions to insure an abundance of sun-



At 2 a.m. Marshall Cooksey (Ga. Tech, Dr. Bob Huffman (AFCRC) and Charles Smith (Camera Service Co., Atlanta) ready equipment during experiments at Eglin AFB.

light to irradiate the atom cloud and at the same time to give maximum contrast for the ground observing stations which had to photograph the radiating cloud.

In addition to illuminating the cloud via the resonance radiation phenomenon, the sunlight is sufficiently powerful to ionize certain atomic constituents. During the Firefly series, atomic cesium, with an ionization potential of 3.9 electron volts, was commonly used. When exposed to sunlight, the cesium gave an ionized cloud which could be tracked by radar and other radio frequency equipment.

During the past year, 15 rockets have been fired in support of the Firefly project. The first two flights were made with the Aerobee Hi rocket at Holloman Air Force Base on May 12 and May 22. The other 13 launches were made from Eglin Air Force Base during September and October, in which the rocket was a two-stage vehicle with the Nike as first stage and Cajun as second stage.

The Aerobee rocket was capable of carrying a 200-lb. payload to heights well in excess of the 130 km altitude sought on the first two firings. The Nike-Cajun system, being smaller than the Aerobee, could carry only a 50-lb. payload to the same 130 km height. However, since the objectives of the experiments were to explore the region between 85 and 130 km, there was no need for a larger and more costly rocket.

Since all of the launches are similar, the Aerobee flight of May 22 will be chosen to illustrate the research program.

The rocket was launched at 04:15 (MST) on May 22 and carried a payload of 85 lbs of cesium nitrate and 3 lbs of sodium nitrate. Local sunrise on May 22 was 04:57 and the first signs of twilight were already evident to the observer. However, the sky was still sufficiently dark to give a good background for photographing the cloud.

At 4:17:10 the payload was vaporized into the air and immediately a bluish-pink cloud appeared in the sky. The cloud continued to grow and expand for 30 minutes before it was dissipated to such an extent that it was no longer visible.

The cloud was photographed from four observing stations by multiple camera apparatus similar to that shown in the accompanying illustrations. The stations were located at distances up to 135 km from the launch site.

The two atoms which provided the visible light were sodium and cesium. Since these atoms were vaporized in a fully sunlit region of the sky, the sunlight was absorbed and then re-radiated as resonance radiation. The yellow color observed both visually and by camera came from the well known sodium yellow doublet at wavelengths of 5890 and 5896 A. The blue color came from the cesium atom radiation at a wavelength of 4555 A.

The cesium atom also had a strong resonant line at a wavelength of 8521 A.

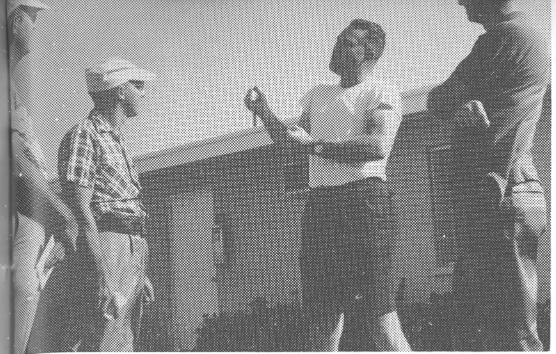
This line, being in the infrared, could not be seen visually but was easily photographed on infrared film through a narrow band interference filter. Each of the four observing stations was equipped with two K-24 cameras. One of these cameras was loaded with Tri-X film and had the lens covered with a narrow band interference filter which used only a very narrow band of light (100 angstroms wide) centered about the sodium D lines at 5890-5896 A. The other camera was loaded with infrared film and had a narrow band filter to pass only the cesium radiation at a wavelength of 8521 A.

Although final analysis of the data has not yet been carried out, the following tentative results have been obtained:

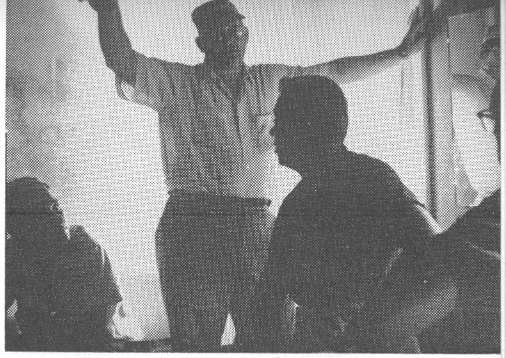
(1) An initial cloud altitude of 117 km was obtained from the film by triangulation methods.

(2) The post-burst cloud rose to an atltitude of 125 km during the first 8 minutes and then leveled off at about 122 km. The cause of this rise and subsequent leveling off is not known although several theories are being explored.

(3) The wind velocity apparently changed during the lifetime of the cloud and the following results were obtained:

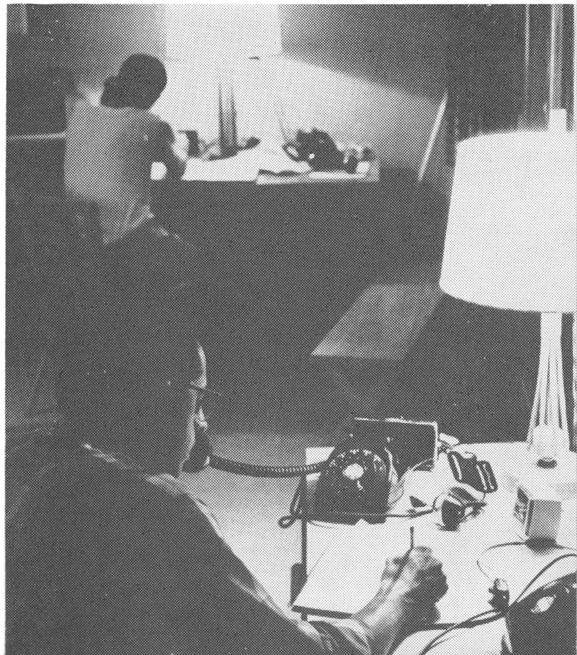


Later account of the problems of tracking a cloud that drifted directly overhead engages Tech researchers (l to r) James Johnson, John Brown, Cooksey, Dr. Edwards.



Photographs by Phillips

Then a night drive to Pensacola and Dr. Edwards swaps cameras and confers with Duke Ellington, Ed Garrett, Don Swafford in dark motel room before the next morning's shot.



Back at headquarters in motel, Dr. Edwards and Stanford's Dr. Gallagher (background) keep telephones busy just before launch.

Mrs. John Brown, one of wives who volunteered to help, became expert on operation of 20-inch photometer. She has a degree in physics. At left is Harley Ferguson.

Time	Wind Direction °E of N	Drift Speed m/sec
(a) 1st 3 min.	72	108
(b) 3 to 10 min.	59	120
(c) 10 to 12 min.	83	113
(d) 12 to 23 min.	74	87

(4) In 15 minutes the cloud increased in size from its initial container diameter of approximately 40 cm to a diameter of 22 kilometers.

Studies of this rapid growth will be made to better determine diffusion coefficients in the upper atmosphere.

Similar results have been obtained from the other 14 rocket launches and the data are in the process of being reduced.

By the proper choice of chemicals, the artificial contamination technique can lead to a better understanding of other parameters which have not appeared in the above cesium-sodium type experiment. For example, laboratory studies have indicated that CCl_4 vaporized into the upper atmosphere will react exclusively with the nitrogen atoms to form cyanogen molecules. These molecules will then produce radiation in the red region of the spectrum and can be photographed from ground stations. This experiment has not yet been tried. However, should it be successful we would be able to determine the extent to which molecular nitrogen is dissociated in the upper atmosphere.

The above article has briefly described the work being conducted at Georgia Tech. Project Firefly is under the overall direction of Dr. N. W. Rosenberg of the Air Force Cambridge Research Center of the Air Research and Development Command. Paralleling the Georgia Tech effort, Dr. P. H. Gallagher of Stanford University has been conducting and coordinating the research on radio frequency scatter from the ionized portions of the cloud. Dr. C. D. Cooper of the Physics Department, University of Georgia, has been in charge of spectrographic studies.

BACKGROUND

Poking at the Upper Atmosphere

Scientists and engineers have long been interested in the physics of the portion of our atmosphere which is above 100,000 feet in altitude, and thus beyond the reach of balloons. This region is commonly called the upper atmosphere. The first textbook of the upper atmosphere was written in 1935 by an Indian scientist, S. K. Mitra.

In spite of the early interest and work on the upper atmosphere, the first manmade object to explore this fascinating region was the WAC Corporal rocket, launched in 1945. In 1946 upper atmosphere research got underway in a modest manner and made use of the captured German V-2 rocket. "We had been poking around up there for many years," explains Dr. Edwards, "but it was only recently that good, relatively cheap rocket hardware became available for research work." Since 1946 a host of rockets, both large and small, have been used to probe the upper atmosphere and near space regions.

Although hundreds of rockets containing a wide assortment of observing equipment have been launched in the past decade, the surface has only been scratched in our attempt to understand the physics of the regions above 100,000 feet. For example, the temperature, one of the first things to be measured, is still a matter of some dispute. The 1952 edition of Mitra's book gave the temperature at 400 km as 3450°K. The 1956 edition of the ARDC Model Atmosphere listed 1169°K, and estimates from the first satellite observations gave 1400°K for the same 400 km altitude. Clearly it is too early to conclude that the temperature in this region is known.

The early rockets also contained equipment to measure pressure, density, composition, meteoric content, solar radiation, airglow radiation, magnetic field and other effects. Present day rockets and satellites are still being instrumented with equipment to measure these same quantities since the available information is still not sufficient to give a coherent picture of the upper atmosphere.

Satellites have done much to add to our knowledge of the upper atmosphere. However, they cannot give all the answers for a number of reasons, including their high cost and inability to orbit in the atmosphere below about 160 km.

Due to the cost and complexity of rocket launches, the majority of the upper atmosphere data have come from a few locations where suitable launching facilities have been established. Excluding the Soviet Union, for which information is lacking, the majority of the studies have been made from Holloman Air Force Base-White Sands Proving Ground, New Mexico; U. S. Air Force Missile Test Center, Florida; Ft. Churchill, Canada; Wallops Island, Virginia, and more recently Eglin Air Force Base, Florida and Vandenberg Air Force Base, California. British and French workers have also conducted some research from bases in North Africa and Australia but these efforts have been on a very modest scale compared to U. S. efforts.

Upper atmosphere and near space research is still virgin territory. Many more nuggets similar to the Van Allen radiation belts are undoubtedly available to the enterprising scientist.

Collusion on Collisions

A BRITISH PHYSICIST well-known for his work in atomic collision theory is visiting for a year with scientists at Georgia Institute of Technology. He is Dr. Coulter McDowell, who at 28 has already published a dozen theoretical papers, most of them on subjects related to taming the H-bomb.

Dr. McDowell is a native of Belfast, Northern Ireland. He obtained his Ph.D. in theoretical physics at Queens University in Belfast and since then has been teaching and doing research at the University of London. At the invitation of Georgia Tech, Dr. and Mrs. McDowell came to Atlanta in August. They expect to stay until next summer.

Dr. McDowell is working primarly with Tech's Dr. Earl McDaniel, a young physicist with similar interests. Dr. McDaniel is a Georgia Tech graduate who obtained his Ph.D. at the University of Michigan. Tech physicist Dave Martin, another University of Michigan Ph.D. is also contributing to the studies. Both McDaniel and Martin are experienced experimental physicists in areas related to atomic collisions.

As Dr. McDowell explains, "I think it is essential at some time in one's career to work with experimentalists to find out some of the snags involved. Not all theory is easily tested in the laboratory,

DRS. McDANIEL AND McDOWELL

just as it is often difficult to devise an experiment that can be analyzed theoretically. It is good for us to spend some time together to learn what each other is up against."

Drs. McDowell and McDaniel had previously collaborated by mail on a research paper. Both men are interested in ion physics, gaseous electronics, and other topics related to thermonuclear reactions. One of the main objectives of physicists in this field is the control of the fusion process.

When asked how long he thought it would take to tame fusion, Dr. McDowell remarked, "Well, it's certainly not one of the things you want to bet on, any more than you want to bet on what happens at Cape Canaveral. But I shouldn't be surprised to see a major breakthrough in about five years. By that I mean a controlled reaction in the laboratory. Making this feasible for commercial power production is quite another matter, however, and may take much longer, maybe 25 years or so."

Drs. McDowell, McDaniel and Martin are doing their research in Tech's new Radioisotopes and Bioengineering Laboratory. Some of the work is on contracts with the Air Force and the Atomic Energy Commission and is directly re lated to the fusion problem.

A REPORT

Minerals Advisory Committee

THE DEVELOPMENT of Georgia's mineral resources is a task worthy of the cooperation and coordination of all interested groups.

Acting on this sound premise, President E. D. Harrison of Georgia Tech early in 1959 requested the formation of a Minerals Advisory Committee. The committee, consisting of some 30 leading men from Georgia industry, government and research organizations, was formed and held four meetings during the year. The primary purpose of the committee is to advise Georgia Tech on matters pertaining to its Minerals Research and Development Program.

The chairman of the Minerals Advisory Committee is Mr. Nelson Severinghaus, president of Consolidated Quarries.

In the first meeting on March 2, 1959, brief reports were presented on the status of programs and plans by the U. S. Geological Survey; Georgia State Department of Mines, Mining and Geology; the geology schools of Emory, Georgia, Georgia Tech; and Georgia Tech's Minerals Engineering Group (a part of the Material Sciences Division, Engineering Experiment Station).

In the second meeting, April 6, 1959, the following subjects were among those discussed: (a) the potentials of certain minerals and mineral products in Georgia, including cement, limestone and aluminum from clays; (b) waste product utilization, including pink and sandy kaolin, lime, clay and fine-sand from sand washeries, sand from feldspar flotation, waste stone, and low-grade iron ores; (c) the need for summarizing geologic and mineral information obtained in ground-water surveys; (d) the development of new industry in the State based on aluminum, beryl, and heavy minerals including titanium and zircon; (e) the product studies of the Industrial Development Branch of Tech, including the cement, glass, tile, and whiteware reports.

Georgia Tech's Minerals Development Program was one of the subjects discussed at the July 17 meeting. Tech's plans include: (a) completion of a Georgia minerals index, cross-referenced by mineral, county, and author (based on a bibliography by Drs. J. G. Lester and A. T. Allen of Emory); (b) increased effort on a preliminary limestone resources survey; (c) studies of the feasibility of producing sillimanite products containing 60 per cent sillimanite by an inexpensive slip-casting technique; (d) continuation of a magnetic survey of Georgia (of particular interest to the petroleum industry); and (e) installation of bench and pilot scale equipment for mineral beneficiation studies. It was emphasized that Tech, in its State supported basic research, should continue to concentrate on such basic experimental procedures as electrokinetics, ultrasonics, electro-dialysis, and electron bombardment.

Georgia Tech's work for the Southeastern River Basin Study Committee was also described.

In the most recent meeting of the committee on October 2 potentials for abrasives were discussed. A report was received on a preliminary reconnaisance survey for limestone in twelve counties in southwestern Georgia. The most notable areas of "fresh" limestone were found in Baker, Calhoun, Decatur, Early, Miller, and Randolph counties. Abrasives such as silicon carbide were discussed.

Van Toole

Dr. Fetner and graduate nuclear science class view cellular changes on TV screen. Camera and microscope are in background.

TV's Tiniest Show

by L. W. Ross
Assistant Research Engineer

NOT EVEN MICROBES are safe nowadays from the penetrating gaze of the One-eyed Monster, television. At Georgia Tech closed-circuit television is proving to be a valuable aid in research and laboratory instruction in radiation biology.

Dr. Robert H. Fetner, Associate Professor of Applied Biology enhances the capabilities of Tech's Radiation Biology Laboratory with a closed-circuit system consisting of a standard portable TV camera and a conventional table model TV receiver.

Dr. Fetner is currently studying cellular changes of microorganisms exposed to ionizing radiation. A television camera attached to the eyepiece of a microscope is placed in the shielded room of the Radioisotopes and Bioengineering Laboratory. Here the specimen is irradiated by high intensity x-rays. Safely seated in another room students and researchers may observe the changes in the organisms as they occur.

Television also aids in classroom lectures. The TV system allows the entire class to view the same phenomenon under one microscope. The large (21-inch) television screen provides a picture much enlarged compared to the normal view through the microscope. Dr. Fetner is thus able to point out minute changes in living systems that would be difficult or impossible to show otherwise. (The low light intensities required to illuminate the specimen for the TV camera allow living systems to be observed undisturbed.)

"I foresee routine use of television in undergraduate biology courses," remarked Dr. Fetner, "We use it now in the lab periods and graduate courses." He emphasized that the equipment is relatively inexpensive, especially when compared to the cost of multiple research microscopes in the laboratories.

Dr. Fetner anticipates even further use of television as radiation studies expand. Georgia Tech's research reactor facility, for example, will provide many immediate opportunities for closed-circuit television in research.

New Division, New Chief

ON THE MASTHEAD of this issue of the *Research Engineer* (page 2) there appear a new name and a new division for the first time. Officially effective November 1, 1959, Maurice W. Long is Chief, Electronics Division.

But to those familiar with research activities at Georgia Tech the name is not new and the establishment of the new division is not surprising. Maurice Long holds three degrees from Georgia Tech, the latest being his doctorate. He has been associated with Tech's radar research program almost since its beginning eleven years ago, and has been largely responsible for the rapid growth of the Radar Branch in recent years.

The Electronics Division is a logical outgrowth of the Physical Sciences Division, which had grown to more than twice the size of the next largest division of the Station. The Radar Branch of the Physical Sciences Division had also become the largest research group at Georgia Tech. The new division consists of the Radar Branch (with Dr. Long remaining as Head) and the Communications Branch (with William B. Wrigley as Head).

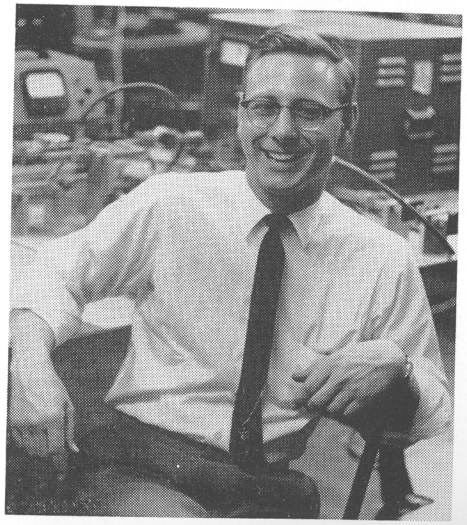
Georgia Tech's first studies in radar began around 1948. The studies grew rapidly into a major program as the Government awarded research and development contracts and the Board of Regents supported basic research.

In 1955 the Radar Branch was created and Long was appointed Head. Under his leadership the Branch expanded to its present size, and during the same period Long worked toward his Ph.D. in physics. He obtained the degree in June of this year. The Station's Director, Dr. James Boyd, states that in the process of enlarging Tech's program, Long became a "recognized national authority in microwave radar." At 34 Dr. Long is Tech's youngest division chief.

Research activities in the Electronics Division are presently devoted to communications and radar. Communications studies concern advanced techniques of modulating and detecting radio signals, the ionosphere's effects on radio signals, and mutual interference of communication equipments. Current programs in radar are directed toward finding new means for attaining improved radar performance, particularly greater range and angular resolution.

The Physical Sciences Division, under Dr. Arthur L. Bennett, Chief, will continue to direct the expanding research activities of the Physics Branch, the Defense Branch, and the AC Network Calculator. The Analysis Branch has been renamed the Statistical Analysis Group and placed under the direction of the Rich Electronic Computer Center. Dr. John H. MacKay was named Head, Statistical Analysis Group, in July.

DR. LONG IS A TECH GRADUATE.



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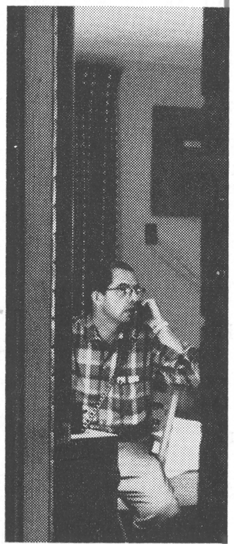
Edited In Retrospect



ALTHOUGH we have already devoted six pages and the cover of this issue to Tech's research on the physics of the upper atmosphere, we can't leave this story without describing what we witnessed of its hectic, pioneering drama.

We had the good fortune to spend a couple of days at the Air Force's Gulf Test Range during the latest series of experiments in Project Firefly. Luckily the weather was fine and, although only one rocket was fired each morning, it seemed that there was always a countdown in progress. Almost as soon as one cloud disappeared, preparations began for the next. At about dawn the cameras were unloaded and most of the film was sent to the processing lab. Observation teams then converged at project headquarters—a motel room—to recap the details of the shot and to make notes to correct errors for the next one. In the afternoon and late into the evening equipment was repaired, readjusted, repositioned. It seemed no one ever slept.

At 2 a.m. the radio and telephone communication system began to recite periodic weather reports, expected "az-el" (azimuth-elevation) of the next burst, and the countdown. Cameras were loaded and tested. Crises developed and were ingeniously scotched: At Port St. Joe interference fouled the radio voice but a nearby car radio picked up the signal beautifully. (A few hours after the burst in observer at Biloxi discovered a camera malfunction had occurred by carefully listening to a tape recording made at the site.)

At about "zero minus ten seconds" those stationed not too many miles away began to look toward the launching pad. A flash appeared, and for the first few seconds cheers of encouragement followed the rocket's flaming path. Then there was the anxious wait. At zero plus two minutes shouts of "Burst!" closely followed by the clatter and buzz of automatic camera mechanisms signaled the appearance of the fuzzy pink cloud in the dark sky.

Another step was made into the unknown.