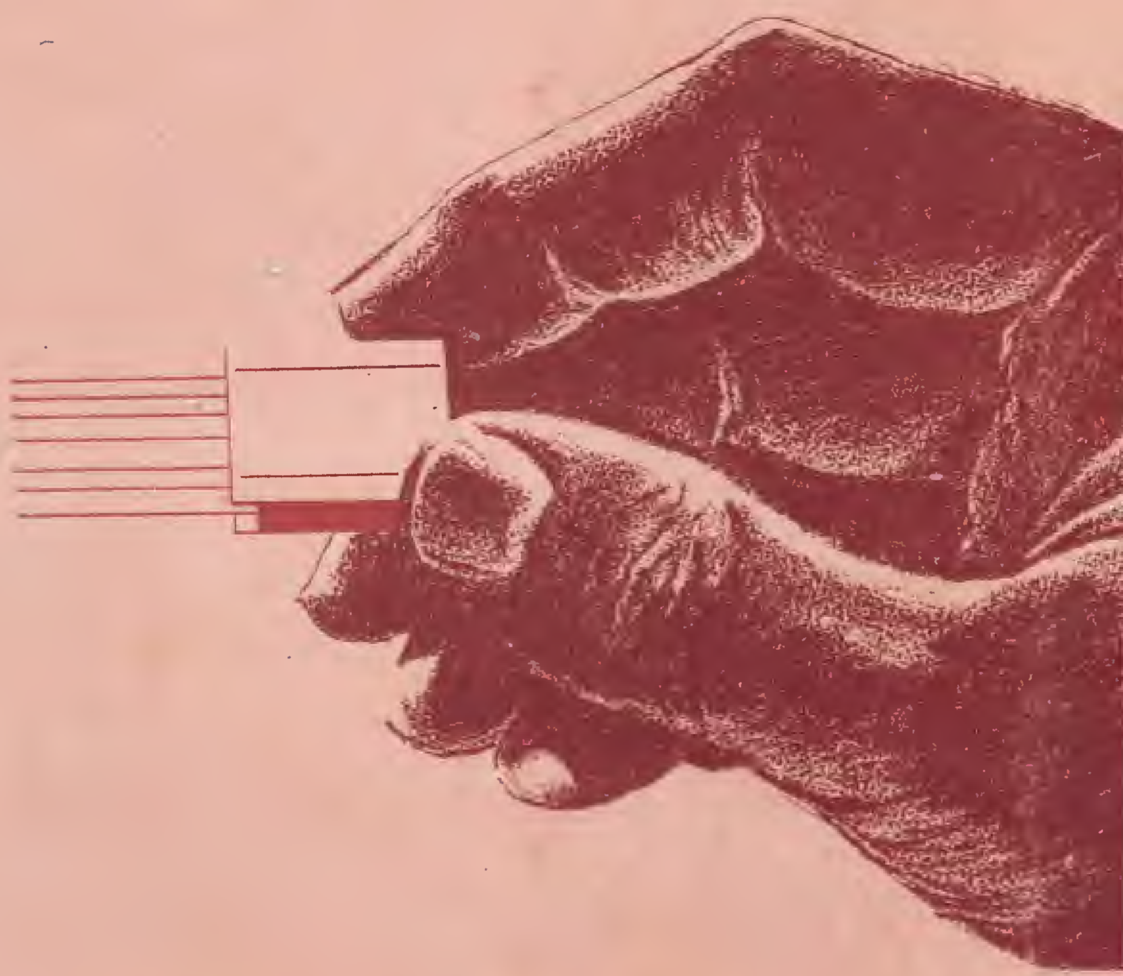
Capabilities and Facilities



EMR

ELECTRO-MECHANICAL RESEARCH, INC.

. . . The EMR Story

EMR today is a company that is justly proud of its accomplishments, its reputation, and its present capabilities.

EMR has contributed many significant technical advances in data acquisition and processing that have brought sophistication to the field when it was needed most. The company has been by far the largest supplier of telemetry instrumentation for over 15 years. EMR instruments have won a growing reputation for reliability and quality, a direct outgrowth of the long-standing company policy to produce the finest instrumentation possible.

EMR growth is a reflection of success and technical leadership. The evolution of the aerospace industry toward more complex, sophisticated systems has been matched at EMR by growth in the technical areas of aerospace instrumentation and communications. For this reason, EMR has enjoyed outstanding success in competition for large space-electronics systems where technical competence and management capability count heavily.

A natural byproduct of handling large complex systems programs is the accrual of a body of experience and new techniques in areas closely associated with data acquisition and processing. EMR now has technical groups with substantial experience in electro-optical systems, bandwidth compression systems, electromagnetic systems, reconnaissance systems, oceanographic systems and others. In each of these areas EMR has capabilities which cannot be found elsewhere. To develop these fully the company has diversified its self-sponsored research to concentrate on a spectrum of promising new technologies.

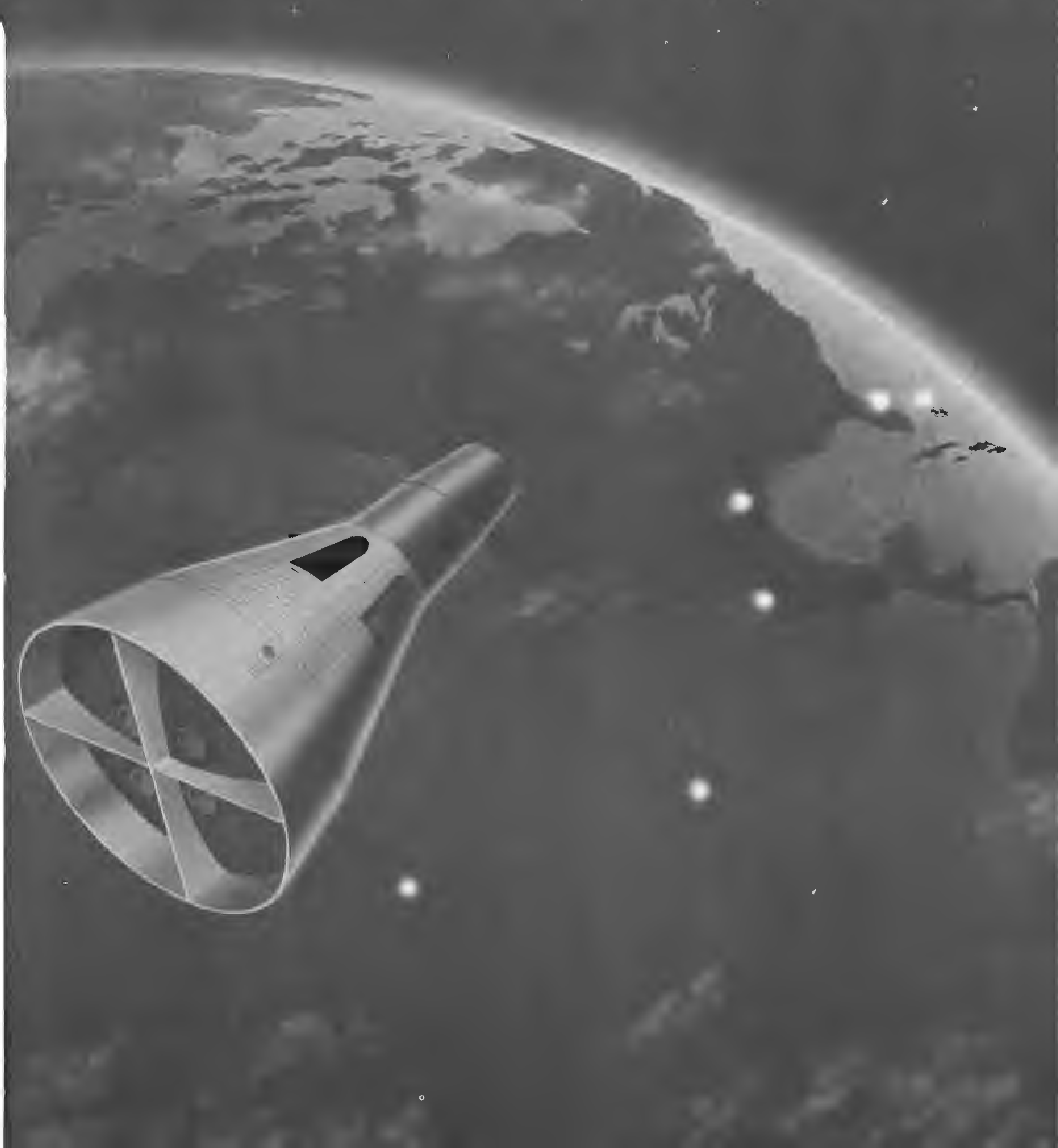
AN UNSURPASSED RECORD

A History of Success

Since the earliest space program, EMR products and systems have been recognized as pre-eminent. The growth of the aerospace industry has been more than matched by the growth of EMR both as an innovator and exploiter of technical know-how. A review of programs successfully managed by the company in the recent past, demonstrates the foundation for EMR's solid reputation.

Some of these programs are described in the following section.

WORLD-WIDE RANGE...

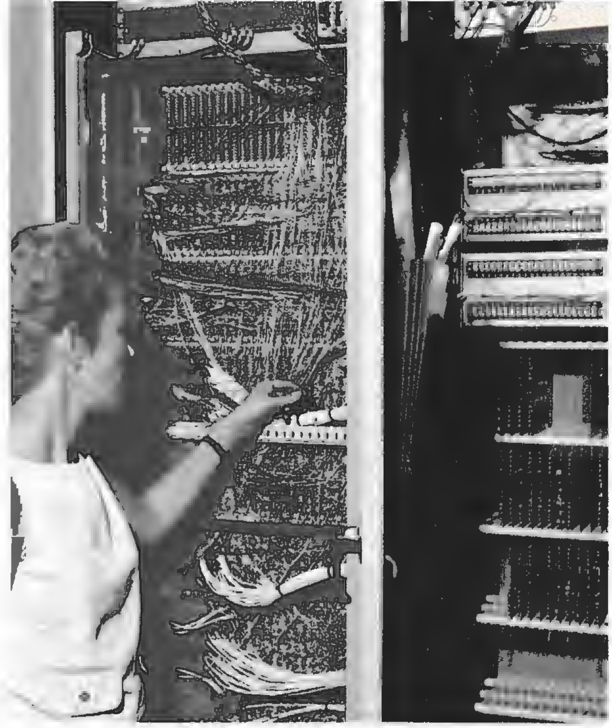


Continuous Telemetry Coverage of an Orbiting Vehicle

Future manned long-duration space flights will pose a whole galaxy of data-acquisition, communication, and command problems that have never before been encountered. Complex equipment operation, heretofore unmapped radiation areas, the long-term responses of man himself to the unfamiliar space environment, and hundreds of other items must be recorded separately and in detail.

To meet these requirements, NASA awarded to EMR well over half of a multimillion-dollar program to upgrade the stations in its world-wide Manned Space Flight Network. EMR's selection as a major contractor on this program is a natural result of the company's exceptional performance in the development and manufacture of large data-processing centers--a record that has been enhanced by the reliable day-to-day operation of more than 350 installations.

NASA accepts delivery of fifteenth MSFTP-1 station



MSFTP-1 systems are designed for rapid access to all test points and circuit assemblies

EMR is supplying 20 complex ground data-processing systems--each consisting of 11 racks of electronic equipment designed specifically for the rapid acquisition, processing, and distribution of PCM telemetry signals. These telemetry data processors incorporate many of the unique capabilities that have made the company an outstanding supplier of precision high-speed decommutation equipment. The system can be programmed to accept any of the many PCM formats envisioned for future NASA long-duration man-in-space programs. For the first time, variable-word-length data within a frame and in any word pattern can be accepted. Thus, data accuracy can be tailored to fit system requirements so that all data is not forced into a format which is dictated by the highest accuracy requirement of the system.

The new system allows remote-automatic or manual format selection, including bit rate, on command so that various mission formats may be programmed and placed on standby. When a new mission requirement occurs, a preprogrammed format is activated immediately. Mission formats are all programmed from the same central control area. With automatic format selection, the operator can pick up and track various satellites and spacecraft, one after the other, as they pass overhead.

By data dialing the operator can acquire and display any channel rapidly. An automatic checkout subsystem assures the operator that his ground station is operating properly or localizes malfunctions to a file of printed-circuit cards.

ACQUISITION AND PROCESSING

The acquisition function is extremely flexible since it can closely match the airborne telemetry format for any one of a wide variety of space vehicles. This portion of the MSFTP-1 station contains a PCM signal conditioner for filtering, restoring, limiting, and maintaining synchronization with the received PCM signal. It will lock on an incoming bit rate from 10 to 1,200,000 bits per second. A serial-to-parallel converter accepts the resultant reconditioned serial NRZ PCM data and provides various parallel digital outputs and synchronization signals to the distribution portion of the MSFTP-1 equipment.. Data words can be from 4 to 64 bits in length and words of various lengths can occupy any frame position as long as they are constant from frame to frame. Primary frames, up to 4,096 bits in length, are synchronized by codes of from 7 to 64 bits. Word synchronization codes can be 1, 2, or 3 bits in length. Each system installation processes any NASA-approved PCM signal such as split-phase, RZ, NRZC, NRZM, or NRZS, and accepts either forward or backward magnetic tape playback.

Nearly 10 miles of wiring are used in the assembly of each MSFTP-1 station

DISTRIBUTION

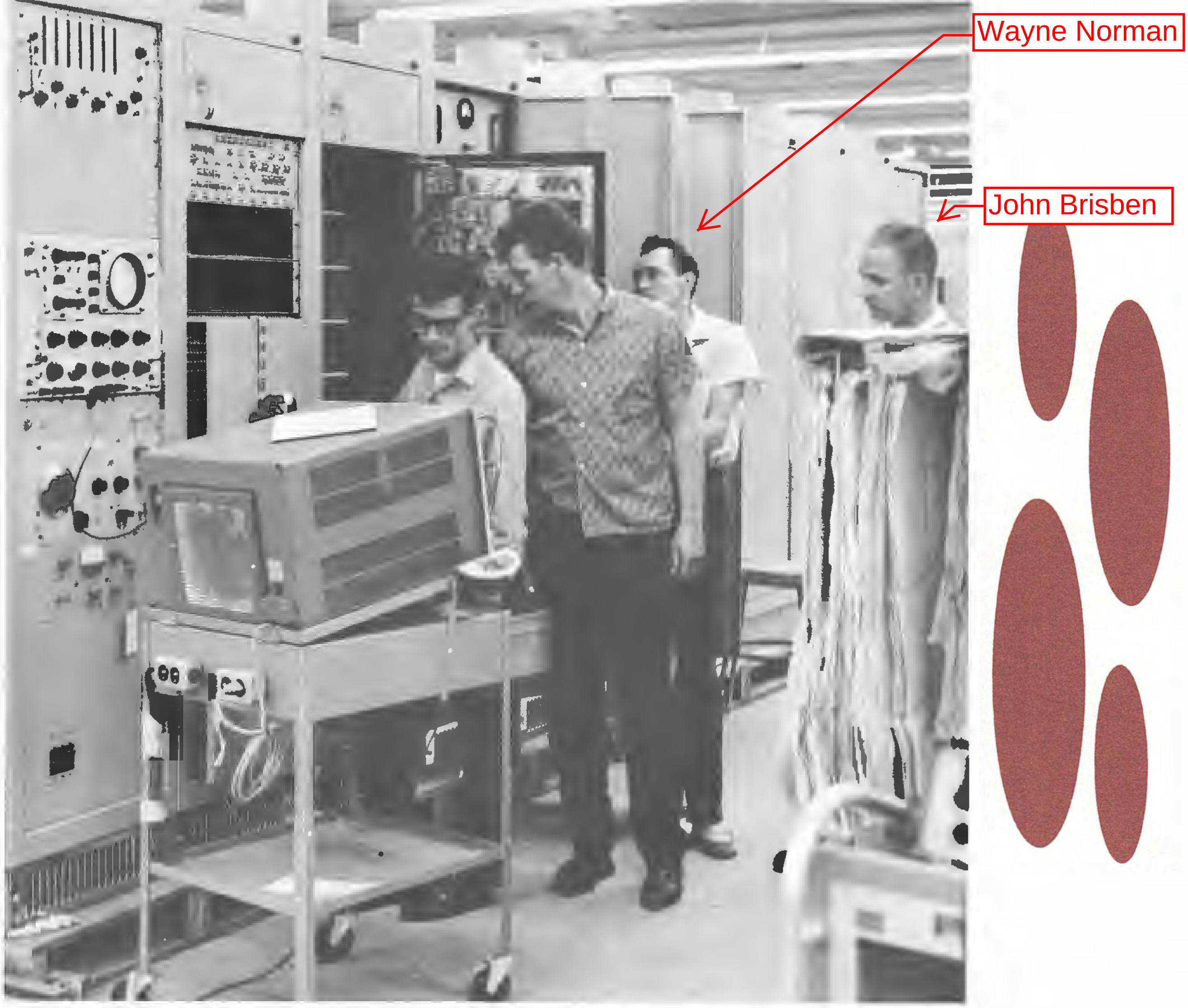
The distribution equipment includes the decommutation and output (or peripheral) units needed for presentation of the data to the user. Data to be decommutated is routed to its ultimate destinations through programmed patchboards that are electronically switched in or out of the circuitry to accommodate various formats. The format patchboards (one acquisition and one distribution patchboard for each format) are used to select the proper signal-conditioner plug-in unit and rearrange the internal logic to comply with different mission formats. This includes adjusting the synchronizers to accept different synchronization codes and distributing different data words from the various multiplexes to the peripheral equipment. An MSFTP-1 station can recognize strapped channels and distribute them to the appropriate peripheral equipment. Stripping (selecting a group of channels from specific frames within the subframe of the output multiplex) and distributing the stripped channel groups to the peripheral equipment are also a part of the distribution function.

Outputs to the peripheral equipment are either readout commands or data readouts. The readout commands transfer the data into the peripheral equipment. These commands consist of timing signals, synchronization status signals (search, check, and lock), and channel-location numbering signals. In addition, any channel can be decommutated and stored in the primary frame or any subframe. Sixty bits are provided for this function.

The MSFTP-1 equipment supplies output data in three forms: parallel binary, BCD, and analog. All the parallel binary data may be read out on command, either in 64-bit form or using the eight most significant bits. In addition, any channel within a frame (or subframe) can be transferred to any one of a hundred binary-to-analog converters. Additional binary-to-analog converters have a resolution of one part in 256 and can supply 0 to +10 volts into a 10,000-ohm load.

SELF- AND MARGINAL-CHECK FEATURES

Comprehensive self- and marginal-check functions are integral with the main equipment and permit quick and obvious verification of proper station operation without the necessity for a thorough qualification



EMR technicians check out completed ground station for NASA's Manned Space Flight Network

test. These integrated simulation and checkout functions also simplify calibration procedures and therefore render them less vulnerable to human error.

Major checkout of these stations is performed by a PCM simulator capable of generating PCM signals with characteristics similar to those expected from operational receivers. This simulator can exercise the complete MSFTP-1 station using five different word lengths, bit rates from 10 to 1,000,000 bits per second, variable output amplitudes from 0 to ±15 volts, odd or even parity, missing pulses, and all probable combinations of synchronization codes.

Other checking functions incorporated in the stations are:

- A printed-circuit card tester which is capable of isolating a malfunction to within a particular stage on the card under test.

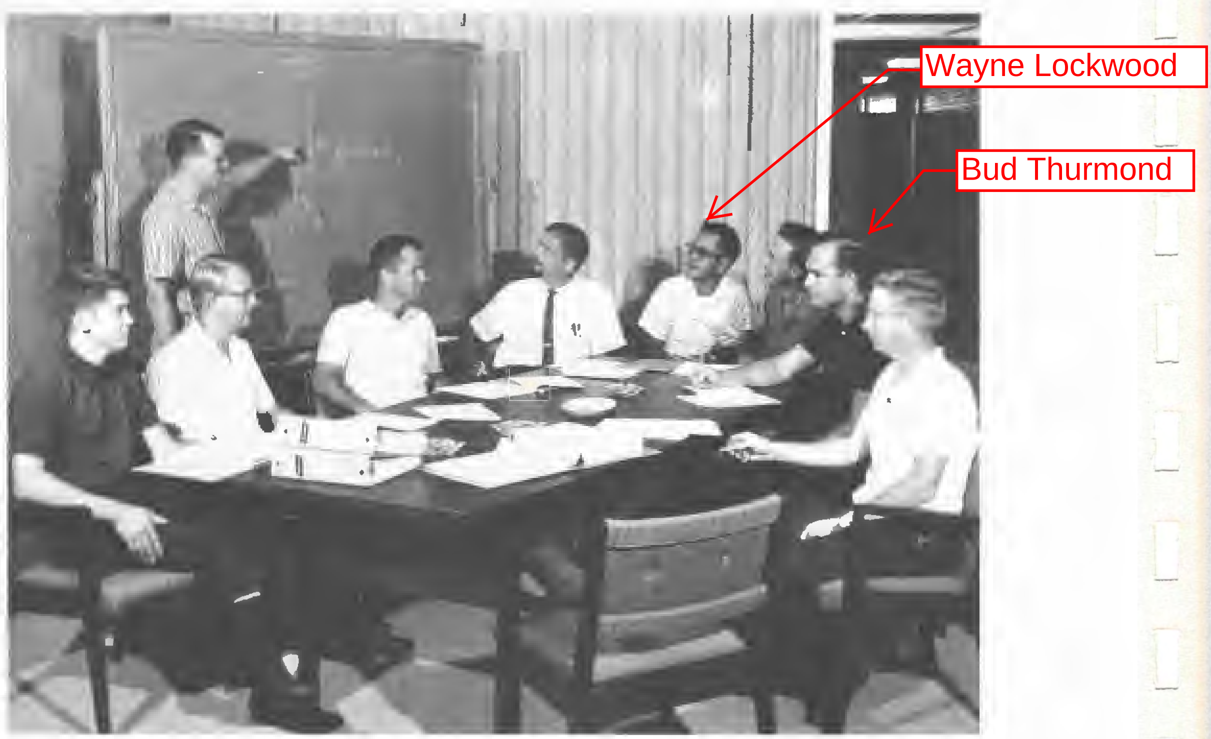
- Marginal checking circuits which are capable of applying high and low power-supply voltages to the equipment to determine which circuits may fail under these marginal conditions. Indicators are provided to alert the operator when the equipment is being tested.

- A five-inch oscilloscope which is provided for checking waveshapes.

- A digital voltmeter which is used for checking and adjusting the digital-to-analog converter cards.

- A pulse generator which is used to set up test conditions in the equipment.

- A one-megacycle counter which is used for accurate determination of pulse-repetition rates.

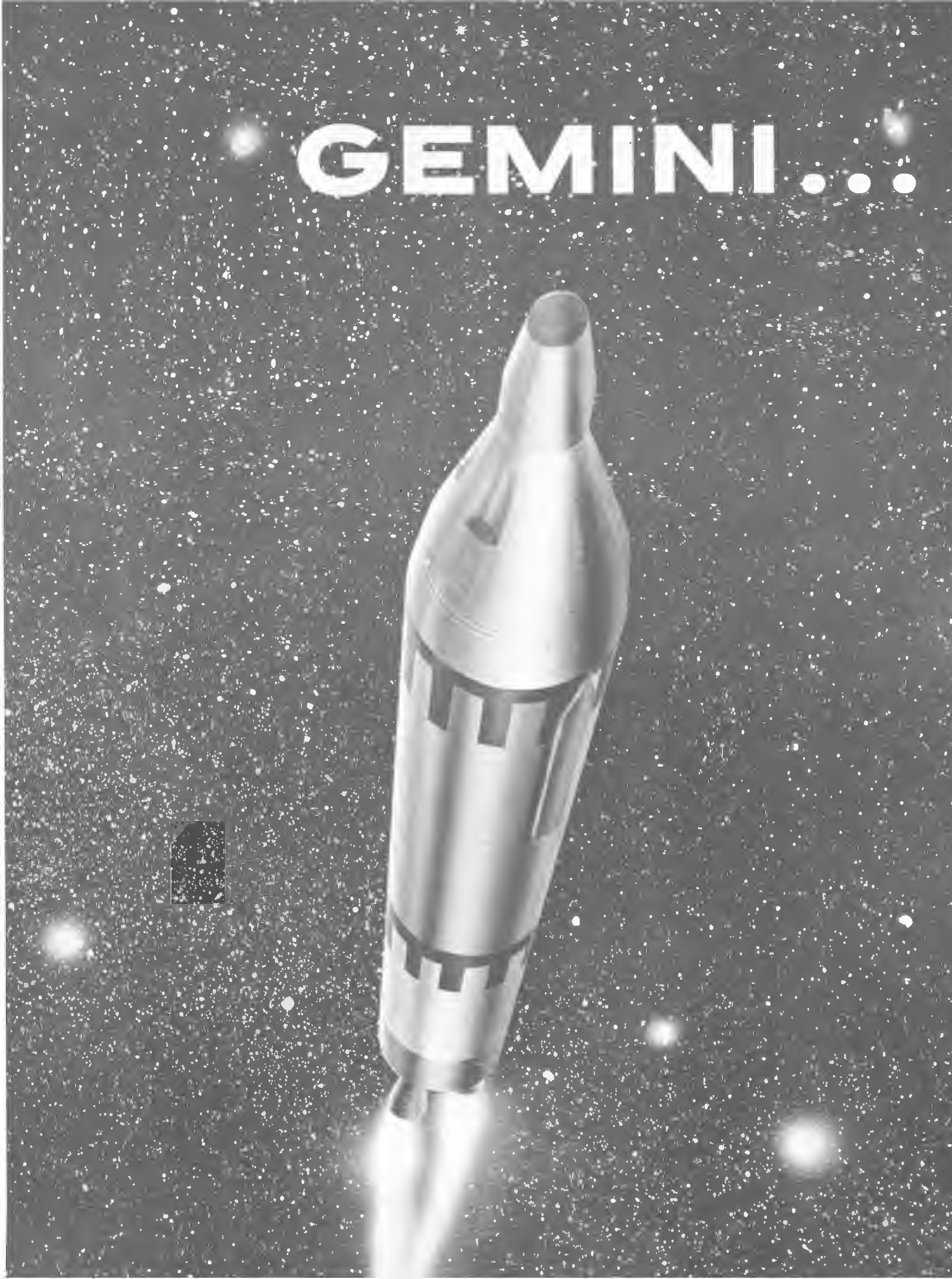


EMR engineers prepared an extensive MSFTP-1 course for training NASA personnel.

SERVICES

In keeping with EMR's traditional policy, the company is providing extensive training and field services to make NASA's operation of the complex stations efficient and trouble free. EMR field service personnel perform site surveys at each of the NASA range stations, conduct training courses for NASA personnel, both in Sarasota and at NASA range sites, and provide technical assistance in simulated missions to familiarize NASA personnel with the operation of the new equipment.

An example of these extra services is an intensive five-week training course recently attended by 40 senior members of the NASA World-Wide down-range tracking team who were selected to operate the new systems. The rigorous program, planned by EMR's professional training team, was conducted by the engineers responsible for the development of the MSFTP-1 system.


GEMINI...

Complete System Monitoring in Space

Project Gemini, a major step in U.S. manned spacecraft development, supplies the techniques required for future trips to the moon and beyond. For the first time, astronauts can orbit the earth for two weeks or more, rendezvous and dock with a target vehicle in space, and make precision re-entries and ground landings at preselected points.

EMR was chosen by the NASA prime contractor, the McDonnell Aircraft Corp., to supply the critical spacecraft instrumentation, recording, and telemetry equipment for monitoring the crew's reactions to long-duration space flights and measuring internal and external spacecraft environments. In addition, EMR is also providing two types of ground support checkout equipment for spacecraft-telemetry checkout prior to launch.

Gemini Spaceborne packages have 37, 000 parts per cubic foot and consume approximately six watts.

SPACECRAFT INSTRUMENTATION

EMR's high-reliability spacecraft telemetry system relays all data pertaining to the craft and its two-man crew during orbital maneuvers. Some 370 data inputs are multiplexed and encoded by 3100 transistors in a total package of less than 650 cubic inches that consumes approximately 6 watts of power. A reliability equivalent to 4092 mean hours between failures is predicted for this system. The high-density packaging results in a count of 37, 000 parts per cubic foot.

EMR's multiplexer-encoder is a data-encoding system specifically designed to meet the unique requirements of the Gemini vehicle instrumentation program. This PCM system incorporates EMR-developed low-power redundant and nonredundant functional circuitry modules in a specialized high-density package constructed within the Gemini mission constraints of environment, installation volume, data capacity, power consumption, and operational reliability.

The encoded data outputs of the PCM system are completely compatible with IRIG standards and the EMR Model 285 Digital Data Decommutator ground installation. A combination of redundant piece-part circuitry for those portions of the system that are serial with the data-encoding process and nonredundant circuitry for specialized functions ensure the reliability of the system. This arrangement provides minimum complexity

Gemini airborne package with typical modules before encapsulation

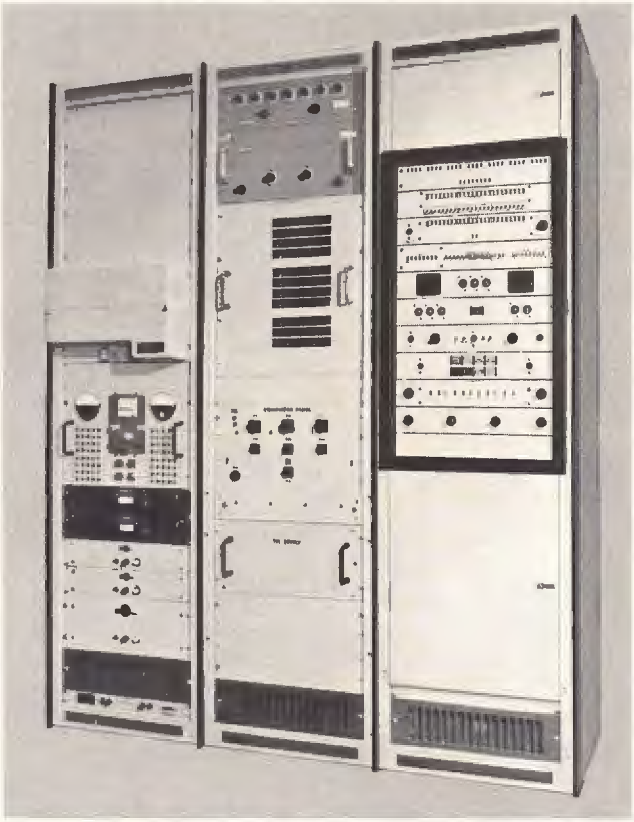
Technician checks out initial assembly of airborne programmer modules

consistent with the allied equipment objectives of minimum power consumption and physical volume.

The PCM portion of the Gemini transmission system is composed of one programmer, two low-level multiplexers, and two high-level multiplexers. The system may be expanded to accommodate additional data multiplexers of either type.

PROGRAMMER--The programmer can operate as a self-contained data-handling unit and provides the functions of data multiplexing, analog-to-digital data conversion, and digital data multiplexing. It also includes the required timing and sampling functions to support the multiplexing and encoding functions.

MULTIPLEXERS--The high-level multiplexer functions as a high-level analog commutator and on-off digital data multiplexer. The low-level multiplexer is a differential input analog commutator. Each multiplexer contains an independent timing chain and digital logic to support the required sampling functions, but receives operating power from the programmer unit. Matched solid-state switches in series- and quad-redundancy arrangements are utilized to provide reliable high-level analog commutation. A three-tier switch configuration is used which permits the parallel excitation of groups of first-tier switches for the word gate, reducing the complexity of the arithmetic and system power consumption. The switch configuration for the low-level channels is of similar design except that a differential input is implemented by switching both transducer input lines. The common output of the low-level commutator is amplified by a chopped differential amplifier to apply a single-ended signal to the master commutator



Test set verifies system operation prior to launch.

GROUND CHECK-OUT EQUIPMENT

EMR is supplying two types of ground-support checkout equipment for Project Gemini. The first performs overall spacecraft systems predelivery and preflight checkout, and the second automatically checks and qualifies the data-transmission system before its installation in the capsule.

The complete installation in the capsule is checked out by means of an EMR Model 285 high-speed PCM ground station. The Model 285 can handle the widest range of PCM signal formats and data rates. It also supplies both serial and parallel binary and BCD outputs in various forms for computer entry, tape-recording, or entry into peripheral equipment such as tape punch. In addition to standard decimal and analog displays, the Gemini spacecraft checkout station incorporates a number of ancillary displays for displaying the characteristics of a particular channel or group of channels. For example, selected channels may be displayed on a bar-chart oscilloscope, on strip-chart recorders, on analog meters, and on decimal lights (up to 25 channels). Event recorders allow recording of up to 200 channels of bilevel or event data. Another output facility is a high-speed printer which prints out any 21-decimal digits selected from the eight-decimal-digit computer words and three-decimal-digit data words.

The predelivery and preflight checkout test set performs all the functions necessary for a complete bench verification of the spaceborne data-transmission system. For qualification with a permanent printed record, checkout and printout of telemetry performance can be completed in less than a half day. It supplies appropriate signals to the multiplexer-encoder under test to check the high- and low-level accuracy, overvoltage, common-mode rejection, computer bilevel and bilevel pulse, and worst-case accuracy.

The system decodes all information in the PCM hard-line output of the multiplexer-encoder being tested and compares each encoded output signal from the multiplexer-encoder to the digital equivalent of the input signal. It prints and displays the channel number, test step (input voltage in percentage of maximum voltage) and data (decimal equivalent of the output) or error of all analog channels.

Displays and other indicators include all synchronization, computer, bilevel, and bilevel-pulse output signals from the multiplexer-encoder; a count of digital (bilevel) and bilevel-pulse output signals from the multiplexer-encoder; a count of all digital errors; and, on the display panel, the input analog signals to the multiplexer-encoder in BCD and binary equivalent.

RELIABILITY

The exceptional reliability of the Gemini system is obtained by the judicious use of redundant piece parts coupled with low-power circuits to reduce stresses and heat dissipation. The internal temperature of the telemetry system is further limited by complementary transistor configurations used specifically to minimize resistive losses.

The length of the system mission is 336 hours, and the present EMR reliability estimate yields a probability of mission success of 0.91.

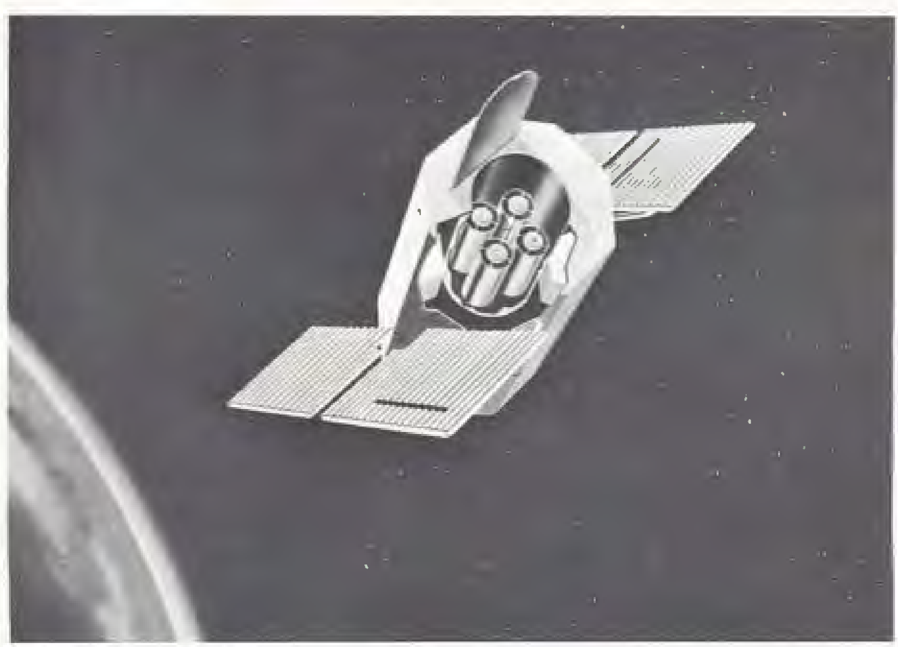

CELESCOPE....

Prime Space Astronomy Experiment of OAO

When The NASA Orbiting Astronomical Observatory goes into orbit it will carry astrophysical experiments designed to advance modern astronomy a giant step ahead in understanding the universe.

At least one of these experiments, Project Celescope, incorporates techniques so advanced and sophisticated that no equipment like it can be found in an astronomical observatory today. The equipment called for by Project Celescope requires such a unique combination of electronics and optics that it demanded a company with the broadest range of special technical skills combined with top-flight technical management. The special group with exactly the right skills -- in optics, in digital redundant circuitry, in digital television, and in advanced systems analysis capability -- is the EMR Advanced Systems Department of the Sarasota Division, and they were chosen by the Smithsonian Astrophysical Observatory to design and build the electro-optical equipment for Project Celescope.

This satellite experiment will contain the most sophisticated electro-optics incorporated in a satellite to date; many techniques that will be used are entirely new. Among techniques employed for the first time



Artist's conception of the Celescope experiment as it will look in an Orbiting Astronomical Observatory. OAO is cut away to show optics.

in a space environment will be digital television, a new ultraviolet television pickup tube, and the first practical space test of large precision optics. Despite its complexity the system is expected to operate for over one year in space without failure.

WHAT CELESCOPE IS

Project Celescope is part of the NASA Orbiting Astronomical Observatory (OAO) organized under the Smithsonian program for observational astrophysics from space.

The object of Project Celescope is to map the radiant intensity of the sky in three vacuum ultraviolet regions and to obtain ultraviolet spectra of a large number of stars. The vacuum ultraviolet spectrum is of particular interest to astronomers but is largely unknown because of atmospheric masking.

EMR SATELLITE EQUIPMENT--Equipment supplied by EMR in OAO will scan both stars and nubulosities transmitting video information to the ground in both analog and digital form. On the ground, digital data processing equipment will automatically print out a star catalog of the 50,000 stars which are expected to be measured during the 12-month life of the satellite. This material is expected to provide astronomers with a wealth of information concerning the composition of interstellar dust, the theory of hot star atmospheres, understanding of planetary nebulae, and possibly understanding of the hot atmosphere of cool stars.

> The satellite equipment supplied by EMR consists of seven subsystems: UVicon Cameras, Camera Controls, Camera Selector, Analog Data Processing, Digital Data Processing, Command and Program Control, and Power Supplies.

TELESCOPES AND TV PICKUP

While the satellite is stabilized in space four 12-inch Schwarzschild telescopes image an area of the sky on four UVicon TV Camera pickup tubes. Three of these are optically filtered to receive ultraviolet radiation from three different portions of the ultraviolet spectrum. The fourth observes the ultraviolet spectrum from a slitless spectroscope.

A monochromator is being used to plot the spectral response characteristics of an ultraviolet filter.

DIGITAL TELEVISION--When a digital-television command is initiated, each of 512 lines is scanned in 512 steps. A step scan is made, the beam is turned on, and a decision is made whether information is present. If information is present the beam is held on until digital encoding is completed. Encoding includes radiant intensity and position coordinates. Digital information is collected and transmitted to the ground when the satellite passes over the receiving stations.

GROUND SUPPORT

EMR will supply two ground-support systems to Smithsonian to display Project Celescope data.

One set of this equipment will be in portable form to be used in preliminary system checkout and during prelaunch and launch phases. The other system will be installed at Smithsonian Astrophysical Observatory for preliminary data evaluation.

Ground equipment includes circuits to process digital and analog data in order to recreate the telemetered television scenes. EMR will provide two electronic systems: one to produce a photographic sky map; the other a storage tube on which a star-map image may be stored indefinitely for detailed observation. Data will be fed to a NASA language translator and computer for further processing.

Either analog or digital television scanning may be used as determined by command controls initiated on the ground. Command controls are transmitted to the spacecraft command decoder. An EMR command and program control unit accepts a binary-code command and provides any one of 21 off-on adjustments and 24 parameter adjustments. Each of the 24 parameters can be further set at one of eight levels of adjustment. Such parameters as sweep speed, beam current, target voltage, exposure time, and others can be controlled. Exposure times ranging from one second to thirty seconds are expected to be obtainable with the satellite stabilized.

Upon receiving an initiate command, analog television scans in conventional fashion a 512 line raster. Video output from the analog television is transmitted directly to the ground. Analog television will be used primarily for qualitative viewing and for scanning nebulosities.

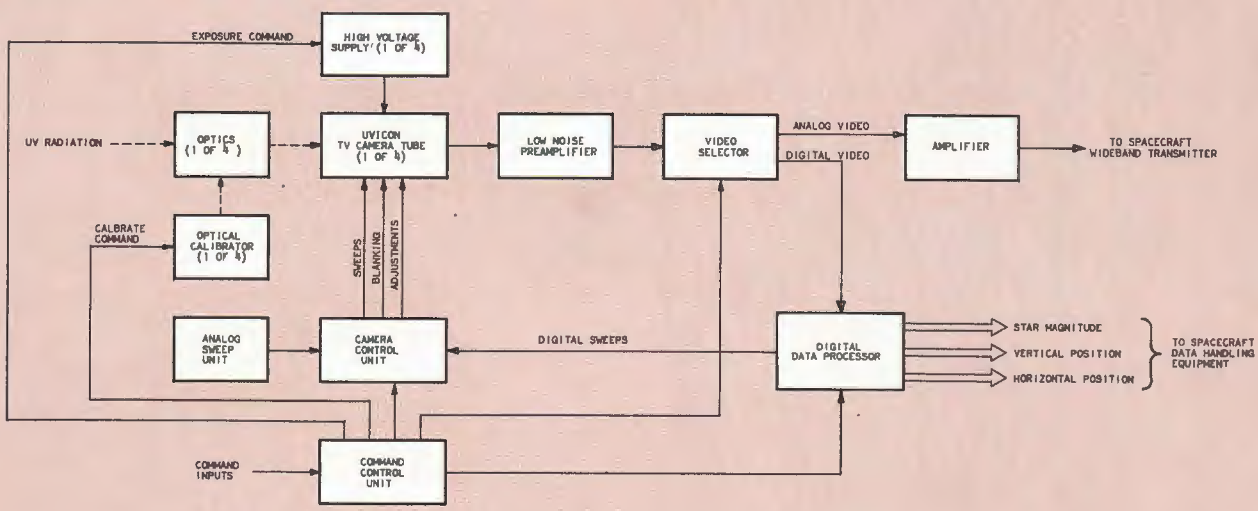
An electro-optical 10-mc analog-to-digital converter used in compressed digital TV studies.

RELIABILITY

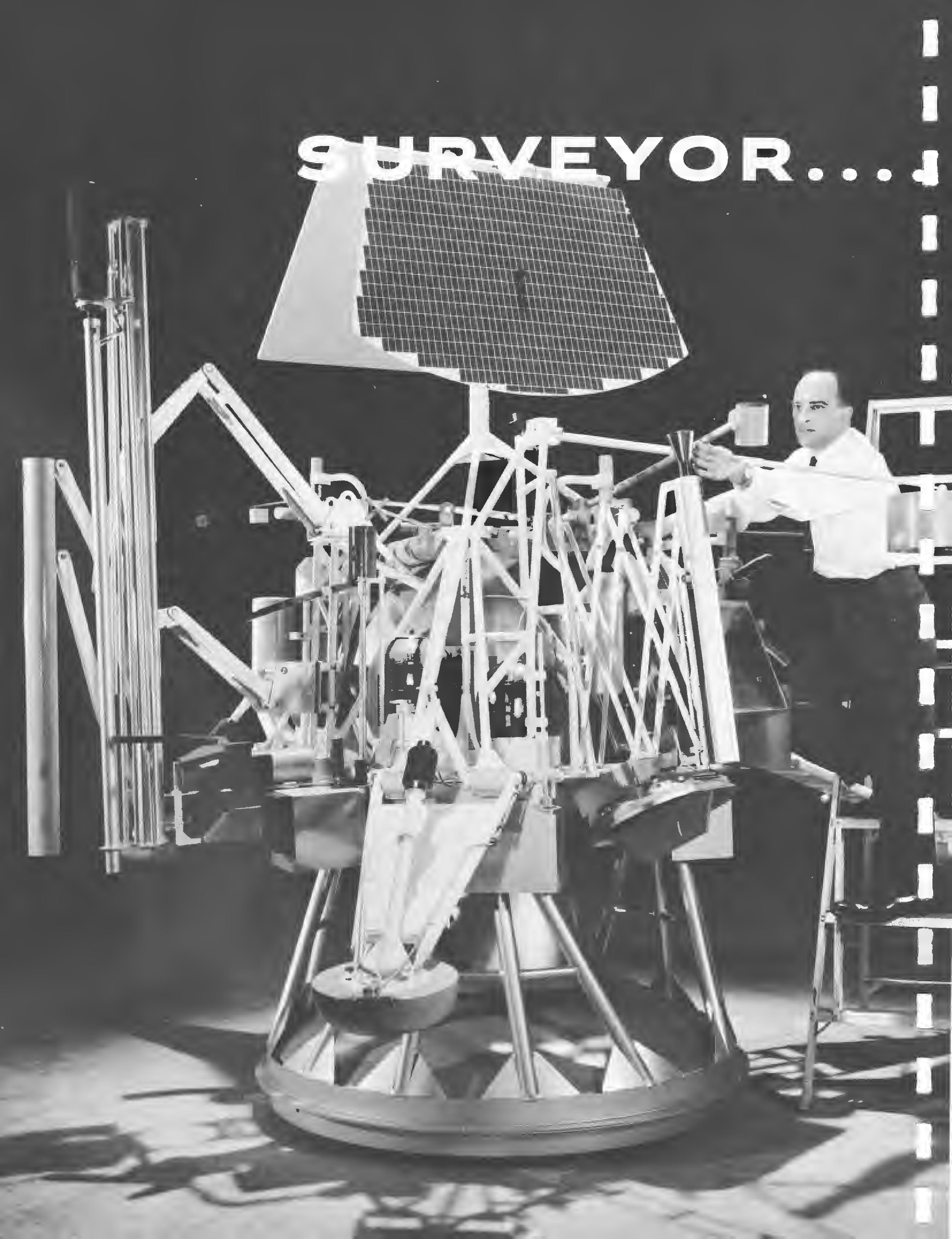
EMR will go to extreme lengths to insure the reliability of the spacecraft electronics in Project Celescope.

The system will be designed for a year's operation with 95% confidence. All of the components will be chosen from government approved high-reliability components parts lists. Micropower circuitry will be used as well as component derating to improve reliability. Also, redundant parts, redundant circuitry, and parallel systems operation will be used wherever possible; and finally, all circuits will employ welded circuit connections, modular construction, and encapsulation to reduce effects of space environments.

GENERALIZED BLOCK DIAGRAM
FOR PROJECT CELESCOPE PAYLOAD



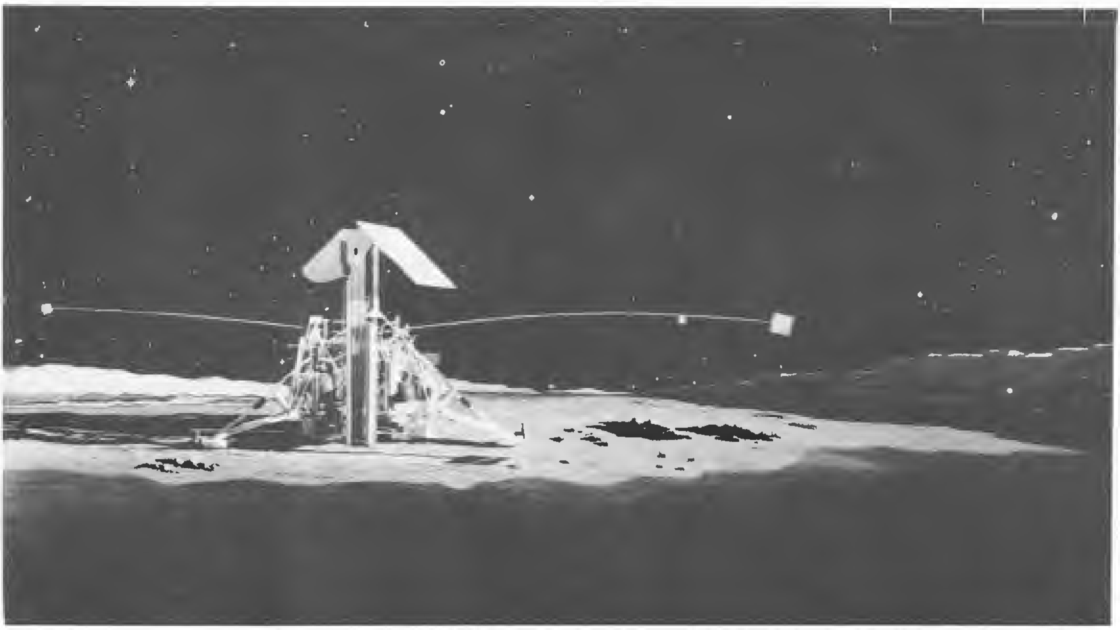
SURVEYOR...



World-wide Ground Data Processing for Moon Surface Survey

Of the unusual and sophisticated scientific satellite experiments scheduled for launching few are as ingenious or potentially rewarding as the proposed Surveyor Spacecraft.

Designed to automatically analyze and televise the moon's surface, the first Surveyor in a series of seven is scheduled to make a "soft" landing on the moon in 1963. After the landing, four cameras aboard the spacecraft will send television pictures of the moon's surface back to earth, each camera transmitting pictures at the rate of one every few seconds. More than 200 of the Surveyor's 750 pounds will be scientific and engineering instrumentation. Besides the four cameras, this instrumentation will consist of a seismometer to record moon quakes or meteoritic impacts; a magnetometer to determine if the moon has a magnetic field; instruments to measure the moon's gravity, radiation, and atmosphere; a drill designed to penetrate the moon's surface to a depth of from 18 to 60 inches; and mineral analyzers to analyze moon-crust samples collected from the hole. One of the TV cameras will be used to monitor the drill so that scientists on earth can observe the drilling operations.



The Surveyor spacecraft as it might look in operation on the surface of the moon.

After NASA's Jet Propulsion Laboratory (JPL) had completed a 1-1/2 year study of Surveyor's feasibility, JPL appointed the Hughes Aircraft Company prime contract negotiator for the construction of Surveyor and its ground and spaceborne instrumentation: Of all of Surveyor's instrumentation, among the most important is the communication and data acquisition equipment; without it, little of the experimental data that Surveyor will accumulate on the moon's surface would be available. For this important phase of the program, Hughes chose Electro-Mechanical Research, Inc.

EMR EQUIPMENT

EMR will supply Hughes with 58 EMR Model 167 Phase-Locked-Loop Discriminators and more than 10 EMR Model 185 Digital Decommutators to be installed in ground stations scattered around the globe.

FM DISCRIMINATORS--The Model 167 Discriminator, a precision instrument used for FM telemetry and data-recording systems, separates individual subcarriers from a multiplex and then demodulates the subcarriers by means of an optimized phase-locked-loop detector to produce an output voltage proportional to the frequency deviation of the subcarriers. The design of the Model 167 is such that the parameters of the phase-locked-loop are always optimum for any combination of channel selector and output filter that results in a deviation ratio of one or more. This unique feature enables the Model 167 to surpass the signal-to-noise performance of any other available discriminator. The combination of the input band-pass filter and the phase-locked-loop, detector results in 66-db rejection of full-scale modulation on an adjacent ±7.5% deviation IRIG channel, even in the extreme case where the interfering signal has an amplitude 16 db greater than the desired signal at the input to the discriminator. This permits each subcarrier signal in a subcarrier multiplex to be as great as 5 volts rms. Plug-in channel selectors will be supplied for Surveyor discriminators covering 16 subcarrier frequencies ranging from 0.40 to 150.0 kc.

DIGITAL DECOMMUTATORS--The EMR 185 Series digital decommutators can be supplied in various configurations to handle PAM, PDM, PCM, and subcommutated time-multiplex inputs. To meet Surveyor requirements, special 185 Decommutators will be supplied which process only PCM. Up to 64 channels are available as analog outputs. Plug-in patchboards for main frame and subframe programming are available at the front panel. This feature makes the Model 185 particularly well suited for the Surveyor Program since each of the ground stations contain a complete Model 185 Decommutator back-up facility.

Switching from one station to the other can be accomplished in seconds by removing and replacing patchboards; also several mission formats can be preprogrammed on patchboards and mission changes can be effected in seconds.

The 185 Series handles from 10 to 128 channels per frame at sample or word rates in the range of 8 to 5500 per second. Incoming signals of any type are converted to digital form and all internal signal processing is primarily digital. Maximum use of digital circuitry results in high accuracy, great flexibility in synchronization and filtering, simplified and precise scale compensation, elimination of decay in analog outputs, and exceptionally rapid acquisition of synchronization and data.

Output data distribution and display functions are separate from input data conditioning and decoding functions to assure a free choice of both mission and type of output presentation. Outputs include but are not limited to meter displays, binary and decimal light displays, printer drive, voltage or current suitable for driving recorders, and bar-graph oscilloscope display. All of these output functions may be performed simultaneously, if so desired, offering exceptional flexibility in data presentation and analysis.

The 185 Series employs solid-state circuitry and modular construction throughout. In typical applications its compact design permits an entire data system to be housed in a single standard rack cabinet.

Simulation and checkout functions are an integral part of the 185 Series. Meters and test point selector switches at the rear of logic drawers serve as a quick check of key voltages. Test points available at the front panel afford access to critical waveforms greatly expediting maintenance and trouble-shooting.

The 185 Series consists of a number of basic slide-out drawers housed in a standard telemetry rack. These drawers may be combined in various ways to form ground decommutations systems of greater or less input flexibility and output capacity.

WEST GERMAN CONSORTIUM..

Huge Data Complex for Aircraft Tests

Competition for military aircraft contracts demands that the modern aircraft manufacturer know as fully as possible the exact performance of his vehicle at each step from design through manufacture. He must generate information which permits him to carry out the next step with as complete confidence as it is possible to achieve. Vehicle performance specifications too must be backed up by the solid evidence of actual flight-performance records.

Both economic success and technical achievement in the aircraft industry depend on reducing unknowns in a particular design to a practical minimum. In this field more than any other exhaustive thorough testing is a must if all contributions to a superior design are to be properly weighed.

Hundreds of subsystems are contained in modern day aircraft. These range from simple mechanical devices through elaborate complex electro-hydraulic mechanisms. To evaluate such systems properly, many hundreds or even thousands of data measurements must be made.

The complete data complex delivered to West Germany early in 1962.

V/STOL FLIGHT TESTS

When the design groups of several West German aircraft manufacturers formed a consortium to build aircraft they called on EMR to build and install the complete instrumentation system for flight testing. EMR supplied the manufacturers a complete airborne- and ground-based instrumentation, tape recording and telemetry system. The complete instrumentation system conforms to U. S. IRIG Standards for PAM/FM/FM and FM/FM.

AIRBORNE SYSTEM

In the airborne portion of the system, EMR supplied commutators and amplifiers for pulse amplitude time-multiplex telemetry; voltage-controlled and millivolt-controlled subcarrier oscillators, and calibration units for frequency-multiplex telemetry; and FM transmission equipment. All equipment except RF transmitters is completely transistorized.

In early flight tests 290 channels of data will be telemetered over two separate radio links in the 450-megacycle band. For later advanced flight tests the system will be expanded, permitting 560 data channels to be recorded by an airborne tape recorder while at the same time, 100 of the data channels are transmitted over a single radio link. Data signals in early tests range in frequency from 0 to 2.5 kc and full-scale amplitude ranges include both millivolt and 5-volt levels. In later tests data signals will range in frequency from 0 to 60 kc and again levels include millivolt and 5-volt full-scale levels. The transition from early flight-test stages to later stages is designed in such a way that nearly all equipment used in early stages is also used in later flight tests.

GROUND SYSTEM

In the ground data-reduction system, EMR is supplying a versatile complex of ground-station equipment for reception, recording, and playback of both airborne-and ground-recorded data. This equipment includes antennas and receivers as well as 21 FM data discriminators, 14-track tape-recording equipment, tape-speed-compensation equipment, calibration equipment, and both analog and digital decommutators. Ground based auto-cal equipment operates on receipt of the programmed demand either in real time from the telemetry link or in post-flight time from tape playback. Sixteen of the discriminator outputs may be time correlated for use in certain critical structural flight tests. The digital decommutators, in addition to providing 16 analog outputs, also provides five digital outputs which drive a high-speed printer in real time.

Exceptionally flexible system patching and interconnection permits many ground-station configurations to meet changing requirements of the flight-test program.

Rack wiring from earliest stages is designed for flexibility--test points are made accessible--system expansion capability is prewired in.

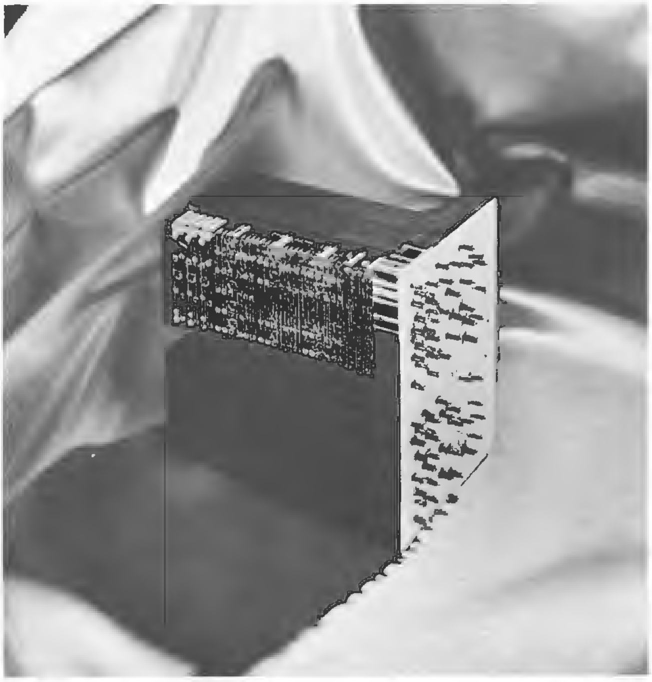
X-20...

Pioneer of Modern Spacecraft Instrumentation

The X-20 program, one of America's most significant space-development efforts, contributed an immense body of knowledge applicable to future aerospace programs before its cancellation in December 1963. This Air Force program was intended to develop a manned space glider that would rocket into space like a winged missile, go into orbit if desired, then re-enter the atmosphere and maneuver like an airplane. The pilot would be able to land the vehicle in conventional aircraft fashion.

X-20 vehicle development embraced many unknown areas at and beyond the current technological frontier. Consequently, the test phase of the program demanded data acquisition, data-processing, and data analysis systems of unprecedented complexity. Responsibility for the X-20 test-instrumentation subsystem, at that time the largest instrumentation contract ever awarded, was given to Electro-Mechanical Research, Inc., after an exhaustive survey of competitive companies

Mock-up of a portion of the airborne PCM system shows welded-wire construction and wire-wrapped terminals.



by the prime contractor, The Boeing Company. Among factors contributing most strongly to award of the X-20 contract to EMR were the company's comprehensive technical knowledge in all areas of the instrumentation system, a competent management team, experience in building telemetry equipment unequaled by any other company in the industry, and capabilities for handling the major portion of the contract in-house with existing facilities.

EMR supplied all equipment for collecting and encoding test data within the X-20 vehicle as well as ground equipment for receiving, displaying, recording, and processing the data. Installations at all locations and operator training both fell within the scope of EMR responsibility.

SPACECRAFT SYSTEM

The X-20 airborne test instrumentation subsystem included pulse-code-modulation (PCM) and frequency-modulation (FM) telemetry subsystems, frequency-translation equipment, a time-code-generator, and a video tape recorder for data storage. Both the PCM and FM telemetry data signals were combined through advanced frequency-translation techniques into a single data-signal multiplex for both transmission and in-vehicle recording.

Modules are welded in a carefully controlled, programmed sequence.

Milt Litweiller

PCM airborne deck undergoing final checkout test at EMR.

TIME-MULTIPLEX SUBSYSTEM--The time-multiplex telemetry employed a synchronous mechanical commutator and electronic commutators which permitted sampling of nearly 900 data signals. Signal levels ranged from 20 mv to 5 volts and sampling rates were 2 sps, 20 sps, 50 sps and 200 sps. By means of cross strapping, the number of data channels sampled at these rates could be varied to suit specific mission requirements. Similarly, sampling rates could be increased to 3200 sps.

A primary reason for EMR's selection as X-20 subcontractor was the proprietary prior development of a fully engineered PCM subsystem which met the program's requirements. This exceptionally flexible PCM system employs all-silicon solid-state circuitry, welded construction, high-density packaging, and vacuum-encapsulated modules to assure a rugged compact unit capable of withstanding wide temperature range, high random vibration, and large shocks and accelerations without effect.

The EMR system multiplexes, and digitizes with 8-bit accuracy, low-level transducer signals in the range of 0 to 20 mv, and high-level signals in the 0- to 5-volt range. Signals can be floating, single-ended, or balanced. Common-mode rejection is excellent. Common-mode signals of 5 volts dc and 1 volt peak-to-peak ac up to 2.5 kc cause no more than 0.1% full-scale change in the output.

Programmed, solid-state switches with outstanding characteristics provided input signal multiplexing. Through a unique circuit design, back current from this electronic switch was so small that source impedances as high as 5000 ohms could be used with less than 0.1% error. The incorporation of ac coupling and synchronously clamped amplifiers eliminated long-term amplifier drifts.

X-20 data words consisted of nine bits including parity; the basic bit rate was 144,000 bps. Digitized data was converted to NRZ form before transmission. No word synchronization was included in the format; however, optimized quasirandom frame-synchronization codes were to be used to identify each of the commutation and subcommutation frames. These synchronization codes were based on statistical analysis of system performance using a priori knowledge of system characteristics.

FM SUBSYSTEM--The FM telemetry subsystem consisted of 42 subcarrier oscillators which were frequency modulated by data signals. Each of the 41 subcarrier center frequencies was translated to separate higher frequencies. All 41 translated subcarrier signals, the one untranslated subcarrier signal, and the PCM signal were linearly combined into a frequency multiplex by two separate mixing matrices. The frequency multiplex signals were then either transmitted to the ground over an rf link or recorded on board by the video recorder.

GROUND DATA RECOVERY SYSTEM

The ground instrumentation system for receiving all this data was conceived as a highly complex world-wide network of stations that could provide either "on-line" or "off-line" data reduction. Six types of ground installations were to be installed at three locations. In general, equipment included video tape recorders, FM discriminators, FM detranslators, PCM ground stations, a large quantity of visual readout equipment, elaborate flight-control displays, and various computer-entry equipment to prepare data for computer analysis and inertial-guidance computation.

BOEING AND EDWARDS AFB INSTALLATIONS--One station, intended for installation at the Boeing Company, Seattle, Washington, was designed for test-instrumentation subsystem tests, vehicle tests, data reduction, and data processing for computer entry. In addition, this equipment could be utilized for airborne equipment calibration and maintenance in Seattle. Two fixed stations and one trailer-mounted system were planned for Edwards Air Force Base. The two fixed stations were to perform primary data reduction during the air-launch test program, while the trailer-installed station was to be used as a back-up and glider-checkout station.

ATLANTIC MISSILE RANGE INSTALLATION--The complex data facility for Cape Kennedy was designed to supply real-time data to display centers for operation of the mission. The Atlantic Missile Range Flight Test Control Center at Cape Kennedy was to be the central control point for all early phases of a mission and to control down-range landing on abort operations.

FLIGHT CONTROL AND DISPLAY--Displays supplied by EMR were to provide real-time data to a number of flight-control console operators in the flight control center. Functionally, a large elevated display shows numerical data of vital events as they occur during the flight. Each console operator continuously monitors a particular major group of data such as physiological, booster, aero, and structure from prelaunch until the end of the flight. Emergency conditions can be flashed on consoles and display boards so that the flight director may take immediate action to ensure the safety of the astronauts.

EMR equipment also conditions and transmits received data to other EMR equipment for preparation and entry into a computer for processing and analysis. All telemetry data is recorded by ground tape recorders and played back immediately to conventional "quick-look" telemetry displays such as bar-chart oscillographs, binary light displays, decimal displays, digital printers, and various types of chart and strip recorders.

IG and PCM Data Processor Subsystem for X-20.

Thus, scientists can observe test channels while the test progresses and note unexpected behavior for later detailed analysis. Tapes from the airborne recorder can also be played back through the system to verify or clarify transmitted data.

OTHER RANGE INSTRUMENTATION--Important data-reduction equipment is duplicated in a trailer-mounted system to back up the primary flight instrumentation. Immediately preceding launch, EMR-installed blockhouse equipment is used for resetting the airborne time-code generator and for controlling the airborne tape recorder.

NEW TECHNIQUES USED

Because of the broad scope, complexity, and exceptionally stringent reliability required on the X-20 program many new management tools, packaging and production methods, and reliability techniques were developed by EMR. For example, a complete laboratory setup was built that can closely approximate X-20 system operation. This system simulator permits examination of a large number of system parameter variations prior to engineering development. As actual equipment was built, it was integrated into the simulator until the simulator for all practical purposes became the system itself. Tests using the system simulator were also conducted with other subsystems to ensure that the total vehicle system would function as planned.

RELIABILITY--In the numerical assessment of MTBF, the circuits were analyzed for drift characteristics and failure probabilities. The calculated MTBF for most portions of the airborne system was so high that spare parts were being provisioned on the basis of accidental breakage rather than failure. A metallurgical laboratory performed chemical analyses of component lead materials to assure that they were as specified. To assure uniform production-line circuit welds, this laboratory developed and maintained weld schedules based on metallurgical analyses of the best welding techniques. Each production welder was periodically calibrated for the various weld schedules employed throughout the system.

Racks of transistors are electrically cycled to pre-age them before use in critical circuits.

The X-20 reliability program included a comprehensive facility for "burning in" and matching critical parts. All parts were electrically mounted in test racks for immersion in temperature-controlled silicon oil baths. The parts were subjected to an electrical/-temperature test cycle. The entire test was automated to reject bad parts and print out a performance record of each part. Life tests were run on statistically large samples of the transistors to be used and their performance carefully plotted to ensure that reliability goals were met.

Part failure analysis extended to breadboarding of every critical X-20 circuit. Each of these circuits underwent operational and environmental tests to determine which parts were likely to fail as well as the cause attributed to the failure.

TELSTAR...

Telemetry Monitoring of First Active Communications Satellite

At 4:35 a.m. EDT on July 10, 1962, a new era in intercontinental communications began--Telstar, the world's first active communications satellite, was successfully launched. Within 24 hours it transmitted the first trans-Atlantic live television program from France to millions of viewers in America.

SCIENTIFIC DATA OBTAINED

The outstanding success of this experiment has been widely publicized but less known is the fact that Telstar is equipped to obtain needed scientific data on its environment in space and to measure its own performance during all phases of its active life. Space poses problems for Telstar beyond

Telstar satellite, shown receiving final adjustment, transmits over 115 data points to EMR ground decommutators.

the reception and regeneration of communication signals. High-energy protons circulating in the inner Van Allen belt through which Telstar travels can affect power and electronic components adversely. Temperature components were resolved and their effect determined. A complete record of launch conditions, both of vibration and acceleration, was obtained to aid in the development of future long-life communications satellites. After the acquisition and assimilation of all this information, the optimum operational design was derived.

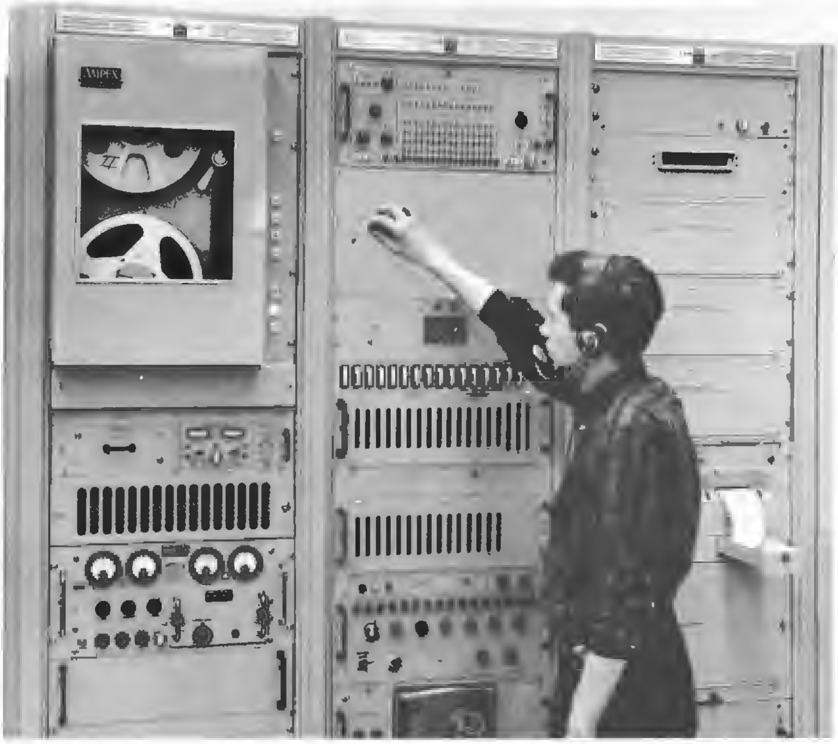
Bell Telephone Laboratories chose EMR to supply the PCM telemetry ground decommutators for processing the Telstar data. Three EMR Model 185 Decommutation Systems were delivered to Bell Telephone Laboratories six months before Telstar's launch: one to the main receiving center near Andover, Maine; another to BTL's facility in Hillside, New Jersey, where the satellite was assembled; and the third was installed in a mobile van used for prelaunch checkout and telemetering during launch at Cape Kennedy. The first ground-station system was delivered in less than three months, despite special system design requirements.

115 DIFFERENT MEASUREMENTS

In all, 115 separate items are measured and reported, including such parameters as the density and energies of free protons and electrons in the Van Allen belt (as well as the new radiation belt created in a nuclear space blast), temperature at the skin of the satellite and inside the electronic chassis, pressure inside the chassis, the amount of sunlight being received at several points on the skin, and the currents and voltages of dozens of electronic components.

AT & T anticipates using a number of Telstar satellites. With 40 polar-orbit and 15 equatorial-orbit satellites, effective point-to-point communications between any two points on earth could be maintained 99.9% of the time. Global communications could be maintained by approximately 25 ideally located ground stations.

All data is telemetered to decommutation stations by means of a PCM/-FM/AM signal; i.e., a pulse-code-modulation FM signal which in turn amplitude modulates a 136-mc carrier. Approximately 400 scientists, engineers, and technicians of Bell Laboratories are analyzing this information to obtain additional knowledge of space and to derive new concepts for the "Telstars" of the future.



Bell Telephone Technician adjusts EMR Model 185 station at Andover, Maine, during the Telstar in-orbit repair.

IN-ORBIT REPAIR

EMR's Model 185 PCM data-processing stations were in use when prolonged exposure to severe radiation on circuit components of the orbiting Telstar caused a breakdown in critical switching circuits. Telemetry data received from the satellite was instrumental in pinpointing the problem for Bell Telephone scientists, who were able to duplicate the failure under laboratory conditions. With this assurance of the probable cause, they established a new switching logic in the satellite by a series of commands to existing circuits. When activated, the new switch caused failure-producing ions to be discharged from the affected components, making Telstar fully operational.


TITAN. . . .

Three Missile Generations of Total Responsibility
. . . Outstanding Success

The Titan missile is one of the most powerful and accurate ICBM's in the U. S. missile arsenal.

In test since 1959, the Titan missile in operational form is now housed in silos ready for immediate use. During test phases which qualified this important missile for field operation, EMR had total responsibility for on-board telemetry.

In three missile generations of total responsibility for the USAF Titan telemetry system, EMR's 14-band telemeter has been proven an outstanding success. Evidence of this is the fact that in 20 Titan flights, each carrying three complete telemetry packages with a flight duration of 16 minutes, no telemetry failure occurred.

TITAN TELEMETRY

Three distinct versions of the 101-channel airborne telemetry transmitting package used in the Titan have been produced by EMR. The earliest version, 58 of which were supplied from May, 1959, to December, 1959 con-

The Titan telemetry package

Titan telemetry package
in final production

tained all tube-type units and mechanical commutator, later retro-fitted to an electronic commutator. The "second-generation" packages, 57 of which were shipped between May 1959 and March 1960, were partially transistorized. Sixty-eight completely solid-state packages were delivered in 1961 and 1962.

Each Titan missile contained one to four of these packages which transmitted data on 13 continuous channels and one 88-bit commutated channel.

THE PACKAGE--The complete pressurized package, up to 4 of which were flown in each Titan, contained 15 FM subcarrier oscillators that, in conjunction with an electronic commutator, provided 99 data channels and a calibration channel. Thirteen channels conveyed continuous (FM) information, one wide-band channel was time shared by 86 pulse-duration-modulated (PDM/FM) data sources, and one channel provided a coded signal for automatic calibration of the ground-station discriminators.

SUBCARRIER OSCILLATORS--The first group of 13 wide-band data inputs were applied to EMR Model 171B transistorized, voltage-controlled subcarrier oscillators, operating with a linearity of ±0.1% and a harmonic distortion of less than 1% at a modulation index of 5. Voltage limiters in each channel clamped data-signal excursions which were beyond the 0- to 5-volt input range.

A front-panel control provides the option of modulating the 70-kc channel by a continuous-data input or by an EMR Model 181D solid-state commutator (90 x 10). The basic switching elements in this highly reliable electronic commutator are silicon diodes controlled by signals generated in a self-contained counter system.

PDM TELEMETRY--Pulse-duration modulation of the commutated channels is performed by an EMR Model 800A transistorized PAM-to-PDM converter. This unit contains sample-and-hold provisions and an extremely linear rundown circuit which generates a rundown cycle upon receipt of a trigger signal generated in the commutator. The output of this converter is a train of 5-volt pulses varying in width from 160 microseconds for a zero-volt input to 660 microseconds for a 5-volt input. In the system, overvoltage limiting is effected at the input to this converter.

All oscillator outputs are mixed, and pre-emphasis is effected, in an EMR Model 178B transistorized isolation amplifier.

TRANSMITTER--The mixed subcarrier output of the isolation amplifier modulates an EMR Model 121 VHF FM transmitter. This transmitter features quartz-line frequency stabilization with negligible spurious outputs and highly linear 125-kc modulation in the 225- to 260-mc band.

EMR Model 181 electronic commutators for the Titan package await final test.

Reliable transmission is provided by a 100-watt EMR Model 822A VHF Power Amplifier. Upon external command during preflight checkout, a relay causes the Model 822A to provide reduced rf power (2 to 5 watts). A nominal 55-watt output can be obtained as a function of a power-supply wiring option.

OSCILLATOR CALIBRATION--A relay switching network at the input to all oscillator channels makes possible the application of precise calibration voltages upon external command. A calibration-code oscillator, normally at 560-cps center frequency, identifies the calibration cycle for automatic calibration of the discriminators in the receiving station during the periods when the calibration voltage is applied to the data-channel oscillators. The cal-code oscillator is deviated to one band edge by the calibration command voltage at the same time as the calibration relay applies the calibration potential to each of the other oscillators.

HOUSING--Transducers within the package monitor its internal temperature and air pressure. A running-time meter on the front panel records operating time.

Transmitter/power amplifier assembly is placed in oven during qualification test.

Qualification test of Titan telemetry in progress. Automatic test setup halts tests when preset limit is exceeded.

The extremely rigid, light-weight housing for the entire telemetry package is a hermetically sealed magnesium cannister 20 inches long and 13 inches in diameter. Vibration and shock moments are minimized by suspending the electronics chassis from the front panel by means of tapered gibs located in the plane of the exterior mounting lugs. The weight of the entire assembly is less than 72 pounds. Normal pressurization of the package is 6 psig (dry air).

RELIABILITY PROGRAM

The outstanding reliability of the Titan telemeter is the result of a comprehensive reliability-testing program carefully conducted during all phases of design and manufacture, from the earliest production stages until the package is shipped. As described below, the complete package and all its major subassemblies are subjected to tests that simulate anticipated environmental stresses, thereby inducing failures that might otherwise occur during end use.

All reliability tests are rigidly outlined and controlled and are performed on a round-the-clock basis when the nature of the test requires.

During environmental qualification of the telemeter, the complete package is subjected to ±7g vibration from 5 to 2000 cps as well as temperature from -35°F to +125°F.

Acceptance testing for each package includes a Component Reliability Test, a Functional Test Program, a Package Reliability Test, and a Production Environmental Test--performed in that order.

The Component Reliability Test is a 50-hour cycled temperature run to +75°C on those subassemblies of the package which can produce a catastrophic failure of the system. The setup provides for automatic shutdown and alarm should the monitored electrical parameters go out of tolerance. When a shutdown occurs, the test is not resumed until a "fix" has been made and the faulty component has been replaced. If the trouble occurs in the early stages of the test, the test is begun over again.

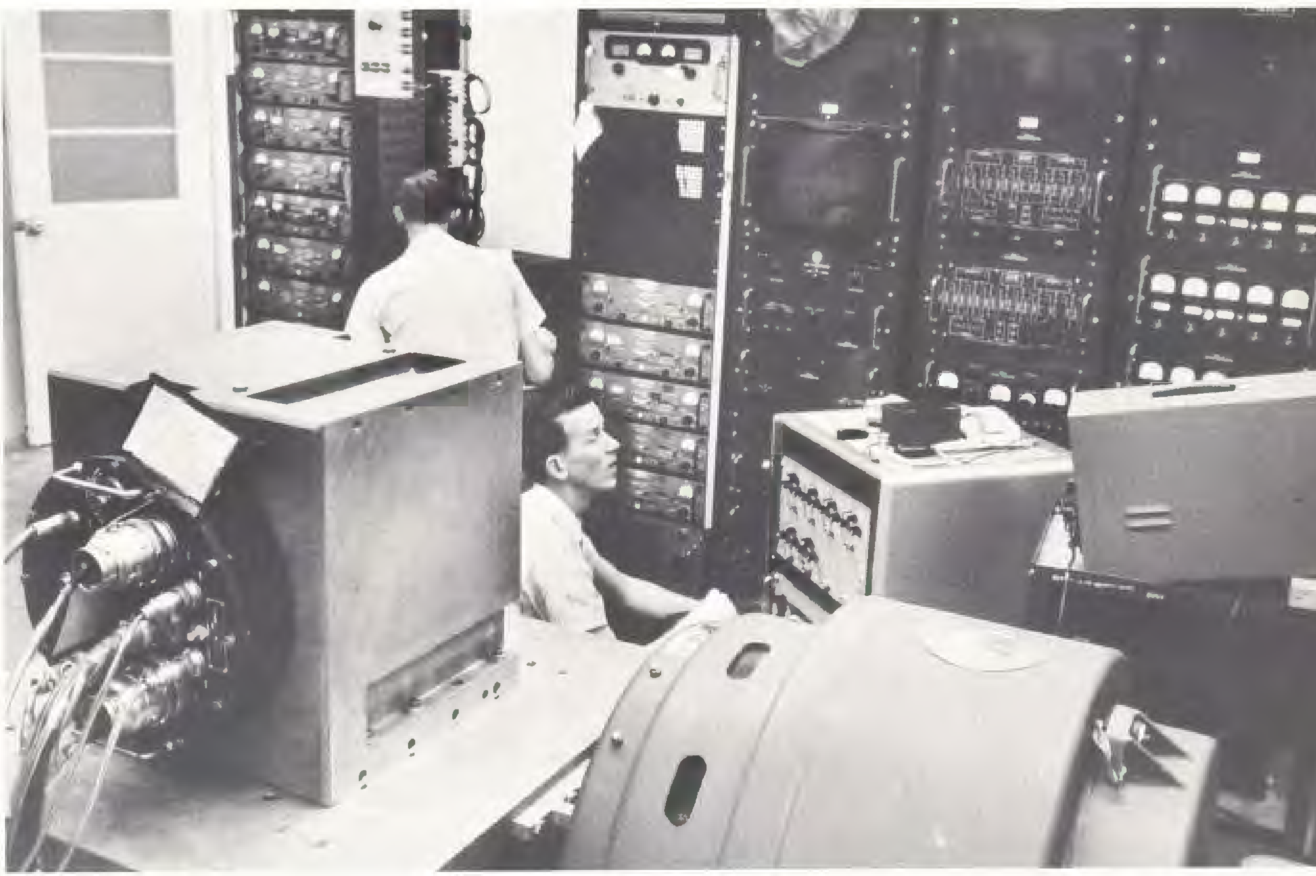
In the Functional Test Program, accurate determination is made of such system characteristics as subcarrier-channel linearity, crosstalk, and repeatability, commutator back current, system pre-emphasis, and system stability from day to day. In general, system linearities are better than 1% for all channels; crosstalk and interference is less than 1%. Any subassembly not within specifications is reworked or replaced.

During the Package Reliability Test, a five-hour run, continuous records are made of: rf deviation, rf frequency, rf power output; oscillator linearity, bandwidth, and center frequency; and PAM-to-PDM converter linearity. Again, rework or replacement is effected for any out-of-tolerance condition.

The Production Environmental Test subjects the operative package to 3g peak sinusoidal vibration, limited to 0.50 inch double amplitude, from 5 to 2000 cps. During the test, all channel outputs, rf frequency, and rf power output are monitored and recorded. Package pressure is measured after completion of the test, and pressure-switch operation is checked at the same time. Subcarrier beats and disturbances, transients, and dc level shifts must not exceed stringent limits before, during, and after the test.

As a result of this thorough reliability testing and EMR's normal reliability program, the telemeter package that is shipped is capable of unattended, failure-free operation for long periods. Because of this exceptional performance of the EMR Titan telemetry, the company received an unsolicited commendation letter, which stated in part:

> "To date, 7 of your telemetry packages have been flown and the results evaluated so far would indicate that they performed very well... in all measurement areas, good instrumentation data was received, commutator signals looked clean... RF stability was good."



Entire Titan package undergoing vibration test at EMR.

MERCURY....

From Boilerplate to Manned Orbit

The success of Project Mercury alone has stood against Russian success in orbiting spacecraft with human passengers.

In many ways the Mercury Program has been more dramatically successful. At each stage it has had world-wide attention focused on it. By the time manned suborbital flights were made it was virtually a necessity that U. S. scientists call their shots successfully if U. S. prestige were not to suffer badly. That these shots were unqualified successes is a tribute to the conduct of the Mercury Program and the companies which participated in it.

From first tests of boilerplate Mercury capsules through manned orbital flights, EMR has supplied telemetry components which have contributed to the progress of the Mercury Program.

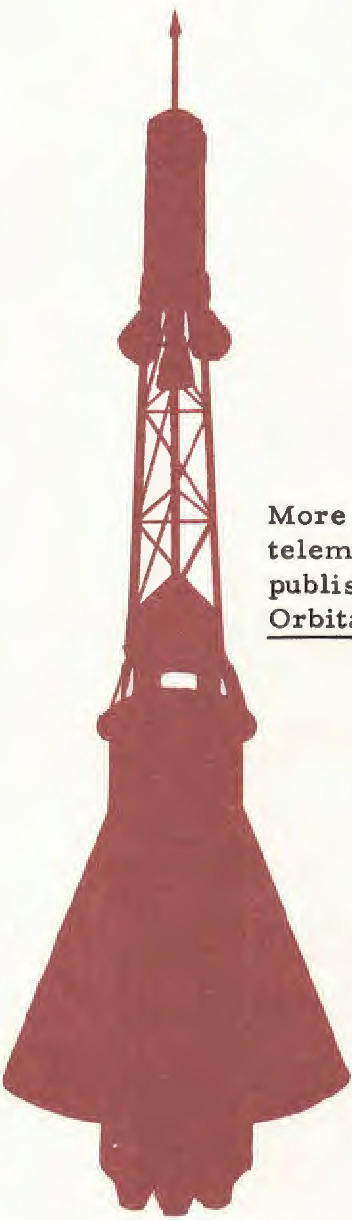
EARLY FLIGHT TESTS

Illustrative of company flight test experience is the following excerpt from the September 14th issue of Aviation Week, regarding the Mercury Program. The application is typical and the successful results are also typical.

"First Big Joe test of a boilerplate Mercury capsule fell

Telemetry transmitter for Mercury under vibration test.

EMR Model 121 Transmitter used in Mercury program



short of planned goals last week when its Atlas booster malfunctioned, but the test still provided valuable re-entry data...

"Instrumentation was carried to monitor pressure, speed, gyro signals, control jets and several other items and to telemeter 32 channels of information to ground stations through two transmitters broadcasting on standard FM bands. Recorders also taped instrument readings for analysis after recovery. To overcome interference from ionization of the air around the capsule during re-entry, a third transmitter-recorder taped data during a four-minute period and broadcast it after the re-entry blackout was over...

"Telemetry data was received at Cape Canaveral, Antigua, Grand Turk Isle and on recovery ships. Control jet system was made by Minneapolis-Honeywell Regulator Co., antennas by General Electric and telemetry by Electro-Mechanical Research, Inc...."

More recently during Colonel Glenn's successful orbiting flight, the telemetry performance received special commendation in NASA's published report of the flight. (Results of the First U.S. Manned Orbital Space Flight, February 20, 1962, page 142.)

"The telemetry subsystem reception and performance was outstandingly good. All stations acquired and lost signals at or near the horizon. No major operator error or equipment malfunction was reported that influenced mission monitoring and control. The maximum range of telemetry reception varied from 500 to 1,100 miles.

"The malfunction of the landing-bag-deploy microswitch was first indicated by the telemetry system as the spacecraft passed Cape Canaveral at the end of the first orbit...

"No problems were encountered with the data transmission system; all high-speed and low-speed data lines were operational during the entire mission..."

ORBITAL SPACECRAFT TELEMETRY

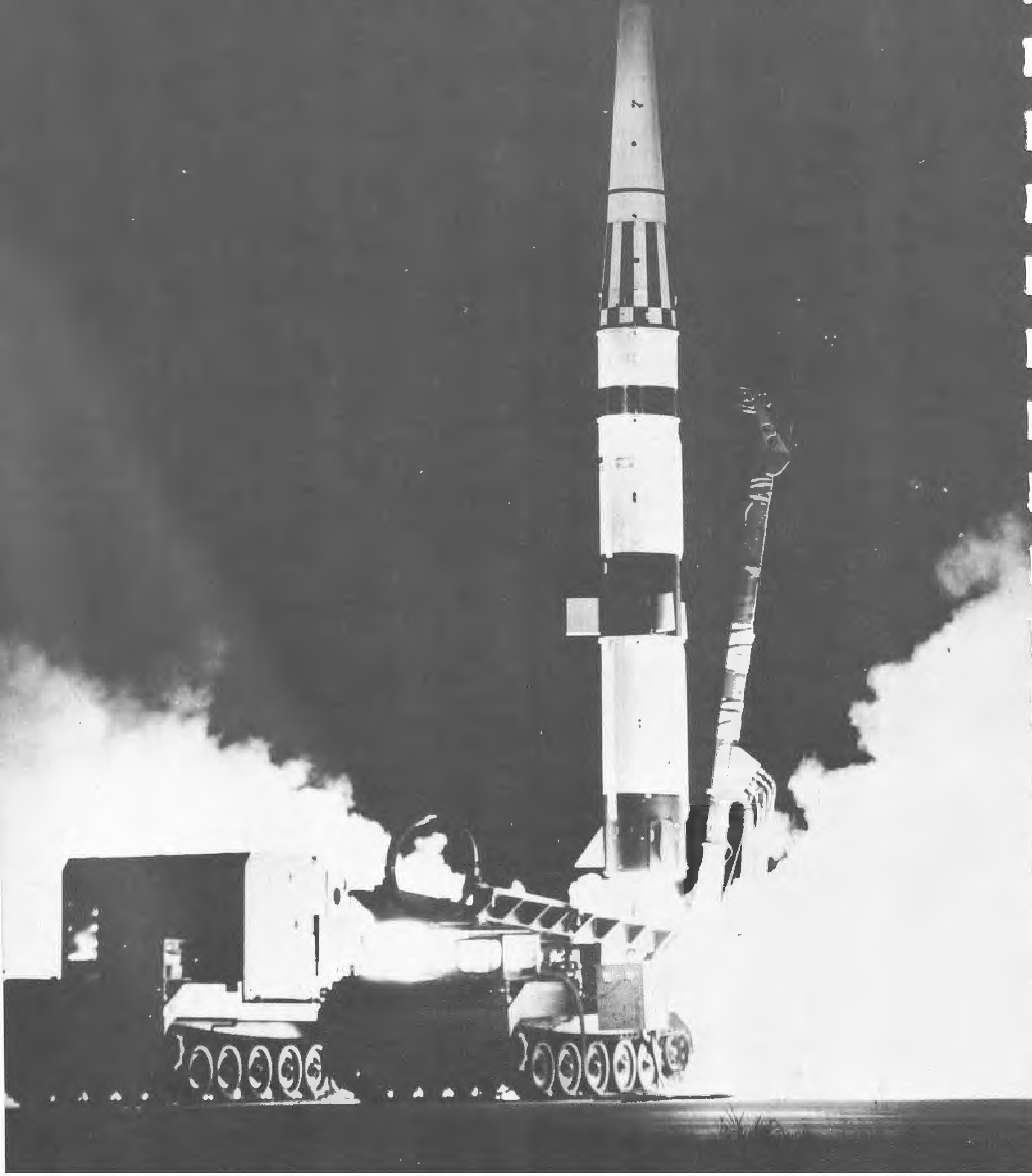
In the first U.S. attempt to orbit a man, vital data concerning all aspects of both man and Mercury spacecraft was gathered, coded and sent to the earth by EMR telemetry equipment. The many decisions which must be made on the ground to ensure the safe return of spacecraft and man depend upon the telemetry data received about the performance of the spacecraft and the man. Such data as temperature, vibration, position, radiation, and many others were transmitted to the ground by EMR telemetry for analysis.

Eighteen EMR Model 184C subcarrier oscillators (two nine-channel systems) were carried by the manned capsule as part of the instrumentation. Each of these miniature FM oscillators is packaged in a 1-1/2" cube. Eight of them handle a single measurement each; the ninth contains 90 additional channels of time-multiplexed data. All these measurements are combined by other EMR electronic equipment into a single signal multiplex. This signal is transmitted to the ground receiving stations by two EMR Model 121 FM transmitters. For this mission, one of the EMR telemetry transmitters has been specially modified to include a code key. Should the main voice transmitter fail during the mission, the astronaut can use the telemetry transmitter for communication.

EMR's part in this mission did not end with the Mercury spacecraft. After the multiplex signal was received on the ground, EMR data-processing equipment was used as primary instrumentation to process the data and present it to NASA scientists for review. Data vital to the safety of the mission was presented on monitors for instant review, and all data was recorded for later detailed analysis.

EMR ground data-processing equipment includes Model 67 and 165 FM discriminators to separate and demodulate FM data channels and M-Series decommutators for handling the numerous time-multiplexed data channels.

PERSHING....

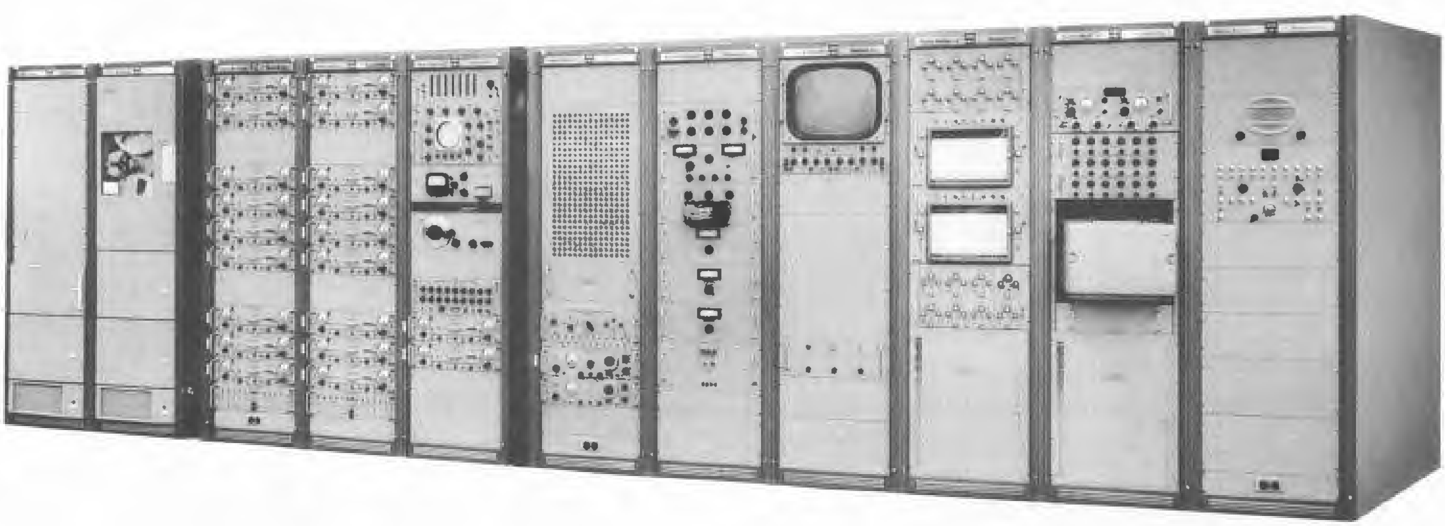


From Range Data Reception to Computer Entry in a Day

The cold-war missile race has reached a crucial new stage of development. The country that is able to protect its missile launching sites from surprise attack--either by "hardening" or mobilizing missiles--will have a definite advantage over its antagonist. It is obvious that it is vitally important to the security of the United States to achieve this capability.

MOBILE MISSILES

Of the two methods of protecting launching sites, mobile missiles have definite advantages over hardened missile sites in cost, construction time, and quantity production. An example is the recently developed Pershing. A lightweight, smaller, solid-fuel successor to the highly reliable Redstone, the Pershing promises to be one of our most successful bids to win the current mobility race. Because of its quick-launch capabilities and relatively small mass, it can be transported, erected, and fired in a matter of minutes. It is both air and ground transportable, providing it with extremely high mobility so that it can operate on a shoot-and-run principle. With enough operational Pershings in the field, complete destruction of these missiles by an enemy first-strike attack would be virtually impossible.



Pershing Missile System (MADRE)

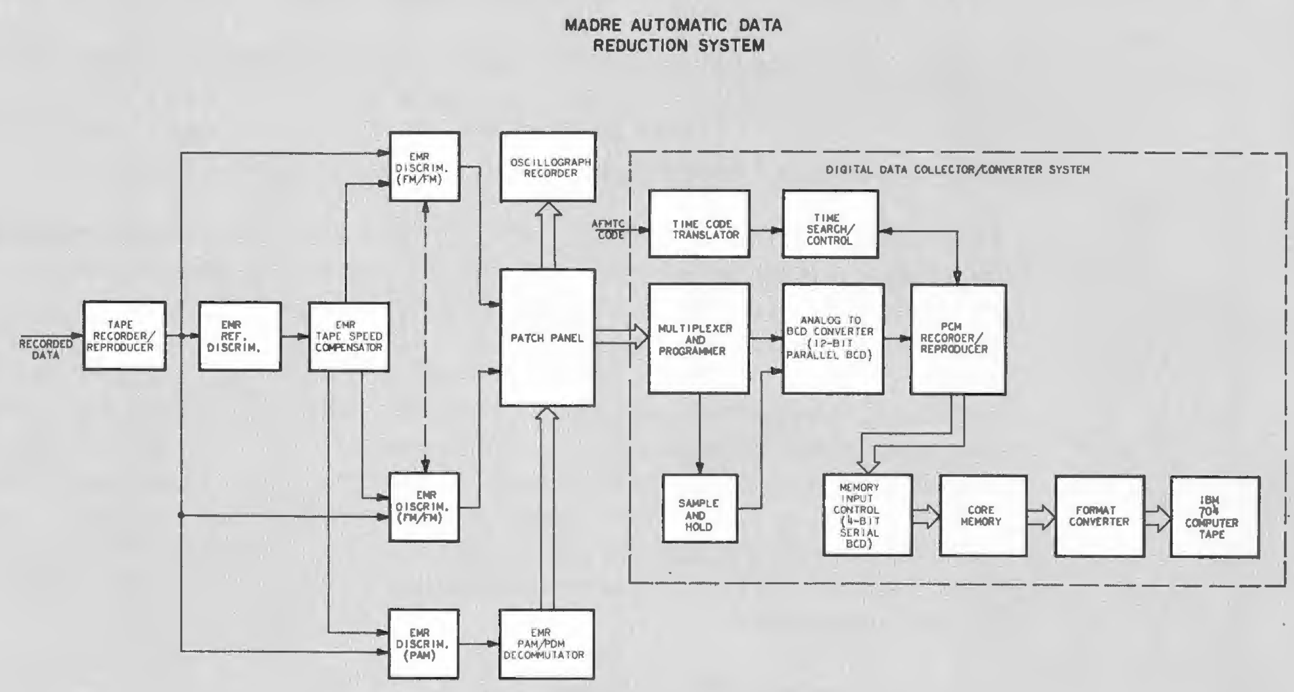
However, in order to make the Pershing and other mobile missiles operational new techniques had to be developed to make the missiles reliable, rugged, simplified, and versatile. Since rapid development was of the utmost importance, it became obvious that the huge quantity of test data would have to be processed automatically by digital computers.

THE MADRE SYSTEM

MADRE (Martin Automatic Data Reduction Equipment), a high-speed digital acquisition and computing system, was successfully developed to fulfill this function. This system is designed to expedite flight data from the launching pad to computer in a single day. Telemetered flight data recorded during test is decommutated by the MADRE Analog Station and presented in analog form to the MADRE Digital Station. The Digital Station then converts the outputs of the Analog Station to digital form in the proper format for further processing by an IBM 704 Computer.

To expedite the construction of MADRE, Pershing prime contractor Martin selected EMR as the data-system contractor to supply eleven racks of analog equipment for the system and assume over-all technical responsibility. The resultant EMR Automatic Data Reduction System processes a minimum of 65 multiplexed channels of prerecorded analog magnetic tape data. In addition, it provides adequate capabilities to either record the reduced data directly or to convert the data to digital form and place it in the proper format for subsequent computer analysis.

FM GROUND STATION--Composite data from the magnetic tape is played into the analog section by a Magnetic Tape Recorder/Reproducer and directed to EMR Model 67F Subcarrier Discriminators, where each subcarrier signal is selected by the appropriate discriminator bandpass filter. Discrimination of each subcarrier produces analog data outputs, one time-shared pulse-amplitude-modulated (PAM) signal, a timing sequence, and a reference signal for automatic tape speed error compensation. The EMR Model 96F-12 Tape Speed Compensators operate from the reference signal and automatically compensate each subcarrier discriminator for errors in tape speed during recording or playback. The PAM signal is further processed by an EMR Decommutation System, which produces additional analog data outputs. Sampling is at a rate of 20, 000 samples per second; encoding accuracy is ± 0. 2%.



ANALOG DATA HANDLING--The analog outputs from the discriminators or decommutator may be recorded either on a high-frequency recorder, or on one of two low-frequency recorders. A total of 36 high-frequency channels and 16 low-frequency channels are simultaneously available for this purpose.

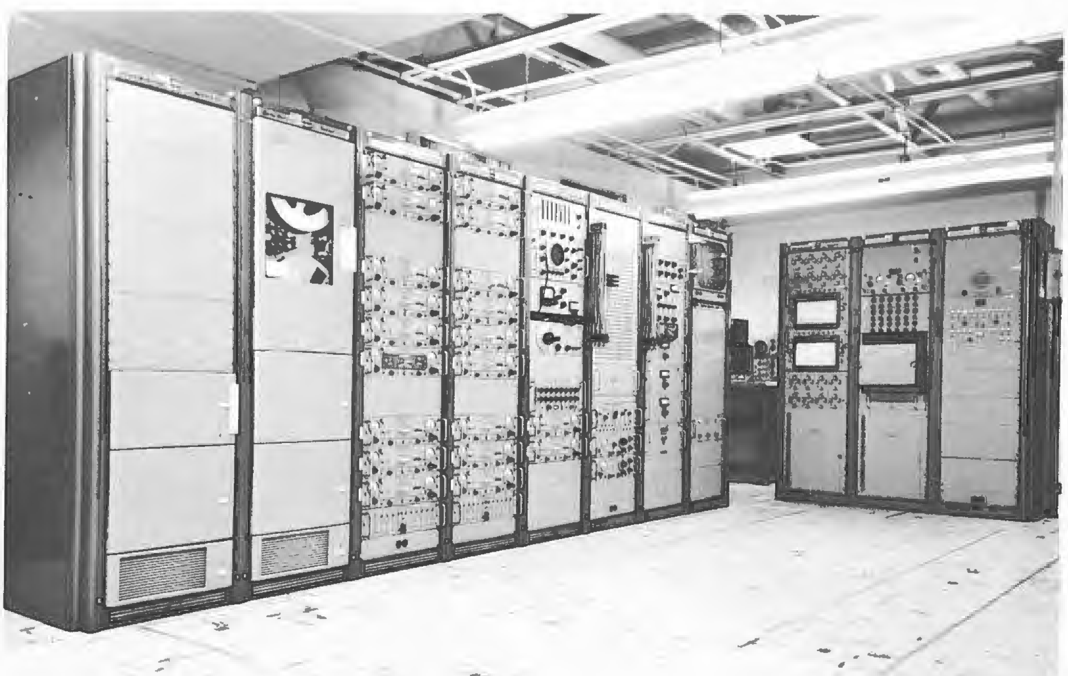
The analog outputs to be digitized are fed into the Data Collecting System of the digital section, which is capable of accepting up to 100 analog signals from the analog patch panel. As shown in the system block diagram, the Multiplex sequentially gates the selected input channels received from the Analog Station into the input of the Sample and Hold. The Sample and Hold circuit samples a one microsecond segment of the input signal and holds this signal as the input to the Analog-to-BCD Converter which converts the analog input signal to a three-decade binary-coded-decimal (BCD) number, with the output appearing on twelve parallel lines. This twelve-bit parallel BCD signal is recorded on 12 tracks of the 16-track Intermediate Tape Recorder/Reproducer.

A 1 kc, 100 pps AFMTC "fast" code is detected by the Time Code Translator, and updates the milliseconds and seconds counters in the Time Search/Control. Serial BCD time code from the Time Search/Control is recorded on one track of the Intermediate Tape Recorder.

In the Data Processing mode, the Time Search Control accepts serial BCD time information (seconds and milliseconds) from the tape and compares the seconds with manually inserted information to search for the corresponding time interval on tape. During search, all other system functions are inhibited. When START TIME coincidence is detected, a signal is sent to the Intermediate Tape Recorder to change to the selected playback speed. After a delay to permit the tape to reach this speed, the 12-bit parallel output of the tape reproducer is converted in the Memory Input Control to four-bit serial BCD format, and temporarily stored in the Core Memory. The Format Converter modifies the format of the digital signal so that it may be processed by the computers.

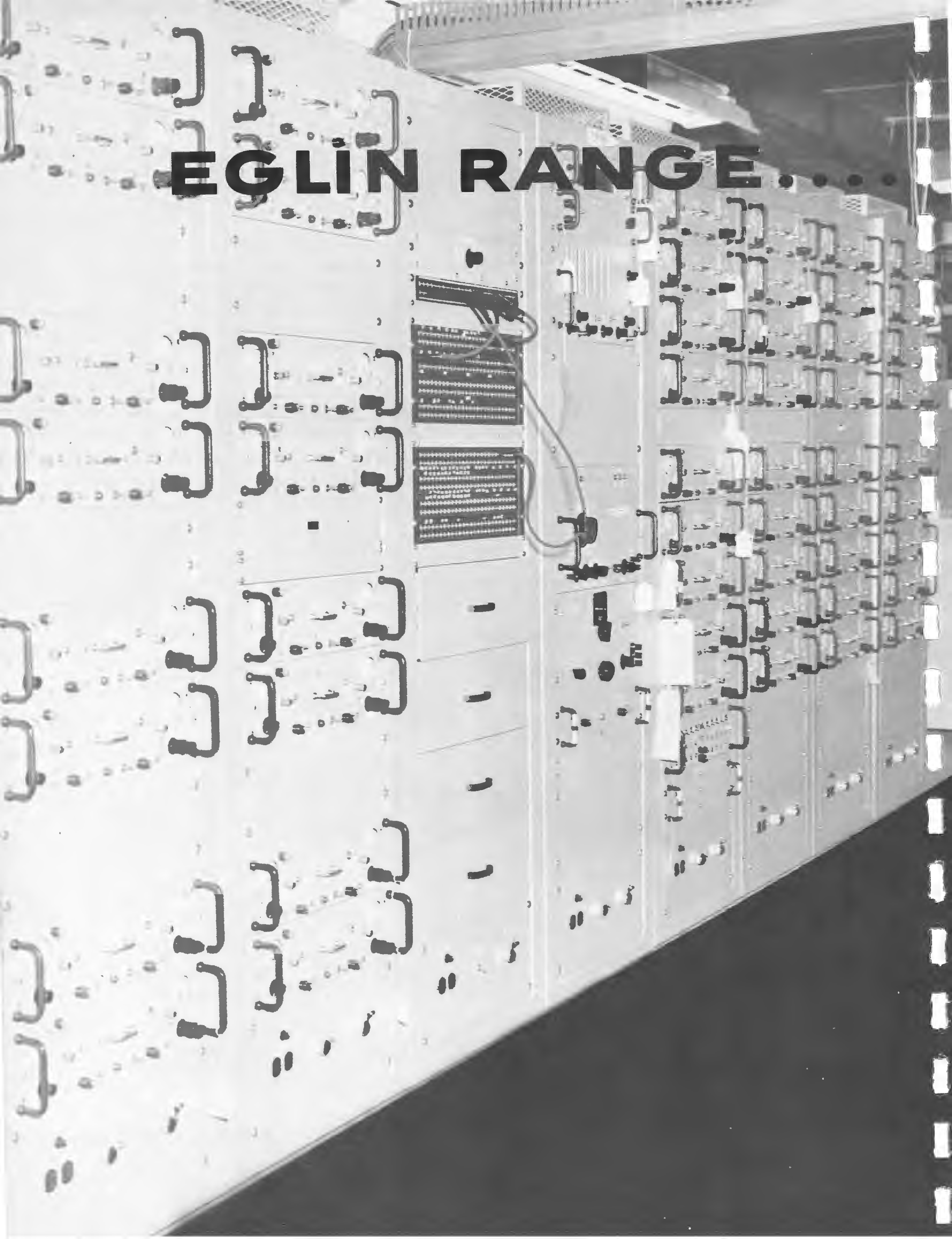
CENTRALIZED OPERATION--Completely centralized operation of all station functions is afforded by a central control panel, which contains all primary power and recorder controls and associated indicators. Test equipment included in the system permits pre-operational adjustment and trouble-shooting. In addition, a 390-jack central patch-panel enables the operator to combine analog and digital lines in any desired combination.

After six months of operation, all EMR equipment in this complex system proved to be extremely satisfactory and no failure reports were received.



MADRE system installation in the Martin-Marietta Co.

EGLIN RANGE....



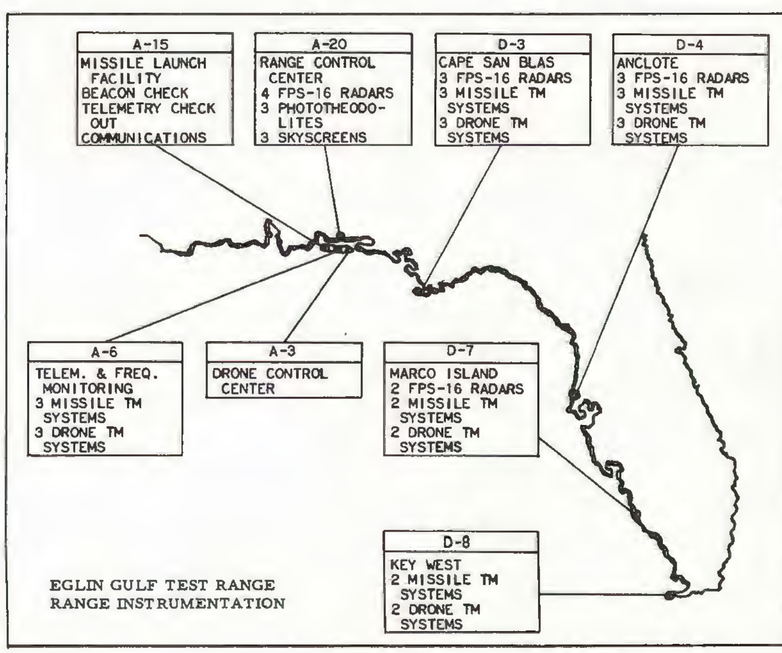
Complete Telemetry and Digital Data Transmission for Vast "Electronic Scoreboard"

At a time when the defense of our country depends so strongly on the development of new and more sophisticated weapons, testing our defenses against modern weapons becomes a problem of considerable dimensions.

In the past to test aircraft and anti-aircraft weapons was a relatively simple procedure requiring only elementary instrumentation. With the advent of high-speed, high-altitude jets and anti-aircraft missiles, however, simplicity has given way to some of the most complex and vast electronic testing systems devised by man.

THE EGLIN RANGE

Such is the case with the Eglin Gulf Test Range centered at Eglin Air Force Base, Florida. Covering 450 miles of Florida's Gulf coast from the Eglin Air Force Base near Pensacola to Key West, the range is one of unusual complexity involving a very large amount of telemetering at eight range sites, a digital data transmission system for transmitting the telemetered data, and a central station where all the data from the eight sites is assimilated.



EGLIN GULF TEST RANGE
RANGE INSTRUMENTATION

The system is capable of handling simultaneously up to three missiles flown against three remotely controlled drones. The range is used to perform operational tests of Air Force interceptor missiles and to train Air Defense Command missile squadrons.

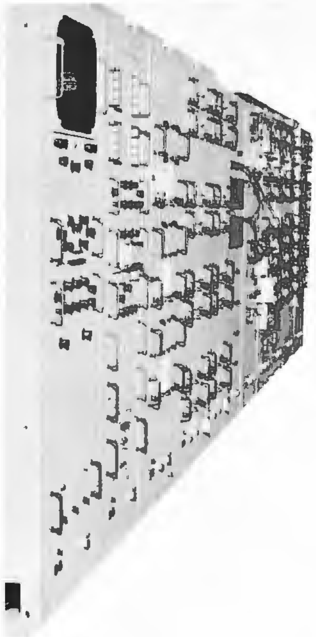
EMR RANGE TELEMETRY--EMR was responsible for supplying, testing, and installing the entire telemetry and data transmission equipment for the system. When the complete system was initially installed, the telemetry portion of the system operated perfectly on the first test flight made to check out the system and has continued to be outstanding during the day-to-day range flight tests since installation. The prime contractor on the project--ITT Laboratories, Nutley, New Jersey--expressed extreme satisfaction with company performance and equipment operation at the conclusion of the contract in 1960.

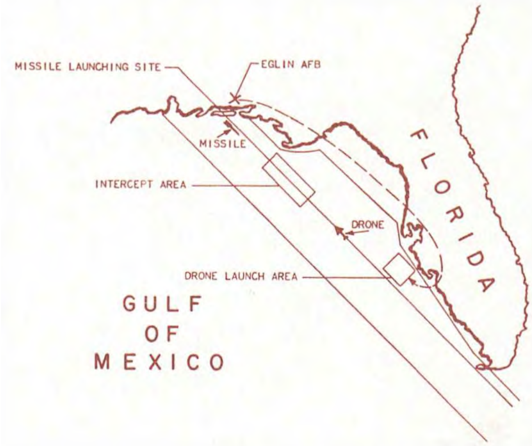
The facilities that are provided for the Eglin Range are unique in that they enable multiple flight testing; control of both drones and missiles is accomplished on the ground; and all of the sites and functions are closely tied together to form an integrated range.

REMOTE PILOT CONTROL--A ground-based pilot is presented with flight-performance information such as heading, altitude, engine rpm, etc., from telemetered flight-performance information and radar tracking information. From the number of telemetry receiving sites located along the flight path, a chain telemetry control system selects the one receiving the best data. The data received at this site is then transmitted by the telemetry data-transmission system and presented on the instrument panel of the drone controller's console. In a similar manner, the best radar positional information is selected by the radar data chain control, transmitted through the radar secondary data-handling system, and presented on the drone controller's plotting board.

When the ground-based pilot, utilizing both the telemetry and radar information, initiates commands to the drone control system for changing the attitude of the drone, these commands are relayed by the control system to the UHF command guidance system, which in turn transmits them to the drone.

TELEMETRY--EMR ground-based telemetering for both missiles and drones at the eight range sites generally consists of tape recorders to record missile composite signals; up to 16 FM discriminators and bandswitching discriminators for FM data reduction; PDM/PAM decommutation equipment for demultiplexing time-multiplex signals; fourteen-channel direct-readout oscillographic recorders for data monitoring; and other quick-look facilities. Also included in the range instrumentation are numerous bandswitching channel selectors, crystal-reference





oscillators, complex patching and switching facilities, calibrators, test equipment, antenna systems, FM receivers, and spectrum display units. Complete back-up equipment is supplied in duplicate at each site to assure that no loss of data occurs during a flight. Besides supplying equipment, EMR conducted indoctrination lectures and equipment check-out demonstrations in plant to familiarize maintenance and operating personnel with the equipment. In addition, a crew of company installation personnel worked on the range sites installing, checking out and mating equipment with other system components and conducting on-site indoctrination for applicable personnel.

DATA TRANSMISSION

In order to present the ground-based pilot with the necessary flight control information to control the drones, a telemetry data-transmission encoder converts drone telemetry data to an eight-bit-plus-sign digital code. This signal is reduced to a sufficiently low rate to be accepted by standard telephone transmission lines by converting it into an NRZ signal and feeding it alternately to two parallel transmission lines. At the receiving end in the control center, digital signals from the two transmission lines are combined and converted into analog signals to drive the pilot's instrument panel.

EMR conceived, designed, manufactured, and installed this digital data-transmission system which is now in operation on range. The entire portion of the Eglin Test Range Instrumentation System performed by EMR was valued at over $2,250,000. During the entire 15-month program no major delivery slippages occurred and final equipment delivery was made one week ahead of the scheduled date. All telemetry has operated perfectly and exactly as anticipated. Although exact equipment failure rates are not known, it is known that the telemetry equipment service record has been excellent, and that the Air Force has accepted the entire system.

707/KC135....

Telemetry System Tests First Jetliner/Jet Tanker

When the Boeing Airplane Company started to develop the first American commercial jetliner and jet tanker, the Boeing 707 and KC135, it was faced with a serious testing problem.

Boeing's previous flight-test experience had shown that the then standard methods of recording test-flight data were too cumbersome, time consuming, and expensive for the highly complex, precision machines used in modern air travel. Up to that time, all data taken during flight-test programs had been recorded on oscillographs, strip-chart recorders, and photorecorders; thus, almost all flight-test data processing had to be accomplished manually, requiring months of exhaustive interpretation for a few days of actual flight time.

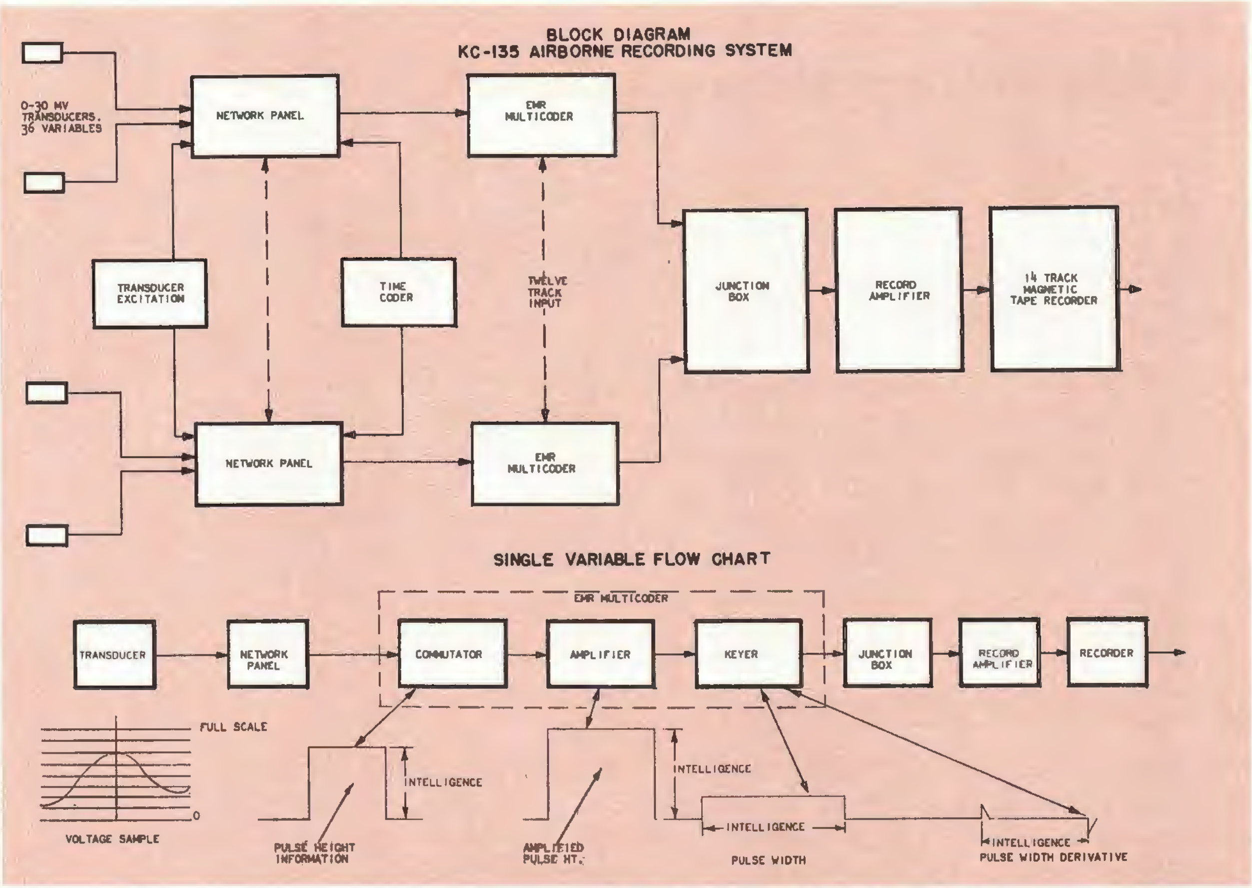
NEW TEST PHILOSOPHY

For this reason, Boeing's Flight Test Staff decided in January of 1955 to start development of an airborne magnetic-tape recording system to be mated with a digital data processing facility. The entire system--known as the Low-Level, Low-Speed, Pulse-Width-Modulated (LLLS-PWM) Magnetic Tape System--was to be designed to permit publication of final processed data within 24 hours after test-flight termination, at lower cost. Although it was known that the initial capital investment for the system would be higher than the instruments currently in use, it was felt that the reduction in the enormous cost of evaluating the data manually would more than offset the original expenditure.

THE EMR FLIGHT-TEST SYSTEM--Time-multiplex telemetry had not yet been developed that could handle the low-level signal requirements (analog potentials in the ± 15 mv range). To help them develop this totally new telemetry system, the Boeing staff turned to EMR--one of the oldest, most reliable telemetry firms in the country.

After two years of intensive investigation, EMR produced a telemetry system using standard pulse-width modulation (PWM) telemetry with the following modifications:

1. A standard 45X20 mode was changed to a 45X2-1/2 mode. By reducing the tape-recording speed by the same factor (from 30 ips to 3-3/4 ips) a tape-recorded signal was produced in standard PWM format.



This permitted slightly over two hours of continuous recording on one 2500-foot reel of tape containing 12 tracks of PWM information.

2. The airborne system accepted the output of 420 transducers in the ±15 mv range, each sampled 2-1/2 times per second. Using the 12-track tape, this permitted eight million readings to be recorded during two hours of flight time.

3. A Remington Rand 1103A computer was used for digital data processing because of its ability to accept variations of character spacing and gap lengths on the input tape. Conversion of the recorded PWM flight data to 1103A computer input tape was accomplished by an electronic digital converter reading one PWM track at a time, but at eight times the speed at which the data was recorded in flight. All computations of the flight data were made by the 1103A after the data had been digitized. Extensive editing techniques were used to limit processing to essential data by means of a separate ground facility provided with strip-chart analog recorders.

This system was designed to handle only quasistatic functions, such as variables formerly recorded by photo-panels and strip-chart recorders; however, it had adequate response to handle 80% to 90% of the data required on the 707 and KC135. The telemetry portion of the system produced by EMR was of such remarkable simplicity, capacity, and accuracy that data normally requiring five months of interpretation were handled in under 2.5 days. Thus, a tremendous reduction in data-processing time and cost was achieved through the pioneering efforts of EMR in the field of low-speed, low-level telemetry.

MAJOR PROBLEMS SOLVED

Typical of the problems EMR engineers encountered in producing the LLLS-PWM system was the data-smoothing requirements. Inherent damping of the oscillograph galvanometers and other recording devices originally used to record the test flight data had eliminated the spurious or unwanted dynamic components from the data records. The almost instantaneous response of EMR's highly accurate PWM system, however, faithfully recorded the actual signal amplitude at each moment of sampling. Elaborate means had to be devised, therefore, to protect the low-range transducers from acceleration environments and from spurious electrically-induced pickups.

Even more difficult to solve was the common-mode rejection problem. The highly sensitive PWM d-c amplifiers would not tolerate fluctuations in common-mode potentials beyond approximately 1/8 volt. If EMR engineers had not come up with the simple but effective solution to this problem, the entire system would have been inoperative.

These and many other problems encountered in this pioneering effort were solved through the extensive experience and skill of the EMR development engineers and the close liaison that was established between EMR and Boeing personnel. By means of the LLLS-PWM system Boeing claimed that PWM data-processing time for the KC135 program averaged only 2.5 days and cost $17.00 per 1000 data points, compared to $125.00 per 1000 points for oscillograph data, and $225.00 for photo-panel data. Although the 707 program was a great deal more complex than the KC135, requiring final computed answers for such parameters as Mach number, true airspeed, engine thrust, lift coefficient, drag coefficient and range parameters, the cost increased to only $22.00 per 1000 data points. At the completion of the project EMR had successfully produced, through the exceptional cooperation and liaison it had established with Boeing, a totally new device to meet Boeing's specific needs in a field in which no prior experience existed.


PLUS . . .

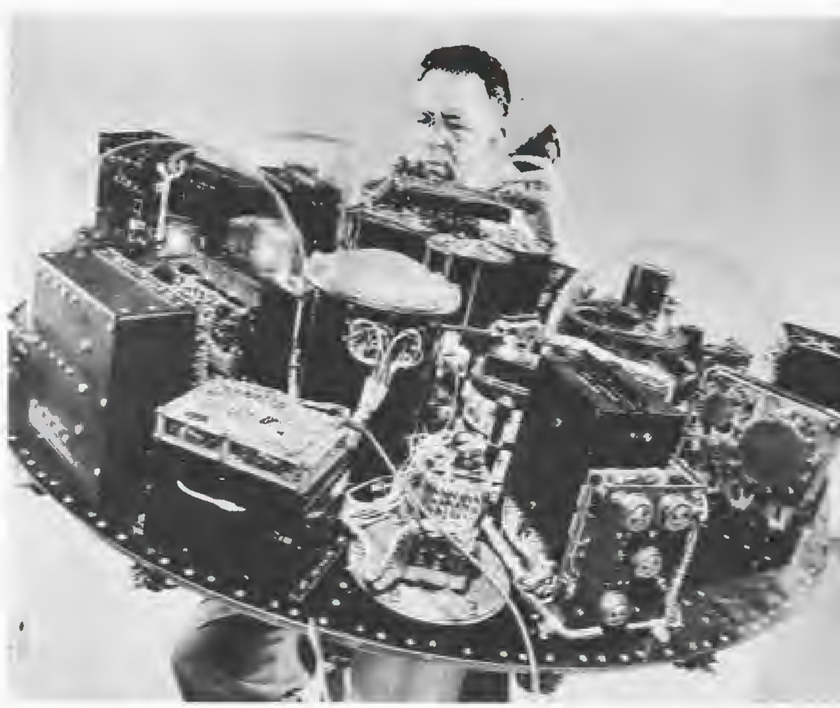
Hundreds of Project Associations

EMR divisions have manufactured and installed more airborne telemetry than any other single company in the industry. Thousands of complete airborne systems for FM/FM, PDM and PAM telemetering have been supplied in many combinations.

PROJECTS

A complete list of missile, aircraft, and satellite programs for which EMR has supplied or is supplying equipment includes virtually every project in the last fifteen years. Among these are: Dyna-Soar, Skybolt, Surveyor, Titan, Subroc, Polaris, Atlas, Thor, Pershing, Redstone, Saturn, Scout, Centaur 6, Centaur 7, Nimbus, Jupiter, Bomarc, Minuteman, Nike Ajax, Nike Hercules, Nike Zeus, Hound Dog, Talos, Terrier, Matador, Navaho, Snark, Big Joe, and Firebee; also Corporal, Delta-Thor, F9F06K2 (target drone), Lacrosse, Sparrow II, Viking, Bumblebee, Project Mercury (man-in-space), Ranger, Project Vanguard (earth satellites), Injun, Project Score (talking satellite), UK-1 (satellite), Tiros I, Tiros II, Tiros III, Tiros IV, Samos, S-3 (energetic particle satellite series), and S-17 (orbiting solar observatory); also KC-135 (jet tanker), B-52, B-58, X-15, X-7, X-3, and Chance-Vought Crusader.

Field performance of EMR systems has always been outstanding as is shown



The Tiros weather satellite

by both service records and reputation within the industry. The reputation is supported by consistently high sales records to the same customers year after year.

CUSTOMERS

Company customers include well-known industrial concerns, educational institutions, and Government agencies: AC Spark Plug, Aerojet-General, American Bosch Arma, Arnoux, Atlantic Pipeline, AVCO, Avro, Baird Atomic, Bell Telephone, Beckman, Beech, Bendix, Blackburn Aircraft Ltd., Boeing Burroughs, Canadair, Datamation, Daystrom, Delco, Douglas, DuPont, Eastman Kodak, Erie Resistor, Ethyl Corp., Fairchild Aircraft, General Devices, General Electric, Goodyear Aircraft, Grumman, Hallamore, N. V. Hollandse, Signalapparaten, Hughes Aircraft, Internation Tel. & Tel., Kidde, Land-Air, Ling Temco, Litton, Lockheed, Magnavox, Marquardt, Martin, McDonnell, Melpar, Minneapolis-Honeywell, Motorola, North American Aviation, Northrup, Olympic Radio, Pacific Gas and Electric, Pan American World Airways, Panellit, Philco, Phillips Petroleum, Piper Aircraft, Public Service Gas and Electric of New Jersey, RCA, Reaction Motors, Republic Aviation, Reeves Instrument, Ryan Aeronautical, SAAB Overseas, Sandia Corp., Seeburg, Space Technology Labs, Sperry Rand, Stavid, Telecomputing, Temco, Texas Instruments, Thiokol, Trunkline Gas, United Aircraft, United Electrodynamics, Vitro, Video Corp., Westinghouse Electric.

The Skybolt telemetry transmitter.

One of three EMR PCM telemetry ground stations which check operation of Bell Laboratories' Telstar communications satellite.

U. S. Air Force Academy, University of California, Case Institute of Technology, University of Dayton, University of Illinois, The State University of Iowa, The Johns Hopkins University, MIT, University of Michigan, University of Minnesota, Oklahoma State University, University of Pennsylvania.

In addition to all the major missile prime contractors, EMR customers in the U. S. Government include: Arnold Engineering Development Center (USAF), Diamond Ordnance Fuze Lab, Edwards AFB, Eglin AFB, Kirtland AFB, all NASA test ranges and data centers, National Security Agency, Naval Air Development Center, Naval Ammunition Depot, Naval Electronics Lab, Naval Ordnance Lab, Naval Research Lab, Navy Purchasing Office (LA), Patrick AFB, Patuxent River NAS, Picatinny Arsenal, Point Mugu NAS, Redstone Arsenal, U. S. Weather Bureau, White Sands Proving Grounds, National Advisory Committee for Aeronautics, and Wright Air Development Center.

QUALITY IN PRODUCTION

EMR's standard product line has established an unchallenged reputation for long-term rugged and accurate performance in all the electronic fields that the company has entered. Some of these products are described on the following pages.

PRODUCTS....

Known for Advanced Performance and Durability

EMR has had more overall experience in designing, manufacturing, and installing both airborne and ground telemetry equipment than any other company in the industry.

Catalog products for data acquisition, transmission, and processing include several hundred different pieces of equipment. As an example of the scope of the company business, EMR has sold more than 16,000 FM subcarrier oscillators since the company has been founded and has supplied over 10,000 subcarrier discriminators or more than the rest of the industry combined.

The first successful telemetry FM discriminator was designed at EMR by G. S. Sloughter now president of the Company. The reliability and basic quality of this typical product can be seen from the fact that EMR discriminator No. 1 (Model 27) was in active use at the Applied Physics Laboratory, Johns Hopkins University, from 1949 until late 1959 and is still being used experimentally.

SUBCARRIER OSCILLATORS--EMR manufactures a complete line of telemetry FM subcarrier oscillators. Categories in scheduled production and readily available include voltage- and millivolt-controlled types, strain gage

Model 238 Millivolt-Controlled Oscillator is only 13/16 inch wide.

controlled oscillators, reactance-controlled oscillators, and potentiometer or dc-amplifier-controlled oscillators. Complementary equipment such as isolation amplifiers, mixers, and chopper-stabilized dc amplifiers are also available.

A line of calibration units complements the airborne FM subcarrier oscillators. Crystal reference oscillators are available for automatic system frequency calibration, and a phase-sensitive demodulator permits calibrating out effects of power-supply frequency variation.

FM GROUND EQUIPMENT

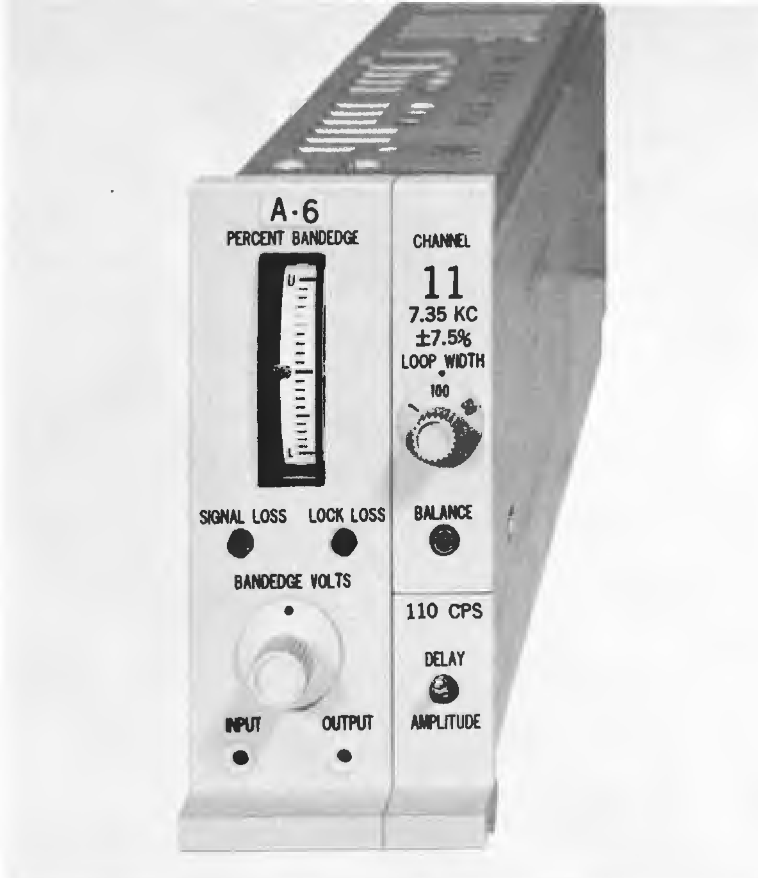
GENERAL--EMR's dominance in the field of FM ground equipment is based upon a standard product line that includes pulse-averaging and phase-locked-loop discriminators, band-switching channel selectors, tape-speed compensators, automatic calibration devices, laboratory-standard frequency calibrators, crystal reference oscillators, amplifiers and bandswitching VCO's. FM ground stations produced by EMR are associated with such well-known programs as PACE, Project Apollo (boilerplate missions), Subroc, Agena, Project Asset, Hound Dog, Pershing, Skybolt, and many others. EMR FM and time-multiplex ground data-reduction stations are standard for all U.S. government missile test ranges, and complete FM stations have been supplied for the NASA/Goddard Sounding Rocket Programs.

EMR now offers a line of miniature solid-state modularized FM equipment from which ground stations can be assembled with custom characteristics. Known as the 200 series, this line consists of units that are matched throughout--even to the standard Model 222A Rack, which can handle several modular combinations.

SUBCARRIER DISCRIMINATORS--Throughout the years, EMR discriminators have continually established new industry standards. For instance, the EMR Model 67F Discriminator is the <u>only</u> telemetry instrument mentioned in the IRIG Telemetering Standards.

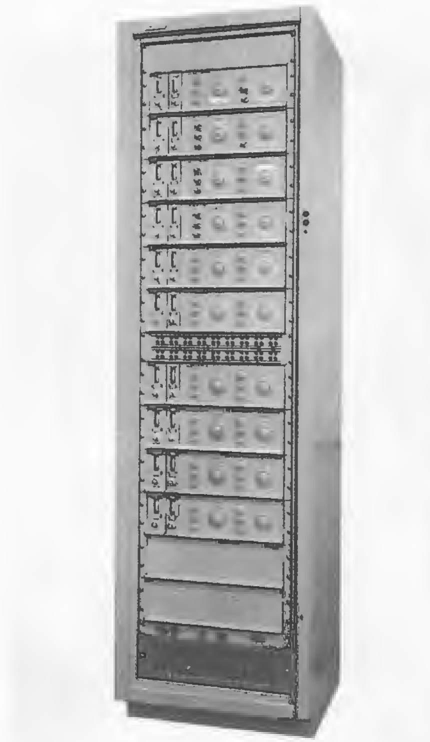
The Model 167 was EMR's first solid-state discriminator with a phase-locked loop. Phase-locked-loop detection in this and later discriminators resulted in remarkable signal-to-noise performance because of the automatic optimization of loop bandwidth and damping regardless of the channel selector used and output filter chosen. This has permitted EMR discriminators to acquire actual flight-test data at signal-to-noise ratios which other discriminators could not match.

The Model 210--performance and reliability in a small package

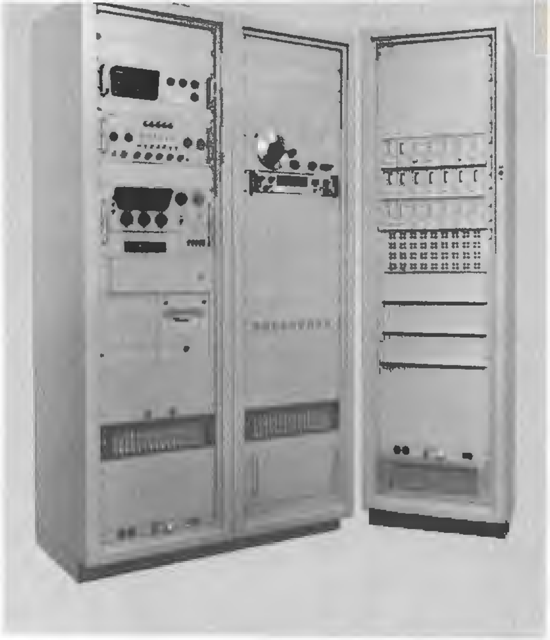


EMR drew upon this vast experience to design discriminators for the 200-series FM ground telemetry equipment. The Model 210 Discriminator is the basic element around which these stations are built; the various available bandswitching and band-tuning units all employ the proven circuitry of the finely constructed Model 210. With a 100-ma output capability, the Model 210 can drive the highest frequency galvanometers available; its 30-db tape-speed-compensation ratio is guaranteed, and its stability of 0.15% of bandwidth for 15 hours of operation had not previously been obtained by any unit on the market. Though moderately priced, it also has 0.05% linearity, a 60-db dynamic input range, and a 60-db rejection of adjacent IRIG-channel modulation.

Other 200-series discriminators having the same electrical characteristics as the Model 210 are the Model 214, 229, and 244. The Model 214 is an extremely versatile bandswitching assembly that utilizes any combination of 18 channel selectors and 18 output filters mounted in a rack. The Model 229 Tunable Discriminator combines the advanced electronic and mechanical design characteristics of the Model 210 with the flexibility afforded by continuous tuning across and beyond the complete range of IRIG telemetry subcarrier channels. The EMR Model 244 Bandswitching Discriminator can be used to select any one of the 23 IRIG-standard telemetry channels rapidly and accurately, and is designed for ground checkout of subcarrier oscillators whenever IRIG telemetry channels are used.



Rack of tunable discriminators for TEL 4 Installation



The EMR telemetry systems in the TEL 4 blockhouse at Cape Kennedy include this two-rack discriminator test analyzer and 18-channel discriminator system

The Model 267, an economically priced subcarrier discriminator, combines the pulse-averaging detection technique used in the service-proven EMR Model 67 Discriminator with the compactness and outstanding mechanical design of the Model 210. In applications where flexibility is not essential, the Model 267 provides a low-cost means for accurate recovery of data from FM subcarriers. The Model 270 is a precision instrument designed especially to cover the frequencies between 10 kc and 5 mc with deviations of ±5 or ±45%. A pulse-averaging discriminator, the Model 270 utilizes interchangeable plug-in channel selectors and output filters.

GROUND DECOMMUTATOR EQUIPMENT

As early as 1958, EMR's group of digital specialists began the development of highly accurate, dependable PCM data-processing units. This work, when combined with EMR's early and continuing research in analog systems resulted in the Model 185 PAM/PDM and PCM modular decommutation equipment. Over 50 complete systems are now operating in various parts of the world. Based on the off-the-shelf building block principle, the Model 185 design permits a customer to select a system that meets his particular requirements. The Model 185 will accept 40% to 90% PAM with either a two- or three-channel frame-sync, PDM, differentiated PDM, and PCM. PCM inputs range from 5- to 33-bit frame-synchronization words, 5 to 128 words per frame, and rates up to 80,000 bits per second. Frame-synchronization word length is independent of data word length.

Outstanding success on this series led to the development of the all-new Model 285 PCM Data Processor, which is designed to meet every requirement for a modern PCM telemetry data-processing ground station. Chosen for such assignments as the Gemini Aerospace Ground Equipment (AGE) and the world-wide NASA Manned Space Flight Tracking Range, its exceptional flexibility make it ideal for a wide variety of mission requirements. This new data processor accepts variable-word-length data within a frame, has a very wide bit-rate range--from one bit per second to 1,000,000 bits per second--and up to four independent subdecommutators. It also includes broadside LSB, MSB, BCD, truncated or untruncated, and parallel recording outputs. Integral self-checking and marginal-testing subsystems are incorporated for complete system checkout.

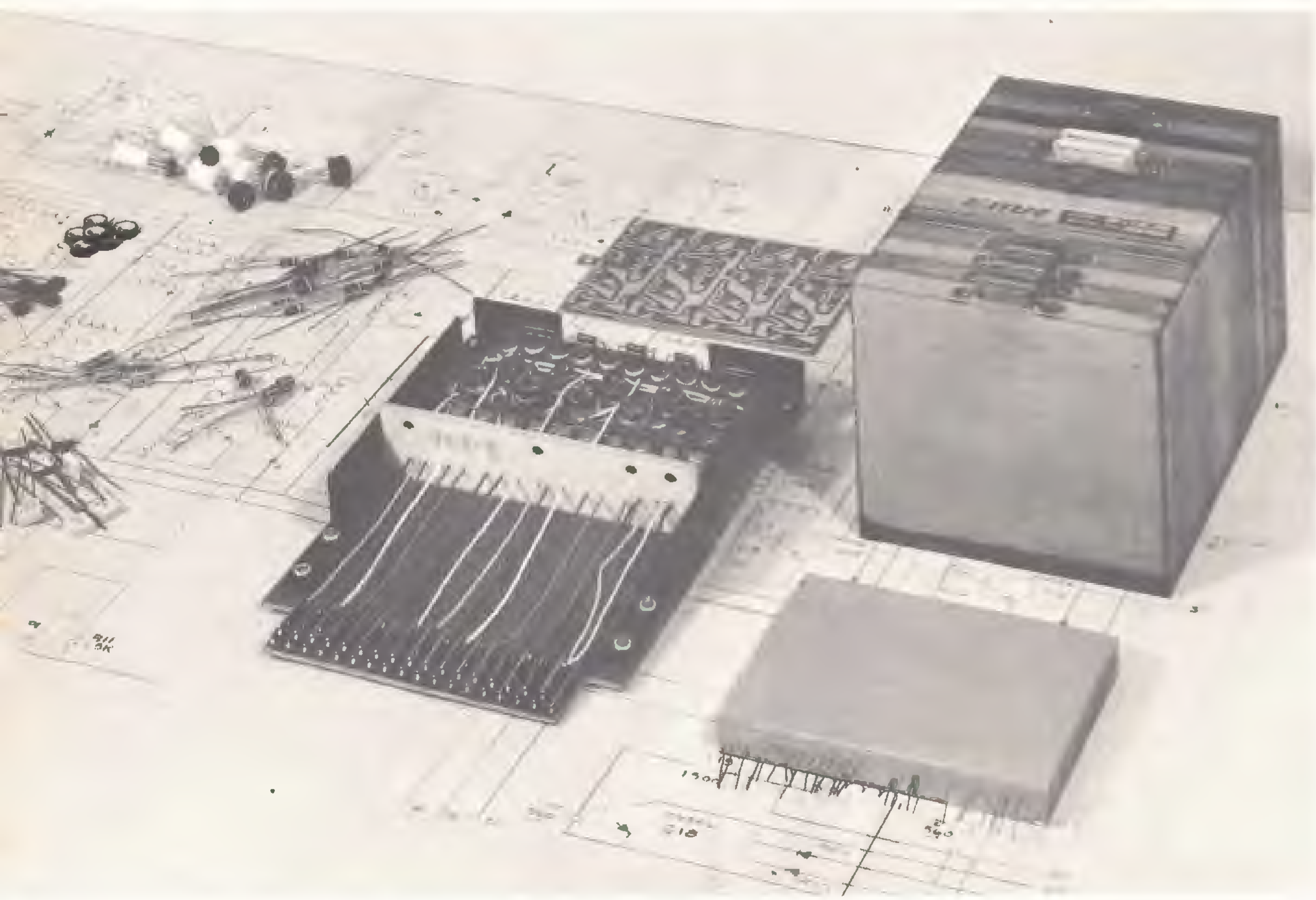
The latest Model 385 is a Model 285 with magnetic-core-memory programming, a random-access element that is extremely adaptable to the control and addressing functions of a decommutator/data processor. For a given memory size, one large format or two or more smaller ones can be handled with equal facility. The core-memory-stored program can be loaded, controlled, or changed by a computer--a feature that is becoming increasingly important in many modern applications.

AIRBORNE PCM SYSTEMS

The superior performance of EMR's airborne PCM systems is the result of many years of research and development by EMR's digital scientists. These systems range from complicated high-speed assemblies for manned spacecraft to small low-power units for satellites. The Gemini and X-20 systems described in detail under "Major Programs," are examples of the former. The EMR PCM multiplexer-encoder used in the Gemini system is composed of a programmer, two low-level multiplexers, and two high-level multiplexers, although the system may be easily expanded to accommodate additional data multiplexers of either type. The Gemini package is very compact, having a component density of 37,000 parts per cubic foot. Its total power consumption of only six watts, its adaptability, and its ability to meet a majority of mission requirements make it ideal for manned orbital missions. This system has a total of 369 channels available with accuracy ranging from 1.0% to 0.5%. The output bit rate is 5.12 kilobits per second.

The X-20 system included FM as well as PCM data processing and, at the time the contract was let, was the largest test instrumentation program initiated. X-20 data words consisted of nine bits including parity, and the basic data rate was 144,000 bps. The system was designed to sample nearly 900 data signals.

The Model 271 and the PCM data processor manufactured by EMR for the S-17 Orbiting Solar Observatory are typical low-power high-reliability PCM multiplexer-encoders for orbiting satellites or deep-space long-mission probes. A given Model 271 system can be assembled rapidly from standard modules, obviating much of the engineering required for tailoring a PCM system for particular missions. It includes an analog commutator, a digital commutator, an analog-to-digital converter, timing circuits, modulator, and a power converter. Some of its outstanding features are a power requirement of only 250 milliwatts, an accuracy of 0.1% with 10-bit resolution, a mean time between failures exceeding 50,000 hours, a weight of 42 ounces, and a volume of less than 70 cubic inches for a 32-channel system.



EMR Model 271 Low-Power PCM Telemeter

The PCM equipment for the S-17 Orbiting Solar Observatory is composed of two digital multiplexer/encoder assemblies and two analog subcommutator assemblies. Designed to sample various data generated within the satellite and convert it to a PCM code for transmission to ground stations, the system is expected to operate for a year with a 0.99 probability of perfect operation. This system offers several additional advantages for satellite applications: only 300 ounces of weight in a 284-cubic-inch package for the entire system, a total of 28 digital and 96 analog inputs, and a power consumption of 920 milliwatts for the encoder and 200 milliwatts for each of the two commutators.

Reliability is the common denominator for all EMR airborne PCM systems. It is attained by minimization of the number of included components, by rigorous selection of components, and by a design that allows particularly wide tolerances for the component parameters. Among the most important of EMR's system approaches to reliability are circuit redundancy (the "quad" concept), functional redundancy (elective-block rendundancy), and highly stable nonredundant systems (using highly refined ultrareliable circuits). These arrangements are supported by the use of special low-power techniques and microminiature components that make redundant (multipath arrangements) practical. The extremely high efficiency, hence low power dissipation, of EMR's low-power circuitry also makes possible an unusually high packing density. Mechanically, most EMR spaceborne units employ wire-wrapped terminals and encapsulation to form rugged shock-impervious units.

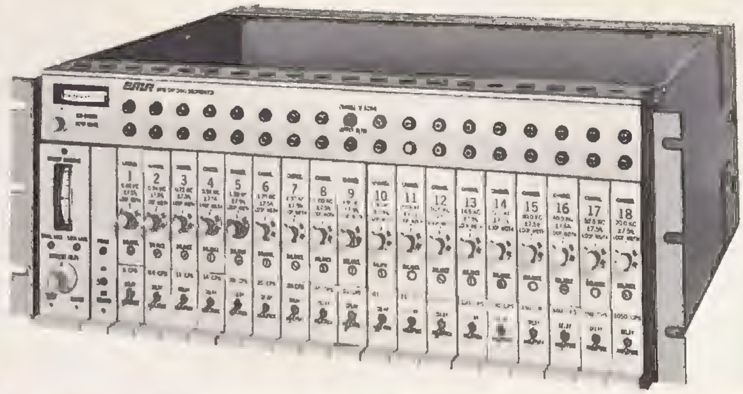
VHF RADIO TRANSMITTERS

The requirements imposed on radio transmitters flown in guided missiles and experimental aircraft for the purposes of transmitting telemetry data are extremely rigorous in terms of frequency stability and spurious radiation. Existing crystal-control techniques, using crystal oscillators and frequency multipliers, are often unusable and generally unsatisfactory. EMR has developed a technique whereby fused quartz, coated with fired silver, is used as a tuned circuit operating at the transmitter output frequency. The stability exceeds that achievable with crystal oscillators. Spurious radiation, as a function of frequency multiplication, is eliminated.

CHECK-OUT EQUIPMENT

Telemetry ground stations periodically require alignment prior to use. EMR manufactures a number of extremely stable units designed to facilitate preflight checkout with a high degree of accuracy. Among these useful adjuncts to any telemetry data-gathering station are a bandswitching voltage-controlled oscillator, a frequency calibrator, a signal simulator, and fixed-frequency VCO's. For checkout and calibration of PCM data systems, a PCM signal simulator is available.

The Model 214 Bandswitching
Phase-Locked-Loop
Discriminator



The Model 244
Bandswitching
Phase-Locked-Loop
Discriminator

The Model 219 PCM
Signal Conditioner

The Model 229 Tunable
Phase-Locked-Loop
Discriminator

AREAS OF TECHNICAL COMPETENCE

Management of large programs demands considerable finesse in many areas. As a consequence EMR has technical groups with substantial experience in areas closely allied to data acquisition and processing. In many of these areas, through self-sponsored research, and accumulation of experience, a strong capability for directing special aerospace electronic programs exists at EMR.

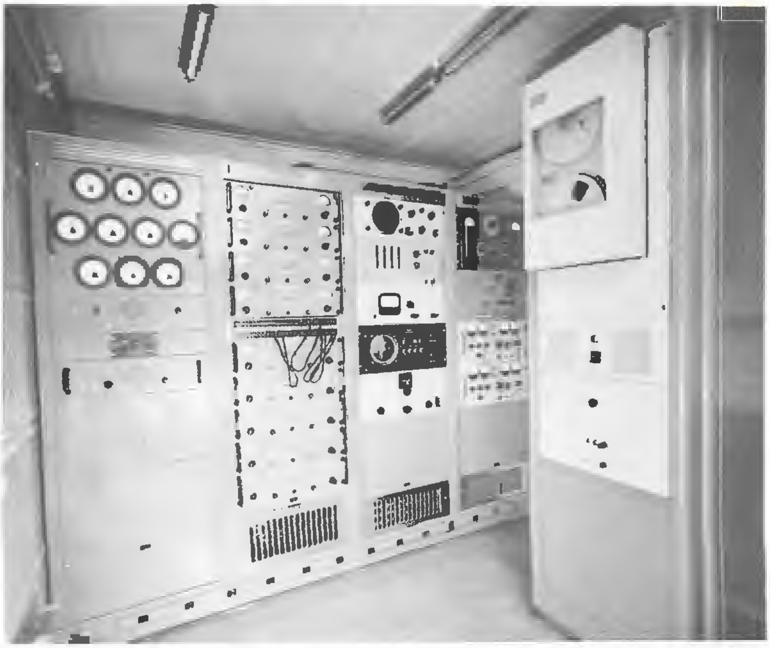
Major areas of technical competence in the company are detailed in this section.

INSTRUMENTATION SUBSYSTEMS

Electro-Mechanical Research, Inc. and its combined divisions provide more over-all experience and a broader range of capability in the data acquisition and processing fields than any other company in the industry.

At the inception of the first missile programs in 1947 the company was called on to perform broad studies in the fields of missile telemetry. These studies led to recommendations for, and subsequent development of the basic equipment which today makes up modern telemetry data acquisition and processing systems. The first successful airborne data-sampling commutators, PDM components, and FM telemetry were developed by EMR under these Navy contracts, as was MADAM, the first automatic digital data-handling machine in field use.

EMR systems have ranged from simple single-function frequency-multiplex systems to very large, complex systems incorporating both time- and frequency-multiplex functions combined with elaborate recording, normalizing, correction, data-conditioning, and format-conversion circuitry. Many of these stations have served as the "front end" of computer-entry equipment and in some cases, the company has



Inside the telemetry instrumentation truck delivered to the Pacific Missile Range.

The Ryan Firebee drone telemetry package.

designed and delivered the buffering and format conversion equipment for this. EMR systems have been installed both by the company and by the customer in every conceivable location. Among these are mobile instrumentation vans, picket ships, missile ranges, static test facilities, naval vessels, down-range islands, aircraft, military vehicles, and numerous others.

Since 1948, the company has designed and manufactured more than 330 complete FM, digital decommutation, and PAM/PDM decommutation ground-station systems of various types. These stations, ranging in size from one to more than 100 racks, have been supplied primarily to military establishments and military prime contractors.

Typical of the airborne systems designed by EMR is the FM telemetering package produced for Ryan used in the Firebee Drone program. This telemetry package contained subcarrier oscillators, mixer, power supply, calibration equipment, transmitter and RF amplifier, making up an airborne 12-channel FM/FM telemetry system. Indicative of company ability to meet accelerated deadlines is the fact that delivery of the first telemetry package in this program was accomplished only seven weeks after receipt of the request for proposal.

INSTRUMENTATION VANS

EMR has designed, manufactured, road-tested and delivered a number of semi-trailer and heavy-duty-truck-type- mobile instrumentation vans in the past several years. All vans are constructed with a carefully designed loading plan to assure optimum over-the-road characteristics. Large equipment is shock mounted both vertically and horizontally. Mounting is such that no special hold-down precautions need be taken before travel over the roughest terrain and equipment is ready for immediate use at destination.

For the U. S. Navy NATC, Patuxent River, Maryland, under contract N600(421)48916, the company delivered a complete semi-trailer van-type telemetry station for completing flight-performance and -handling trials on the latest Navy aircraft. The instrumentation van is a comprehensive data handling and data reduction facility containing FM/FM, PDM, chart recording, tape recording, transmitting and receiving, and intercommunication facilities. The van is fully air-conditioned and includes workbench and test instrument facilities for maintenance. This van is specially constructed to permit its use in land-based, mobile operations or for data handling from an aircraft-carrier flight deck.

In 1959 and 1960, the company supplied three mobile, heated and air-conditioned FM/FM telemetry trucks to U. S. NADC, Johnsville, Pa. under Contract No. N62269-854. All trucks have built-in electric power generators to permit full operation away from primary power sources.

Installing racks of telemetry equipment in the Bell Labs. van to be used with their Telstar communications satellite.

These mobile trucks are in use on the Pacific Missile Range in connection with the F9F-6K2 RD&E Target Drone Program. Equipment installed in each mobile ground station includes tracking antennae, receivers, discriminators and tape-recording equipment necessary to receive, reduce, record and play back data from up to nine FM/FM data channels. Aircraft-type instruments are mounted on a panel to assist in monitoring the test. A company-designed automatic expanded-range altimeter is among these instruments. Company personnel under supervision of the Navy conducted field qualification trials and acceptance tests for the instrumented vehicles at a nearby Army vehicular proving ground. Tests under all specified vehicular environments were uniformly excellent. Delivery was made on schedule.

In February, 1961, EMR delivered a mobile telemetry checkout system to the U. S. Naval Air Station, Patuxent River, Maryland. A mobile telemetry system is incorporated in a heavy-duty truck chassis similar to those delivered to the Pacific Missile Range. The instrumentation system comprises a receiver/discriminator group, a presentation group for PDM and FM data, and intercommunication facilities. Self-contained power supplies are also included.

The Tiros weather satellite

SATELLITE SYSTEMS

Data systems for satellite and spacecraft applications represent an important share of the business of Electro-Mechanical Research, Inc. EMR has supplied many systems for spaceborne data acquisition and for ground data recovery and processing. Over-all company experience in designing, manufacturing and installing such equipment is greater than that of any other single company in the industry.

Reliability demands for satellite instrumentation are particularly severe, of course, and EMR equipment has performed in outstanding fashion in such applications. For example, both Tiros I and Tiros II contain considerable subsystem equipment designed and manufactured by EMR. During early phases of this contract, the company performed many reliability and performance studies on components and major parts of this system; participated in much of the circuit design; and designed and fabricated the beacon tracking transmitter and switching portions of the control circuitry. The outstanding performance of the EMR-designed and manufactured switch in performing hundreds of thousands of command-control operations is one evidence of company capability in this area. Some company experience was also gained on video tape-recorders, video telemetry transmitters, solar cells, satellite power supplies, and a host of space environmental problems.

In another highly successful satellite, Project SCORE, EMR-designed subcarrier-beacon transmitters provided the signals by which the satellite was tracked, and also generated telemetry data. In this satellite, known as the Atlas "Talking Satellite," company equipment operated perfectly for the life of the satellite.

Broad company experience in data systems for satellites has led to several contracts of an advisory nature in which EMR has acted to recommend satellite data systems and manage portions of satellite launch programs. In one of these, "Study of Satellite Telemetry Systems," from NASA, Goddard Space Flight Center the contract calls for the study of data transmission systems for satellite applications. The study is primarily concerned with earth satellites and encompasses the entire range of NASA requirements in this area. The study, now in progress, includes surveys of modulation, transmission, reception, demodulation, and processing methods for use in satellite applications.

Beacon transmitter used in Project Score "talking satellite".

Results of the EMR study will include recommendations for modifications of presently used methods to improve quality and quantity of the final processed data and to increase the speed with which the data can be reduced. The study will also take into account expected increases in data transmission load as well as development of criteria for system analysis to permit choice of the best telemetering system to handle a given data transmission situation.

ELECTRO-OPTICAL SYSTEMS

Today, one of the relatively unexplored yet potentially most profitable areas for future research is that commonly called electro-optics. Electro-optics or the scientific combination of electronics and optics into comprehensive systems is one of the fields which now receive major emphasis within EMR applied research programs. In particular, such techniques as they apply to the rapidly expanding aerospace science domain are being investigated heavily. EMR experts in this field rank among the foremost. Recognition of company competence in electro-optics is implicit in the award of the Project Celescope prime contract to EMR by the Smithsonian Institution Astrophysical Observatory. This project, discussed in detail previously, is the most important and complex electro-optical experiment yet to be put in a spacecraft.

The following paragraphs discuss some of the research and development activity in this area.

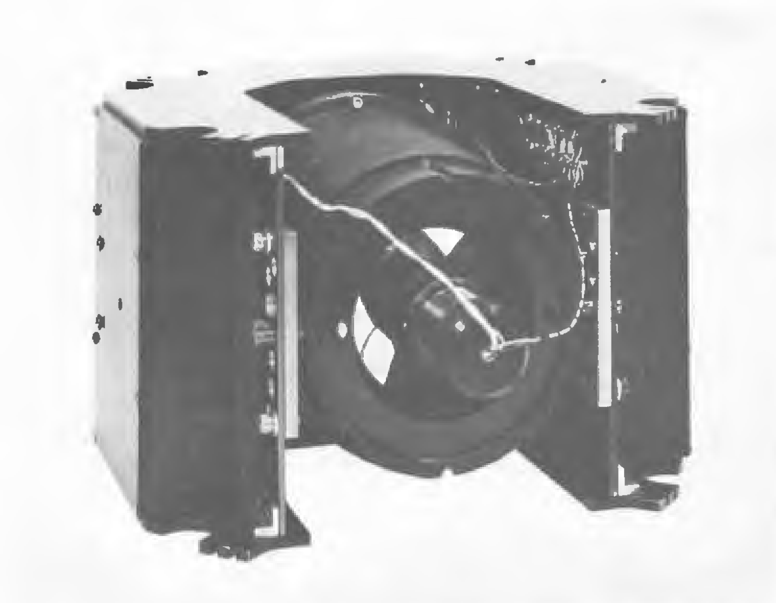
Applications of spectrometric techniques must increasingly rely on methods other than film recording and, to a lesser extent, must even operate without any form of data storage because of the difficulty of the environment, the necessity of securing real time data and the complexity and cost of capsule recovery operations. A study was begun to

The picture shows a precision monochromator with quartz optics on which optical measurements are performed. In this test the quantum efficiency of a photomultiplier tube is being determined.

The effect of temperature on the energy resolution of a photomultiplier is being studied with this electro-optical equipment.

develop a spectroradiometer which would provide real time electric analogs for digitized wide-wavelength-range spectra. The instrument was initially conceived as a missile-borne device in order to examine the feasibility of measuring and telemetering spectral data. As a result of this program, the preliminary design for a family of such instruments was completed, performance specifications and system analyses were completed, and certain of the more advanced concepts were reduced to practice. This instrument, in any of its derivative forms, could be produced with a very short development schedule. Collateral with this, an analytical study was completed in which the transfer function of a spectrometer using electronic detection and transmission, was described in terms consonant with established communication theory.

Wide field imaging optical reconnaissance instruments, using the most recent advances in detection and information processing technology have also been studied in the context of silent satellite reconnaissance. Designs have been evolved having unprecedented sensitivity and information handling capability consistent with present communication performance criteria. In connection with this project, methods have been devised for eliminating the effects of star backgrounds that would normally interfere with the function of acquiring and tracking a moving target. Systems using this technique scan the global horizon in search of objects that have an apparent motion which differs from that of the normal star background. A missile is distinguished from the stars by a rate and angle of motion with respect to the satellite's frame of reference that deviates from the path of the normal star traces.



Ultraviolet target radiometer for Project Trump.

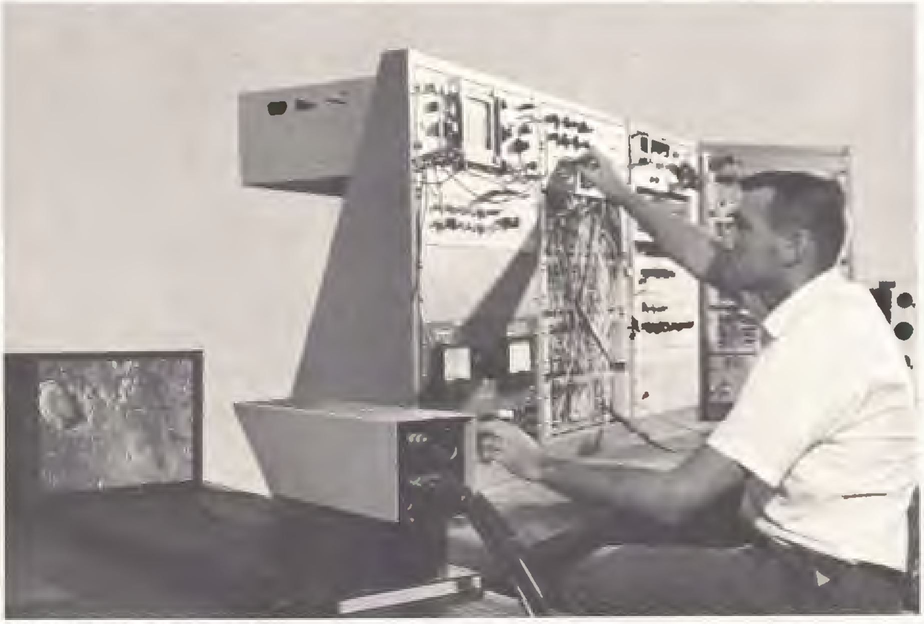
Sensor studies at EMR have encompassed practically the entire communications spectrum from ultraviolet through visible and infrared to VHF. The ultraviolet target radiometer developed for Project Trump is a case in point. During the operational phase of this program, instrumented NIKE-JAVELIN rockets are fired synchronously with missiles to measure the plume radiation in the ultraviolet spectrum during the boost and early unpowered phase of the missile flight.

Rockets carrying the radiometers are fired shortly after launch of the target missile. The inherent payload spin is used as the azimuth scanning mechanism. The spin axis is oriented closely to vertical during the measurement period and has a nominal spin rate of four revolutions per second.

During the measurement scan, a signal is generated each time the target missile appears in the field of view. The amplitude of this signal is a function of target irradience--its shape is a function of target spatial energy distribution. The ultraviolet detector within the telescope is an EMR solar-blind photomultiplier.

EXPERIMENTAL DIGITAL TELEVISION SYSTEM (EDITS)--Several years of company-sponsored studies and such government-sponsored programs as the Celescope Electro-Optical Satellite Payload, Celescope Sensor Study, and the Manned Spacecraft Advanced Television Study has resulted in a laboratory instrument that is of singular importance to the advancement of digital television--EMR's Experimental Digital Television System (EDITS).

EDITS is a variable-parameter digital television research tool that is capable of providing direct statistical analyses of video signals and is designed primarily for television compression research in earth reconnaissance and planetary exploration systems. It offers a practically unlimited variety of parameter variations and combinations. Its specific purpose is to explore the effects of bit errors on PCM pictures, redundancy elimination and efficient encoding, picture (actual video) statistics, display and conversion problems, and subjective picture parameters. The system is currently supporting on a daily basis a comparative study of 15 television compression systems. In addition, it is being used to receive, reproduce, and statistically analyze pictures of weather, reconnaissance material, aircraft, line drawings, and other subjects sent to EMR from government agencies. In these applications, EMR's system design has been characterized by flexibility, moderate cost, low engineering time requirements, and short time schedules. To meet the requirements of these programs, EDITS is implemented with digital modules, thus enabling EMR to proceed virtually from logic diagrams directly to a working digital subsystem.



EDITS (Experimental Digital Television System) provides direct statistical analysis of video signals.

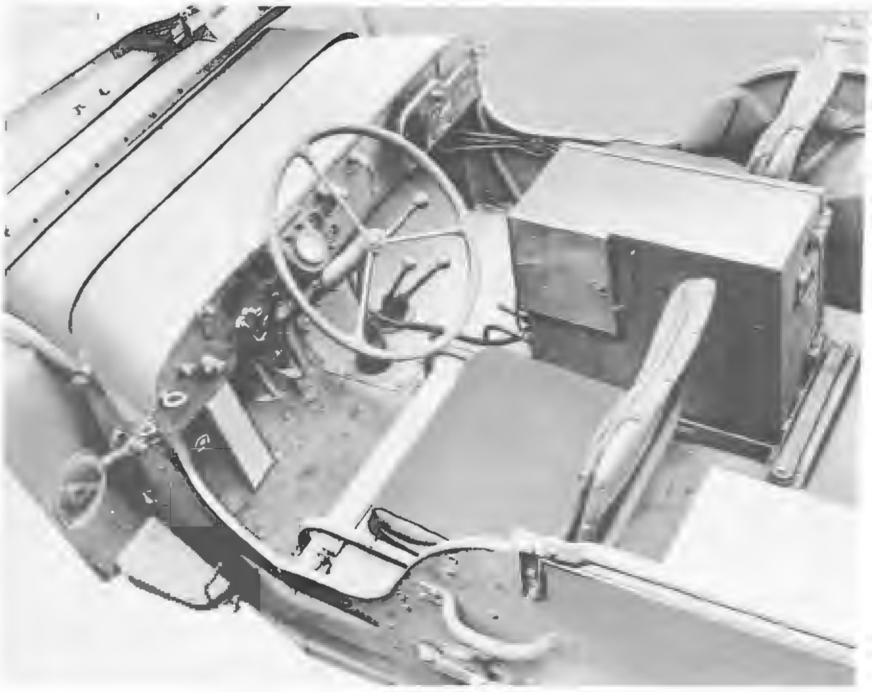
MAGNETIC SYSTEMS

EMR was founded during World War II to apply geophysical detection techniques, perfected by Schlumberger, to the war effort. During World War II, EMR engineering was responsible for many land and underwater magnetic mine detectors. A magnetic mine detection system that automatically stopped jeeps and tanks when they approached land mines was successfully developed by EMR for the Army Corps of Engineers.

In 1954 the company supplied an underwater mine detector to the Bureau of Ships. This advanced system included servos, playback monitor, 25-cycle amplifier, modulator/oscillator, motor generator set, "fish", and other associated components. Advantages of this equipment over previous systems were:

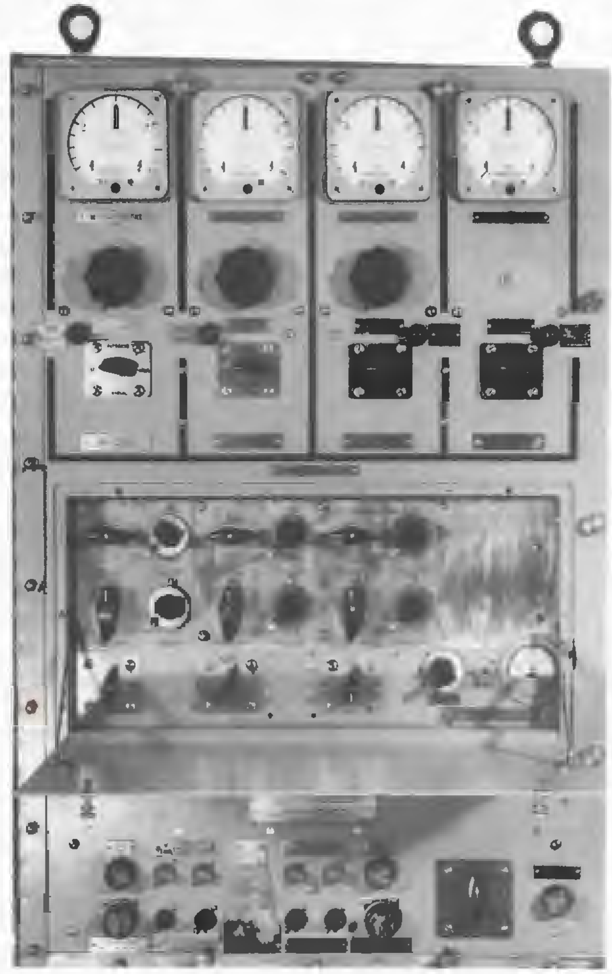
a) Reduced sensitivity to surface noise.

b) Reduced noise attributable to other effects, such as erratic paths, velocity fluctuations in the water, and deflections of the coils.



Jeep mounted mine detector developed by EMR automatically stopped jeep.

Degaussing unit developed by EMR for the U. S. Navy and installed on a Navy minesweeper.



Broad experience in magnetic metal detectors has led to highly successful development of degaussing equipment for the U. S. Navy.

On Contract NObs 53346 EMR supplied automatic degaussing equipment to the Bureau of Ships, U. S. Naval Repair Facility, San Diego, California, for the mine sweeper, U. S. S. Thrasher. This equipment, built and installed by EMR, consisted of control unit, power unit, motor generator set, control starter and magnetometer unit. The mast-mounted magnetometer in this system comprises three components which measure the earth's magnetic field. Current in degaussing coils surrounding the ship is then automatically adjusted to eliminate local magnetic perturbation caused by the ship. This degaussing system is so successful in practice that the U. S. Navy has standardized on it for all minesweepers and designated it EMS-1.

EMR also developed an underwater magnetic detector, designated AN/PRS-5, for locating ferrous and non-ferrous metals. This device is used by naval underwater demolition teams for locating underwater mines at beach approaches.

Another EMR research team originated a method of magnetizing small discrete areas of barium ferrite material. By radially magnetizing a flat disk of this material with the proper code pattern and reading out the pattern by means of a pickup coil, it is possible to obtain an accurate digital-code reading which is a measure of the angle the disk has turned through. This has been applied to a line of shaft-position digital encoders with exceptional characteristics. Since these devices are all magnetic and noncontacting, they impose no load on the shaft they are reading, they are remarkably rugged, they may be read out without deterioration for indeterminate periods of time, and they can be read "on-the-fly" at high speeds with no ill effects. Such devices are particularly valuable in reading out shaft positions in machine tool, radar, weather forecasting, and fire control devices.

As a natural outgrowth of military magnetic systems, EMR has developed a metal locator which permits detection of both ferrous and non-ferrous metals. Circuitry is such that this device operates for long periods of time in industrial environments without adjustment. It is particularly useful for locating ferrous and non-ferrous metal in food or drug process plants.

Control unit of EMR's industrial metal detector.

FIELD SERVICES

EMR's field service organization is a smoothly functioning group of technically competent specialists specially trained in four major areas: field engineering, customer services, spares provisioning, and manuals and training. Each area is strengthened by its relationship to the others. Field engineers, for example, frequently provide customer service in the form of a training course, using lesson guides and technical manuals for reference material.

FIELD ENGINEERING--Field engineering teams provide support for installation, maintenance, operation, and modification on all programs requesting this service. Each team thoroughly indoctrinates itself in its assigned program by following the equipment from the drafting boards through manufacturing. In most cases, the field engineering team performs the acceptance tests on the equipment before it is shipped, and then again for the customer when the equipment arrives at its destination and is installed. Every effort is made to preserve team integrity; when assignments are changed, teams are shifted as complete units so that each team member knows the capabilities of each of his team mates, and the group continues to function at optimum efficiency regardless of the assignment.

CUSTOMER SERVICES--EMR has placed customer services groups strategically throughout the United States to facilitate repair, adjustment, and technical consultation for the standard product line. These groups are never more than a phone call away from the customer and are prepared to give service day and night. Maintenance centers are used as bases and are fully equipped to provide nonemergency repair, adjustment and alignment, and modifications to all of EMR's standard products. The customer services group also provides instruction for customer personnel in the operation and maintenance of all EMR equipment.

SPARES PROVISIONING--The spares provisioning group is permanently based at EMR-Sarasota to provide logistic support for field engineers and customer services groups. Spares provisioning obtains and distributes all necessary installation tools and spare parts for major programs in the field. This group is also in charge of all spares documentation and prepares provisioning spares lists, estimates the costs, writes pertinent portions of proposals, and generates all the parts lists for technical manuals. To perform these functions as quickly and effectively as possible, direct communication lines have been established between spares provisioning and all pertinent departments of the Sarasota Division such as Procurement, Manufacturing, Reliability, and Marketing. Thus, requests for spares can be filled almost as soon as they are placed.

MANUALS AND TRAINING--This dual-function group consists of technical writers, instructors, editors, illustrators, and typists who collectively generate all technical manuals and training materials for EMR's Sarasota Division. Technical manuals produced by this group include operating and service instructions for all standard products and major programs. In addition, this group prepares all necessary training course lesson guides and supporting material for both customers and EMR personnel.

EMR MANAGEMENT PROFILE

Dynamic and Adaptive

Its Philosophy — Decentralized operating functions with sufficient autonomy to preserve initiative and dynamic creativeness throughout the fabric of organization. Discipline by chartered responsibility — not by edict.

Its Personality — Dynamic leadership, close participation, forceful innovations, technical competence, functional specialties, boundless resources.

MANAGEMENT AT EMR...

A Planned Integration of the Following Factors:

o Dynamics:	Demonstrated by a primary goal of industry pre-eminence based on aggressive and knowledgeable management.
o Balance:	Achieved by managerial selections employing equilibrium of talents in all operating organizations.
o Standards:	Maintained through a high technical acumen in individual fields of specializations, proven facility for teamwork, complete dedication to specific assignments.
o Leadership:	Demonstrated within our industry through tangible achievement. Achieved within our ranks through optimum use of all available resources.
o Planning:	Recognized to be a pertinent factor in our past successful operations.
o Control:	Acknowledged to be the most important tangible output of management when applied within enlightened limits.
o Human Relations:	Characterized by a distaste for artificial stratification of the organization, coupled with a recognition of individual values and ethics.
o Incentives:	Provided for the individual by rewarding personal growth with advancement. Provided for the total company through attractive profit-sharing provisions.
o Loyalty:	Proven by an impressive record of less than 1% turnover of professional personnel over the last three years.

MANAGEMENT METHODS

The EMR concept of large program management combines the essential ingredients of corporate authority, maturity, and aggressiveness. In order to properly perform the functions of management, these talents must be combined and disciplined within an appropriate framework of procedures and delegated responsibilities. These procedures are developed in an orderly fashion consistent with the evolution and growth of programs and their scope.

ORGANIZATION FOR LARGE PROGRAM MANAGEMENT

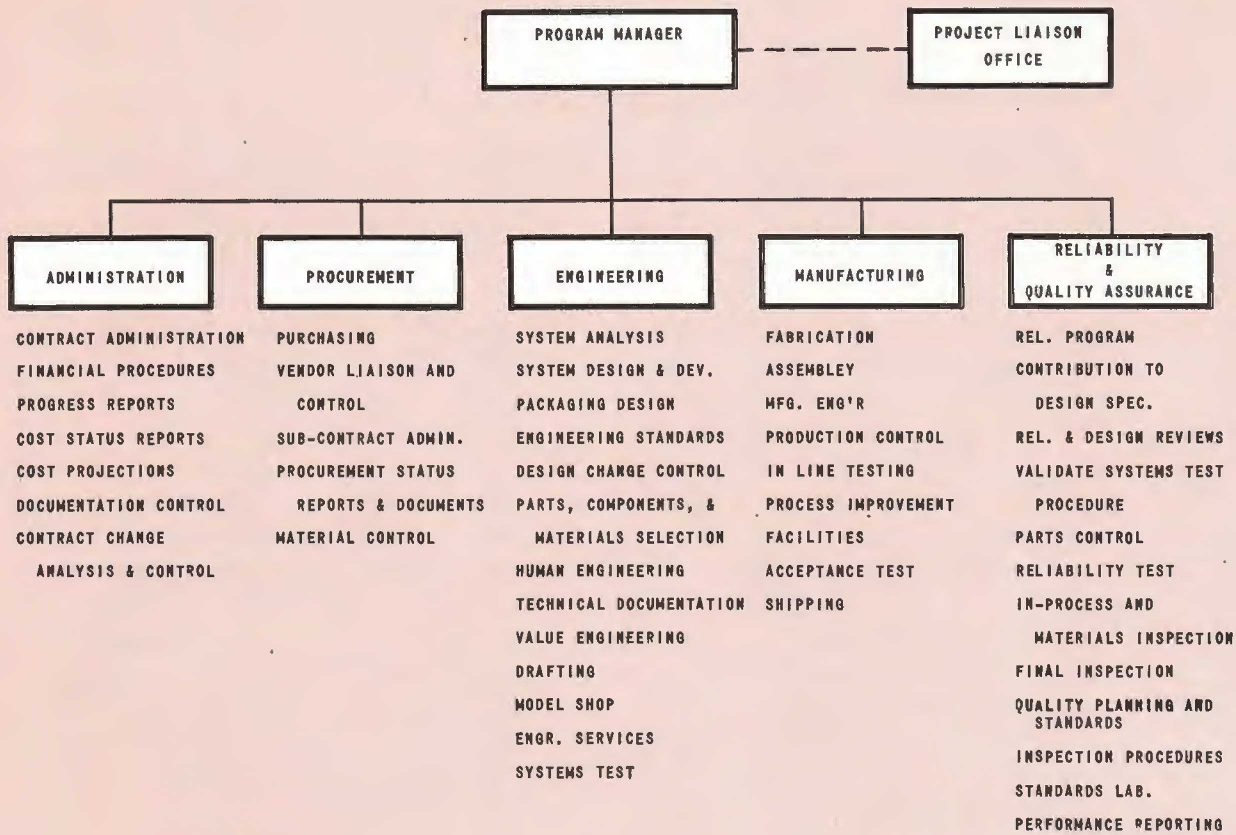
Through successive innovations, specialized techniques have been developed at EMR to engender characteristics that provide program management concepts to achieve the following qualities:

--Maximum utilization of available skills and resources.
--The advantages of cross-correlation of techniques from similar programs.
--Optimum utilization of senior technical talents.
--Efficient cost and schedule controls using streamlined feedback techniques.
--Rapid reaction and efficiency in adjusting to program changes.

Program direction is a prime responsibility of the Sarasota Division General Manager and the Program Manager he assigns to the project. Reporting directly to the President, the General Manager can immediately expedite policy resolution and may draw on all corporate resources as appropriate to the conduct of a specific program.

Reporting directly to the Program Manager is a team of managers responsible for Engineering, Procurement, Quality Assurance and Reliability, Marketing and Manufacturing. The allocation of functional responsibilities within a program management structure illustrates a logical configuration with built-in "checks and balances."

This professional management group is highly skilled in handling the rapidly changing directions of space-oriented technology. By making maximum use of available skills and resources, cross correlation of techniques from similar programs, and senior technical talents, optimum efficiency in all programs is assured. The entire divisional organization is infused with disciplines totally responsive to governmental contracts.



FUNCTIONAL ORGANIZATION FOR LARGE PROGRAM MANAGEMENT

UTILIZATION OF RESOURCES

Using programming techniques, the project management is implemented within a comprehensive project structure. These programming techniques provide the maximum deployment of company-wide facilities and talents as they are required for project support. This approach assures the efficient and effective mobilization of all task units to meet varying program needs, results in a minimum liaison complex, and makes most efficient use of the capabilities available within the contributing operating organizations. This procedure also helps avoid the duplication of Company capabilities with a consequent economy of program costs. The concept is equally applicable to the early design stages, the hardware phase and the field support activities during the evolution of the program.

PROGRAM MANAGEMENT

The Program Manager serves as the focal point for all operating matters pertaining to the project within EMR, with the prime contractor, and with other associated agencies. He has authority to plan, assign, and budget program tasks, as well as to require fiscal and status reports. He has the responsibility of monitoring all program operations, establishing standards of performance, preparing requests for added corporate resources, establishing consistent program policies, and above all, providing unifying leadership for the program.

Initially, the planning and implementing of the project organization, and the explicit definition of interfaces of responsibility constitute his primary tasks. As the program progresses, the primary preoccupation of the Program Manager shifts toward close monitoring of equipment design status, equipment fabrication and test, and reliability verification. Near the final phases of the program his major attention is focused on preparations for production, with attendant requirements for cost reduction, production tooling, change management, and system confidence testing. During all phases of the program, the Program Manager works very closely with the Prime Contractor to ensure absolutely the realization of all program objectives.

When other EMR Divisions participate in the program they are directed by the Program Manager utilizing direct lines of communication and authority to operating managers in any of the participating EMR Divisions. In the case where work is to be performed outside the Sarasota Division, funds are released only after agreement between the Program Manager and the affected Division has been reached with respect to a detailed program plan. If necessary, and as an expedient, areas of conflict in planning, or performance, are resolved at the General Manager level.

An integrated team of functional managers, responsible for the day-to-day problems associated with the control, design application, and testing of individual units and subsystems, reports directly to the Program Manager. Thus, Program Management is responsible for Administration, Engineering, Manufacturing, Purchasing, Field Services and Support, Quality Assurance and Reliability, and Engineering Services.

In order to apply the maximum depth and maturity of key personnel resources to the management of the program, the use of a "double boxed" organization configuration (i.e., parallel redundancy in the organizational network) is established for certain managerial functions. In these cases, a fully qualified assistant assigned to the program on a full-time basis reports to the Manager.

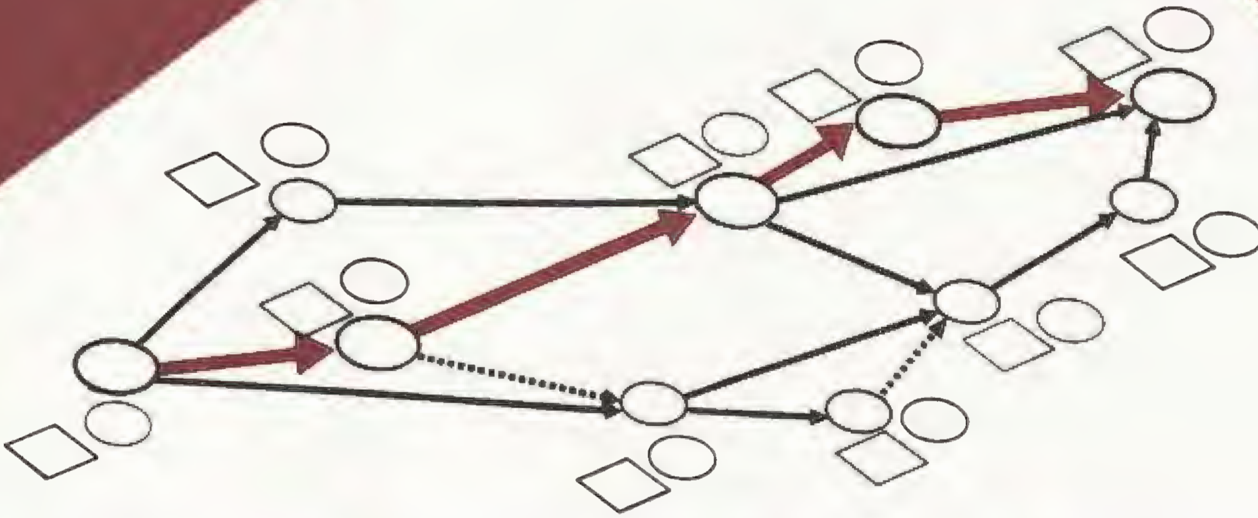
OTHER SPECIAL MANAGEMENT TALENTS

Sophisticated management of complex programs requires a complement of standard management functions such as personnel management, manufacturing, subcontracting and procurement, marketing, etc. It is a matter of pride that these groups operate within a disciplined framework of efficiency and teamwork and have made vital contributions toward the total growth and success of the Sarasota Division.

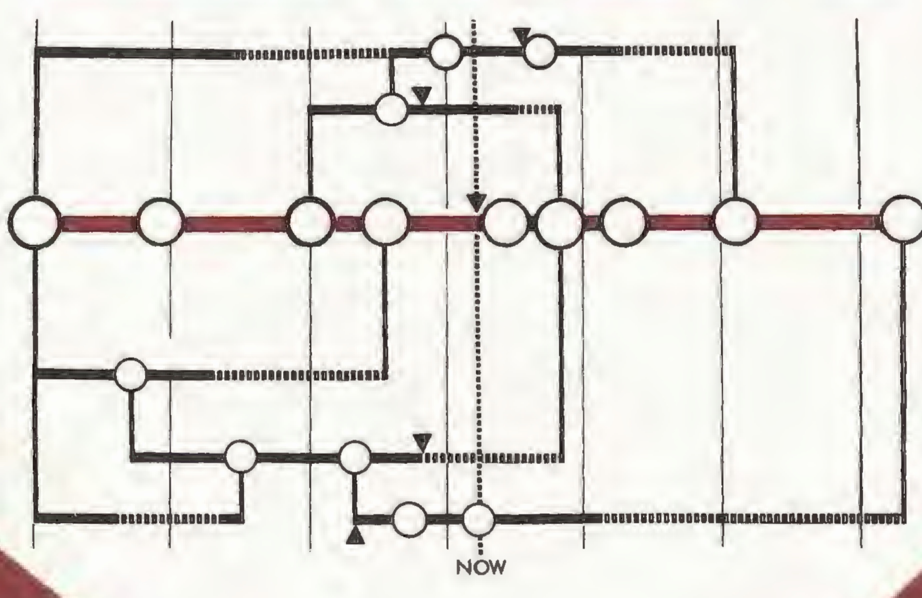
From these functional groups a great many procedural innovations have originated. Rather than describe these in great detail or delineate the statistics of improvements in operation that have been achieved, a few examples of the more general innovations are included in the following paragraphs:

- Cost and Product Performance Improvement Methods
  Cost reduction programs have been implemented at operating levels by (1) the use of practices designed to minimize direct overhead and general and administrative costs; (2) careful monitoring of customer-sponsored and self-sponsored research programs; and (3) application of value engineering to EMR products and processes. Utilization of value engineering disciplines and techniques provides meaningful and logical directions for achieving lowest total cost, while maintaining essential functions. It necessitates an objective appraisal and analysis to achieve a cost without adversely affecting the essential operating characteristics. The basic principle of value engineering is to conduct reviews of a product, project or process by personnel who are qualified, but not previously involved with the subject being treated. EMR, especially with certain product lines having high rates of production, has shown significant results from application of these formal costs reduction programs.

- Program Evolution and Review Techniques (PERT)
  EMR has developed a comprehensive capability and appreciation for the use of PERT techniques for scheduling and as a vehicle for progress reporting. The extend of its usage ranges from the presentation of total program networks to detailed analyses of



PERT



the myriad of individual tasks which comprise the fine structure of the program.

The PERT approach to scheduling has been applied by EMR to a whole spectrum of programs. Typical examples include the total Dyna-Soar Test Instrumentation System and current self-sponsored Product Development Programs.

Working knowledge of PERT is utilized at all operating levels. Therefore, data for the master networks is obtained directly from the level of supervision responsible for working to the committed schedule. Data for the networks is collated under one administrative group which is also charged with the responsibility of analysis and eventual follow-up against planned progress. Experience has been gained in presenting the networks in the several accepted formats, and in hand-computing flow times for networks of approximately two hundred events, or smaller. Facilities for machine analyses of networks, including cost parameters, are planned for the near future.

- <u>Master Scheduling and Cost Controls</u>
  Enlightened management decisions applicable to cost controls, schedules and budgets require that current status information and projections of future status be readily available at many levels of detail. This fundamental requirement can only be met with comprehensive systems for the collection, dissemination and analysis of operating data. Such requirements can be satisfied by programming techniques which encompass not only in-house operations, but also those of contributing subcontractors.

COST AND SCHEDULE REPORTING - I

In order to provide the required input data for the system, two standardized forms are used. These forms are distributed to the various line managers that have received assignments to perform specific tasks which form the elements of the over-all program. The manager of each of these tasks schedules the fine details on one of these standardized forms. A composite of the individual task schedules then constitutes the fine structure of the master phasing schedules. These master phasing charts are presented in a similar format and are applicable to the over-all program or its major phases. As the program progresses, actual performance data at the task level is displayed adjacent to the estimated flow time as originally projected on this form. Progress can be quickly compared with the projections for the purpose of flagging discrepancies and enabling corrective action to be taken promptly. Using this build-up of scheduling data it is possible to derive "big picture" presentation of the total program, and at the same time maintain detailed performance records at the task level.

A companion cost estimate form is also utilized. It is generated on the basis of the scheduling flow time projections and is originated for the same level of task effort. Estimated manpower in various labor categories--purchased equipment, parts, travel, and subcontracts--are also projected on a monthly basis. Marginal notes on the form are to be utilized for specifying requirements for additional capital equipment or facilities which are necessary for conducting the task within the projected time.

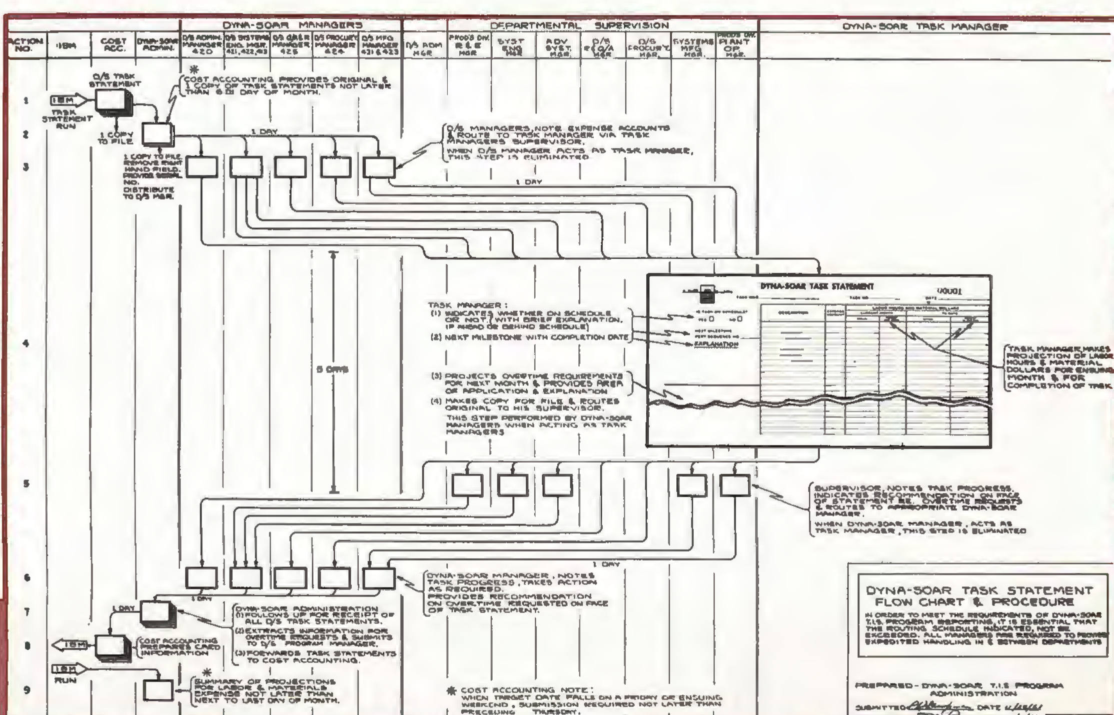
Once the schedule and cost estimate charts are generated by the Task Manager, they are submitted to the Program Manager for approval. Subsequently, the charts are summarized into larger areas of the total program and submitted to division and corporate management for final approval. Once approved, the schedule projections and cost estimates for the task constitute the official basis upon which the program is monitored and controlled. During the course of the program the cost estimate forms are reviewed by the Task Manager for his current projections of the labor and material required to complete the assigned task.

COST AND SCHEDULE REPORTING - II

An extension of this concept has been developed for the Dyna-Soar Test Instrumentation Program at EMR for The Boeing Company. In this case the various equipments which form the total subsystem have been logically segregated according to the various functional components. Each of these components is further designed for various common subtask functions such as design and development, production, engineering, etc.

The cost and schedule projections for each of these program segments are given an identifying code. The cost estimates are generated in the sequence which was previously described. An added sophistication has been realized by tabulating these individual cost projections by IBM tabulation equipment. Thus, these projections are accumulated by the same procedures used for actual costs. Therefore, the system can operate in a closed-loop fashion since cost experience and cost projections are accumulated and presented side-by-side. Furthermore, the IBM equipment can summarize the raw data in any combination of interest. Thus, cost experience and projections can be quickly printed out for one functional subassembly, a subsystem, or the total program. Furthermore, time history of projections and experience for any combination or permutation of cost elements can be summarized and presented. The schematic diagram shown below illustrates the flow of data in the system. The essential output of this system is a summary of IBM tabulations of data which are provided to management on a monthly basis; special reports can be produced on request. Such reports, even those with special combinations of data, are produced within several hours. The results which have been achieved with this program have been gratifying, especially when dealing with reprogramming requirements for changes in program direction.

Comparison of experienced costs to date, estimated schedule accomplishments to date, schedule projections and current estimated costs to complete vs. originally estimated costs to complete provide a detailed insight into the task cost and schedule status. With summary data derived from these comparisons, it is possible to analyze the over-all program status on a mathematical basis and to apply corrective action at the task level in a timely and efficient fashion. The over-all result is a very flexible and powerful system for distilling performance and projection data into a meaningful form for monitoring and control at all levels of management.



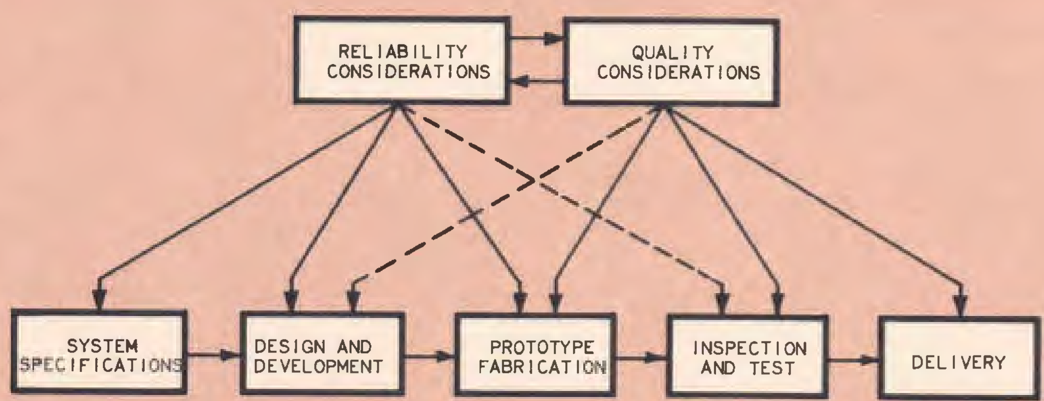
RELIABILITY AND QUALITY ASSURANCE

Thorough, Competent, Responsible

EMR management concepts give heavy weighting to reliability considerations. This orientation has evolved as a logical recognition of one of the basic obligations of our industry.

EMPHASIS

EMR feels that quality and reliability considerations are as important as those of engineering and manufacturing in the context of space technology. This is particularly true for man-machine systems in which failure of the machine may jeopardize the man. As a consequence, reliability and quality assurance are an integral part of our conduct of the entire development process.



INTERRELATIONSHIP BETWEEN RELIABILITY AND QUALITY IN SYSTEM DEVELOPMENT

Reliability and quality determinations effectively reinforce and act mutually to produce a product which is both fully adequate for its intended use, and one which meets the procurement specification point-for-point.

Since reliability cannot be forced into an end-product after development, EMR's basic philosophy is that reliability must be achieved in design, assured in production, and demonstrated during reliability tests and end-product use.

DESIGN AND RELIABILITY... A Team Effort

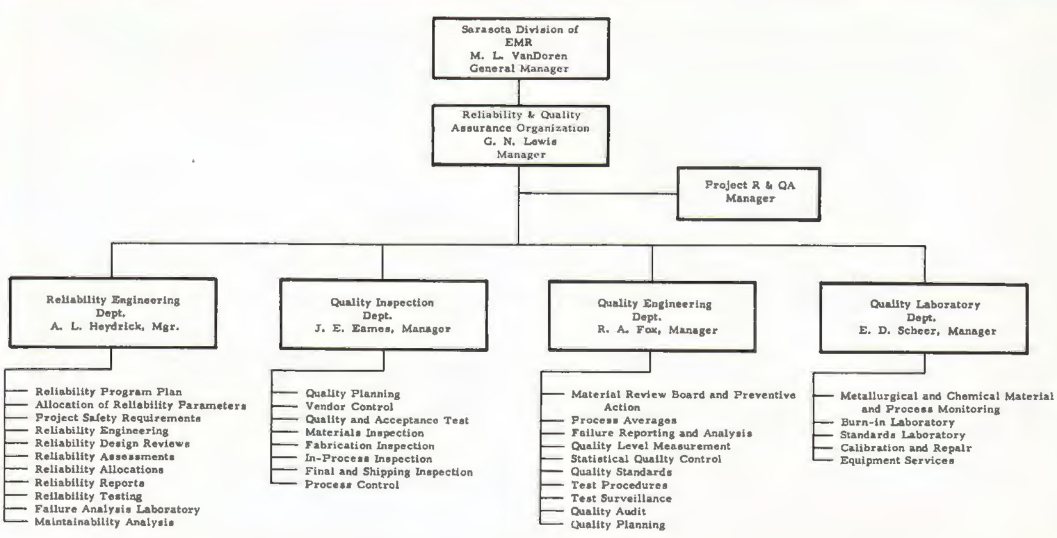
EMR Management has assigned the achievement of reliability goals as a basic responsibility of the design engineer. To provide him with specialized guidance within a framework of normal line supervision and control, the Reliability Organization has been established as a service function reporting directly to Division Management.

If, at any time during the design phase, it is apparent that the inherent reliability of a design will not fulfill its reliability objective, the Reliability Organization is responsible for immediately notifying the Project Engineer of the corrective action that must be taken. The reliability deficiencies are specially defined and the areas of design change are recommended.

The Quality Control function of Reliability and Quality Assurance Department is vested with the authority to stop any phase of manufacturing or test that is resulting, or will result, in degradation of inherent reliability or deviation from contractual specifications.

The reliability organization also has responsibility for: (1) preparing and coordinating reliability programs that will result in fulfillment of the system-reliability objectives; (2) providing empirical knowledge, methods, and techniques to design personnel; and (3) keeping abreast of advances in the state of the art in reliability sciences and techniques.

Taken as a whole, these functions establish reliability as a prime requisite in all EMR operations, from engineering concept to customer use.



RELIABILITY & QUALITY ASSURANCE FUNCTIONS

STAFFING

The emphasis that EMR places on reliability is best demonstrated by the high ratio of reliability engineers to design engineers--at present approximately one to seven. The quality of this group, in terms of training and experience, is exceptionally high:

- Training and Affiliations--All of the personnel are college graduates in electrical, mechanical, or statistical engineering; two hold more than one bachelor's degree, and another has a master's degree in electronics. Each of the men is affiliated with one or more of the following professional organizations: IRE, SAME, ASQC and ASA.

- Experience--The reliability manager and his staff have an aggregate of 43 years experience in reliability, electronic design, packaging, component selection, quality control, statistics, and test. The manager has 12 years experience in reliability; the engineers have from 2 to 10 years experience with an average of 6.2 years.

RELIABILITY PLAN

The reliability program is divided into three phases for control purposes:

...Design Achievement Phase: Details the controls, actions and techniques necessary to achieve specified reliability.

...Production Assurance Phase: Details the Quality Assurance activities required to assure that achieved reliability is not degraded during production.

...End-Product Verification: Details the test and evaluation techniques that the equipment must undergo.

DESIGN ACHIEVEMENT PHASE--This phase consists of thorough control and analysis of design while equipment is undergoing development.

- Reliability Allocation - Reliability allocations or budgets are performed as soon as possible to give design engineers specific reliability goals for the various subassemblies in the over-all system design. These allocations are developed as the results of trade-off studies which begin during the proposal stage and continue up to the time of final Design Drawing release. The assigned reliability engineer acts as a consultant to the design engineer while trade-off consideration are in process. Mean-time-to-failure projections and evaluations of the most probable failure modes of the proposed designs are weighted in the trade-off evaluation.

- Electronic Parts Control - The design reliability analyses are based upon conservative projections of part performance and lifetime characteristics under the expected stresses. To provide a realistic basis for these projections and select the most applicable components, Reliability Engineering at EMR has built up an extensive backlog of data on part performance under satellite and missile-borne environments. Actual failure-rate data is continually accumulated from all qualified sources as they become available. Every effort is made to use parts which have received preferred status on applicable programs. Parts which do not have such a history are considered non-standard and require special approval for use in the final design.

- Compatibility - Compatibility studies are conducted to assure that related subassemblies are mutually compatible when assembled, considering all environments that the equipment will encounter from manufacture through use. Factors included in these interface studies are:

  --Thermal dependence.

  --Radio frequency interference.

  --Electrical power considerations.

  --Assembly mating and mounting tolerances.

  --Electrical tolerance build-up resulting from variations in test equipment accuracy and precision.

- Packaging Selection and Analysis - Optimization of packaging is considered from the point of view of system reliability, weight, volume, flexibility, producibility, maintainability, and cost. Subsequent review assesses the packaging to determine immunity to external environments, ability to withstand worst-case combinations of environments and electrical stresses, and conformance to maintainability requirements.

- Part Application Study - The selected parts are investigated as a function of the circuit to prevent overstressing and circuit dependence on uncontrolled component parameters. The reliability engineer reviews and approves the study on a parallel basis with the design engineer.

- Circuit Selection and Analysis - Reliability at the circuit level is enhanced by using standard circuits with well-defined performance characteristics. Prior to approval, preliminary schematics and parts lists are analyzed by Reliability Engineering and the design engineer to ascertain if the selected circuit can be used for similar applications, or if existing standard circuits from other programs are applicable.

  For final approval, worst-case circuit analyses are conducted by the circuit designers to assure that circuit tolerances are consistent with part tolerances and circuit application. Drift analyses are conducted to establish minimum acceptable standards for component performance and to eliminate the possible use of poorly analyzed circuits or improperly applied parts.

- Design Reviews - Following the preliminary design review which occurs during the preparation of the design proposal, two additional formal design reviews are conducted:

  --A Critical Design Review is normally conducted at the subassembly level after designs are completed but prior to prototype drawing release.

  --Hardware Reviews are usually planned on the major equipment level after qualification tests. They provide the opportunity for a detailed evaluation of the system in the pre-production configuration.

  The design reviews are formalized through the medium of a standard instruction defining the purpose of reviews, scope to be covered, assignment of required investigation and action, and the required reporting and completion of required investigations and actions. Each review is chaired by the Reliability & Quality Assurance Department.

- Engineering Tests and Accelerated Life Testing - From inception of design to the delivery of production models, engineering tests are conducted on circuits and packaged modules. These tests are designed to check performance parameters, reliability, and modes of failure over a wide range of thermal and vibration conditions.

  Critical units are tested under accelerated conditions to foreshorten the time required to achieve meaningful test results. These procedures are similar to those developed and documented by Rome Air Development Center.

A CASE IN POINT...

Part Reliability Analysis by Digital Computer

Functional or drift failure in circuits due to changes in electronic part parameters present a more serious potential problem area than any other mode of circuit failure. To anticipate and prevent drift failures and to expand the scope of circuit analyses, EMR is preparing to perform digital simulations of circuit performance as a function of part parameter variations. A general-purpose digital computer will be used for these simulations as well as other analyses carried out by design engineers and theoretical circuit analysts. The versatility of the computer and its availability as a working tool will provide an exceptional degree of added sophistication to EMR's reliability studies.

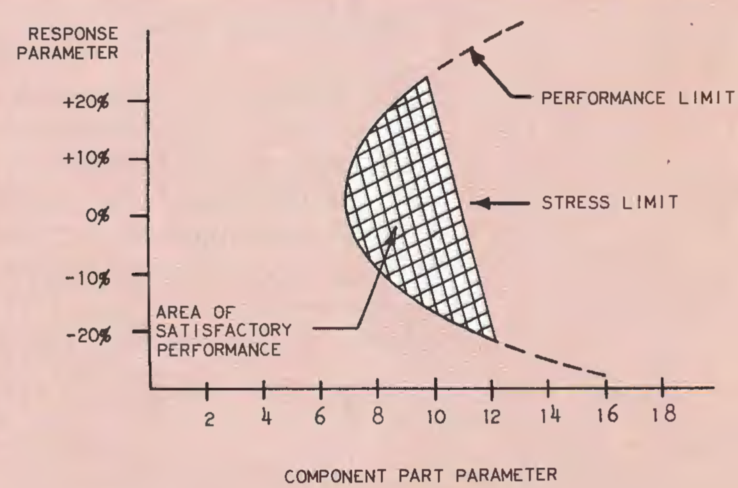
By describing circuit output as a function of circuit parameters in the form of a set of simultaneous computer equations, worst-case analyses can be made with all part parameters, circuit input signals, and power supply voltages at extremes of their tolerance limits. If the circuit output parameters exceed specified tolerances, the circuit can be redesigned or the part tolerances can be tightened before the circuit is built and tested.

Hand computation of these equations is both tedious and time consuming, and is therefore limited to approximate calculations. By using the digital computer, a complete set of combinations and permutations of parameter limits can be analyzed for each circuit in a fraction of the time normally required.

The circuit-response table shown below illustrates the type of tabular results that will be provided by the computer. Such data can be graphically transcribed into a Schmoo chart presentation.

CIRCUIT-RESPONSE TABLE NO. ________

Component	Nominal Value	Incremental Change	Test Value	% Variation from Nominal	Circuit Response
R-1	4.7	---	4.7	0.0	-10.0
R-1	4.7	+.1	4.8	+2.1	-10.0
R-1	4.7	+.1	4.9	+4.3	- 9.0
R-1	4.7	+.1	5.0	+6.4	- 7.0
R-1	4.7	+.1	5.1	+8.5	- 5.0
R-1	4.7	+.1	5.2	+10.6	- 1.0



SCHMOO PLOT

PRODUCTION ASSURANCE PHASE--The objective of the assurance phase is to achieve the inherent reliability during the manufacturing phase. This is basically a quality-control function. For completeness, standard procedures have been generated and are in use to provide the necessary controls in such areas as:

- Vendor Surveys and Control

  The Reliability & Quality Assurance Program selects subcontractors and/or vendors for equipment, materials, and processes that will be included in deliverable systems. The Reliability Engineering Section maintains continuous liaison with vendors who are selected to assure that required reliability programs are being carried out and that required reliability is achieved.

- Manufacturing Process and Workmanship Standards

  Quality Control prepares and/or approves the process and workmanship standards applied to each system. The standards presently applied at EMR are compared against the customer requirements, and revisions are made, as they become necessary, prior to manufacturing.

- Quality Control Procedures

  Fabrication and assembly inspection is performed at the most advanced stages possible with the minimum number of intermediate inspections. Inspectors are provided with copies of the manufacturing operational instructions, drawings, and detailed plans indicating the extent of inspection required at each point. Inspection results at the various stages of manufacture are recorded on coded defect charts. These are forwarded to the Quality Control data section, where weekly reports of in-process quality level are prepared and distributed to the manufacturing and inspection supervisors.

- Data Collection and Failure Analysis

  Any failures encountered during testing of the data system are recorded on EMR trouble reports. Each report is coded and keypunched on punch cards so that statistical evaluations of problems can be obtained from electronic tabulating machines according to any desired sequence. Failure data is analyzed to determine the cause of all failures and to recommend steps which can be taken to prevent recurrence. Whenever it is important to know the cause of part failure, the failed part is dissected in the laboratory.

- Inspection Plans and Documentation

  The inspection plan and documentation requirements for EMR manufactured items are established and prepared by the Reliability & Quality Assurance Department. Those for subcontractor and/or vendor manufactured items are established by the Reliability and Quality Assurance Department in cooperation with the subcontractor and/or vendor, and approved prior to use.

- Test Surveillance Plans

  The test program instituted by EMR is a vital link in the over-all data system reliability program. The objectives which each test phase accomplishes are summarized below.

Component Parts Test

--Eliminates unreliable component parts

--Determines compatibility of parts parameters with electrical designs

--Provides sufficient burn-in time (when required) to stabilize parameters

Design Approval Test

--Establishes equipment reliability in operational environments

--Proves equipment performance over complete environmental range

--Provides engineering with feedback in the event that design modifications are necessary

Acceptance Test

--Provides assurance that production units have same capabilities as qualified prototypes

--Provides reliability test-and-time information to allow assessments to be made on production units

END-PRODUCT VERIFICATION PHASE--Accumulation of data concerning the quality and the reliability characteristics of the project does not cease when the product leaves the plant. The reporting and tabulating programs which have been developed are compatible with programs used by our major customers and can be integrated as necessary to relate the total history of the end item -- from conception to application -- up to the point where information can no longer serve a useful purpose. Results have indicated the usefulness of the Verification Phase in bringing about design improvements which have ultimately increased reliability.

A CASE IN POINT . . .

Encapsulated Circuitry for NASA Satellites

The conservative use of the most reliable components is continually validated on many programs at EMR where reliability demands are stringent. A typical instance is the welded and encapsulated circuitry for satellite PCM telemetry systems presently being built for NASA and Ball Brothers Research Corporation. For these systems, the Electronic Parts Reliability Program controls all electronic piece parts through stringent control specifications encompassing all electrical, mechanical and quality requirements. To assure the achievement of these requirements, each purchased part is given an identifying serial number and is then acceptance tested. Upon receipt, it is aged under electrical stresses and is tested periodically until it is used in a subassembly. Testing of the part continues thereafter where it is possible to make such tests on a consistent basis. Subsequently, the complete subassembly is identified by a serial number and periodically tested until it is incorporated in a larger subassembly, and so on.

A typical example for illustration is a switching transistor which receives wide usage in EMR's MICROPOWER circuitry for these telemeters. The Specification Control Drawing (SCD) for this transistor is a twelve-page document which details performance parameters, test regimes, and test fixtures. In accordance with the SCD, EMR makes 100% incoming tests on all units for the following parameters:

Current gain

Collector-to-emitter voltage

Base-to-emitter voltage

Collector leakage current

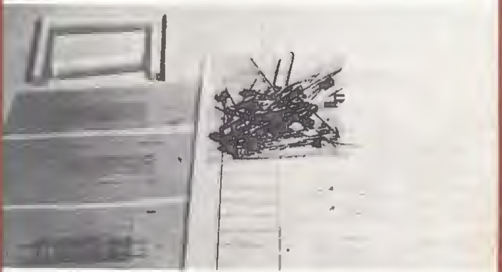
Switching time

These tests are performed at random temperatures over the specified operating range. Transistors are accepted in lots of 100; a failure of one unit in the lot, or an out-of-tolerance condition in two or more units in a lot, requires the return of the complete lot to the vendor for credit.

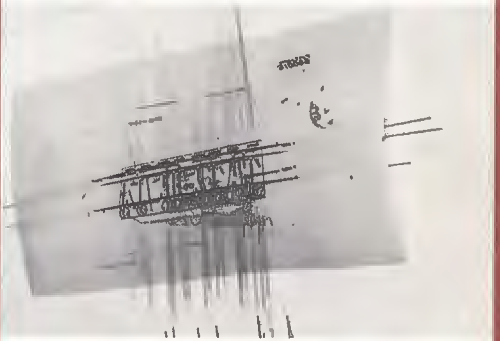
All transistor lots which pass the initial test remain segregated by lot and are then subjected to 1000 hours of aging under cyclic electrical stress. During the aging process, the five tests are repeated periodically at random temperatures. Similar criteria are applied for acceptance or rejection of a lot. Only individual transistors which survive the lot criteria and have exhibited no out-of-tolerance conditions during this test regime are utilized for subassembly.

All records obtained in this continuing test program are analyzed to detect systematic parameter variations indicating abnormality of a component or assembly. These records are kept for permanent reference; digests of the test data appear in contractual progress and technical reports.

Exhaustive environmental tests are performed and recorded...



...for individual components...



...card assemblies...

...and module subassemblies.

COMPANY FACILITIES

Complete and Efficient

An important reason for EMR's position of leadership are the outstanding facilities for research, engineering development, test and production.

Facilities are designed according to modern industrial standards. The greatest flexibility has been maintained to permit space layout to be adapted to current program demands.

Without compromising aesthetics, considerable attention has been given to details which will afford the creative, professional man maximum effectiveness. For example, research and development laboratories are integral with engineering offices. Here engineers have the unrestricted "elbow room" necessary to efficiently develop ideas while laboratory work proceeds.

To support the engineering effort an unusually large amount of precision test equipment is available. On the average nearly $8,000 worth of equipment is available to each engineer. To further assist engineers, a separate well-stocked engineering supply area is integral with each major engineering development area. Drafting service is also broken down into service areas associated with a particular development area.

To assure the creative technical man an opportunity to discuss his problems, comfortable, well-appointed conference rooms are available for meetings.

All buildings and working areas in EMR's plant complex are fully air-conditioned and climate controlled.

Facilities are well equipped with advanced electronic and electro-mechanical equipment, test instruments, environmental facilities, model shops, sheet metal shops, printed circuit shop, machine shops, electroplating lab and paint shop, and electronic production facilities, electron-physics lab, and white room. Plant capacities of nearly 100,000 square feet devoted to manufacturing and 86,000 additional square feet for laboratories and services indicates an ability to more than adequately space allocate, furnish, and operate any program.

AERIAL VIEW OF EMR

ADMINISTRATION AND RESEARCH BLDG — SARASOTA

PRODUCTION—EMR SARASOTA

MANUFACTURING

More than half of all EMR personnel are associated with some phase of the manufacturing process — from procurement of the basic components thru fabrication and assembly to shipment of final products. These total operations within EMR occupy plant areas totaling 100,000 square feet.

Because of the specialized nature of EMR products, manufacturing functions are diversified. Various specialized production groups are closely integrated in an operation tailored to reduce the time to a minimum between receipt of an order and shipment.

EMR assembles precision equipment designed for inclusion in complex instrumentation and data processing systems. For this reason, equipment must be carefully tested at each stage of manufacturing to assure meeting the most exacting standards. Appropriately, the test areas which support electronic manufacturing are nearly as large as the manufacturing area itself and the aggregate value of test equipment allocated for production testing exceeds one-half million dollars.

MANUFACTURING

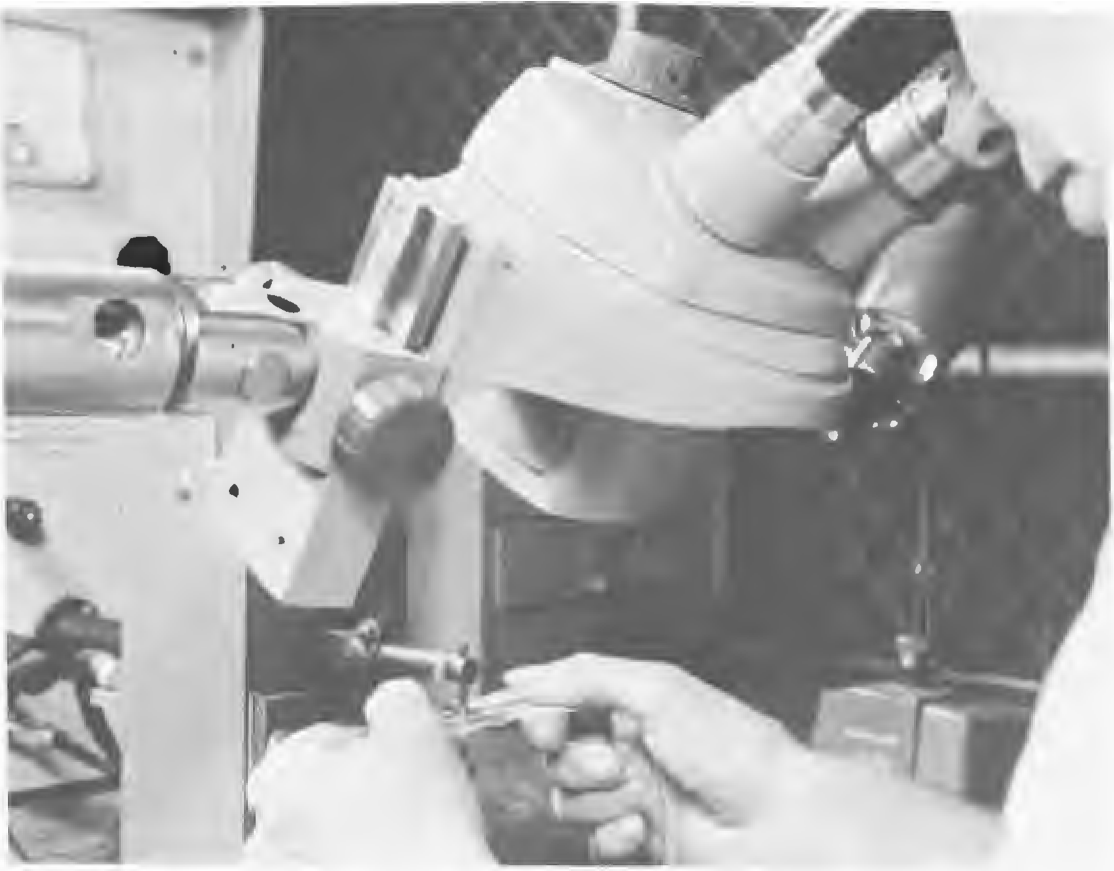
ELECTRONICS

Manufacturing satellite encoders at EMR is a painstaking hand operation — there is no room for mistakes.

An over-all view of one of EMR's manufacturing areas where standard telemetry instruments are produced.

Final production in subcarrier discriminator assembly.

Subcarrier Oscillators in production on the Sarasota Division Manufacturing line.



A welded wire matrix is being assembled for a satellite encoder under a binocular microscope.

Production welding is controlled by metallurgical analysis. Here a weld is being analyzed and photographed.

In the assembly of a large system considerable handwork is necessary to integrate the various precision instruments which make up the system. Here a power regulator is being assembled for a large system.

Cabling assembly in the product manufacturing area.

A portion of EMR assembly area where precision welding of miniature electronic subassemblies is accomplished

MANUFACTURING
ELECTRONICS TEST

A portion of the test area where EMR products are given final exhaustive inspection.

Extensive environmental test facilities within the production area help qualify EMR instruments.

Many special test instruments are built by EMR for checking subassemblies. This test technician is checking a digital decommutation circuit card.

A well equipped standards laboratory calibrates and repairs all company test equipment.

COMPONENT FABRICATION

To achieve a quick reaction production capability EMR performs many in-house fabrication operations. This affords great flexibility in accommodating production changes and permits close cost control. For these reasons EMR established a completely integrated Fabrication facility for sheet-metal fabrication and finishing. An outline of the facilities available includes:

SHEET METAL FABRICATION . . . Major equipment includes: a Wiedemann cordinator for making precision templates; a Wiedeman turret punch press with a high-speed follower-type gauge for punching holes; a government-certified Taylor-Winfield tri-phase spot welder, certified tungsten inert-gas welders; press brakes up to 10 feet long, modified to bend to close tolerances; a precision shear with a 10-foot bed; and punch presses of various tonnage.

PLATING . . . A carefully supervised program of process control in the plating room, operated in conjunction with a Permutit water- and waste-treatment plant, ensures fine-quality electroplated and chemically finished work. Typical finishes produced are cadmium, silver, copper, nickel, black cupric oxide (Ebonol "C"), and chromate conversion coatings (Iridite 8P, 14, and 18P), clear and black anodizing, and gold plating.

PAINTING . . . The high-quality paint finishing accomplished at EMR accrues from the use of filtered, dust-free air in a painting room that contains water-wash spray booths. Meticulous care in handling contributes toward a professional end product. Large drying ovens eight feet high, six feet wide, and six feet deep are used.

Precision printing and lettering are accomplished with Markem machines and silk screens with specially designed indexing jigs.

TERMINAL BOARDS . . . Virtually all types of terminal boards can be fabricated at high-speed drill stations augmented by production equipment for terminal swaging.

QUALITY CONTROL . . . The QC program more than adequately fulfills the requirements of MIL-Q-9858. First-part and 100% in-process inspection ensure highest-quality materials and finished products. The precision measurement instruments used throughout are periodically certified to standards traceable to the National Bureau of Standards.

COMPONENT FABRICATION

A view of a portion of EMR's component fabrication facility.

Spray-painted instrument parts are dried in this thermostatically controlled hot-air drying oven.

The three EMR plating lines shown here can handle virtually any type of plating on a production basis.

Granite-block surface plate and height gage is used by inspector to check part dimensions to close tolerances.

Shearing stock to size in a ten-foot heavy-duty precision shear.

Preparing a precision template on a Wiedemann coordinator.

Turret punch forms chassis holes and slots automatically from a precision template.

A 60-ton, ten-foot press brake for heavy duty bending and forming.

Spot welding on certified three-phase welding machine.

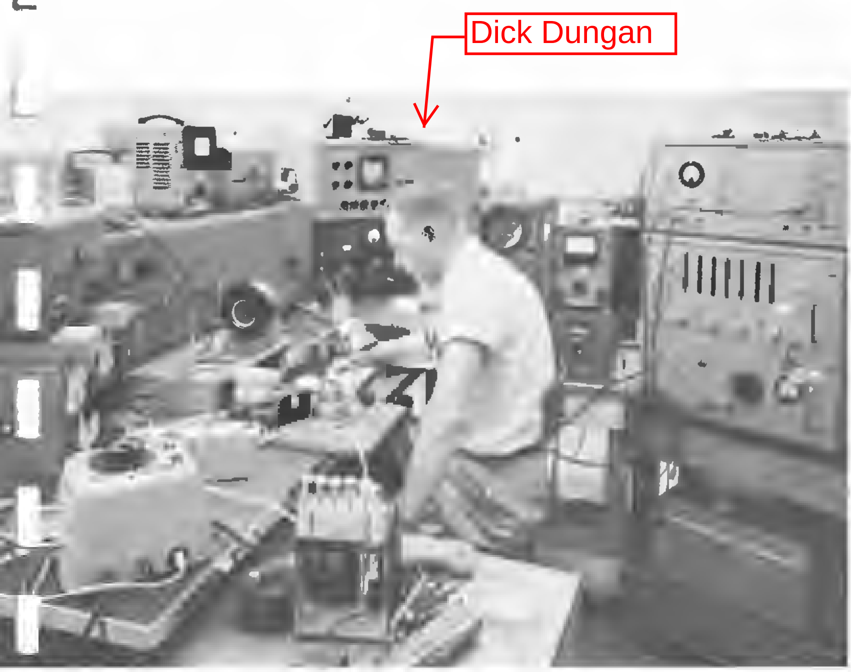
Spray painting in one of EMR's water-wash-equipped paint booths. Gene Waldroop

A special printing machine is used to imprint markings on EMR panels and instrument cases.

ENGINEERING

Company research is conducted in the numerous engineering laboratories occupying nearly 30,000 square feet. These modern, well-equipped laboratories provide the atmosphere of freedom for research. This atmosphere generated by nearly ideal working conditions together with an active company policy of recognition of individual achievement results in EMR's exceptionally high professional morale. The result is a continuity of effort by project teams and high quality in the end product.

ENGINEERING



EMR development technician running a temperature stability test on a prototype FM transmitter.

Design of a transistorized FM discriminator is in its final stages.

A prototype printed-circuit board undergoing inspection.

A modern coil winder in a systems engineering laboratory produces toroids for prototype circuits.

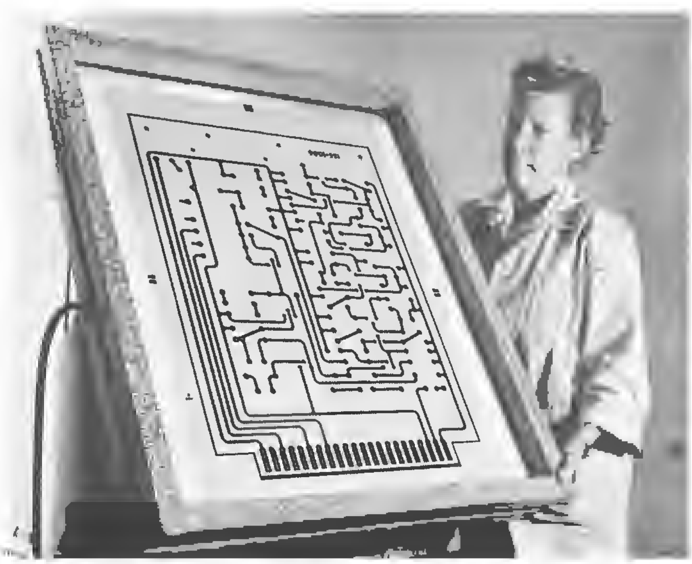
SERVICES

EMR devotes substantial areas to service functions which support the technical components of the company. For example, each major company location maintains libraries which are well stocked with current technical, scientific books and periodicals. Similarly, extensive drafting, model shop, prototype assembly, specialized photographic service, prototype circuit welding, and many other specialized services are provided.

SERVICES

Model Shop facilities are complete and efficient.

A printed circuit laboratory enables EMR to exercise control over a critical phase of engineering development.



Comprehensive photographic facilities include photoreduction capabilities employed in printed-circuit and welded-wire development and production.

A portion of the drafting facilities which support engineering development.

ELECTRO-MECHANICAL RESEARCH, INC.