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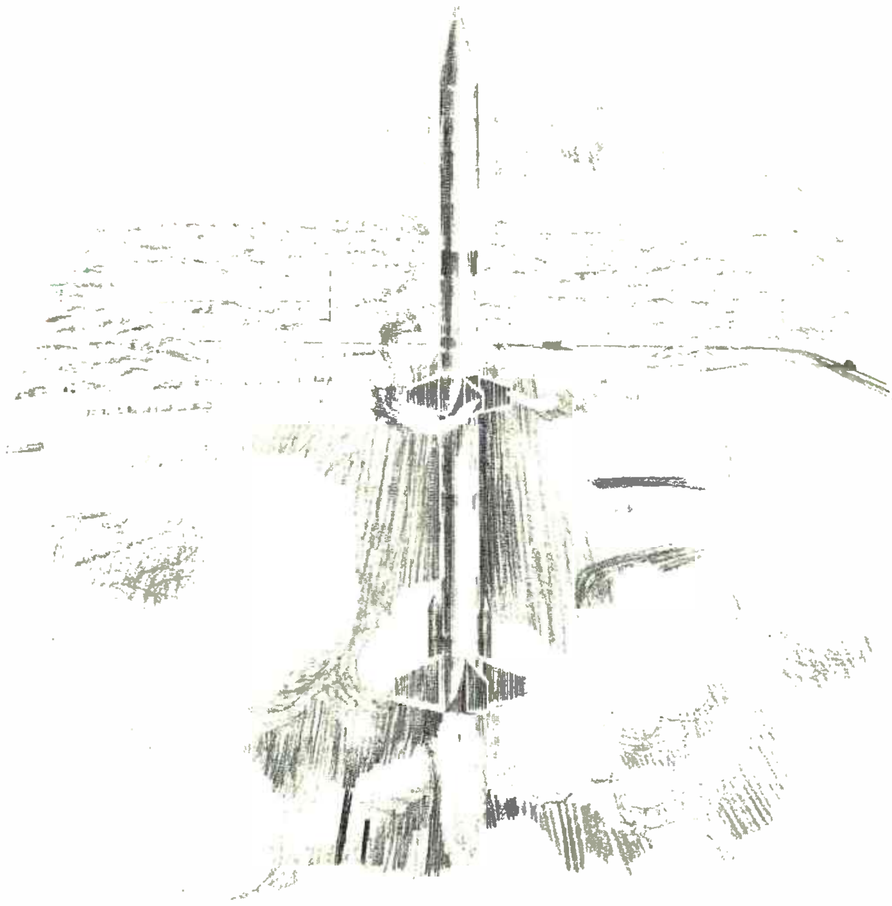
The Lenkurt DEMODULATOR

MISSILE RANGE COMMUNICATIONS



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The success and growth of modern rocketry depends heavily on realistic missile range testing. On the range, effective communications has become an increasingly important component, and is called on to carry large quantities of voice and digital data.

Every missile or rocket booster used by the armed forces or other government agencies must be extensively tested under controlled conditions. Like any new product, it must perform in the field to prove it will actually do the job intended. In the case of a missile, this involves a number of ground tests and eventually a series of launches. It is at this final stage that the missile range becomes invaluable.

The testing of missile systems is carried out primarily at five national test ranges. These include the Eastern Test Range at Cape Kennedy, the Western Test Range and Pacific Missile Range on the West Coast, the White Sands Missile Range in New Mexico, and the Kwajalein Islands Test Site. A number of smaller ranges support specific types of investigation and testing.

Large Areas Needed

The missile range may be over land or water—but always requires vast areas. Small tactical weapons necessitate firing over ranges of thousands of yards, or at the most a few miles. The multi-stage rockets of an intercontinental ballistic missile or the booster of a space probe require hundreds, if not thousands of miles of flying room for realistic testing. The White Sands Missile Range, for example, uses over 4,000 square miles of desert land—yet many of the larger vehicles tested there must be launched from Utah for impact on the range. Large rockets launched from the Pacific and Western ranges may extend out over the ocean nearly to Hawaii—over 2,000 miles away.

However, rocket testing is not just firing a missile from "here to there" and seeing where it lands. Scientific testing demands that as much data as possible be obtained and recorded during every moment of the flight. To do this, the range is equipped with many types of instruments: radar, special cameras, telescopes, and telemetry radio. Some instruments are used to accurately determine the trajectory, while others receive data on physical changes taking place inside the missile itself. Control of the rocket's flight must also be under constant centralized control. Since these functions must be carried out over sometimes vast distances with close coordination, a heavy burden is placed on the communications capability of the range.

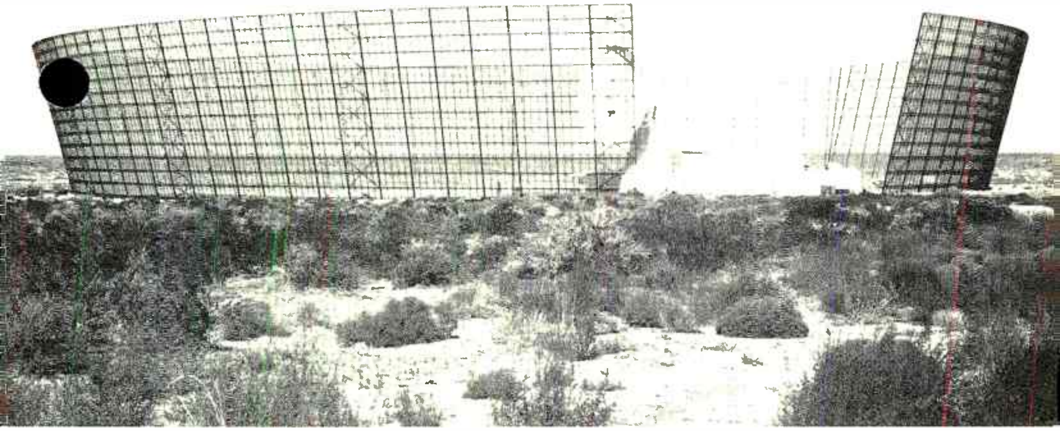

Figure 1. Radar is first range instrument to "see" missile. Installation at White Sands Missile Range is surrounded by clutter shield.

Range Facilities

Range instrumentation is the sensing organ of the test facility. To be in a position to "see" the missile during its flight. these stations must be placed at many locations on the range. The range communications centers provide a nerve system over which flows volumes of tracking and flight performance data.

Two needs appear from the basic mission of the test range: the communication of tracking information to and from many instrument sites, and the reception and handling of performance data direct from the missile. Many instruments are used to determine the trajectory of the missile—an important factor in judging the performance of a new vehicle. Radar installations (Figure 1) are first to "acquire" the missile, and from the radar, pointing information is subsequently supplied to all other instruments on the range.

A variety of optical instruments are used to record the flight. Included are standard still and motion picture cameras, and a number of specially developed telescope-camera combinations. Some are stationary and use a single film plate; multiple exposures accurately trace the path of the missile. Others are adjusted to follow the missile with rapid-sequence photographs, using tracking information obtained from radar through the communications network, and additional manual tracking. For example, a combination telescope and motion-picture camera, the cinetheodolite (Figure 2), is widely used for observation of such parameters as angular velocity, changes in roll, pitch, and yaw, and acceleration. On each frame are recorded the azimuth and elevation angles, and timing information.

Other information on the flight is obtained through telemetry—the radio

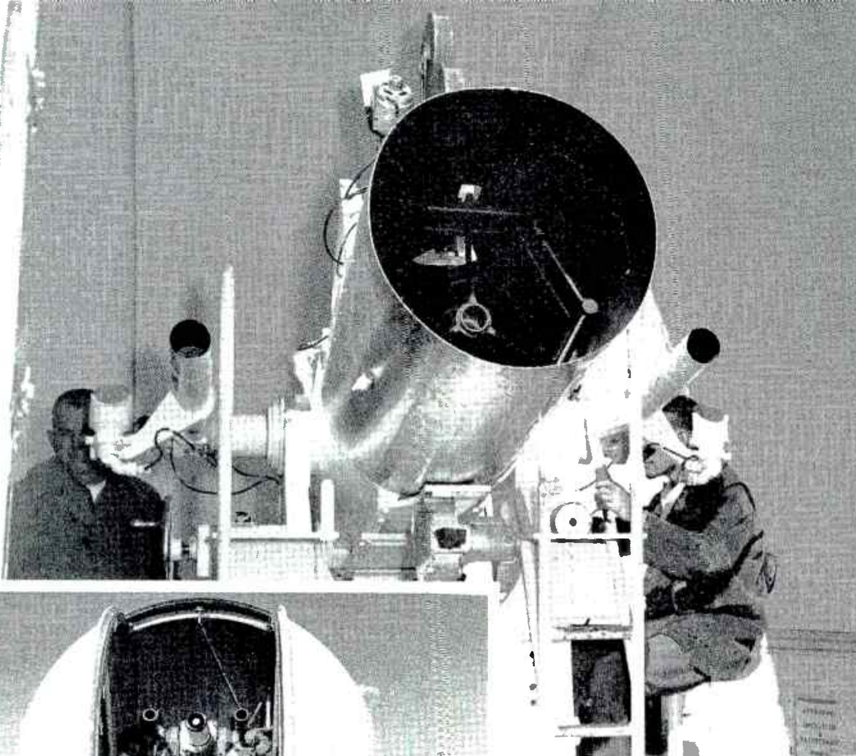
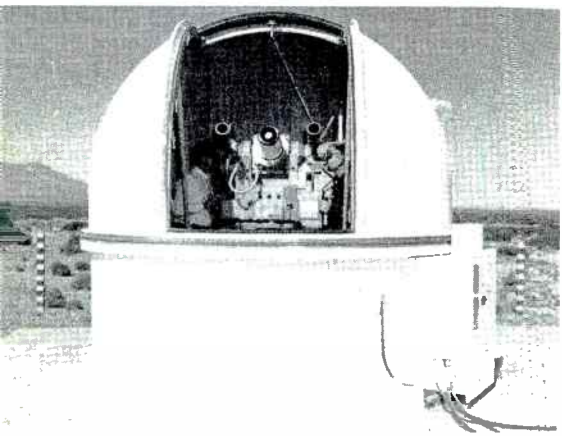

Figure 2. Cinetheodolites optically track missiles for many miles, recording on film changes in trajectory, attitude and other events. After receiving preliminary tracking information over the range communications network, the operators follow the missile manually.

transmission of physical data directly from the missile to the ground.

As a flight progresses over the test range, a great number of functions occur simultaneously: radar supplies tracking information to many sites; optical instruments record trajectory, attitude and events; and telemetry installations receive a constant flow of data from inside the missile. During large tests hundreds of instruments must be in constant coordination with the range control center. At this central point, tracking information is digested and relayed in proper form to each other station, and telemetry data is accepted for immediate or future analysis.

Two distinct functions of missile testing, range tracking and control, and telemetry acquisition, may share the same communications links, or have specialized systems designed for their unique requirements. This article will treat them separately, realizing that either choice may be made at a particular range.

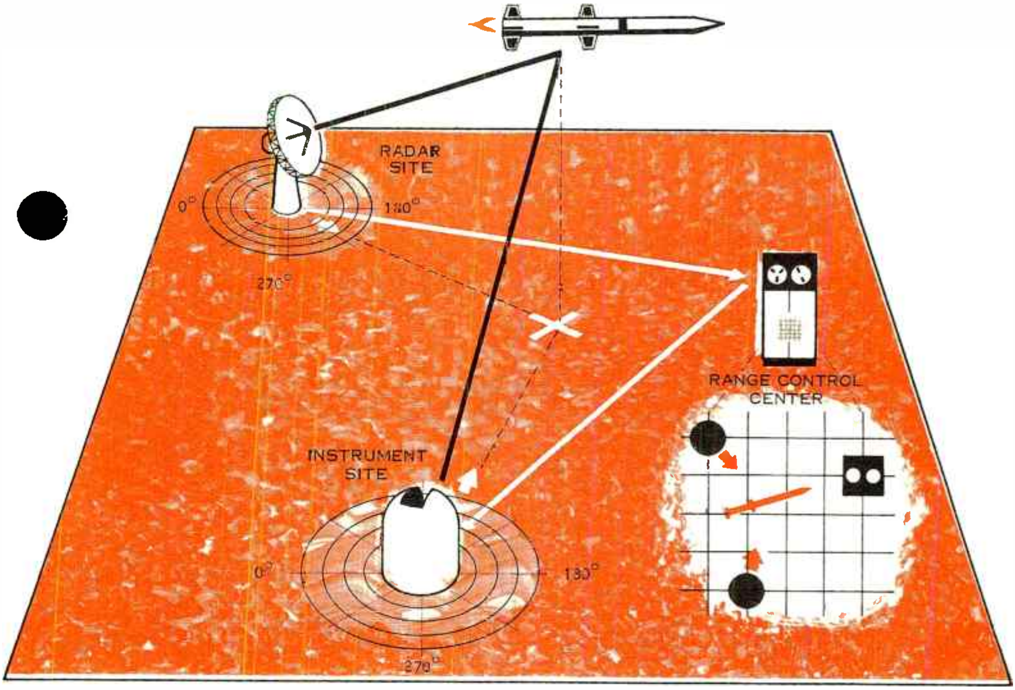

Figure 3. Radar picks up missile after launch, sends polar coordinate tracking information to the range control center. Computer translates to Cartesian system, sending pointing information to other instrument sites.

Instrumentation and Data Control

As a missile is launched and begins its flight over the range, the first requirement of all instrumentation is to find the object, know its trajectory, and be able to track it. Whether the instrument is a camera, telescope or a telemetry antenna, it must know where to look for the missile. Each site will receive guidance from an instrument control system.

Radar tracking stations acquire the missile shortly after launch. Azimuth, elevation and range are transmitted from these sites, through the range communications network, to the range control center. Data from the radar will be sampled 100 times a second, and transmitted in real time at 24 kilobits per second in some applications.

The radar positioning information, in polar coordinates, places the missile in reference to the individual site. Along with azimuth, elevation, and range figures, a quality check signal is included. At the range control center a computer complex analyzes the incoming signals from a number of radar sites on the range, and selects the one installation having the best "fix" on the missile. Once this is done, the computer converts the polar coordinates sent by the radar into a Cartesian (straight line) coordinate system to accurately place the missile over the range (see Figure 3). This Cartesian information is sent

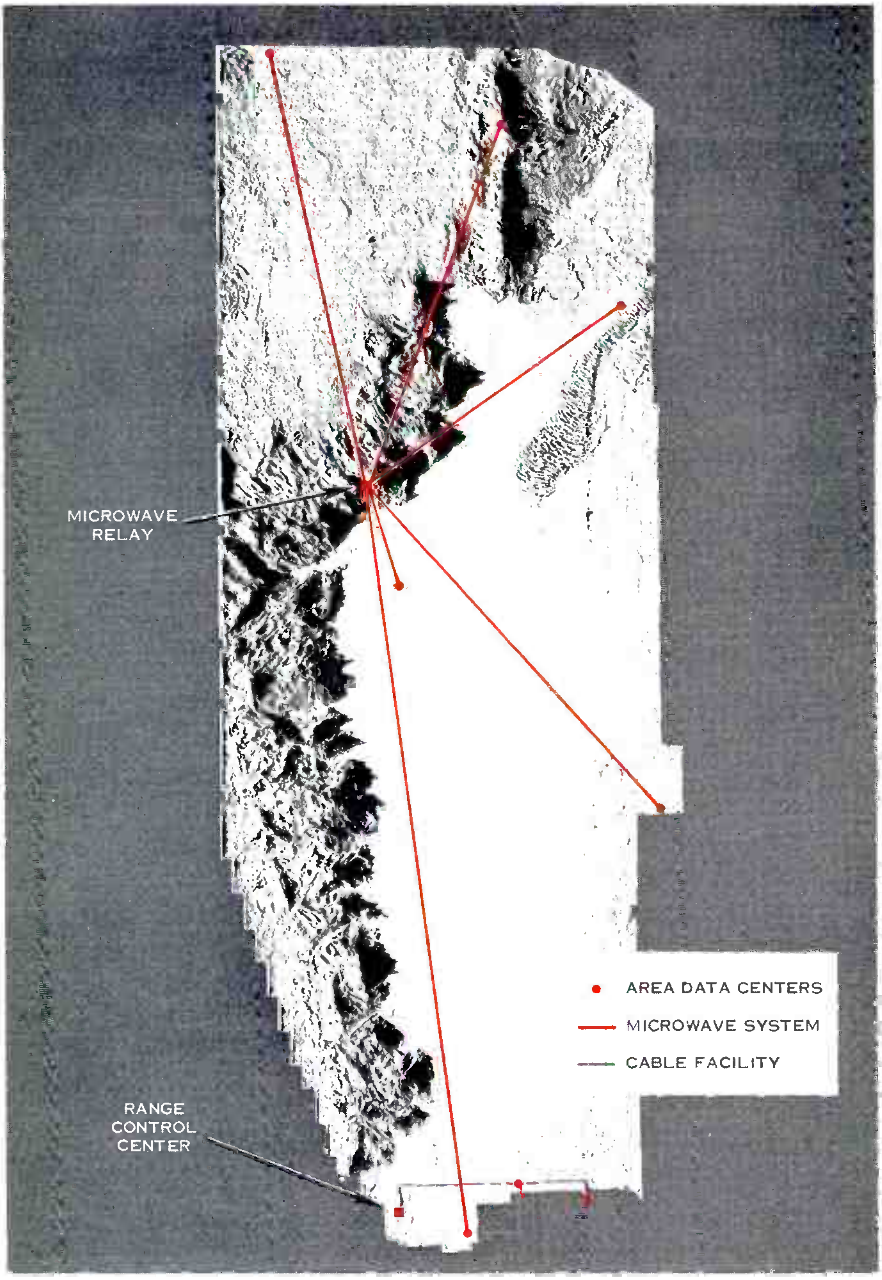

Figure 4. Microwave system recently installed at White Sands Missile Range by Lenkurt relays instrumentation and data control information between area data centers and range control center. Many instruments surround each site, linked by hard line facilities.

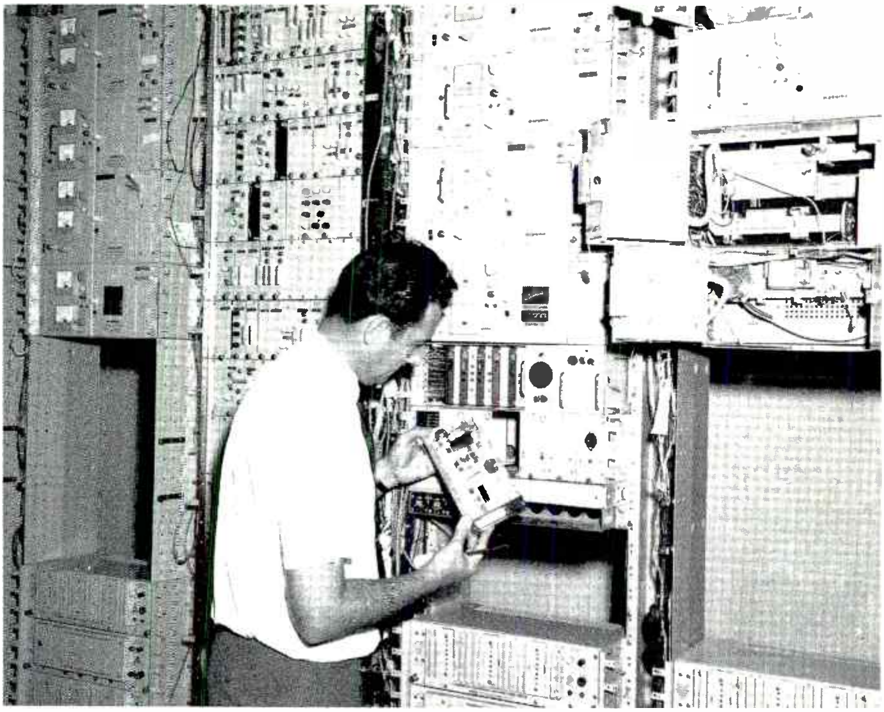

Figure 5. Lenkurt 76 microwave radio system provides updated communications capabilities at White Sands Missile Range. To left of radio is 57B path protection system.

back to observation stations throughout the range where it is translated back to separate polar coordinates to position each station. Tracking signals leave the range control center at 2400 b/s, with typical sampling rates of 10 per second.

Through this sharing of data, each range instrument is coordinated in tracking the missile and can follow it throughout the flight. Control signals from the command center also cue camera shutters and announce start times for certain recording devices.

As the missile continues over the range, other radar stations will become better sources of tracking data, and by continuous analysis the computer will switch these into the system as primary guidance sources.

A number of other functions must be monitored before and during the test flight. Range readiness, the progress of the countdown. and other important prelaunch situations must be collected from the downrange sites, assimilated, and displayed to range control sites. During the test, range safety control is in constant need of tracking information; if a missile is badly off course, command destruct immediately must be put into effect.

Continuous operational status reports must be available to all stations, indicating the conditions of *scheduled, run,*

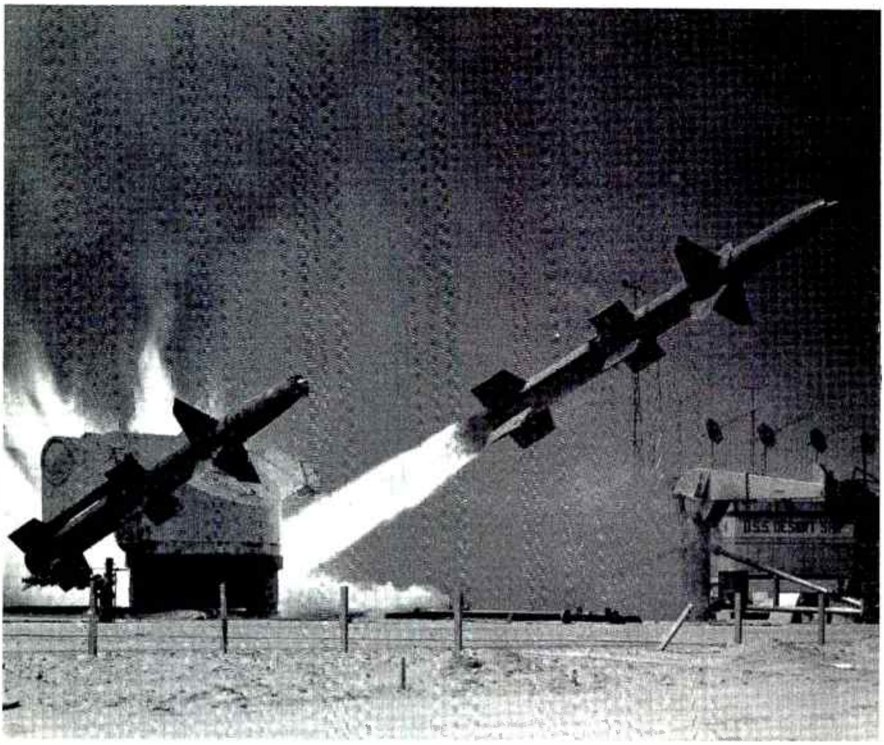

Figure 6. Short and long range missiles must undergo the same demanding tests before they become operational. Here, the TALOS is fired from a simulated ship at White Sands. The missile is under constant surveillance as it passes over the range.

hold, standby, cancelled, rescheduled, and completed missions. All of these functions utilize the range communications system in a heavy flow of traffic between remote sites and the range control center.

Frequent Tests

Activity will vary considerably depending on the nature of the range. An over-water range may be called on more for ICBM tests, resulting in less frequent missions than a range involved with smaller, tactical weapons. White Sands Missile Range, for example, conducts approximately 3,000 firings a year—sometimes as many as 40 in one day. These may extend all the way from small, hand-held weapons and field artillery missiles, to surface-to-air rockets and intermediate range multistage missiles.

The range control center—and in direct support, the range communications system—will at times be in control of perhaps 10 separate operations at one time. And between tests, the turnaround time must be very short. Tracking facilities may have only 30 minutes between operations to readjust to new circumstances. Reliable communications is a necessary component in the overall function of the missile range.

To connect the area data centers with the data processing center at White Sands, Lenkurt has installed an instrumentation data transmission system to update the present network (Figure 4). Multiplexed voice channels and high speed data signals to and from the sites are transmitted through a network of microwave radio stations. When completely operational, the system will have a capacity of 1200 channels. Approximately 100 data sets will be used at the range control center to receive and transmit tracking information. As many as 600 data sets at remote instrument sites will allow all phases of the test program to operate in real time—each in constant communication with the master control consoles. Data at 2400 b/s can be transmitted on a single voice channel; high-speed, wideband data requires a group of 12 channels.

Telemetry

Once most stations have the information needed to accurately track the vehicle under test, the result is the continuous observation and recording of test data. External observations of the missile by radar and specially built telescopes and cameras supply trajectory

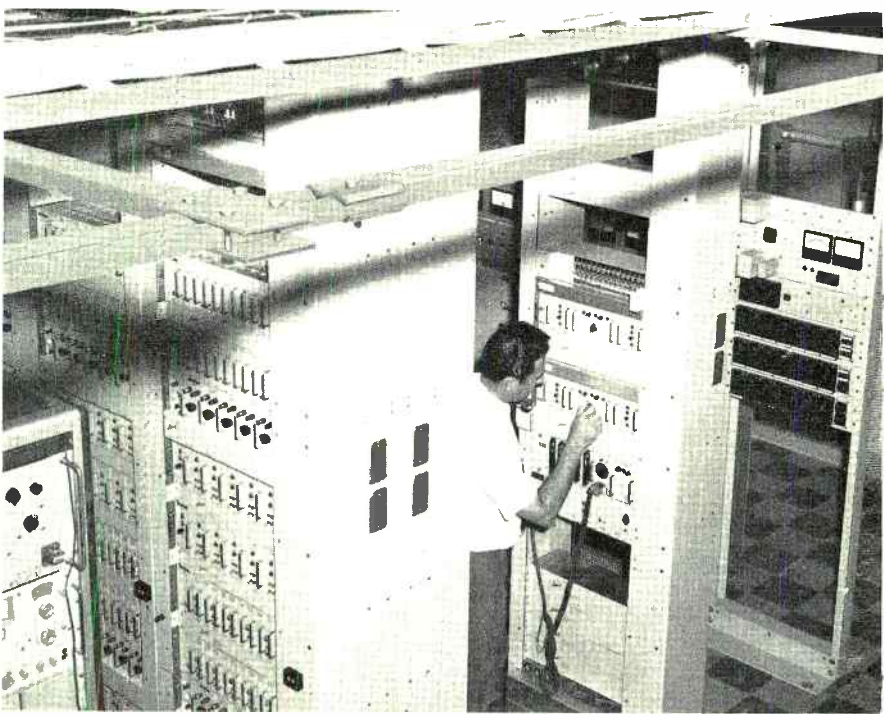

Figure 7. Row upon row of communications equipment fills key stations in the instrumentation and data control system. Here, technician checks Lenkurt multiplex and signaling equipment at White Sands.

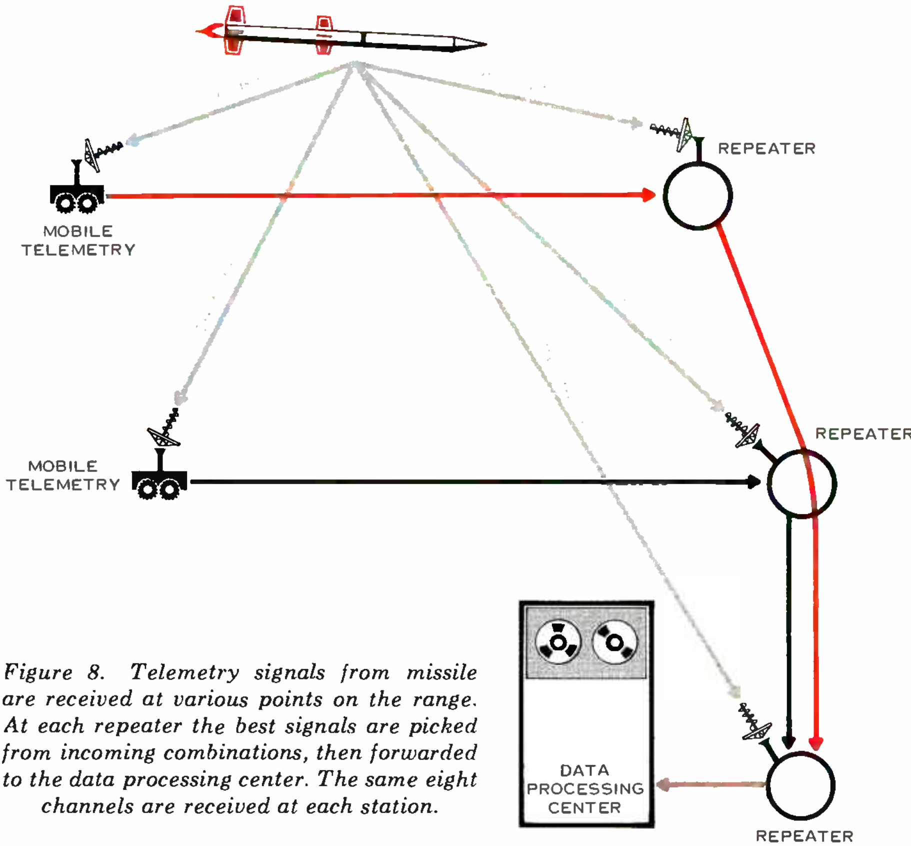

Figure 8. Telemetry signals from missile are received at various points on the range. At each repeater the best signals are picked from incoming combinations, then forwarded to the data processing center. The same eight channels are received at each station.

and other measurements. The observation of dynamic physical phenomena is done by small sensing devices carried on the missile itself and relayed to earth by telemetry radio transmitters.

A number of telemetry acquisition sites, many of them mobile, are placed at appropriate locations on the range. For a landlocked range such as White Sands, these stations may be anywhere within and outside the 100 x 40 mile area. At ranges firing over water, tracking and telemetry stations will be concentrated along the coast, with additional units aboard ships and on islands along the flight path.

Telemetry data from these stations is transmitted to the central data processing installation in real time. Simultaneously, the information is recorded at the site. If a transmission path should fail, data is not lost and can be evaluated at a later time.

Telemetry signals from the missile may be received at a number of sites concurrently. Quality checks are made at each relay point and only the best of several redundant signals received are forwarded.

Figure 8 illustrates how eight channels of data received from the missile might be handled on a typical mission at White Sands. Where two sources come together, the channels are analyzed and compared. The better signal is the one passed on. In this example five different stations are receiving data. The telemetry data center ultimately receives only the best combination of eight channels.

Telemetry data from internal instruments on the missile comes from such variables as temperature, pressure, force, acceleration, and vibration, allowing engineers to survey the operation of the vehicle under actual flight conditions.

By commutation, a number of separate pieces of data may be time division multiplexed onto one channel. The sampling rate and the number of separate inputs will be determined by bandwidth requirements and the rate of change of the particular parameter. A slow-changing characteristic need not be sampled as often as one with rapid variations.

At the telemetry data center, multiplexed signals are separated and recorded. Many also appear in visual form for immediate use.

Accurate Timing

Individual pieces of test data are of limited value unless they can be precisely correlated with all other data. To make this possible, a highly accurate system of timing is made available to each instrument on the range. Where good communication is available, timing signals are generated from a single location and forwarded to all installations. These generators are so stable that they remain within 50 milliseconds of Greenwich Mean Time. In some cases, for instance where tracking ships are thousands of miles away, real time communication is not always possible. It is then necessary to hand carry atomic timing clocks to the remote instruments.

Timing information is included with all telemetry data sent from area data centers. In this way all data inputs may be synchronized for comparison. Radar pulses are also controlled so that measurements at many locations can be made simultaneously. Even camera shutters can be triggered together. And in the communications system data modem clocks are locked to the range timing system for accurate coordination.

The communications system on a missile test range is much like the telephone exchange of an average city. It must provide subscriber loops to a number of individual points, and have the capability to switch these circuits for various applications. The most dramatic difference is the amount of digital data carried by the range system. While the communications system must always have voice circuits for coordination between sites, the great percentage of circuits are dedicated to carrying data signals between remote instruments and the range control center.

Large quantities of information must flow smoothly and reliably through the communications network before and during a flight. Centralized control is thus maintained over the missile itself and numerous instrumentation sites. The physical boundary of control and the actual ability of the test range to satisfy its mission is to a great extent limited by the effectiveness of its communications system.

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