Bell Laboratories **RECORD**

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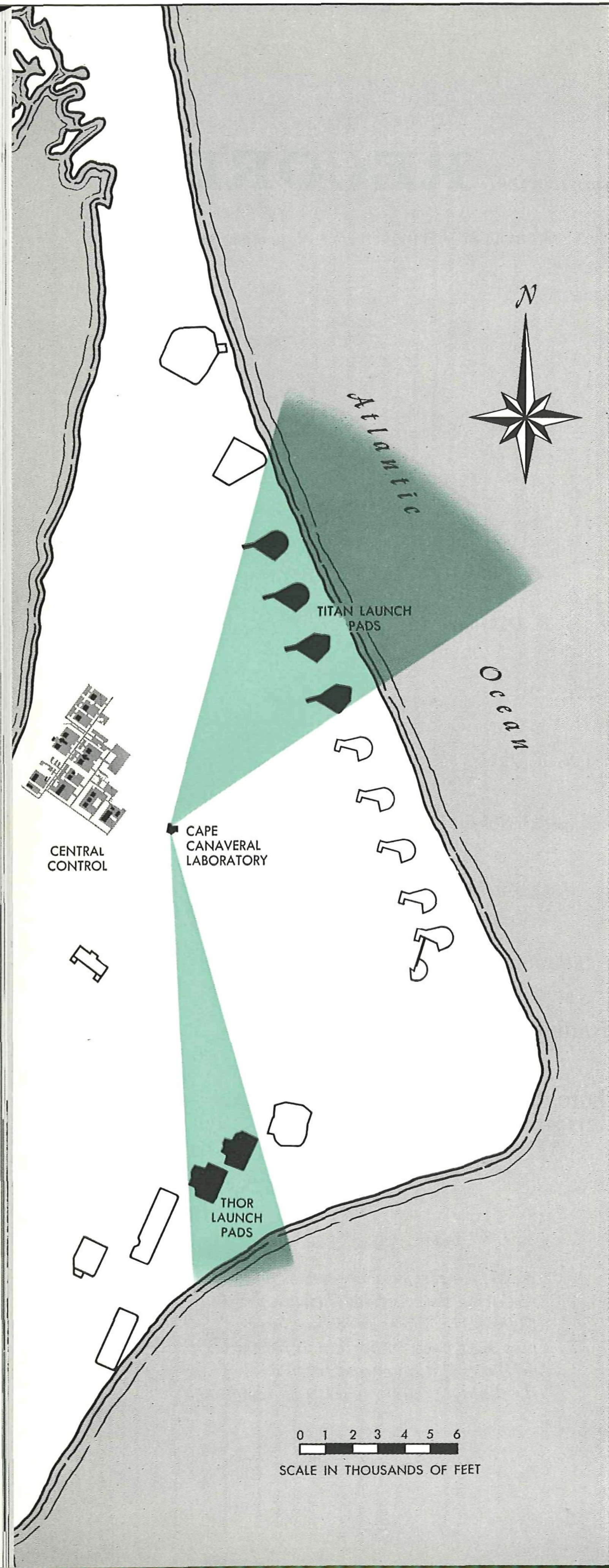
Cover

W. M. Augustyniak prepares solid-state radiation detector for Telstar preflight tests. These detectors have now sent back important information on the radiation encountered during its flight through space. *(See page 380)*



The Cap

As the Delta launch vehicle carrying the Bell System's Telstar communications satellite lifted off the launching pad, thousands throughout the Bell System held their breath. The small group of Bell Laboratories people nearest to the event, however, were too busy doing their normal guidance job to even go outside and watch it. To these men, members of the Cape Canaveral Laboratory, this was in a sense only another in the series of over sixty successful guidance operations accomplished in the past 4 years at the Cape.

The highly successful guidance system, basically unchanged from its first use in 1958, was finally paying off in a big way for the Bell System, after having performed yeoman service in a variety of suborbital and orbital flights. These include many shots of the Titan I ICBM; experiments on re-entry vehicles; four Tiros weather satellites; Transit 4-B, the navigational satellite; Explorer XII, which probed the Van Allen belts; the orbiting solar observatory, OSO; Ariel I, the first International Satellite; and the earlier, passive communication satellite, Echo I.

The Laboratory at Canaveral is located about two miles back from the beach, within sight of the Military and Space Program launching pads which stretch from one end of the Cape to the other. This line-of-sight position is essential, since the Bell Laboratories Guidance System has been used to guide missiles launched from the Titan I pads to the north and the Thor-Delta pads to the south, as shown on the map at left and the photo on page 354. The men that make up the

Location of Bell Laboratories facilities and the launching pads involved in guidance operations.

Canaveral Laboratory

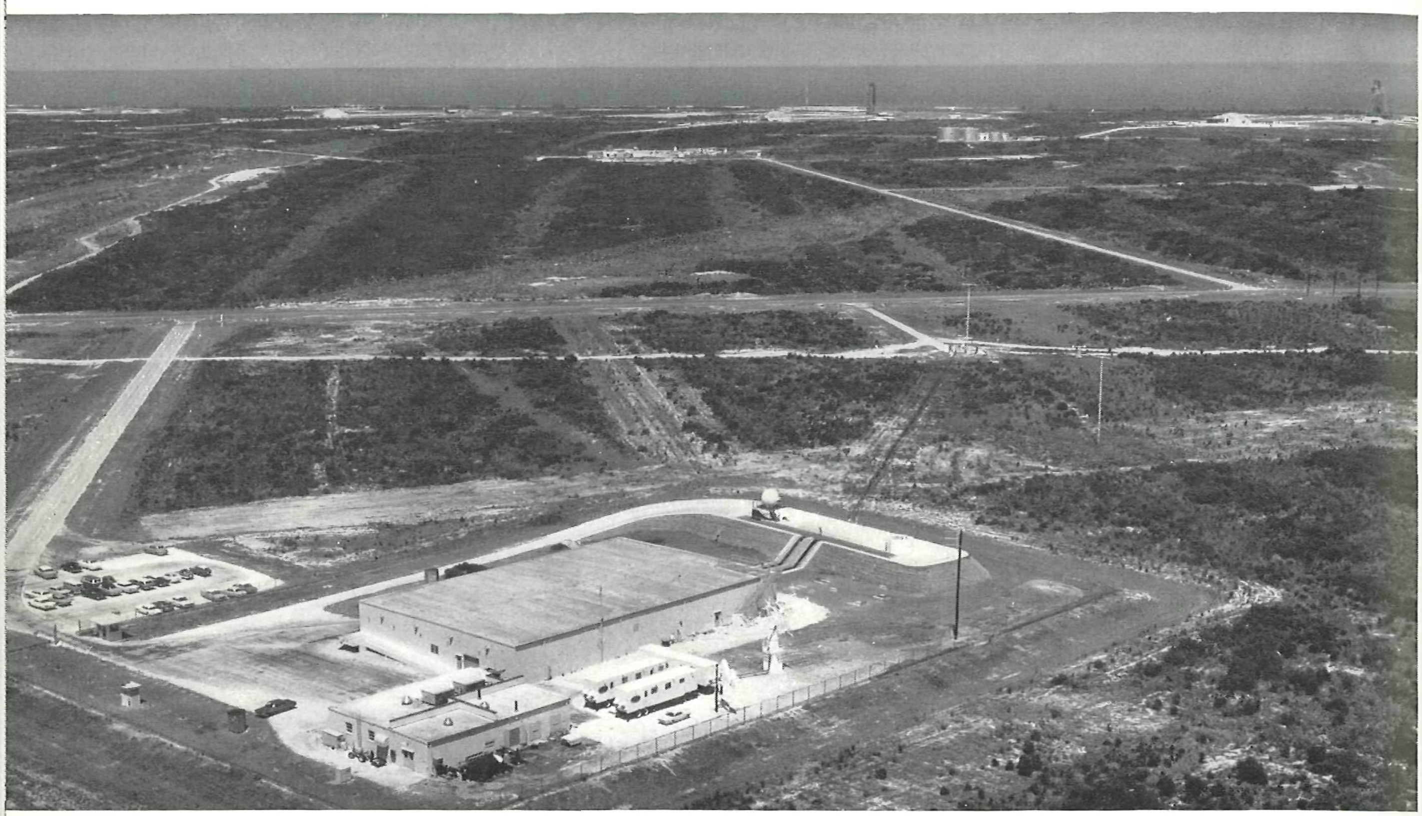
J. B. D'Albora, Jr.

Cape Canaveral Laboratory are relatively few, and many of them have been stationed there since its beginning. The technical and administrative staff is made up of twenty-one Laboratories employees, twelve field engineers assigned to the Laboratories by Western Electric, and twenty-eight resident visitors who provide the basic plant, procurement, mechanical, electrical shops, and the clerical services. This group is swelled presently by engineering and administrative personnel concerned with the Telstar communications satellite project.

Historically, the Cape Canaveral Laboratory (CCL) was established to field test and evaluate the performance of the Command Guidance System designed by the Bell Telephone Laboratories for the Air Force and manufactured by the Western Electric Company. The Laboratory came into being in 1957 with the arrival of the first engineering model of the guidance equipment at its newly built facility on the Cape. The system was put through a comprehensive testing period from which a number of design improvements resulted. On January 22, 1959 the first "closed loop" guidance of a Thor-Able missile was accomplished. During this "closed loop" operation, all orders and commands were transmitted and received properly, and the missile was guided to the desired impact point. The precise impact prediction data obtained permitted the first recovery of a re-entry vehicle at ICBM ranges.

In November 1958, an improved pre-production model of the Guidance System, System No. 3, was shipped to the Cape from the Western Electric plant at Burlington, N. C. It was installed and checked out within two months. Initially, it was "slaved" to System No. 1 to provide duplicate or redundant data on each guidance operation so that its own operation could be studied and evaluated. Not until almost a year later, in March 1960, did System 3 guide its first missile, a Titan I ICBM. During these initial tests at the Cape, Bell Laboratories engineers at Whippany were completing the design of an operational version of the system and Western Electric was going into production. To field test and evaluate the operational concepts, reliability, and guidance accuracy of the production system with actual Titan missiles, one of the production systems was ear-marked for the Canaveral location. This system, No. 7, replaced System 1 and successfully guided twelve Titan I missiles into the MILS network downrange (RECORD, *July*, 1961). Having satisfactorily completed its evaluation tests, System 7 was removed from the Cape, returned to Burlington, N. C., for refurbishing, and delivered to the Air Force for reinstallation at an operational site.

The over-all responsibility for the Cape Canaveral Laboratory rests with the Resident Technical Director, J. B. D'Albora, Jr., who reports to E. P. Felch, Director of Guidance Systems Laboratory at Whippany. The technical staff is divided into a number of task groups, each of which is responsible for specific aspects of the guidance operation. The Ground Guidance Group, for instance, is responsible for the operation, maintenance, improvement, and field evaluation of the ground guidance system. Any modifications required in the guidance system are accomplished and documented by the mechanical and electrical personnel with the aid of the drafting group. The



Aerial view of Cape Canaveral Laboratory, with antenna ramp in foreground, launch pads in background.

Test Planning and Data Analysis Group performs the functions its name implies. Mr. R. G. Kimmell, the Western Electric Supervisor assigned to this location, heads three other groups concerned with checkout of the missile-borne equipment (MBE), reliability, quality control, and periodic maintenance procedures. All staff services are provided by G. J. Mihm, Resident Administrative Manager. Remington Rand UNIVAC has a resident staff to operate and maintain the "Athena" computer used in conjunction with the ground guidance system.

In principle, the Command Guidance System is quite simple. Missile position is continuously determined by a precise ground-based automatic tracking radar. A ground-based transistorized digital computer accepts the position data in suitable form and derives missile velocity (in a three rectangular coordinate system) by noting the change in position as a function of time. The missile position and velocity data so obtained are compared automatically with pre-calculated values (representing the desired trajectory) which have been stored in the computer prior to the flight. Coded steering commands based upon deviations between the actual and desired values are communicated to the missile over the radar beam. An engine cut-off command is sent to the missile when the ground-based computer is satisfied that appropriate conditions for the desired free-flight trajectory have been met.

The accuracy of this Command Guidance System results primarily from the combination of precise radar tracking and a unique computation process involving Darlington's radio-inertial principles for determination of velocity.

Perhaps the flavor of activity at the Canaveral Laboratory may be derived from the highlights of a typical space vehicle guidance operation. Obviously, much preparation is needed both at Whippany and at the Cape to culminate in a five-minute period of guidance. Basic requirements are provided in a number of Air Force and NASA documents applicable to a specific operation. Whippany then generates guidance equations to satsify the trajectory requirements. These equations are implemented in the form of a program tape for the computer by UNIVAC headquarters at St. Paul, Minn.

Test plans are prepared at CCL which specify the operational requirements of the ground guidance system and the guidance equipment in the missile. Approximately one week before launch, the guidance program tape is checked out, using the ground guidance equipment, Athena computer, and an analog computer to simulate the dynamic characteristics of the missile. These checks assure that the system and the program are compatible and operation is normal.

Checks of the missile-borne equipment installed in the vehicle are made in the hangar to insure proper operation. Similar tests are performed when the missile is erected on its launch pad. A number of tests are conducted between the missile equipment and the ground guidance station prior to launch. These tests include a "quick look," RF Interference test, T-minus-6-day acceptance test, T-minus-3-day combined systems test, T-minus-1-day pre-launch countdown, and T-minus-0 launch countdown.

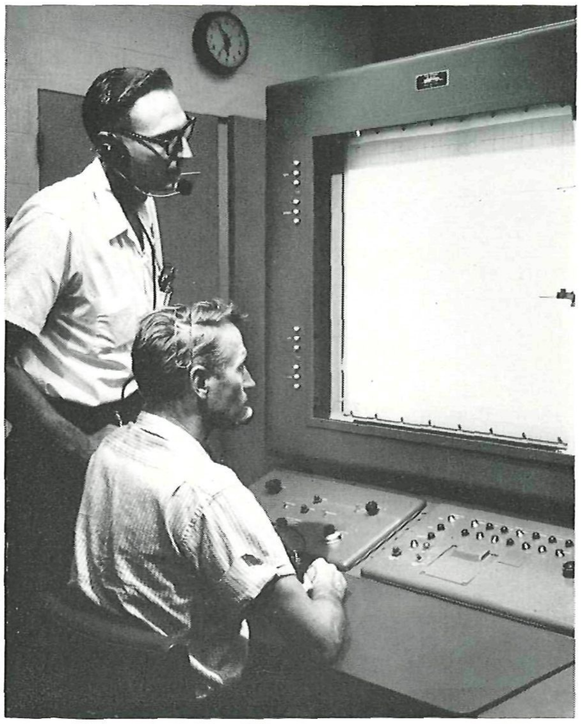
During a launch countdown, one man, designated Radar Control, is responsible for the coordination of all checks performed at the Ground Station. Another, designated Guidance Control, is responsible for coordinating tests between the ground station and missile-borne equipment as well as providing liaison with the test conductor in the block-house.

All areas in the system have been carefully checked and adjusted beforehand to provide the best possible equipment performance. In the antenna area, where adjustments of level and boresighting are critical for accuracy of guidance, extreme care is exercised. Optical and RF alignment of the antenna and boresight telescope are accomplished by using a test mast located 750 feet in front of the antenna mound.

After the boresight telescope optical alignment is completed, the antenna is rotated to a monolith, another optical target located close to the test mast. The location of this monolith has been accurately surveyed by the U. S. Coast and Geodetic Survey Group, and its azimuth relative to true north is used by the computer as the standard azimuth reference. The monolith is also used to align optically the boresight movie camera used for photographing all flights and the "monitoring" TV camera mounted on the elevation shaft of the antenna.

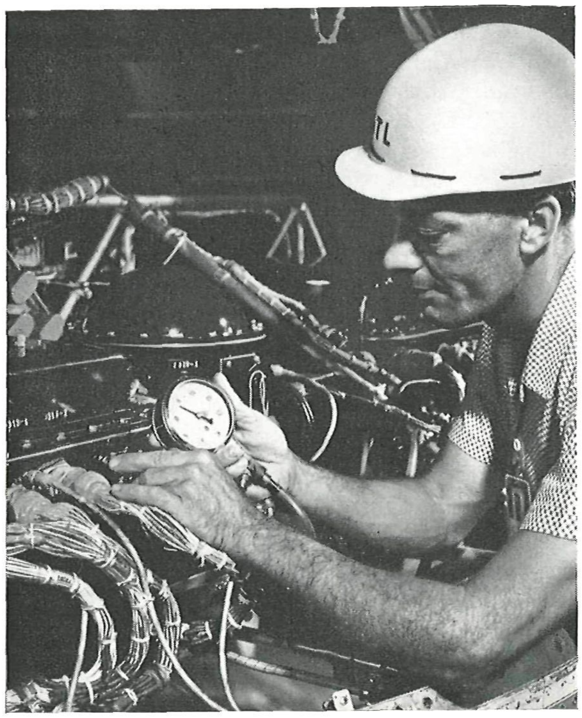
During the guidance system terminal count, final checks are made on the entire guidance system. After the MBE is turned on, a standard program of pitch and yaw orders is transmitted from the Ground Station to insure proper operation of the missile equipment. Responses to these orders are monitored at the RIME (Radio Inertial Missile Equipment) Monitor, located in the block-house, via leads in the umbilical cable connected to the missile.

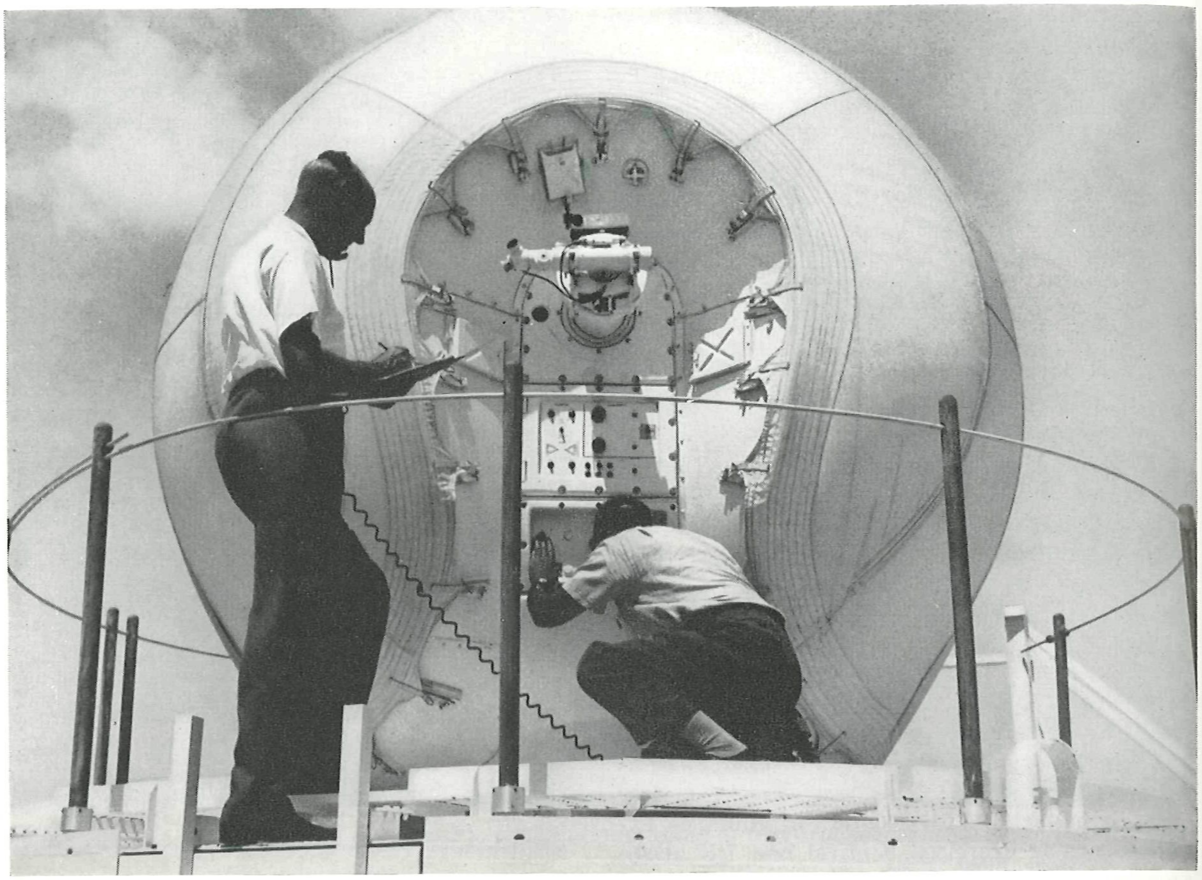
If all tests indicate that the systems are "Go," the guidance program is started and the com-



R. G. Kimmel, Western Electric (left), and Larry Gant, Bell Laboratories, watch as the Delta vehicle track is traced automatically on plotting board.

E. A. Baker checks out the missile-borne guidance equipment installed in the missile prior to launch.





J. C. Crowley and R. J. Tellman check level indicators inside the tracking antenna at Cape Canaveral.

puter is ready to guide—the test phase is over and the pre-guidance phase begins. In this phase, Guidance Control, Radar Control and the console operators constantly monitor the status of their equipment. As the count proceeds towards zero, all subsystems are placed in a state of final readiness and are so indicated on the status board.

The status board includes the block-house and missile guidance equipment status as well as ground station status. When the missile is transferred from ground power to airborne power all lights must be green, indicating a "Go" condition. Word of this "Guidance Go" condition is transmitted to the Test Conductor's status board. If, after this time, any subsystem goes out of the "ready" state, and is not restored quickly, an automatic engine shutdown will result when the count reaches "zero."

As the missile lifts off its launching pad, the plotting board in the control room comes to life. The actual elevation and range of the missile derived from the radar tracking data are continuously plotted on a chart and visually compared with a pre-traced programmed trajectory. Deviations from the programmed path are an indication of missile performance. A second pen on the plotting board simultaneously plots deviations from the desired launch azimuth. In addition to the traces of trajectory and launch azimuth on the plotting board, indications of pitch and yaw orders and command signals which are transmitted to the MBE are also displayed. Such signals include orders to gimbal the engines in the yaw or pitch plane, and discrete commands for engine cut-off.

The missile position information supplied to the plotting board at Bell Laboratories Guidance Center is simultaneously transmitted to the Range Safety Officer (RSO). The RSO has the responsibility of determining that the missile is within established safety limits and, if not, determining at what point it should be destroyed. In addition to the plotting board positional information, the guidance system also furnishes data to the IBM 7090 Impact Predictor computer which supplies information to the RSO regarding where the missile would fall if the engines were cut off at any given time. The data supplied to the RSO by Bell Laboratories is used as a back-up for information normally supplied by tracking radars under the direct control of the Range Safety Officer.

The initial period of flight is controlled by a programmer installed in the missile. As the space vehicle leaves the atmosphere, the ground guidance system starts guiding the first stage. If the missile position and velocity are not those desired, corrective orders are issued. No attempt is made to return the vehicle exactly to the original trajectory, but rather computations are made to choose the trajectory closest to it which will still insure that the satellite will arrive at a desired insertion point for the designed orbit. The time of sustainer engine cut-off is as vital as the attitude of the vehicle, since this determines the terminal velocity. The need for accuracy in a ballistic missile system can be appreciated if one realizes that a variation of one foot per second from the desired velocity (approximately 18,000 feet per second) would result in an error in range of one mile at ICBM ranges. Once the sustainer engine cut-off is commanded, the guidance function is completed.

After the flight, but before sending all data to Whippany for reduction, study and analysis, the local Data Analysis Group reviews the data to determine if anomalies exist which would require further explanation. Some of these data include a strip chart recording from a twenty-four channel "Events Recorder" of signals and data indicating system performance during the flight. This recording includes automatic gain control level, range errors, azimuth and elevation errors, magnetron current, transmitted pulses, the time and duration of orders and commands, as well as a record of pulses received from the MBE. Also included are coded Atlantic Missile Range timing pulses, so that these records can be compared with those recorded by others during the flight. The computer records on magnetic tape all data supplied to it from the radar as well as information on orders and commands transmitted to the missile. Whippany processes the magnetic tape and returns a printed copy to the Data Analysis Group at Cape Canaveral for their information and additional study.

Although far removed from the metropolitan headquarters of Bell Telephone Laboratories, and even from the Western Electric Company manufacturing plants, the Cape Canaveral Branch Laboratory is performing an essential mission in support of the national military and scientific space exploration program.

Thor-Able, first vehicle to be guided by Command Guidance System, blasts off from the Cape.