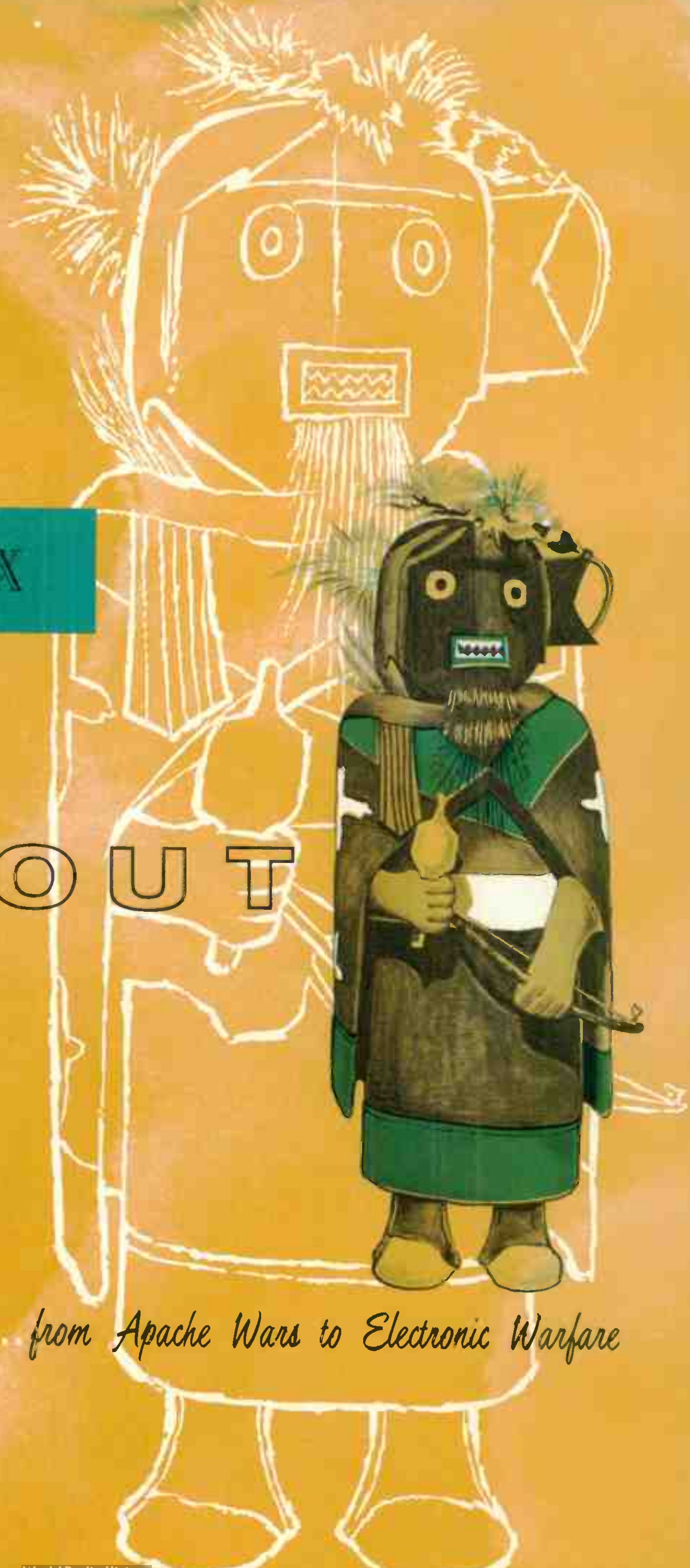
AMPEX

READOUT

MAY-JUNE, 1959



IN THIS ISSUE: Fort Huachuca... *from Apache Wars to Electronic Warfare*

The troublemakers...

Clubs were once the ultimate weapon. The owner of a cudgel enjoyed a distinct advantage when settling small differences with an unfortunate neighbor whose only weapons were his bare hands. This well-beaten neighbor, somewhat dissatisfied with the outcome of the first encounter, probably became the first of a long line of troublemaking disturbers of the *status quo.* At the next quarrel, he "neutralized" the club-wielder from a distance by means of a thrown stone.

And so it went. As the club evolved into the sword, mace and lance, the descendants of the original missile-launching innovator came up with slings, arrows and catapults.

Then another radical appeared to disrupt the theory and practice of classical warfare. He introduced gunpowder and the gun; the armored knight...heretofore the ultimate weapon...faded into history. But as explosives and other weapons became better, so did the means of counteracting them. Better naval cannon brought armored ships. Fighter planes brought better fighter planes. Thanks to that ubiquitous spoilsport, the inventor, war again settled down to the traditional seesaw between offense and defense. Victory usually went to the side who was there first with the most, as the saying goes.

The troublemaker now made another appearance, this time in the guise of the nuclear scientist, to upset the established order of things with the A- and H-bombs. Where once the most telling blows of battle had been dealt by the chemical change of high explosive, the physical change used in nuclear arms became the "irresistible force." Whether this will become man's long-sought ultimate weapon remains to be seen. If there are defenses against it, like the club and the gun, its ascendancy will be temporary.

Perhaps the only safeguard now is man's growing up. Meanwhile, we must depend upon the old resort of being first with the most. Seemingly, having the most is not causing too much trouble; part of the plan to be first is covered in the first article in this issue.

READOUT

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Instrumentation Division

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Fred W. Fisher, Manager of Advertising
Perry McClure, Editor

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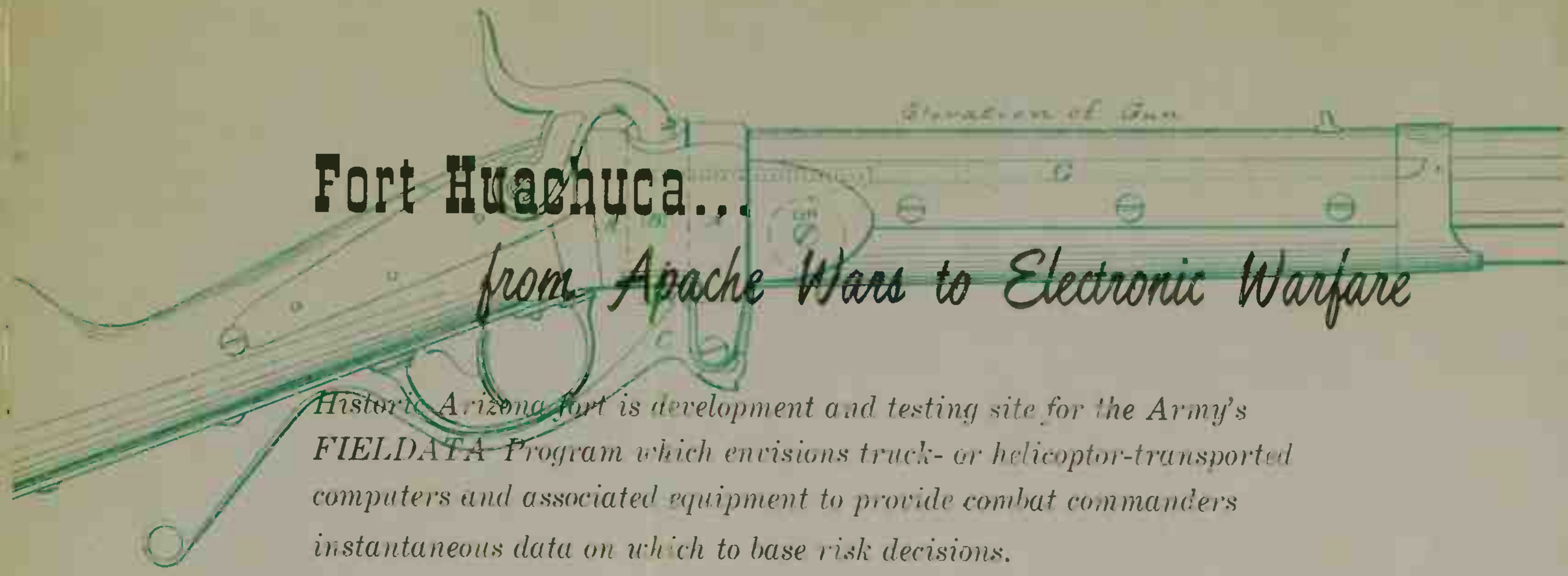
Cover: Abstracted from ceremonial dolls of the Arizona Indian tribes.

READOUT is published at 860 Charter Street, Redwood City, California. Design by MacDonald & Associates, Palo Alto. Printing by Peninsula Lithograph Company, Redwood City.

A 15th Century knight—the "ultimate weapon" of his day.



Fort Huachuca...

from Apache Wars to Electronic Warfare

Historic Arizona fort is development and testing site for the Army's FIELDATA Program which envisions truck- or helicoptor-transported computers and associated equipment to provide combat commanders instantaneous data on which to base risk decisions.

From cavalry sabers to "electronic brains"—this summarizes the history of Fort Huachuca, Arizona. From here, veterans of Lee and Grant rode against marauding Apaches in the 70's and 80's, using tactics learned during the Civil War.

Cavalry and infantry units from the fort accompanied "Blackjack" Pershing in his hunt for Pancho Villa in 1916 after Villa raided Columbus, New Mexico. Threats of Mexican collaboration with Germany again made the old post hum during WW I and troops from Huachuca actually fought and won a two-day battle against the Mexicans at Nogales, a border town. After the Armistice, garrison life was routine until Huachuca became a military reservation during WW II. 1947 saw it closed and witnessed the disbanding of the last company of U. S. Army Indian Scouts, a once-important adjunct of the Army in the Old West.

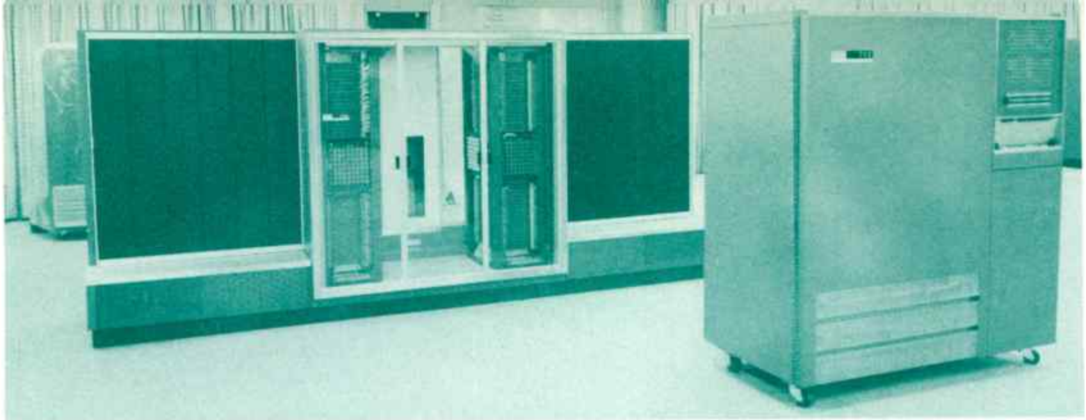
Briefly reactivated in 1951 to train Aviation Engineers, it again became part of the past in 1953—but not for long. Like the fabled cat, the old fort started a new life in February, 1954, when it was chosen for the U. S. Army Electronic Proving Ground (USAEPG).

Activities of the Electronic Warfare Center were transferred from Fort Monmouth, New Jersey, to Huachuca, and it became the test site for electronic warfare materiel.

COMPUTERS FOR FIELD COMMANDERS

So the fort established by the legendary "Long Knives," as the Indians called the saber-wielding cavalrymen, saw the dedication last March of a modern, large-capacity computer center. This center is a major step in the Army's new program to develop a tactical Automatic Data Processing System (ADPS) to meet the military speed-up essential to Atomic Age survival.

Eventually, ADP will be applied to a variety of Army operations to electronically store and process information to make it instantaneously available when needed. Its most spectacular function will be to furnish the battlefield commander timely, accurate data on friendly as well as enemy capabilities to help him make the all-important command decisions better and more rapidly. To accomplish this, a system of truck- or helicopter-transported computers and associated equipment is envisioned and the first steps toward it are already under way at Huachuca and at electronic plants which are building the computers. Ampex Instrumentation Division is participating through the development of special input, output and communications equipment for the computers. These first mobile "brains" and their supporting equipment are to be known as the FIELDATA family.



Part of the new Computer Center at Fort Huachuca. U.S. Army Photo.

FIELDATA—WHAT WILL IT DO?

Lt. Colonel L. W. Murphy of the Signal Corps is chief of the ADP Department at the fort, and is in charge of the FIELDATA development and testing work done there. In his opinion, the application of ADP to military problems was inevitable. He said, "Throughout the military organizations of the world, the coming of the Nuclear Age has brought about major changes in battle plans, troop and weapons deployment, and methods of command decision requiring faster, more automatic communications, evaluation, and administrative procedures. The Army, in planning for the future, has recognized the tremendous potential value of electronic data processing systems in military applications." FIELDATA will be the result of applying this electronic data processing, or ADP, to the problems of the combat commander. Eventually, it will consist of a number of computers interconnected by communications equipment to form a system capable of automatic storage, retrieval, processing, transmission and display of large volumes of data. Intelligence gathered by reconnaissance teams, for instance, will be fed into a computer at a command post. Then, when coded questions are asked of the machine, it will examine stored data, prepare answers and read them out. The commander will thus have immediate access to vital facts which are unobtainable with today's manual filing and processing. For instance, atomic fall-out can be predicted, tactical material on friendly and enemy forces can be derived, aircraft loading tables and meteorological information can be summarized in seconds. Two specific examples of FIELDATA'S capabilities more than prove its importance:

Consider the volume of paper work presently needed to move a division. Two to three days are needed to collate data, and prepare march tables and documents. In a nuclear war, a division shackled by such slowness likely would find that by the time it was ready to move, there would be little point to doing so—even assuming it still constituted an effective force. With ADP, the division will be moving out within four hours of the initial order!

Or take the case of target analysis. Forward observers simply feed a computer the observer-target distance and azimuth. Within five seconds, the machine will advise which guns should fire, the gun-target range, the elevation, and the fuze setting. It will also print out "DO NOT FIRE!" if the shells might endanger friendly emplacements!

To perform their missions, the calculators will deal with huge aggregates of facts concerning combat computation, support and control to provide an orderly examination and analysis of combat factors, elements for estimating any military situations, and a selection of alternate tactical plans. Then, once the commander has made a command decision based on these calculations, the machine will develop the detailed information essential to carrying it out.

THE 5 COMPUTERS

A FIELDATA family of five machines and supporting equipment will comprise the initial mobile ADP system. The computers are presently under construction; all will stress combat reliability under extreme shock, vibration, humidity, dust and temperatures. All will be van-mounted and air-transportable. They include:

MOBIDIC (Mobile Digital Computer). Largest of the group, it will be used at Corps, Army and Theater levels. It is a general-purpose, binary, parallel machine with a 38-bit word length expandable to 50 bits.

BASICPAC (Basic Processor and Computer). A medium-size, general-purpose digital machine fitted for computation and memory storage.

DATA COORDINATOR. This unit will supervise and coordinate operation of an ADP system consisting of several processors, computers and storage devices. It will control the flow of information into and within a data processing center.

LOGICPAC (Logical Processor and Computer). Another medium-size unit. Its speciality is file processing and logical operations such as logistics and personnel-type problems.

INFORMER (Information Storage and Retrieval Processor). Function of this member of the family is to provide a vast and flexible mass-storage capacity.

High-speed printers, electric typewriters, geophysical plotters and Ampex paper-tape readers and magnetic tape recorders will be used to translate the ponderings of the computers into useable form.

Models of Ampex's computer-type tape transport for the FIELDATA system. One transport is shown partly withdrawn from its rack.

MAGNETIC RECORDING EQUIPMENT AND . . .

Under a contract with the U. S. Army Signal Corps Research and Development Laboratory at Fort Monmouth, The Ampex Instrumentation Division is building engineering prototypes of three basic types of equipment for use with the FIELDATA Program.

Computer-Type Tape Transport

This will be an ultra-reliable computer-type magnetic tape transport with read-write speeds of 150 ips and 1 ips. It will have a data-packing density of 300 digital bits per inch per channel or 45,000 characters per second at the faster speed and 300 at the slower. It will read and search at a tape speed of 230 ips.

Data Terminal Tape Transport

The second type of equipment will be a data terminal magnetic tape transport for use with communication lines and other relatively slow data rate devices. Its reading and recording rate will be 300 characters per second and it must offer complete tape interchangeability between systems.

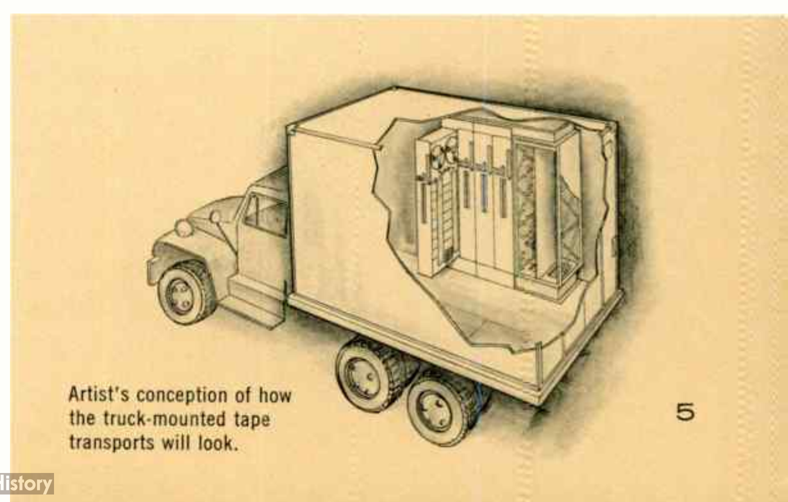
Paper-Tape Reader

A photoelectric paper-tape reader is the third item to be supplied. It will operate at 30 inches per second, and accommodate 11/16-, 7/8- or one-inch, eight-channel punched-paper tape.

Like the computers, this equipment must be invulnerable to the rigors of combat. In fact, Ampex was assigned the development task because Signal Corps sources reported, "No existing magnetic tape transports were considered satisfactory enough for use by Army units in the field in tactical environments."

Specifications for the magnetic-tape transports call for a reliability figure of not more than one statistically detected error per reel of tape—or one error per 10^7 characters. The photoelectric paper-tape reader must have an undetected error rate no greater than one per twenty-four hours of operation, or one per 10^9 characters!

Ampex-developed data terminal transports, and paper-tape readers also will be used with data transmission units being designed.



Artist's conception of how the truck-mounted tape transports will look.

FIELDATA—ITS HISTORY AND FUTURE

For several years, the Army has studied the new or different functions and duties it will perform in the future. As a result, new tactical theories and organizational and deployment plans have evolved. As they took form, the need for accelerating and simplifying the field commander's administrative and tactical decision synthesis was apparent and the advantages of electronic data processing in this streamlining became obvious. Consequently, USCONARC (U. S. Continental Army Command) and the Department of the Army set up a committee in 1956 to determine the feasibility of ADP in tactical military operations. The committee concluded that about sixty different field army functions might benefit through adaptation to computer processing (see partial list, this page.) Various Army agencies were assigned studies of the functions and some are already in the hands of USCONARC for approval. Those passed will be sent to the USAEPG for analysis, adaptation to machine processing, testing, and integration into the overall ADPS.

Implementation of the ADP concept is only one of the responsibilities of the USAEPG which is commanded by Brigadier General F. W. Moorman. To specifically institute ADP, an ADP Division was organized under USAEPG in 1957, and became a Department in 1958. It will further the FIELDATA program by rendering assistance to Army elements preparing ADP application analysis studies; preparation of studies assigned to Huachuca itself; synthesis of concepts to make maximum use of ADP; and computer programming of all studies. In addition, the Department will consolidate all studies to create an integrated, overall system; make machine run-offs of selected studies; and test individual units and the complete ADP system.

To complete this task, the Department established two test facilities at the Proving Ground—the Computer Center and a Field Test Facility. Technical help is supplied by Ramo-Wooldridge Division of Thompson Ramo-Wooldridge, Inc., under the direction of Dr. Eldred Nelson. Among other firms participating in FIELDATA are Sylvania, Philco, Anderson-Nichols, Aeronutronics, Autonetics, Bendix, Collins, Smith-Corona, Broadview Research, Burroughs, Control Instruments and IBM.

Coordination of the whole FIELDATA research and development program is handled by Captain William Luebbert, Chief, Data Equipment Branch, Data Processing Facilities Division, Communications Dept., at Fort Monmouth. He has been with the project from its early stages and played an important part in its progressive phases.

The Computer Center

The recently dedicated center, covering over 20,700 square feet, is among the world's largest and contains one of the largest and fastest computers available—the IBM 709. With this "brain" a new technique will be brought to the testing of the FIELDATA units. It is called "simulation" and here is how it works:

Of the sixty field Army functions considered as possible areas for use of ADP, those approved will be analyzed, adapted to machine processing and tested on the center's computer. This "testing" is the heart of the simulation approach, for the practicability of using a mobile computer for processing a given field function can be established before the rolling machine is ever built! In effect, the applications and the adequacy of

SOME OF THE FIELD ARMY FUNCTIONS UNDER STUDY FOR ADAPTATION TO ADP

COMMAND OPERATIONS	Studies in radio frequency allocation, analysis of signal traffic. Improvement through automation of antiaircraft artillery and field artillery fire control and target analysis.
COMBAT INTELLIGENCE	POW interrogation, intelligence summaries and order-of-battle records.
PERSONNEL & ADMINISTRATION	Studies of troop lists, pay lists, POW records and allotment records.
LOGISTICS	Ration accounting, inventory control, supply requisitions and stock fund accounting.
SPECIAL CATAGORY	Studies in meteorology, language translation and table of distribution and allowance data.

Brig. Gen. Frank W. Moorman, Commanding General at Fort Huachuca. U. S. Army Photo.

Lt. Col. Luther W. Murphy, Chief, Automatic Data Processing Department. U. S. Army Photo.

an Army-wide ADPS, and the necessary characteristics of the mobile equipment, will be known before it is created.

Studies found suitable will then be machine-programmed at the center for the appropriate FIELDATA computer. Design of the prototype ADP system (FIELDATA computers plus supporting units) will proceed only after the primary application areas have been selected and the research done on the necessary field organization, the required information flow and the need for processing centers established. Specifically, the next few months will see the selection of a primary application area for which a prototype ADP will be created. This will be FIELDATA and the first experimental computers, along with the Ampex equipment, will start arriving at Huachuca in December of 1959. These components will be assembled into a prototype, testing continuing all the way, until a system is actually ready for a field workout (see below). Plans now call for getting the FIELDATA family into the field by 1962-63. By 1965-70, the Army will have a much advanced system called ARMYDATA.

In addition to its use in evolving FIELDATA, the center will handle data processing for the overall technical program of the USAEPG. In this role, it will support the efforts of departments other than ADP which are designing and evaluating communications-electronics systems. The agencies utilizing this support are concerned with combat surveillance and avionics, signal communications, electronic warfare, meteorology, and electronic environmental testing.

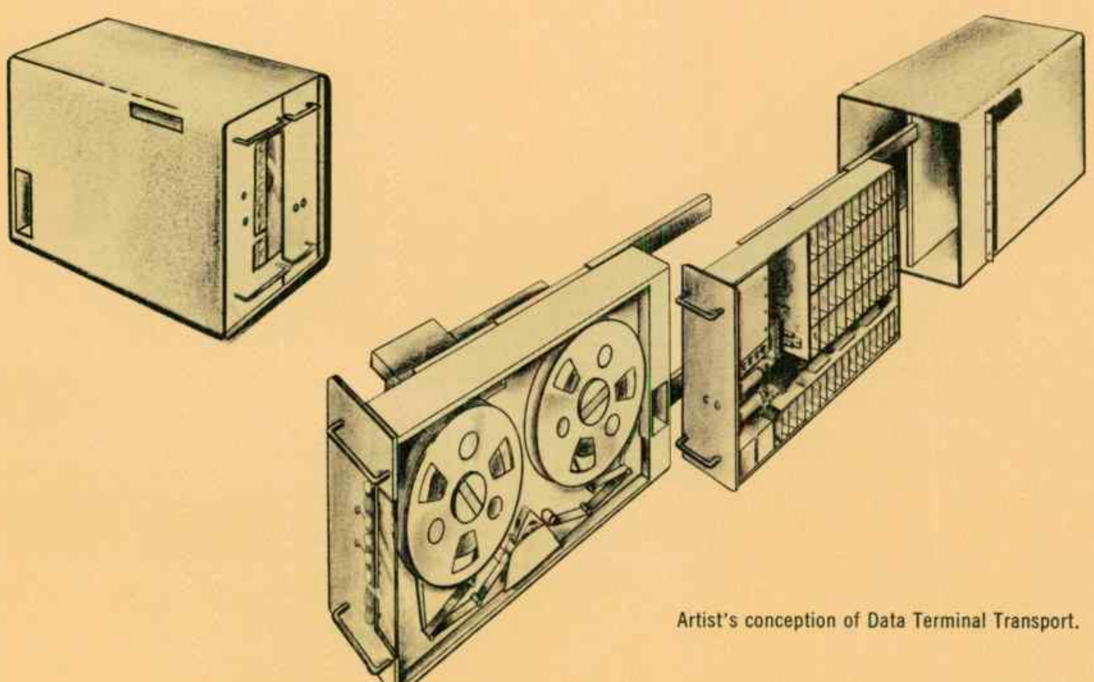
The Field Test Facility

This is the second of the two ADP facilities at the Proving Ground. It will use troop support units engaged in field maneuvers to give FIELDATA and its successors the all-important trial–operation under combat conditions. The maneuvers will have sufficient realism and statistical support to prove or disprove the equipment's ability to stand up under the real thing. Besides putting the system through its paces, these run-throughs will give the personnel training in operating and maintaining the machines, programming, and other phases of computer use.

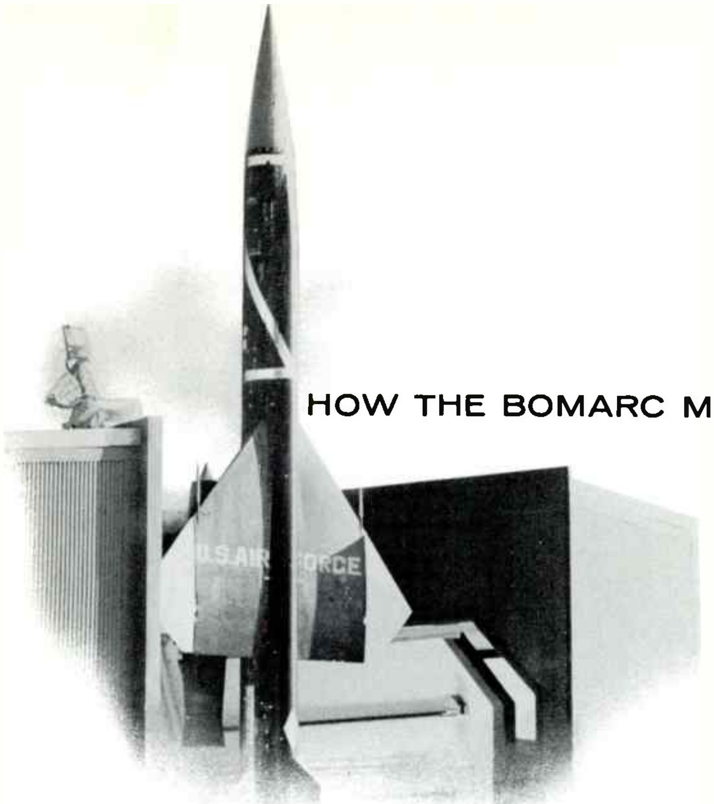
THE ROLE OF THE COMMANDER

While explaining FIELDATA, Lt. Colonel Murphy was asked, "what will FIELDATA and its more advanced successors do to the role of the combat commander? Will the 'electronic brains' take over his functions?" In answer, he pointed out that the computers are not designed to make command decisions and, in fact, can never take over this province of the combat commander. They simply are improved tools to aid the officer in determining what to do. Tactical ADP poses a man-machine relationship essentially different from that of automatic control systems, since the informational flow is from computer to commander. He will combine the machine-derived data with his experience and judgment to make the final risk-decision.

And so, although things have changed mightily at Fort Huachuca since the 1870's, the responsibility of the combat commander when the "chips are down" is still the same. While the methods of obtaining information have ranged from the Indian Scouts of long ago to computers, the final, fateful decision still rests with the man. Computers will only make that decision a better and a faster one.



Artist's conception of Data Terminal Transport.



HOW THE BOMARC MISSILE KEEPS ITS FIGURES IN TRIM AT

The weighty data problems associated with the development of the Bomarc interceptor missile have been considerably lightened since Boeing Airplane Company installed its new data reduction center in Seattle. Here, data processing systems engineer Cecil McGuire and his crew operate one of the smoothest salons in the reducing business.

The data reduction laboratory is located in its own separate working area, provided with its own service and maintenance. As a visitor, you are first escorted into an air-lock, then into the brightly-painted, comfortably air-conditioned interior, where you are greeted by engineer McGuire. Before demonstrating the capabilities of the various racks of interesting-looking equipment lining the walls of the room, he agrees to give you some background on the Bomarc missile itself.

BOMARC is a long-range, high-altitude supersonic missile, with the mission of intercepting and destroying enemy aircraft before they reach their targets. The newest operational version of the Bomarc, the model "B," has an effective range of over 400 miles and a speed in the "several" mach range. Because of its range and flexibility, the Bomarc qualifies as an "area defense weapon"; a single Bomarc base provides effective defense coverage over an area of half a million square miles.

According to the U. S. Air Force, there are at least seventeen Bomarc bases planned or under construction in the United States and Canada. The first operational prototype base is located on Santa Rosa Island, off the coast of northwestern Florida, near Eglin Air Force Base.

Most Bomarc launchings to date have been from the USAF Flight Test Center at Patrick AFB, Florida, beginning with the first successful flight in the spring of 1955. Recently, a Bomarc intercepted and figuratively destroyed a supersonic air-breathing missile, the North American X-10, fastest target drone ever used. In another test, two Bomarc missiles were fired together in "salvo" and within minutes had located and intercepted two remotely-controlled bomber targets flying twenty miles apart.

The Bomarc's guidance system is highly sophisticated, and adaptable to any existing ground control system. It has made successful intercepts while being controlled by a Boeing-designed, portable ground control system, and while under control of the U. S. Air Force's SAGE system. With the latter, intercept missions have been completed off the coast of Florida while being controlled from a SAGE center 1500 miles away.

The SAGE center, in Kingston, New York, demonstrated that its AN/FSQ-7 (XD-2) digital computer could accurately direct and control a test firing half a continent away, keeping track of the target, determining the intercept point, and directing the Bomarc in for the kill. The computer was linked by land line with radio-control transmitters at the Bomarc launch point and with the area's search and tracking radar. With this system, the computer received target information from the radar, generated and sent back guidance information for instantaneous radio transmission to the Bomarc—all without human intervention.

Once the missile is directed to the general target area, it is capable of proceeding to the target without external direction. In other words, the Bomarc incorporates a target-seeking "brain" which enables it to locate and proceed toward the target, altering its course as necessary. An actual collision with the en-

Cecil's Reducing Salon

emy aircraft or missile is not required, as the Bomarc is armed with a proximity fuze for its conventional or nuclear warhead.

On many of its test flights, the Bomarc carries a complex instrumentation payload in place of its warhead. Thus it is possible to monitor the missile's performance throughout its flight, telemeter information to acquisition centers, and obtain a variety of data important to design and development of still more advanced models of the Bomarc.

This is what keeps Cecil's Salon in business. The data reduction laboratory collects the data, processes it, and makes it available for further use in graphic, digital or numerical form. The laboratory processes telemetered data exclusively, supplied in the form of magnetic tape recordings acquired at various stations along the missile range.

On a typical test, Air Force tracking stations stand by to gather the data telemetered from the missile. At the Eglin missile test range, for example, southward from Santa Rosa Island, test data will be recorded on Ampex equipment at Eglin, Cape San Blas, and Anclote, near Tarpon Springs. Within hours, taped data from these stations is winging its way to the laboratory in Seattle.

Shortly after arrival the data is checked and recordings from the various tracking stations are compared to select the best source for each portion of the data. This processing requires from four to six hours to complete. Next the computer tape is written, requiring approximately an hour, and following this are three hours of machine time. Final readout in point form on strip charts, with simultaneous printing of points in numerical form, requires 6 to 8 hours.

Boeing engineers are thus able to get final information on a specific test flight within a period of only two days—information that only a few years ago would have required weeks or even months to reduce. In the event certain information may be required immediately following the flight, it can be obtained by processing through "quick-look" equipment either at the launching site or at the Boeing laboratory.

More than 50 data sources are measured within the missile and telemetered to the ground. Some are measured continuously; some sampled at the rate of 20 times per second by a pulse duration modulation system. Variables measured include accelerations, rates, currents, positions, pressures, temperatures, and error signals.

The display room where hundreds of feet of chart paper record each Bomarc flight.

Incorporated in the data laboratory's processing equipment is a unique Boeing-developed raster straightener, designed to maintain the continuity of flow of information from all the various data points. It might be compared with an automatic pilot, keeping the plane on course even though it may lose contact with ground reference points. The raster straightener keeps the various data in phase even though the actual signal may be temporarily lost. It also has the ability to determine whether the incoming signal is not actually data.

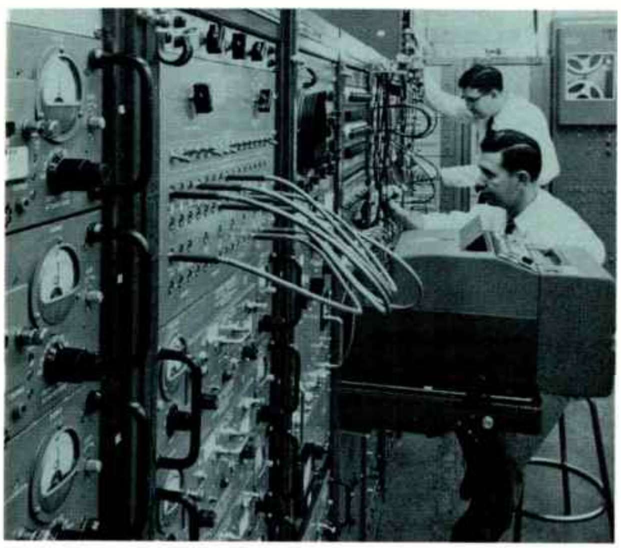
Another instrument used in the laboratory is the Analog-to-Digital converter. This instrument receives the taped data and converts it into digital data in the 1103A format required by the computer.

Ampex equipment used in the laboratory includes a FR-307-309, a FR-107, a FR-114 and a 306-307 combination. The latter was specially developed to permit interchangeable FM and PDM operation, preceding and anticipating the development of the FR-100 Series of Ampex equipment.

Boeing engineers have incorporated various special modifications into some of the Ampex recorders in the laboratory to provide special operational features. For example, the 300 Series recorders have been equipped with photocell-actuated automatic shut-off. Another Boeing feature is a switching arrangement which removes plate voltage from the final stages during fast forward and rewind, thereby protecting data circuitry and galvanometers from the effects of rapidly fluctuating signal voltages.

After you've inspected the data processing equipment, Cecil McGuire or one of his staff will sketch out the information flow diagram on the blackboard for you, and answer any questions which don't fall into the classified category. Next you'll be escorted upstairs to the display room, where on hundreds of feet of chart paper, covering hundreds of thousands of data points, you'll see the complete history of a Bomarc flight.

Before your Bomarc indoctrination is complete, there's one final stop to be made—a look at a "sanitized" and therefore unclassified missile. Here you'll see a "super-Bomarc" being checked out. And if you react as we did, you may find its trim lines, delta wing, underbelly ramjets and 47-foot length considerably more awesome and impressive than you had imagined. And maybe you'll feel like the citizen of Sagamore, Massachusetts, who said after his introduction to the Bomarc: "I feel a hell of a lot safer tonight than I did last night!"



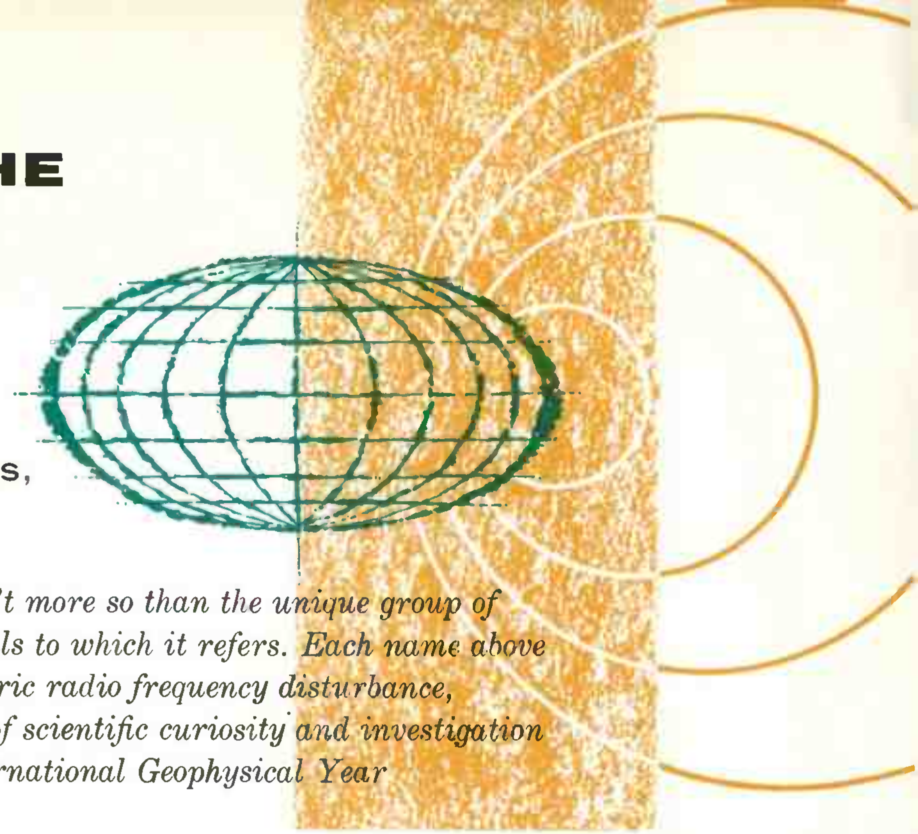
Cecil McGuire (background) checks some of the equipment in his reducing salon.

Col. R. J. Walling, Air Force Plant Representative at Boeing Airplane Company, inspects the first production model of the Bomarc missile with Lysle A. Wood, Boeing vice president and general manager of the company's Pilotless Aircraft Division in Seattle.

THE CASE OF THE ATMOSPHERIC WHISTLER

BY R. W. MURRAY

not to mention dawn chorus, tweeks, clicks and sferics



The title may seem strange, but it isn't more so than the unique group of audio-frequency electromagnetic signals to which it refers. Each name above applies to a peculiar type of atmospheric radio frequency disturbance, and their origin has been the subject of scientific curiosity and investigation which became intense during the International Geophysical Year

All men are curious about the world around them. The most curious frequently become scientists or explorers and do strange and exciting things. They explore new lands or peer through a microscope at the bodies of dissected mosquitoes, as Ross did in India, to discover the cause of malaria. Or they may choose to listen to the strange radio-signals that emanate from the sky above us. Of the men who do the latter, an acknowledged authority is Dr. Robert A. Helliwell, Professor of Electrical Engineering at Stanford University in Palo Alto, California.

With the aid of recently developed techniques of electronic science, he and his colleagues around the world are hard at work recording and analyzing these cosmic noises.

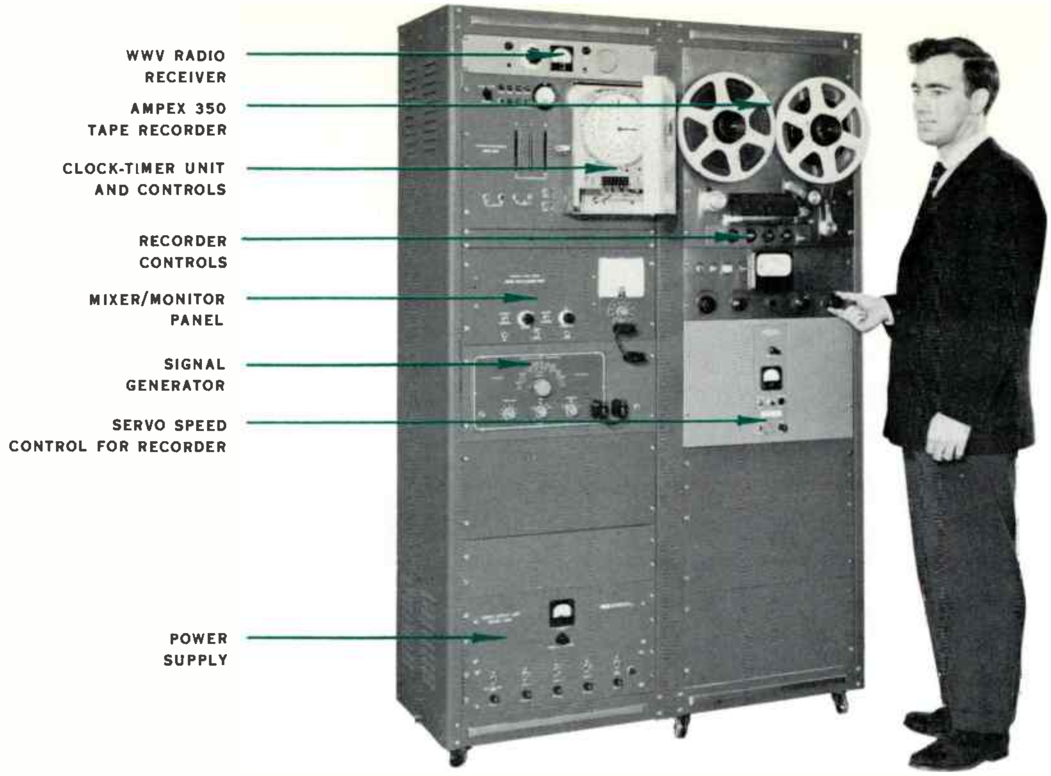
THE WHISTLER AND RADIO COMMUNICATIONS

From these investigations have come many interesting facts. The peculiar nature of whistler propagation is providing a tool for investigating the earth's atmosphere out to thousands of miles. Study of the whistler and other atmospherics has become a valuable tool of research.

Some of the findings may have a bearing on radio communications. One of the strangest discoveries is that the ionosphere and exosphere (region outside the ionosphere) may actually act like a travelling wave tube, and the whistler echo on occasion may be amplified so it is stronger than the normal version of the wave which produced it, when both reach the conjugate point (point of return to earth, explained below).

In the light of Dr. Helliwell's work in January and February 1957, indications are that this echo amplification could seriously hamper radio communications of some types. Ernst Gehrels, a graduate associate, journeyed to the southernmost part of South America and, on the barren wind-swept area just north of Cape Horn, recorded both the direct transmission of radio station NSS in Annapolis, Maryland, and the whistlers resulting from this transmission. It is obvious that if the whistler created by a broadcast were to return with a signal strength near that of the regular broadcast, but delayed a second or more, there would be great reception interference at the station's conjugate point.

Dr. Robert Helliwell points to trace from a recording made on whistler-detecting equipment shown behind him. Peaks in upper curve represent whistlers; height of peak indicates relative amplitude. Lower curve is corresponding frequency distribution.



Whistler-recording equipment designed at Stanford University for Project 6.10 of the International Geophysical Year. At right is the Ampex Model 350 magnetic tape recorder, with clock-timer and auxiliary equipment in the left cabinet. Robert L. Smith, a member of the design team, stands at right.

The possibility exists that we may one day be able to use the whistler effect itself for communication. But before this, we will have to know more about the factors causing seasonal and daily variations and fluctuations in whistler paths and intensities. If we can produce a world "map" of conjugate points as a result of research, it should be feasible under the proper conditions to generate a coded transmission to be sent via "whistler wave" from one conjugate point to the other.

THE HISTORY OF THE WHISTLER

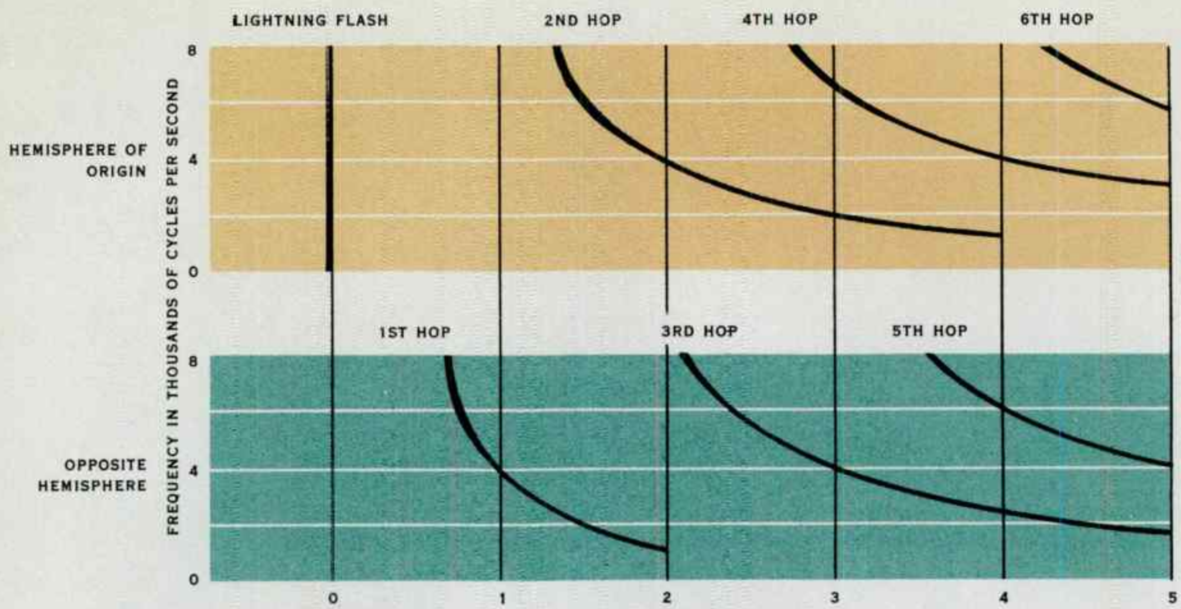
Historically, the whistler was the first of the atmospheric electromagnetic phenomena known generically as "sferics" to be discovered. During World War I, a German scientist, H. Barkhausen, was eavesdropping on Allied telephone conversations, using earphones and a sensitive audio amplifier. As he listened, he became aware of a whistling tone which descended rapidly in pitch over an interval of about a second. The frequencies were unusually low, from one to several thousand cycles per second. He recognized the noises as a new natural phenomenon, and when he published a work on the subject in 1919, he called them "whistlers."

It was almost ten years before another significant event in the sferic field. T. L. Eckersley and co-workers of the Marconi Wireless Company reported in 1928 a correlation between whistler and solar activity. They also noticed that whistlers frequently occurred in trains of echoes preceded by a loud click and with a remarkably even spacing of about three seconds between the click and the first whistler, and between each succeeding member of the same group. They also discovered another atmospheric, a wierd warbling sound like birds chirping at dawn; it was promptly dubbed the "dawn chorus."

It soon became evident that whistlers were caused by lightning flashes, part of the electrical energy being guided in some mysterious way so that it bounced back and forth from hemisphere to hemisphere with time intervals as long as several seconds. This "bouncing" energy made the whistlers, and the click was the direct radiation from the flash. This delay was puzzling because at the speed of light (at which radio waves travel), the interval from hemisphere to hemisphere via normal Kennely-Heaviside reflection should have been no more than a half-second.

Over the ensuing three decades, the whistler's path has become clearer, although all the details are not yet resolved, and much of the understanding is very recent. But by study of this once "unimportant" phenomenon it was possible to predict that far out through what had been assumed to be the void surrounding the earth were many more ionized particles than had been guessed.

Eckersley in 1935 explained whistlers on the basis that the initial lightning flash contained a wide spectrum of energy at frequencies up to thousands of cycles per second, a portion of which managed to penetrate the Kennely-Heaviside layer to form the phenomenon. As it traveled between hemispheres, the energy was



Typical, idealized whistlers, demonstrating delay from hemisphere to hemisphere and change of frequency.

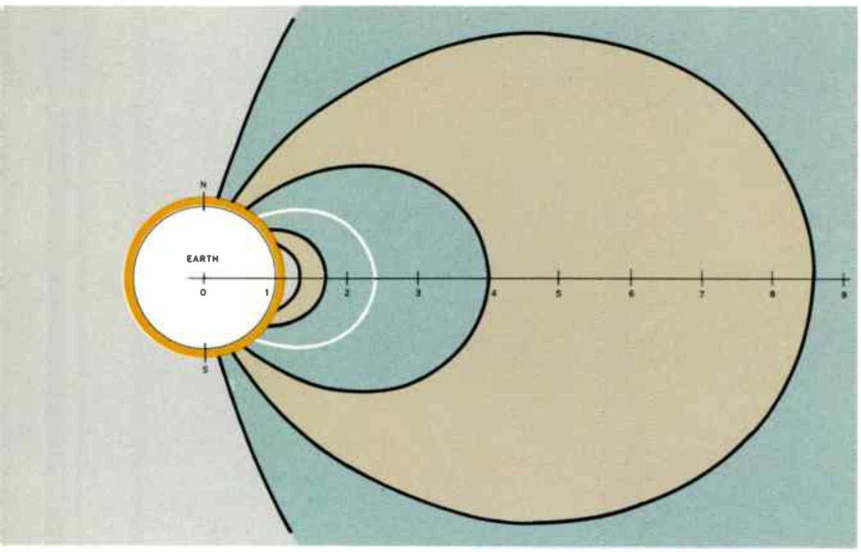
guided by the earth's magnetic lines of force, and he demonstrated mathematically that lower frequencies would travel more slowly than the higher. Thus frequencies that had penetrated the ionic layer would "degrade" into a whistler as the slow frequencies lagged further behind, while the normal transmission from the lightning flash would produce the click noticed by Marconi's group.

But it was L. R. O. Storey who in 1953 produced the first comprehensive theory of the whistler. He postulated that some of the energy of the lightning flashes penetrated the ionosphere and then traveled out into space, guided by the earth's magnetic lines of force. He estimated that the paths would in some cases extend many earth diameters to distances from the the earth of 40,000 miles or more, and that the average, or "group" velocity was only one tenth that of ordinary electromagnetic transmission. This was different from regular radio waves, which are reflected from the ionosphere in almost straight lines, at the speed of light, and at altitudes mostly under 100 miles. Storey further demonstrated that the requirement for guiding the whistler in the curved path is an ionized medium, which he found to have an average densiiy of 600 electrons/cc. No one had suspected so much matter.

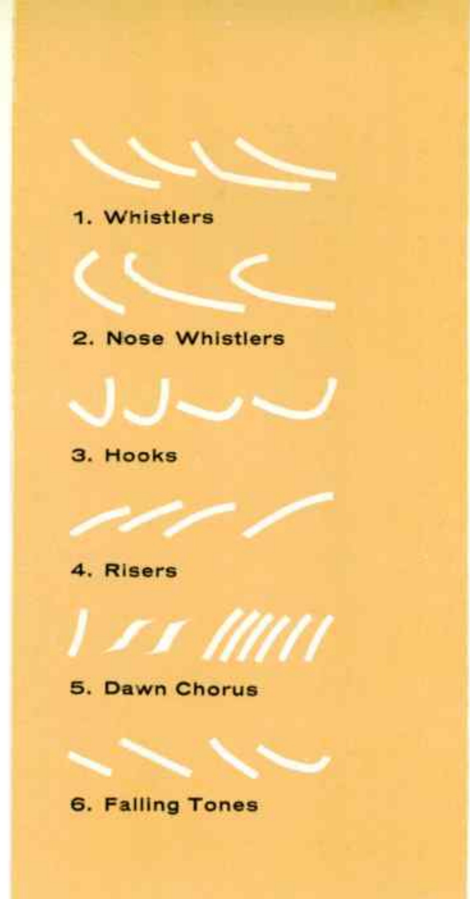
Due to the earth's magnetic field, the charged ions guide the whistler energies from hemisphere to hemisphere. The magnetic field may even align the space charge into so-called "magneto-ionic ducts," acting rather like pipelines for the energy. The whistler returns to earth at what can be visualized as the other end of the line of force guiding it, the points of origin and return being called the geomagnetic conjugate points. Whistler echoes should be strongest at these points, although they may be heard over a wide "circle-of-error." None have been detected at the equator, presumably because there are no lines of force terminating there which also pass through the dispersive regions of the ionsphere.

THE IGY PROGRAM

To assure uniform methods of obtaining data on atmospherics, standard recording equipment was specified for the Whistler-West investigation which covered the United States, Alaska, and New Zealand, and was called project IGY 6.10. The equipment was designed at Stanford by Helliwell's group. Basically it consists of an Ampex model 350 instrumentation-type magnetic tape recorder, an antenna consisting of a single loop of No. 6 soft copper wire in the form of an isosceles triangle approximately thirty feet high, a suitable amplifier system, and a clock system accurate to a hundredth of a second. Several such systems were assembled and distributed to stations scattered over the United States. Additional units went to New Zealand, and Macquarie Island in the Pacific. The chain of stations thus established ran from Alaska to New Zealand. In some situations a portable Ampex 600 tape recorder was substituted for the larger Model 350, and the preamplifier electronics modified for flat response instead



Representation of lines of earth's dipole magnetic field for each ten degrees of geomagnetic latitude. The yellow area encircling the earth represents the known ionosphere, mostly under one hundred miles from the surface; white line is presumed path of a typical whistler. As may be seen, whistlers originating near magnetic poles describe immense paths deep into space.



Idealized oscilloscope trace pattern of common sferics.

of the audio equalization supplied. Similar work was carried on all over the world.

Regular recording was done in accordance with IGY schedules, which called for 1½ to 2 minutes of operation at 35 minutes past each hour. The clocking system automatically switched on the recorders and tuned in U. S. government radio station WWV for a time check at the beginning of each recording period. This timing information was recorded at the start of each tape. Thus all stations could accurately correlate the phenomena they recorded to within a small part of a second. By this means, more meaningful information on time delays, dispersions, and occurrence of the whistlers was obtained. This information, supplemented by satellite probes and other investigations, will eventually provide a better picture of the little-known region of the outer atmosphere, a region that is becoming of vital interest as man considers his first personal ventures into space.

OTHER FORMS OF SFERIC

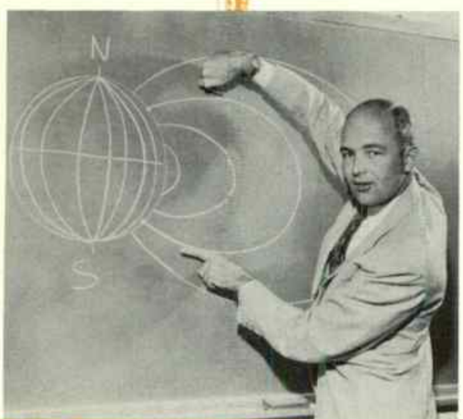
As mentioned, there are many other types of atmospherics. Most investigation has been aimed at the whistler, but increasing interest is being shown in other types. They seem to originate outside the earth. Indications are that they are created in the ionsphere by "streams" and "bunches" of radiation emanating from the sun. These disturbances have also been named by their sound. Thus we have the above mentioned "dawn chorus," and also "hiss," "risers," "hooks," "quasi-constant tones" and others yet unnamed.

All are classified as VLF phenomena. The "dawn chorus" consists of a multitude of warbling tones, sometimes with a background of steady or slowly changing tones. It is common in middle latitudes near dawn. "Hiss" often accompanies the chorus, and is a steady hissing noise. "Risers" are musical tones, lasting a fraction of a second, of rising frequency. They usually start at a few thousand cycles and rise through one or more octaves. A riser preceded by a definite falling tone is called a "hook."

THE FUTURE

One lesson that this Twentieth Century has taught is that one cannot predict the future applications of even seemingly unspectacular discoveries. So it is with whistler investigations. Perhaps the possibility of using "whistler wave" as a means of communication will never materialize, but already what was a scientific curiosity has become an extremely useful and valuable tool for examining the remote regions of the ionosphere and exosphere. We can confidently expect to learn still other secrets of the atmosphere through intensive research into the nature of all forms of atmospherics. The case of the atmospheric whistler is far from closed.

Who's he ?



Bob Helliwell explains, with the aid of a blackboard, the path that a whistler might take in its journey from hemisphere to hemisphere. Teaching courses in ionospheric propagation is just part of his crowded schedule.

Robert A. Helliwell was born in Red Wing, Minnesota, not quite thirty-nine years ago. When he was seven, his family moved to Berkeley, California, and two years later to Palo Alto, where he has lived since.

Attending high school in Palo Alto, he entered Stanford University shortly before World War II, and graduated with an A. B. in Electrical Engineering in 1942. He was appointed to head Stanford's program of ionospheric research which was aimed at the improvement of military communications. Thus he was introduced early in his career to the study of "sferics," a term covering most atmospheric r-f sounds above the level of static. His work soon branched into other areas, including the study of high-frequency direction-finder errors over long-range paths. He also continued with his academic work and obtained his A. M. in 1943 and his E. E. in 1944.

After the war, Bob contined work with atmospheric phenomena, concentrating on very low frequency (VLF) propagation. He developed a new technique for making high-resolution soundings of the ionosphere (that region of the earth's atmosphere lying mostly above 25 miles from the surface and characterized by large-scale dissociation of the remaining atmospheric gases into charged particles or ions). Using his new technique, he acquired much information on the height of the ionosphere and its polarizing effect on electromagnetic radiation. He used this work as the basis for his doctoral dissertation, and was awarded a Ph. D. by Stanford in 1948.

In 1951, he began research into the nature of whistlers and other VLF atmospheric phenomena, a program that is yielding new information of great importance in the fields of wave propagation and atmospheric physics. He also heads a program of synoptic whistler measurements for the International Geophysical Year, an endeavor which will provide a world-wide view of the propagation of this type of sferic.

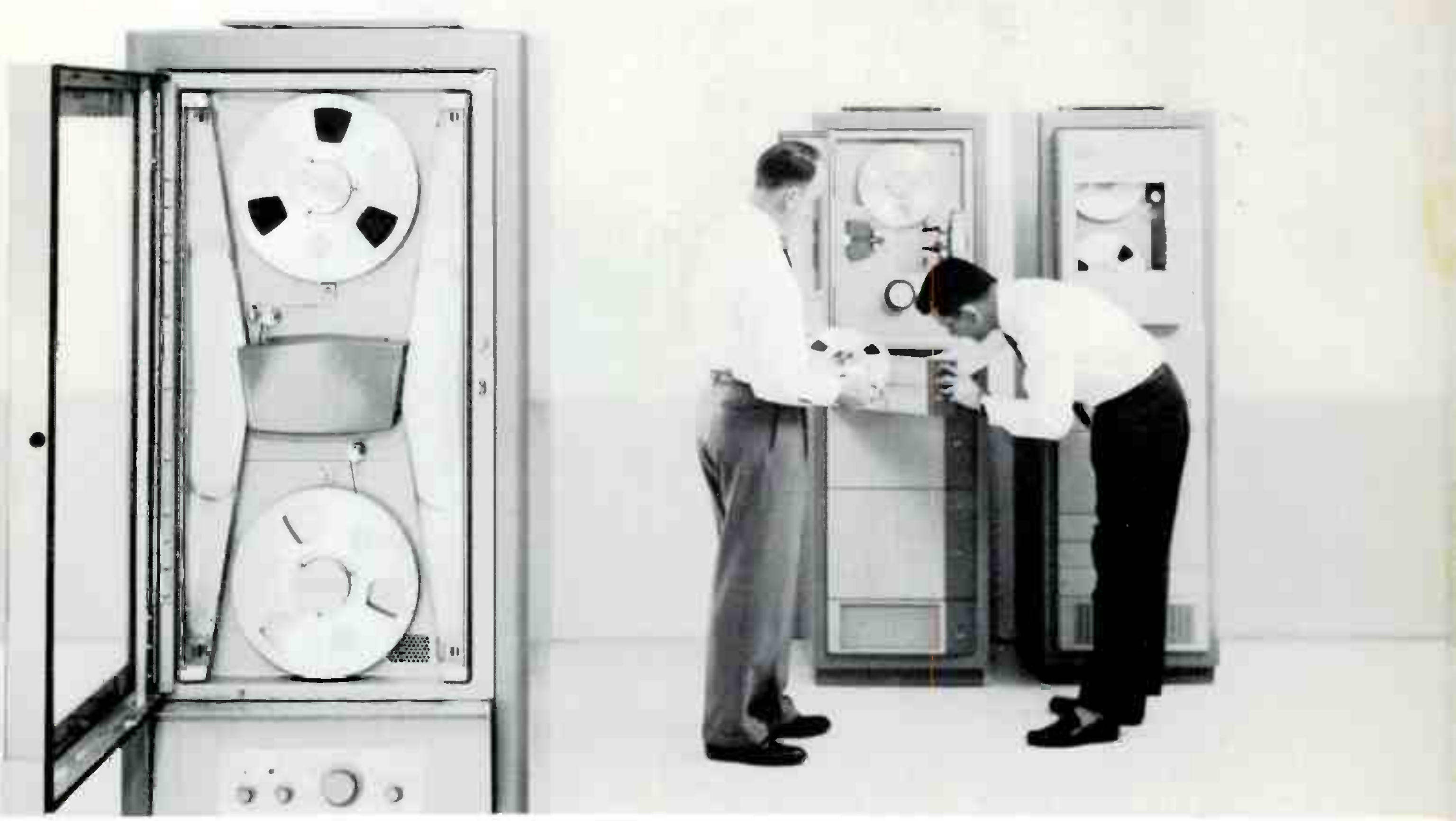
Since graduation, Dr. Helliwell has participated in graduate and undergraduate teaching at Stanford, and now is a full professor in Electrical Engineering. His teaching duties include a course in electronic measurements for senior electrical engineering students, and a graduate course in ionospheric propagation.

Author and co-author of many technical papers dealing with ionospheric phenomena, he also assisted in the preparation of the text *Electronic and Radio Engineering* by F. E. Terman.

He is a member of numerous professional groups and societies, including Phi Beta Kappa, Sigma Xi, Tau Beta Pi, the Institute of Radio Engineers (Senior Member), the American Geophysical Union, and Commissions 3 and 4 of the USA National Committee of the Union of Radio Science Institutes (URSI). He is international president of Commission IV of URSI and, additionally, a member of the Panel on Ionospheric Physics of the USA National Committee for the International Geophysical Year. He was a delegate-at-large to the URSI General Assemblies held in Zurich, Switzerland (1950); Sydney, Australia (1952); the Hague, Netherlands (1954); and at Boulder, Colorado, (1957).

Bob is married and has four children, three boys and one girl. His favorite hobbies are fencing and camping, and he finds time for many community activities. He leads Boy Scout Troop No. 51 on the Stanford campus, and is a member of the local Kiwanis club.

A five-foot bookshelf is a 10-minute task



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A folder on the FR-300 is available if you would like one.

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