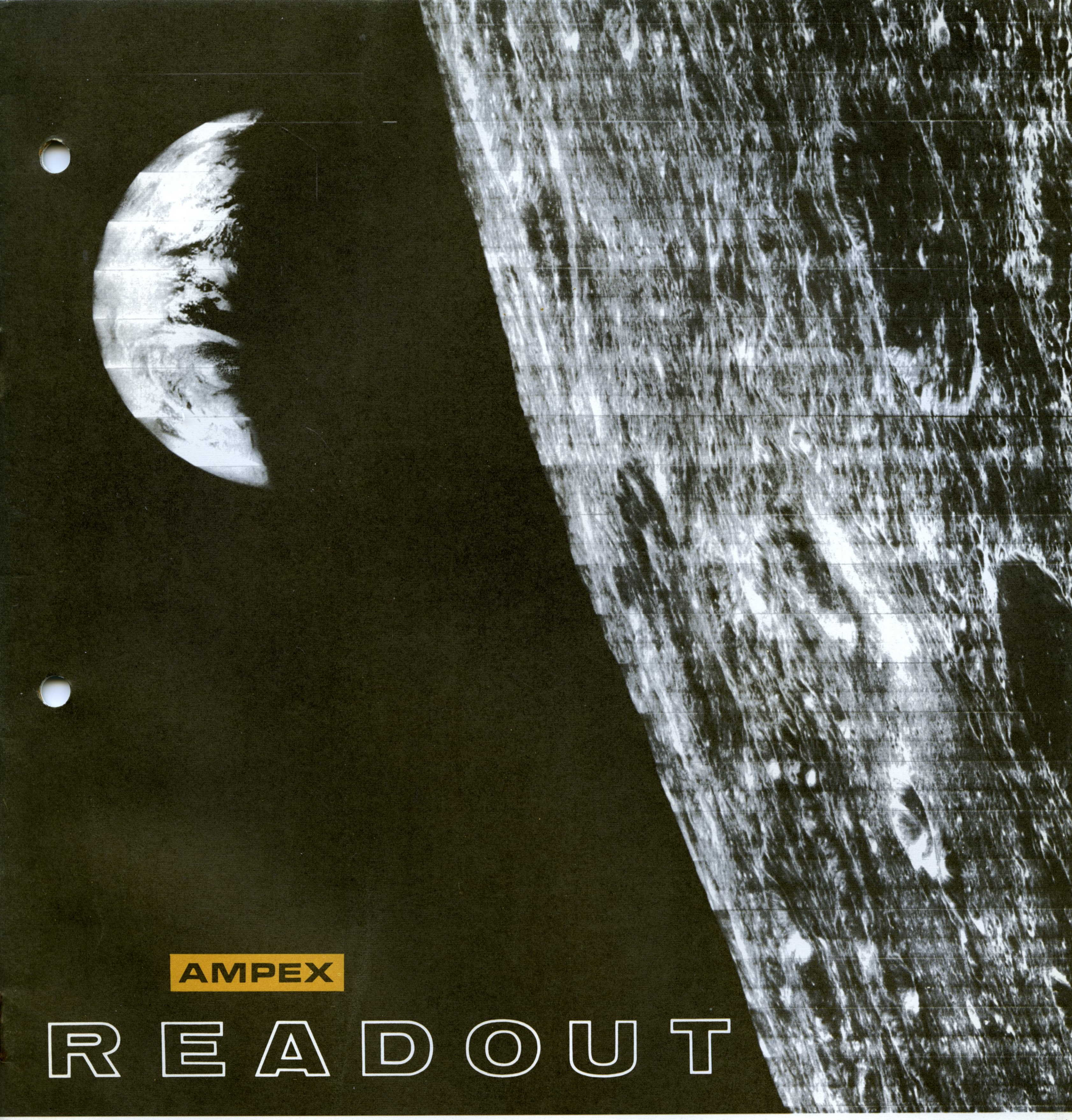


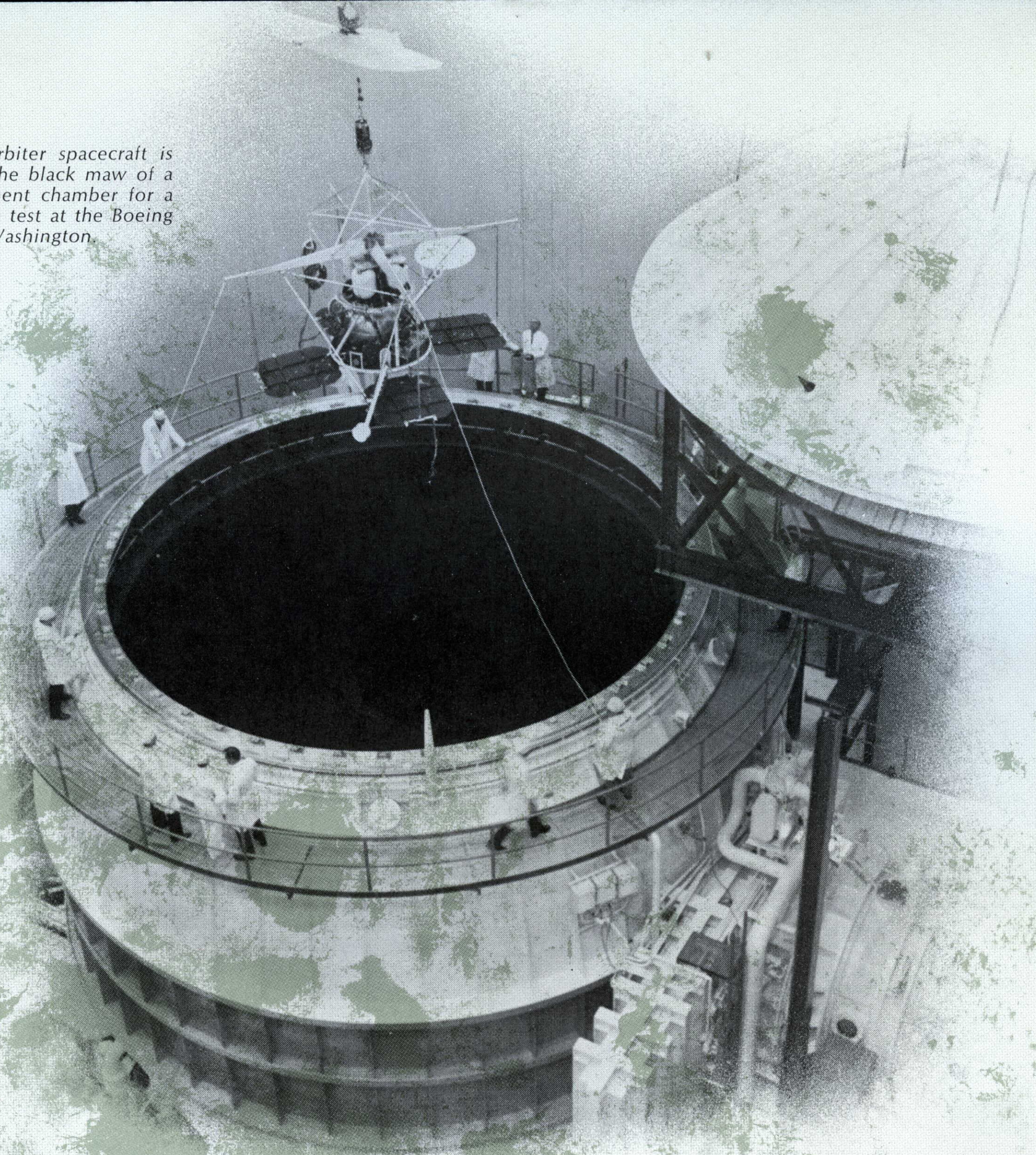
AMPEX

READOUT

In this issue:

- Lunar Orbiter
- Educational Television in Nebraska
- UHF Station: WDCA, Washington, D.C.
- Care and Storage of Computer Tape

A camera-carrying Lunar Orbiter spacecraft is shown being lowered into the black maw of a 50-foot-high space environment chamber for a three-week flight acceptance test at the Boeing Space Center near Seattle, Washington.



lunar orbiter

man's unmanned exploration of the moon

Where on the surface of the Moon can our Astronauts find a landing site not laced with deep crevices or jagged rocks?

How long can they survive when exposed to the Moon's radiation and micrometeoroid bombardment?

How accurate are our present calculations of size, shape and gravitational field of the Moon?

These questions and many others must be answered before man can safely land and move about on the surface of the Moon. The Lunar Orbiter project of the National Aeronautics and Space Administration is one of three unmanned programs set up to provide this vital information.

Fifty Years of Data in One Week

Recently, Oran W. Nicks, NASA's Director of Lunar and Planetary Programs, remarked: "One astronomer has said that more information has been obtained in the first seven days of the Lunar Orbiter I project than in the last 50 years of study of the Moon."

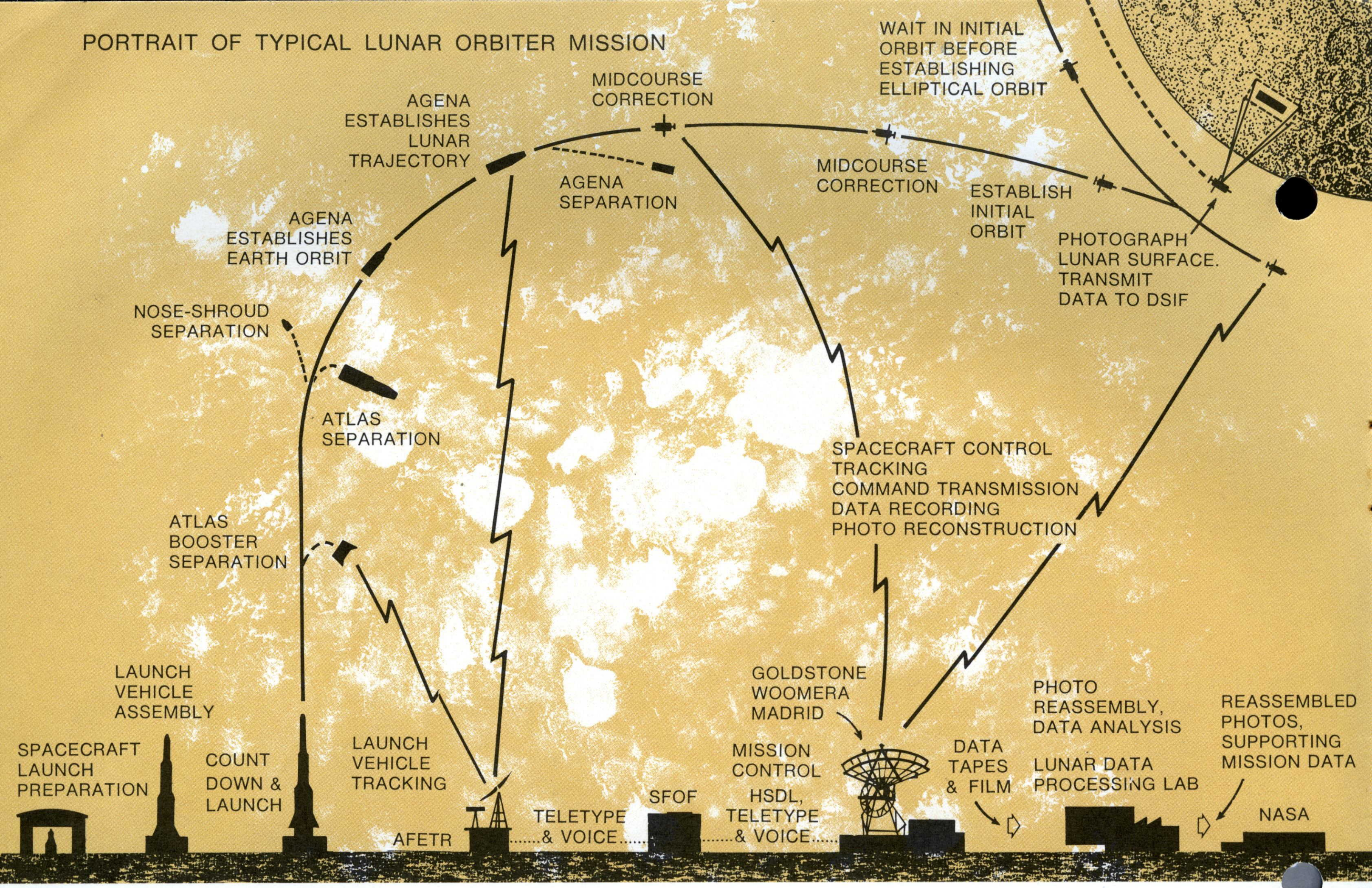
Truly, the matchless cooperation and inspired creativity exhibited in the design and construction of Lunar Orbiter spacecraft and supporting equipment by NASA, the scientific community, and American industry has helped us to take those longer strides that President Kennedy called for in 1961 when he first spoke of the Apollo landing of a man on the Moon and returning him safely to the earth.

Preceding our men on the Moon, are three unmanned missions that are mapping possible landing areas, testing surface strength and composition, and establishing the launch, guidance and navigation technology for a successful manned excursion. Ranger (now completed) and Surveyor are managed by Jet Propulsion Laboratory in Pasadena, California. Overall Lunar Orbiter management is by the Langley Research Center, Hampton, Virginia. Jet Propulsion Laboratory provides tracking and data acquisition support for the Orbiter program.

RANGER, SURVEYOR, ORBITER

RANGER: Hard Landing. Ranger VII, VIII, and IX, gave us our first closeup views of the lunar surface. Multiple television cameras in the Ranger payload were activated minutes prior to impact. The resulting pictures showed the impact area in detail. Although the Ranger program provided more than 17,000 extremely valuable lunar pictures, its coverage was limited in area, and was not intended to provide sufficient information for a manned lunar landing. Besides pictures. Ranger's important contribution was establishing launch, guidance, and navigation technology necessary to travel to the Moon and hit a selected area.

SURVEYOR: Soft Landing. Surveyor spacecraft make soft landings on the Moon and also send back scientific and engineering data. During landing, touchdown dynamics and bearing strength are measured. After the landing, additional data of local surface conditions is collected while pictures are taken by eye-level television cameras scanning the surface. Surveyor I made a spectacular soft landing on June 1, 1966. The Surveyor III is planned for 1967. It will land in one of the areas selected by the Orbiter satellites for a manned landing to confirm the safe conditions at that point on the surface.



Lunar orbit is achieved about 90 hours after liftoff. The final photographic orbit places the spacecraft 28 miles from the Moon at the closest point, 1150 miles at the farthest point.

LUNAR ORBITER: A Flying Photographic Lab Scouts the Surface. Following the success of Ranger and Surveyor, the Lunar Orbiter is providing extensive photographic coverage of large specific areas of the lunar surface. As evidenced by its initial photographs, many large areas of the Moon may be too rough to accommodate a manned landing. The Apollo Lunar Module has a limited landing and maneuvering capability so that the final site (and nearby alternates) must be selected before launch. Lunar Orbiter assignments have been to seek areas large enough, flat enough, and smooth enough for a manned landing.

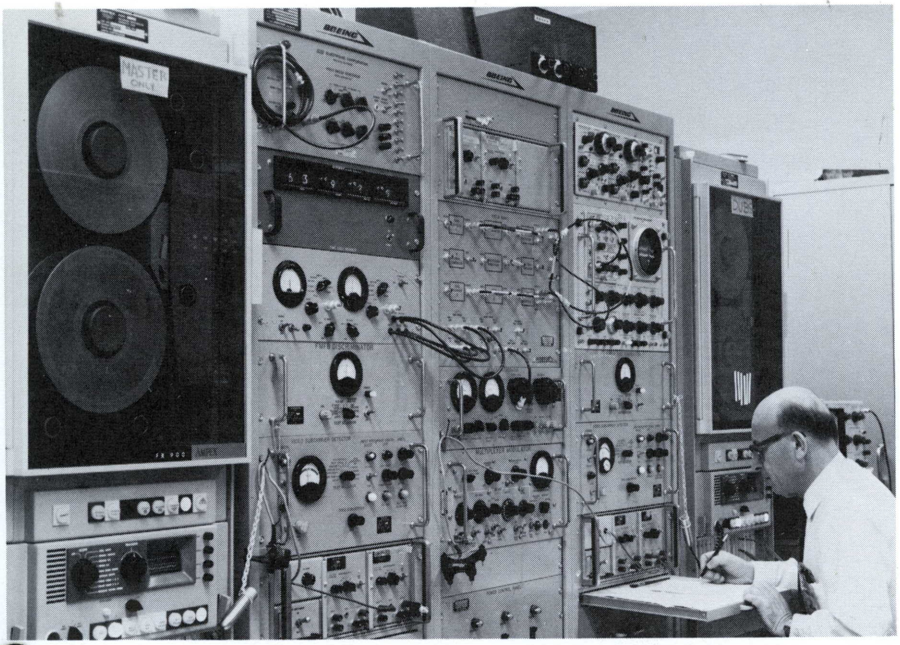
Lunar Orbiter I was launched in August, 1966. In the following 77 days it made 327 orbits and exposed 215 feet of film during 12 days of photography giving us our first detailed knowledge of large areas of the Moon, including our first pictures of the back side. To eliminate any possible radio interference between it and the follow-on missions, the Orbiter I was commanded to crash land on the back side of the Moon in October 1966. Then, in November of 1966, Lunar Orbiter II further delimited the possible landing areas. It covered more than 1.5 million square miles not covered by Orbiter I, including 15,000 miles in the Apollo landing zone. By mid-March 1967, it had made 650 orbits and by careful tracking from the earth, continues to aid scientific understanding of the lunar gravitational field. On the basis of the first two missions, Orbiter III photographed 12 specific areas to make a final selection of where the astronauts will land.

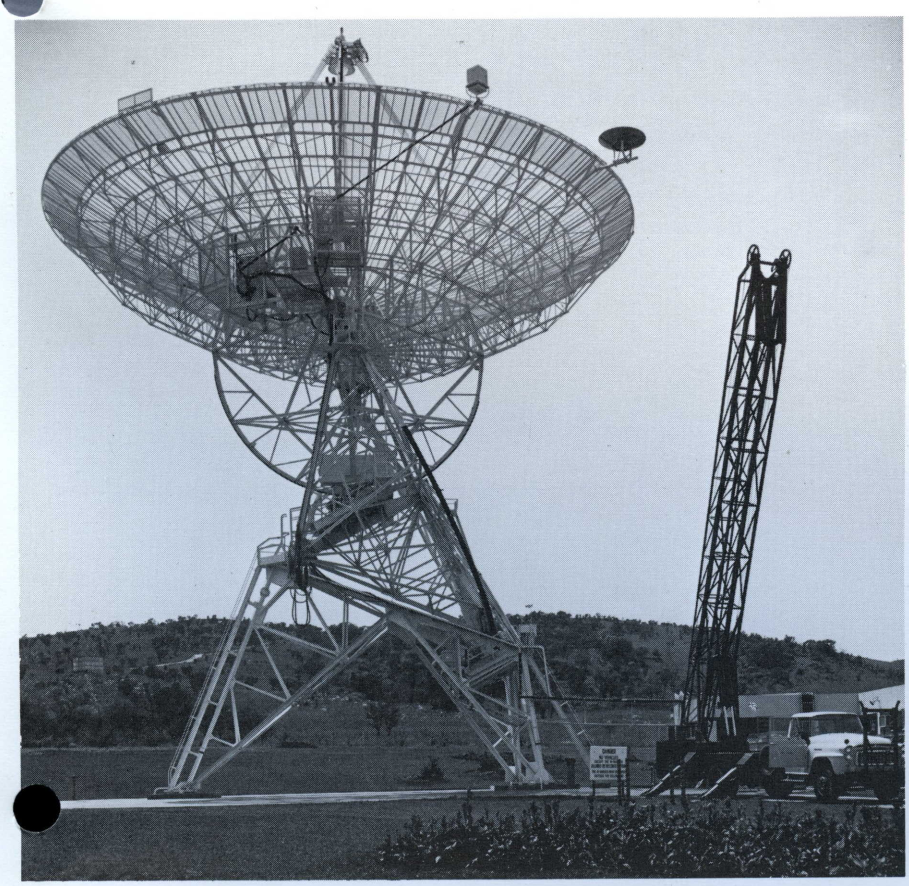
Surface detail of the Moon from the Orbiter program is comparable to the very limited sampling area taken by the Surveyor after landing. Both are far better than we can obtain from the earth. Maximum photographic resolution with earth based telescopes is on the order of 2500 feet, which means that we cannot recognize an object less than one-half mile in diameter. Even enlarging these telescopic photographs would not improve resolution. It would only result in an unrecognizable blur.

In contrast, each Lunar Orbiter provides more than 200 high resolution photographs with a resolution down to 3 feet. This means we can pick out details as small as a card table. Besides the high resolution pictures, wide angle or medium resolution pictures (about 25 feet) of the surrounding area are taken simultaneously (see diagram).

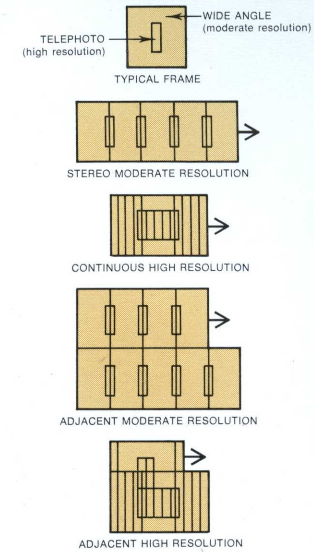
Gerald G. Leeson prepares to reproduce a tape on an Ampex FR-900 at NASA Houston containing pictures from the Lunar Orbiter Moon shot. Leeson, Acting Supervisor, Lunar Orbiter Data Conversion System, is with Lockheed, a support contractor for NASA.

Two Ampex FR-900 predetection recorders at NASA's Langley Research Center. These recorders make copies of master tapes containing Lunar Orbiter pictures received from tracking stations. I. George Recant, Data Analysis Manager, Lunar Orbiter Project, is shown with the recorders and related Boeing Company equipment.





Eighty-five foot antenna at Goldstone Deep Space Network Station, California, which received Lunar Orbiter pictures and instrumentation data.

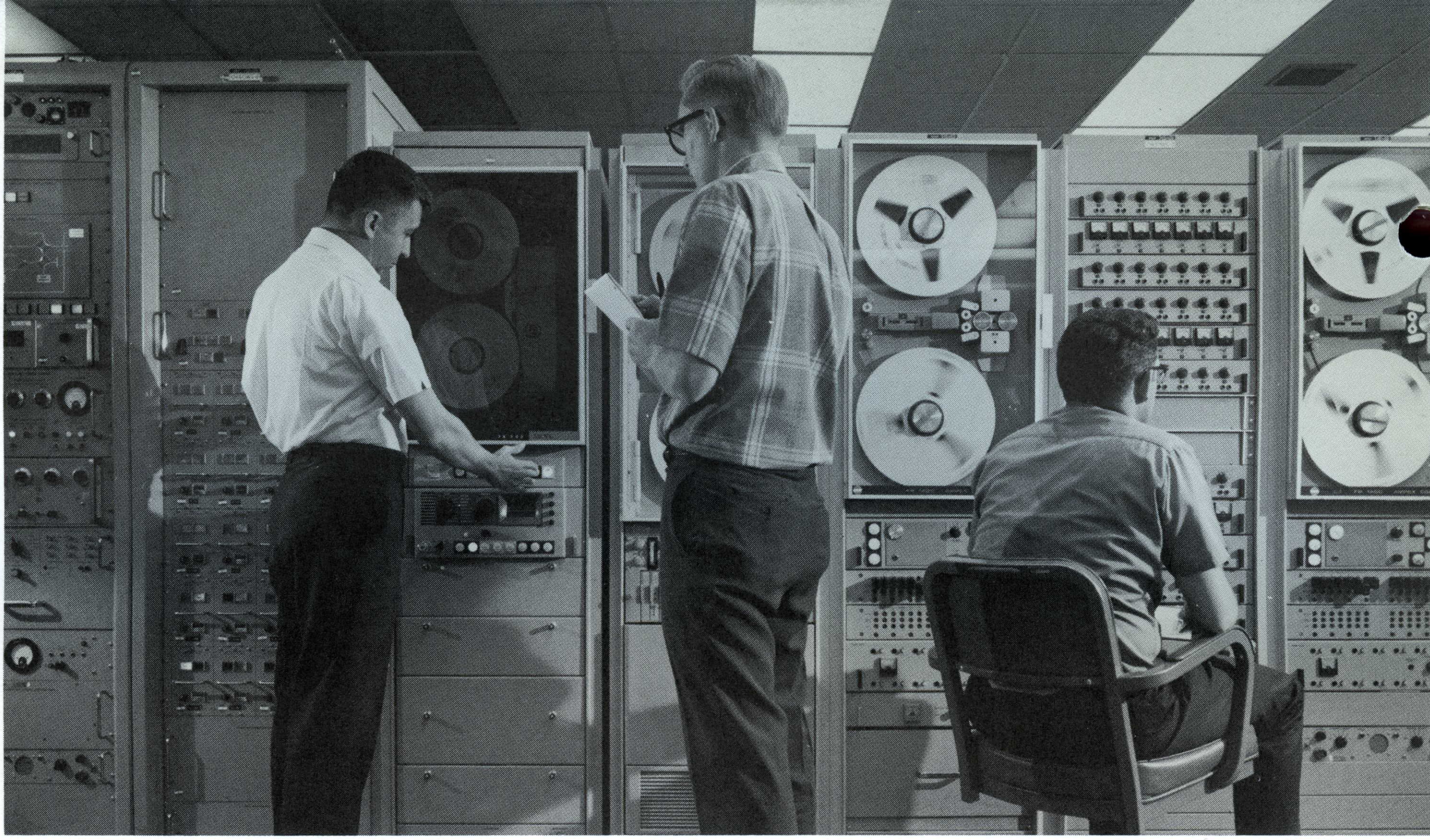


The Orbiter's camera can be ordered to take one picture at a time or to take various sequences: 4, 14, or 20 pictures in a row. And the time interval between exposures can be relatively long, to provide a 50.1% overlap of the moderate-resolution frames (for stereo), or shorter for a 5% overlap of the high-resolution frames. The diagrams indicate four possible mapping schemes. Along one edge of the film, pre-exposed data consisting of resolving power charts and scales are used to interpret the final photographs.

LUNAR ORBITER III ASSIGNMENTS: Affirming Apollo Landing Sites

The first assignment of Lunar Orbiter III was to confirm the suitability of a series of manned landing sites. From data collected by Lunar Orbiter I and II, scientists of NASA and the U.S. Geological Survey have concluded that five areas are considered to be the best candidates for a manned landing, pending additional confirmation from Orbiter III. Along with the five primary target areas, additional alternate sites were photographed. Ideally, NASA would like a string of potential landing sites about 26° apart on the lunar surface, starting from the most eastern landing zone and proceeding to the west. This is because optimum lighting on the lunar surface changes 13° a day and the requirement is for slant illumination of 7 to 20°.

ON BOARD CAMERA: Developing, Scanning and Transmission System. The Lunar Orbiter photography is done by a film camera system designed and built by Eastman Kodak Company. An initial decision was made by NASA and Boeing to use film rather than television as Ranger and Surveyor did. To achieve the same three-foot resolution with television, pictures would have to be made at a lower altitude, which would reduce the area covered, and the overall camera system would be much heavier. The Lunar Orbiter photographic subsystem contains two lenses (a telephoto and a wide angle), a Bimat (dry) developing system, and a scanner to convert pictures to electrical signals for transmission to the earth.



Goldstone Tracking Station, California. Ampex FR-900 at left records picture data. FR-1400's at right record tracking and environmental data.

Because of the high speed of this satellite when pictures are being taken (4000 mph), the camera subsystem has a motion synchronizing device to eliminate blurring of the image.

The flight pattern of Orbiter III permitted it to photograph the location of Surveyor I which soft-landed successfully in June 1966. Altogether, Orbiter III took 212 dual exposure frames. Some pictures were overlapped at least 50% to permit stereo optical analysis.

In addition to its photographic mission, Lunar Orbiter III, like its predecessors, is monitoring meteoroids and radiation intensity in the vicinity of the Moon. Information on the Moon's gravitational field is derived from a detailed analysis of the tracking data. Gravitational data is important in setting up a predictable orbit, both for future orbiter missions and the Apollo landings.

The actual picture taking mission lasted for eight days. Portions of photographs were transmitted to the earth in a priority photographic readout sequence during each orbit between periods of photography, to check picture quality and make preliminary analysis. However, the primary picture transmission is done after the photography is completed in reverse order from which they were taken. Picture transmission was completed by March 1967. Some data was not recovered due to a problem inside the photographic subsystem that developed in final phase of film readout.

In addition to the pictures, lunar environmental and spacecraft performance measurements are being taken at the same time by an instrumentation subsystem. When pictures are not being taken, this data is being transmitted on a 30-kHz carrier. But, during the 30-day photographic mission, it is added to the 10-MHz picture data carrier. Transmission of environment, performance, and scientific data is expected to continue for 11 months.

GROUND DATA ACQUISITION:

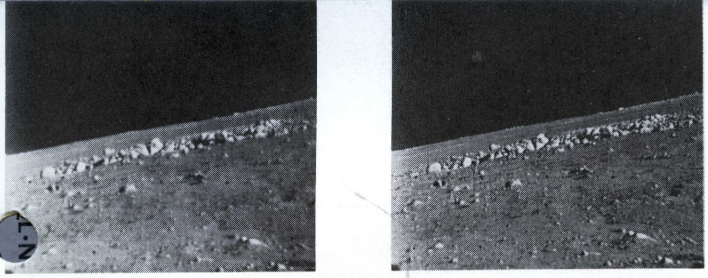
Parallel Recording on Magnetic Tape and 35mm Film

Tracking and data acquisition is the responsibility of the Deep Space Instrumentation Stations of NASA's Jet Propulsion Laboratory. These stations are located in Goldstone, California, Woomera, Australia, and Madrid, Spain. They are located about 120 degrees apart around the world so that at least one station will always be able to communicate with the spacecraft and receive data. Each station is equipped with an 85-foot dish antenna, signal receiving and signal processing equipment, two ground reconstruction equipment devices, one Ampex FR-900 predetection instrumentation recorder, and two or more FR-1400 instrumentation recorders. Readout of one complete picture frame from the satellite takes about 43 minutes. Under the best conditions, Lunar Orbiter III reads and transmits to the earth between two and three frames per orbit. This means that transmitting all 212 frames will take approximately 12 days.

At each station, the radio signals are received by the 85-foot antenna, amplified and processed to separate data from the carrier.

Within the station, the 10-MHz carrier from the receiver is routed simultaneously to an Ampex FR-900 predetection recorder and to photographic ground reconstruction equipment. The ground reconstruction equipment displays the pictures line by line on a kinescope, then photographs them with a special 35mm camera. This converts the raw video information into a photographic image. When transmission from each orbit is complete, the original, unprocessed data recorded on the FR-900 at Goldstone is replayed for transmission by microwave link to the space flight operations facility in Pasadena. Here, it is processed by similar ground reconstruction equipment. From these tape-to-film copies, the initial photographs are made for Mission Control use, and release to news media. After initial quick-look at the stations and Mission Control, prime mission tapes and film are flown to NASA's Langley Research Center for detailed analysis.

The FR-900 is a rotary head recorder like the Ampex videotape television recorders. By means of a rotating head, it records transversely across the width of 2-inch wide tape. Effective head-to-tape speed is 1500 inches per second, even though the actual longitudinal tape speed is only 12.5 ips. When recording Lunar Orbiter data, the 10-MHz carrier from the spacecraft is recorded directly on the tape, substituting for the internally generated 8.5-MHz carrier used in the other non-predetection recorder modes. (In the other recorder modes, this 8.5-MHz carrier is frequency modulated to provide an overall data bandwidth extending from nearly DC (10 Hz) to 5.5 MHz. Overall bandwidth of the Orbiter picture data is 310 kHz modulated onto the 10-MHz carrier.



BEFORE ENHANCEMENT AFTER ENHANCEMENT

SURVEYOR MISSION A
LUNAR TERRAIN

By a novel computer process, Caltech's Jet Propulsion Laboratory clarified the indistinct Moon photograph sent by Surveyor I at left into the sharp, boulder-studded picture at the right.

Lunar Orbiter picture made with its wide angle lens. The priminent crater near the center is Kepler, which extends about twenty miles across and is more than one mile deep.

DATA EVALUATION: A Variety of Analyses

At Langley, tape copies are immediately made of the unprocessed video data using two FR-900's. These tape copies are then replayed into the ground reconstruction equipment to prepare duplicate photographs for study by NASA and other scientists. Since the unprocessed video data on magnetic tape is in an easily reproducible form, many multiple photographic copies can be made. Primary data is still contained in the original films recorded at the stations, but in general, successive copies made by film techniques tend to show more degradation than the copies made from data in unprocessed (predetection) form on magnetic tape.

Instrumentation data on spacecraft tracking and ranging as well as housekeeping information and data gathered by meteoroid and radiation sensors, is also recorded in each station on two Ampex FR-1400 recorders. These data tapes are edited and a master mission tape is prepared for Langley, and other data reduction facilities interested in the scientific experiments.

Data analysis at Langley Research Center is done by a group of experts in various areas of lunar science and space technology. For initial screening and evaluation of the photographs, the evaluation group will include representatives of the NASA Lunar Orbiter Project, the Manned Spacecraft Center in Houston, Bellcomm, the Surveyor Project, the U.S. Geological Survey, the U.S. Air Force Aeronautical Chart and Information Service, and the U.S. Army Map Service. A primary task of this evaluation group will be to plan future Orbiter missions and Surveyor flights. Preliminary mapping will begin after slope and profile information is extracted.

To aid in selecting the Apollo landing site, statistical analysis of portions of the data will be made as rapidly as possible by the Manned Spacecraft Center in Houston by playing the FR-900 tapes into a digital computer. Since the data is in electronic form on magnetic tape, only a simple conversion into a digital format is required before detailed computer programs can be run. With this terrain information, the Manned Spacecraft Center in Houston will be able to make its final decision on the primary landing site and alternate sites for the Apollo project.

ADVANCING THE FOREFRONT OF KNOWLEDGE

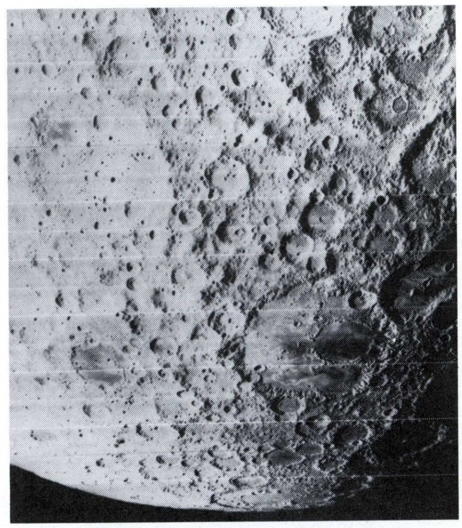
Besides the primary use in the Apollo project, Lunar Orbiter photographs and tapes will be studied over a long period of time for topographic, terrain studies, and systematic geologic investigation to obtain a more comprehensive understanding of the Moon itself.

The mountains of data collected by present and future Orbiter and Surveyor spacecraft will push forward the knowledge of man about his own earth and its only natural satellite. Lord Kelvin's words of nearly 100 years ago have direct application here: "I often say that when you can measure what you're speaking about and express it in numbers, you can know something about it. But when you cannot measure it and you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be."

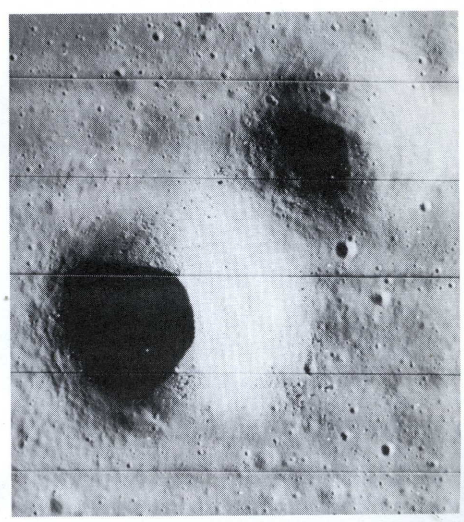
Data, both picture and environmental, received from these unmanned spacecraft clearly provides a degree of measured and numbered information in a quantity far beyond even the far reaching imagination of Kelvin and other 19th century investigators.

INDUSTRIAL TEAM LED BY THE BOEING COMPANY

The Lunar Orbiter prime contractor is The Boeing Co., Seattle, Washington, which designed, built and tested the spacecraft. Major subcontractors for the project are the Eastman Kodak Co., Rochester, New York, for the camera system and the Radio Corporation of America, Camden, New Jersey, for the power and communications systems. Prime contractor for the Atlas booster stage is General Dynamics/Convair, San Diego, California. Prime contractor for the Agena Second Stage is Lockheed Missiles & Space Company, Sunnyvale, California. Among the several dozens of supporting subcontractors is Ampex Corporation which supplied the FR-900 10-MHz predetection recorders and the FR-1400 1.5-MHz instrumentation recorders for lunar picture and data recording.



Southern half of the Moon's hidden side taken by Lunar Orbiter II with its wide angle lens from a distance of 900 miles on November 20, 1966. The area shown covers about 580,000 square miles.



An enlargement of a portion of the twelfth telephoto lens photograph taken of Site 3P-1 by Lunar Orbiter III. It covers a portion of the Lunar surface approximately three-quarters of a mile on a side. It was taken on February 15, 1967 and radioed to the Goldstone Deep Space Network Station.

READOUT® Volume 6 • Number 3 • A Magazine of Ampex Corporation • David R. McClurg, Editor • Designed by MacDonald Associates, 27157 Adonna Court, Los Altos Hills, California • Typography by Advertising Typographers, 408 West Santa Clara Street, San Jose, California. Photos (pages 1-7) courtesy National Aeronautics and Space Administration.

Technical Information: CARE AND STORAGE OF COMPUTER TAPE

By George Armes, Ampex Corporation

More has been written and published on the care and storage of magnetic tape than most other aspects of its use, yet the vast majority of tape related problems continues to be the direct result of improper care and handling of tape. The care and storage of computer tape (or any precision tape) can be summed up with two simple statements: KEEP IT CLEAN; KEEP IT COMFORTABLE. It is an established fact that computer tape doesn't "wear out." Computer tape is retired from service when dropouts exceed an acceptable number. Virtually all dropouts are caused by tape imperfections that lift the tape away from the head, thereby losing the signal. As packing densities and speeds continue to increase, the need for a cleaner, smoother tape surface becomes more imperative. At 800 cpi, each individual character must be supported by a very small portion of the oxide surface compared with a packing density of 200 cpi. An easy way to appreciate this significance is to recall the computer tape/highway analogy. "A standard reel of ½-inch x 2450-foot computer tape, with one nodule or surface defect that will cause a dropout at 800 cpi, is equivalent to a highway 50 feet wide by 557 miles long with one grapefruit sitting on it."

In addition to the shift toward higher packing densities, the new 9-channel format highlights the important consideration of tape edge protection. Figure 1 shows the track layout of both 9-channel and 7-channel tape. Note that the edge tracks of the 9-channel system are much closer to the tape edge, and the guard band (distance between adjacent tracks) is narrower on the 9-channel.

The industry tolerance on ½-inch computer tape is 0.498 inch ± 0.002 inch. This means a tape within specifications could conceivably have the edge tracks of the 9-track configuration fall within 0.001 inch of the edge of the tape. (Remember, the total tolerance of slitting is 0.004 inch.) This alone emphasizes the importance of protecting the edges of computer tape to minimize errors. The majority of dropouts occur on edge tracks of computer tape and are related in one way or another to physical deformation of the tape. Such defects could be nicks, raised edges, wavy edges, etc. Another point is that oxide shed and subsequent redeposits are the result of minute fractures to the edge of the tape. This can occur while the tape is wound in the pack and protected by the reel flanges, if the tape is mishandled.

Keeping Tape Clean. Plastic computer reels are a balanced design incorporating functional requirements and economy. To maintain the price of computer tape as low as possible without sacrificing utility, the standard computer reel is molded from polystyrene. This does not afford the same degree of tape protection as the more rugged, all-metal precision reel used for instrumentation tapes. Computer reel flanges will deflect more readily during handling, and extra precaution must be taken to minimize damage to tape edges. For this reason a functional canister was developed to support and protect the reel and tape during handling and shipment. As libraries grew, many users questioned the necessity of maintaining the bulky canister. Various types of reel bands were introduced to replace the plastic canister and cut storage space. One important fact that has been overlooked, however, is that the canister and reel comprise an overall functional design to protect the tape. The computer reel was designed for shipment, handling, and use solely in conjunction with suitable plastic canister. A reel band of any design is not a functional substitute for a plastic canister.

Computer tape edges are most fragile, and must be protected at all times. Reels should always be handled by the hub and never by the flanges, because this will squeeze the flanges into the tape pack. The normal shuttling operation of a computer will invariably leave the tape pack in an uneven state, with tape edges protruding slightly (Figure 2). Further, plastic computer flanges are not rigid enough to withstand flexing if exposed to rough handling.

Keeping Tape Comfortable. Various recommendations have been published regarding maximum safe limits of temperature and humidity for storage of tape. The easiest way to remember the optimum conditions is that tape performs best under "people conditions": 70°F, 50% RH. Since it is not always practical to maintain tape libraries under these laboratory conditions, what are some realistic tolerances for these parameters? The effects on computer tape from exposure to varying temperatures are gradual, and it is impossible to assign a specific, maximum limitation whereby the tape would immediately go from good to bad if this limit were exceeded. Figure 3 portrays the effects in a different manner than previously used.

This chart plots degree of risk versus environmental conditions. It shows that tape exposed to a condition outside the range normally specified is not necessarily damaged to the point where it is no longer reliable. The normal, "safe range" for computer tape is 60°F to 90°F, and 40 to 60% RH. If, for example, a tape is exposed to temperatures of 100°F for a period of 10 to 12 hours, it can be used after "normalizing" in the proper computer environment for 24 hours. The point is, the tape will represent a higher degree of risk and will be more prone to problems resulting from base film distortion than if the tape had not been exposed to temperatures exceeding 90°F.

Extremes of temperature or humidity cause physical changes in the base film, but do not degrade the magnetic properties or binder. Polyester film, the most stable base film available, will expand or contract under wide environmental changes. The coefficient of Thermal expansion for polyester is 1.5×10^{-5} inch/inch/degree F, and the coefficient of Hygroscopic expansion is 1.1×10^{-5} inch/inch/percent RH. If tape is exposed to 120°F, for example, this will represent a ΔT of 50°F (120°F minus 70°F), and the base film will expand accordingly. This is within the reversible limits of polyester, and if the base film were unrestrained it would expand and contract with no permanent set. However, since the base film is restrained within the tape pack, it cannot move freely; and as it attempts to expand, tremendous pressures are built up within the tape pack, distorting the base film. This pressure can conceivably cause layer-to-layer adhesion. The resulting erratic tension pattern on the tape also creates a condition that is likely to cause tape cinching.

Recertification and Renovation. With the rising expense of maintaining an active tape library, many installations are turning to recertification and renovation of used tapes. Recertification, *per se*, means determining the number of errors on a tape at a given packing density. In order to be effective, it is first necessary to clean the tape to remove surface accumulated dirt, redeposits and trash. There is no way possible to "rejuvenate" computer tape. Computer tape can be cleaned and surface deposits can be removed, but scratches, grooves, edge damage, etc., cannot be corrected by a cleaning operation. Remember, too, that the oxide coating does not lose its magnetic potency through aging. Tape loses its reliability by the accumulation of surface contaminants and physical imperfections. A necessary adjunct to cleaning and recertification is precision winding. The proper tension pattern on computer tape is absolutely necessary for reliable operation.

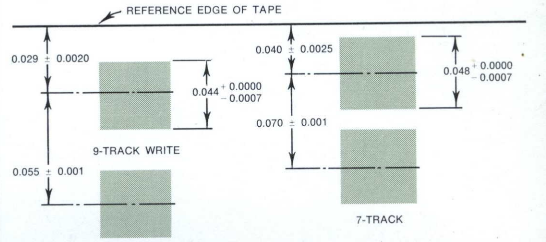


Figure 1. Relation of 7-track and 9-track layout.

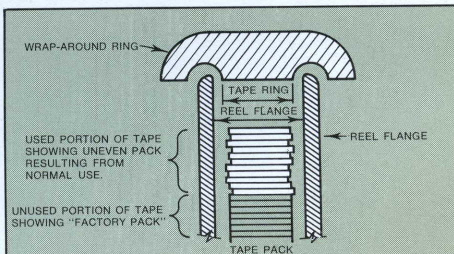


Figure 2. Cross-section of computer reel with wrap-around ring.

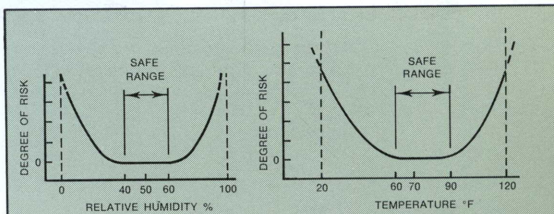


Figure 3. "Comfort Index"

DO'S AND DON'T'S FOR COMPUTER TAPE

DO

... strip ends of tapes that have been damaged.
... clean the tape and remove all residual adhesive when replacing EOT and BOT markers.
... conduct periodic inspection of all utility tapes for damaged tape, reels and containers.
... keep the tape storage area free of all dust and contaminants—paper form shed is the worst.
... use only labels with non-residual adhesive and no shedding—"come clean" type.
... rewind end-to-end.
... clean tape path as frequently as possible.
... inspect takeup reels frequently and replace as required.

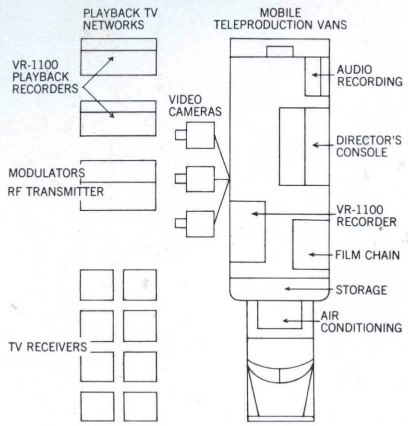
DON'T

... smoke or eat in data centers (especially critical in tape libraries).
... place any notes, markers, etc., in the container with tape.
... use clear cellophane mending tape for any purpose in or around the data center.
... use old or damaged takeup reels.
... handle tape reels by the flanges.
... allow tape to touch clothing.

newest high-speed breakthroughs to the brain: **audio / video / plus**

Ampex Special Products Engineering Group demonstrates its complete "can do" capabilities in today's most imaginative training systems; unfettered by usual electronics brand bondage; augmented by the most advanced tape recording arts. Services include total design, plus contract installation. Send your name to keep posted.

training networks



Seventeen training centers of United States Continental Army Command (CONARC) are now equipped with Ampex videotape replay networks feeding hundreds of classrooms.

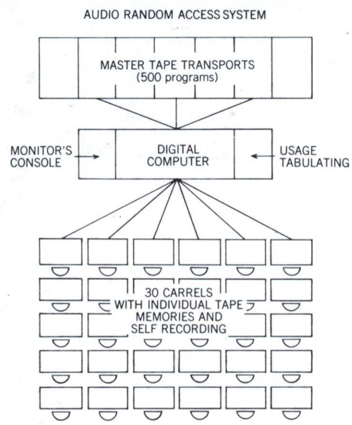
This is one of the largest and most flexible CCTV systems in the world. It records, edits and distributes visual training programs at delivery or revision speeds not possible with film.

Five mobile videotape recording "cruisers" produce up-to-the-minute military training tapes anywhere in the field. Ampex made these vans completely self sufficient, with auxiliary power, air conditioning, professional console, mixing and editing capabilities for video and audio.

Playback systems with Ampex VR-1100 reproducers, RF modulators and transmission permit instant relocation or addition to classroom receivers.

Ampex experience in installation of commercial TV stations (from the ground up) proved valuable here.

learning centers

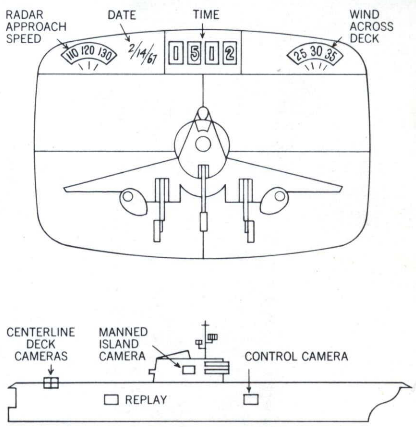


A unique new random-access learning system—designed and developed by Ampex—will permit dial-selection of any of 500 audio lecture, music, documentary or language programs, by students at 30 individual carrels. Continuously. Non-competitive.

It uses a digital computer with high-speed loop tape transports feeding to buffer tape memories in each carrel. Reaction, selection and buffer transfer takes less than 60 seconds. So no matter how often one tape is chosen, its master is never "out." Students can listen, stop, rewind, etc., at leisure; and self-record on a second track. Program and student usage is tabulated for educational research purposes.

This project is made possible by a U.S. Dept. of Health, Education & Welfare grant to Oak Park and River Forest High School, Ill. Another system—a low cost Ampex videotape recorder-teaching model for primary schools—is now operational at Los Alamos, N.M.

special-purpose systems



Installation going aboard the new U.S. Aircraft Carrier President John F. Kennedy means that Pilot Landing Aid Television (PLAT) is now on every U.S. Navy carrier.

This Ampex system helps pilots correct landing techniques while the landing is fresh, by "instant replay." Actual action tapes help train future pilots. Approaches are shown perfectly sychronized with conditions data via split-screen, for detailed review. Since PLAT was introduced landing errors have been greatly reduced.

A similar system is now helping short-field land operations of U.S. Marine Corps pilots. Videotape will also economically replace film for recording repeated events (e.g., catapult, weapons launchings), and aircraft maintenance libraries (e.g., Eastern Airlines).

Other special-purpose systems by Ampex include theatre sound systems, Videofile* system, plus systems for medicine, research and aerospace.

keep posted on new training systems

AMPEX

Ampex Corporation • 401 Broadway • Redwood City • California • U.S.A. • 94063

Bulk Rate
United States Postage
PAID
San Francisco, Calif.
Permit No. 7577

North Sydney, Australia • Rio de Janeiro, Brazil • Toronto, Canada • Bogota, Colombia • Reading, England • Paris, France • Frankfurt/Main, Germany • Hong Kong, B.C.C. • Tokyo, Japan • Mexico City, Mexico • Stockholm, Sweden • Lugano, Switzerland

LITHO IN U.S.A.—G185—4-67

Audio Recording

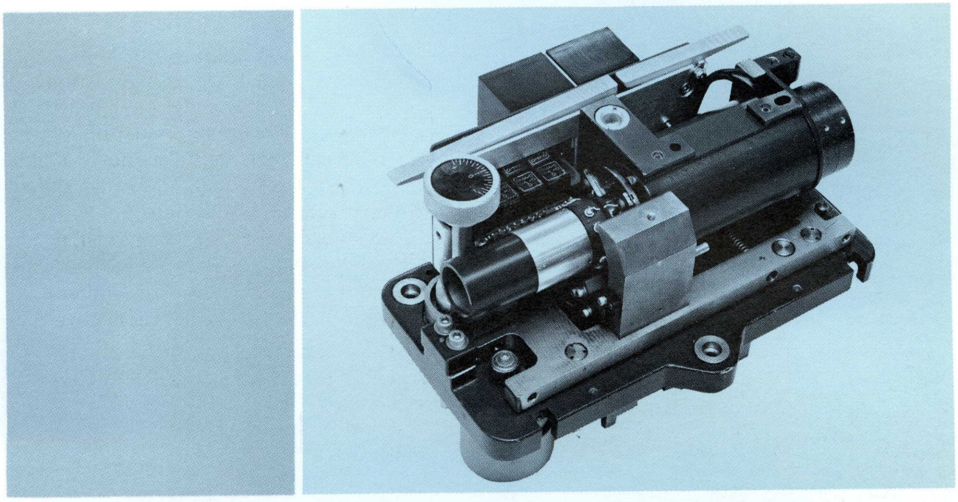
Audio information is stored on photographic films for motion pictures, and on magnetic tape or phonograph discs. Bandwidths for mono and stereo applications go to 15 or 20 kHz. Since the ear is comparatively phase-insensitive, only level amplitude response over the frequency band is important. Current technical objectives relate to providing superior performance (mostly better signal-to-noise ratio, reliability, and convenience) for the same cost, or the same performance at reduced cost. Developments are constrained by standardized tape speeds and track widths. Magnetic tape is superior to audio discs in that discs wear rapidly with use, therefore giving poorer signal-to-noise output on each play, while tape wear is usually negligible and signal-to-noise independent of number of plays. In fact, phonograph discs are commonly made from sound recorded on magnetic tape masters. Audio tracks are recorded both magnetically and optically on motion picture silver-halide film.

Picture Recording

It is estimated that the better quality motion picture films are produced with bandwidths of about 12 MHz. By comparison, the United States video standard for television use (to which video recorders must adapt) is 4.2 MHz with 3.5 MHz subcarrier for black and white, and 4.2 MHz with 3.58 MHz subcarrier for color. Ampex high-band color, for example, uses a 9.16-MHz signal. Though video recording can be extended in bandwidth to give superior resolution, it is tied to the television standard. An advantage of magnetic tape over motion picture film is its superior resistance to abrasion. Though motion picture film degrades with use (the signal-to-noise ratio of the picture decreases) the signal-to-noise ratio of broadcast standard video tape (for example) remains over 40 db with use.

Future developments in video recorders, within the broadcast standard, will result in increased flexibility and convenience (i.e., smaller size) at reduced cost. A wider range of information bandwidth is possible for non-broadcast video recorders. Though the loss in signal-to-noise ratio or resolution is unacceptable, relatively inexpensive recorders can be built if we chose to operate at bandwidths as low as 1.5 MHz. At the other extreme, bandwidths giving picture resolution comparable to the best motion picture films are possible.

Both black-and-white and color video recordings have recently been made on magnetic film plated discs. The discs, with the magnetic heads operating in contact, are used for stop, fast, slow, or normal, forward or backward motion.



FR-900 Rotary Head Assembly. Four heads spaced 90° apart on a drum record and reproduce transverse tracks on 2-inch tape. Rotary transformers remove transients when switching from each of the four heads.

Instrumentation Recording

Instrumentation recording applications range from miniature recorders for satellites and space probes, and very-long-time low bandwidth recorders for geophysical purposes, to wideband (currently 5.5 MHz; in a decade 100 MHz) recorders for predetection purposes (as in recording all signals from a rocket launching of a space probe). It appears that rotary magnetic recording can be used to bandwidths of 10 to 30 MHz, but that more exotic schemes using laser or electron beams, for example, are required for bandwidths to and beyond 100 MHz.

Digital Recording

Magnetic tape has been the repository of most digital data stored for periods longer than one second. When placed on reels (scrolls), the information is accessed and read out sequentially. When placed on strips and filed in boxes (books), individual strips can be randomly accessed and sequentially processed. Drums and discs with magnetic surfaces (usually called random access memories) are useful in digital memories because of their 100 to 200 milliseconds random access to a string of data.

Competing with these erasable memory techniques are permanent memory systems employing silver-halide film exposed by electron or laser beams. It is possible to record a higher density with beams. Readout at an acceptable error rate is the major problem. To date, no photographic read/write digital system has proved superior to magnetic tape storage with respect to any of the three critical factors mentioned earlier, or cost, even ignoring the limitation due to non-erasibility. From the cost standpoint, only magnetic tape and beam exposed media seem to be potentially practical for storing vast amounts of data (10^{11} to 10^{14} bits).

Ferrite core memories are presently the only practical means by which memories larger than 10^7 bits can be used which have cycle times under 3 microseconds and cost-per-bit under 3 cents. They also are used for most main frame memories operating at cycle times down to 1 microsecond. Some main frame memories are now made of magnetic thin films on rods, planes, or wires. Since thin magnetic films have been used as delay lines, we may also classify them as random, sequential memories.

The highest speed memories in a computer are called "scratch pad" memories. Increasingly, scratch pad memories are being designed to use integrated circuits. There is a variety of storage devices used for scratch pad memories such as sonic delay lines, thin magnetic film strips, tunnel diodes and integrated circuits. Integrated circuits (more importantly, large scale integration (LSI) which involves numerous integrated circuits tied together on the same chip) offer the best promise from the standpoint of size, reliability, and cost. Yield considerations here are important, too.

Future Storage Capabilities

To simplify comparison of the most important continuous recording processes, we compare performance on the basis of digital storage (in the accompanying chart). The first two items are available now. The remaining three are under development and will be discussed in the next section.

TYPE	FR-1600	FR-1800H	FR-1800M	FR-1800L	AR-1600	FR-1300	AR-200	CP-100	SP-300	AR-500/550	FR-900/950	FB-400 (Bin)	SP-600
General Description	Lab High Band	Lab High Band	Lab Interm. Band	Lab Interm. Band	Air/Mobile High Band	Lab/Port. Interm. Band	Air/Mobile Interm. Band	Mobile Interm. Band	Portable Interm. Band	Air/Mobile Wideband	Lab Wideband	Lab (bin) Interm. Band	Lab/Port. High Band
Recording Modes	FM and DR Rec/Rep	FM, DR and FSM Rec/Rep	FM, DR and PDM Rec/Rep	FM, DR and PDM Rec/Rep	FM and DR Rec/Rep	FM, DR and PDM Rec/Rep	FM, DR, PDM and PCM Rec only	FM, DR and PDM Rec/Rep	FM and DR Rec/Rep	FM and Pre-detect Rec only	FM and Pre-detect Rec/Rep	FM, DR and FSM Rec/Rep	DR Rec/Rep
Band Widths FM/Direct	500kHz/ 2.0MHz	500kHz/ 1.5MHz	40kHz/ 500kHz	40kHz/ 300kHz	500kHz/ 2.0MHz	20kHz/ 300kHz	20kHz/ 250kHz	20kHz/ 250kHz	2.5kHz/ 40kHz	5.5MHz 5/10 MHz Carrier (PD)	5.5MHz 5/10MHz Carrier (PD)	500kHz/ 1.5MHz	1.5MHz
Channels	7 or 14	7 or 14	7 or 14	7 or 14	7 or 14	7 or 14	7 or 14	7 or 14	4 or 7	1 or 2WB w/2 aux.	1 or 2WB w/2 aux.	7 or 14	4
Tape Widths (inches)	½ or 1	½ or 1	½ or 1	½ or 1	½ or 1	½ or 1	½ or 1	½ or 1	¼ or ½	2	2	½ or 1	¼
Reel Diameters (inches)	10½, 14, 15, 16	10½, 14	10½, 14	10½, 14	10½, 14	10½	10½	10½	7, 10½	8¼	10½	Loop 5 ft.-250 ft.	10½, 12½
Tape Speeds (ips)	Discrete and Continuously Variable						1⅞-60	1⅞-60	1⅞-15	12½/25	12½/25	3¾-120	120
	3¾-240	1⅞-120	1⅞-120	1⅞-120	3¾-120	1⅞-60							
Capstan Servo	200kHz	200kHz or 60Hz	200kHz or 60Hz	20CkHz or 60Hz	200kHz	60Hz	60Hz Rec only	60Hz Rec only	none	integral	integral	60Hz	integral
Record Time at Max. Bandwidth	17½ min.	12 min.	12 min.	12 min.	12 min.	12 min.	12 min.	12 min.	48 min.	50 min. (1 ch.) 25 min. (2 ch.)	60 min. (1 ch.) 30 min. (2 ch.)	Continuous Loop	19 min.
Amplifier Speed Switching Characteristics	6 spd. elec. or single spd. manual	2 or 4 spd. elec. or single spd. manual	2 or 4 spd. elec. or single spd. manual	6 spd. elec. or single spd. manual	6 spd. elec. or single spd. manual	6 spd. elec. or single spd. manual	6 spd. manual	single spd. manual	4 spd. elec.	single spd.	single spd.	electrical or manual	single spd.
Power Required	115/230V 50/60Hz	115/230V 50/60Hz	115/230V 50/60Hz	115/230V 50/60Hz	28vdc or 115/230V 50/60Hz or 115V 400Hz 3ϕ	115/230V 50/60Hz	28vdc or 115/230V 50/60Hz or 115V 400Hz 1ϕ or 3ϕ	28vdc or 115/230V 50/60Hz or 115V 400Hz 1ϕ or 3ϕ	115/230V 50/60Hz	115V, 400Hz 3ϕ	115/230V 50/60Hz	115/230V 50/60Hz	115/230V 50/60Hz

The world's dullest chart... unless you need a recorder.

To tell you that our instrumentation recorders are made to the highest standards of quality would either be belaboring the obvious or sound like braggadocio, depending on how well you know Ampex. □ Let us just add one word that the chart omits: Whatever we make, we take care of. Service is a big part of what you buy from us. Anywhere in the world, any time of day or night that you need Ampex service, one of our engineers is close by. □ For complete information on any of our recorders or the high quality magnetic tape we make for them, write Ampex Corporation, 401 Broadway, Redwood City, California 94063.

AMPEX

AMPEX

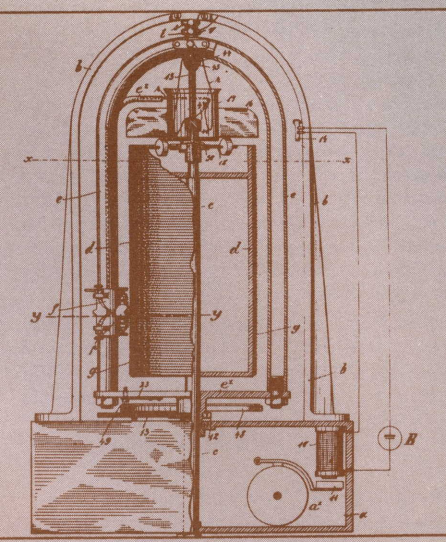
Ampex Corporation • 401 Broadway • Redwood City • California • U.S.A. • 94063

Bulk Rate
United States Postage
PAID
San Francisco, Calif.
Permit No. 7577

North Sydney, Australia • Rio de Janeiro, Brazil • Toronto, Canada • Bogota, Colombia • Reading, England • Paris, France • Frankfurt/Main, Germany • Hong Kong, B.C.C. • Tokyo, Japan • Mexico City, Mexico • Stockholm, Sweden • Lugano, Switzerland

LITHO IN U.S.A.—G253—11-67

INSTRUMENTATION TECHNICAL INFORMATION NUMBER 1



ROTARY-HEAD INSTRUMENTATION RECORDERS: DESCRIPTION AND USES

By R. Horn

The bandwidth of any magnetic tape recorder is basically limited by the magnetic wavelength on tape. To record a bandwidth of more than a few MHz, recorders with stationary heads require excessively high tape speeds with correspondingly low recording time. The problem of extending signal bandwidth to 4 MHz and above was solved by Ampex engineers in 1956, with the first transverse scan rotary head in the VR-1000 Videotape Television Recorder. Since then, parallel rotary head development programs at Ampex have resulted in the high band VR-2000 (world standard for color broadcast and teleproduction) and a related generation of airborne and ground transient-free instrumentation recorders, the FR-900/AR-500 family.

ROTARY HEAD FUNDAMENTALS

A rotary head assembly has a drum with four magnetic transducers at its circumference rotating at high velocity. Effective head to tape speed with this technique is typically 1600 in/sec. With a rotary head, adjacent transversely recorded tracks are discontinuous (see Figure 1). Each transverse track has a duration of about one millisecond and contains about 100 microseconds of redundant or overlapping information also contained in the following track. In the playback process, the rotary head reproduces each track in sequence.

Small timing or phase errors and signal discontinuities in reproduction from track to track are caused by dimensional variations in the tape and head mechanical components, or differences in characteristics of the four heads. For television recording, these signal interruptions are timed to occur during the picture scan blanking intervals, and pose no problem. For instrumentation recording, spurious sidebands caused by the transverse track discontinuities can degrade the data. A solution was found with the introduction of the continuous-signal, transient-free, rotary-head recorders (Ampex

AMPEX

VR-1006, FR-900, FR-950, AR-500, and AR-550.)

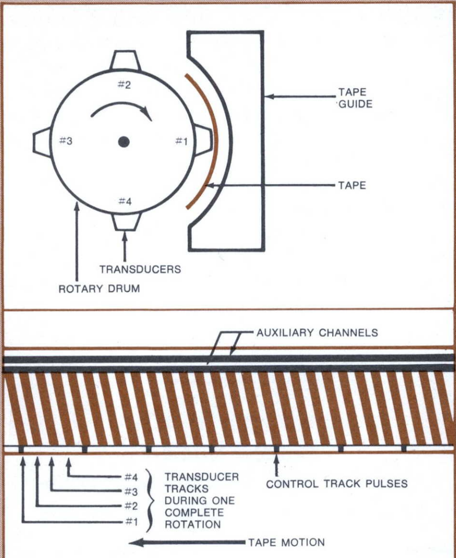


FIGURE 1. End view of rotary head assembly and tape format of single wideband channel transverse scan recorder.

An FM recording technique is used to assure wide dynamic range, high signal-to-noise ratio, and low frequency response (down to 10 Hz). Signal combination between one recorded track and the next is performed prior to limiting and demodulation of the FM signal. If it were necessary for instrumentation applications to keep transients generated through the FM detector to a value of 30 dB below the peak signal level, track-to-track phase errors would have to be held to within a few degrees at the carrier frequency. This would amount to only a very few nanoseconds. In the FR-900 recorder family, transients are avoided by making a slow transition between consecutive tracks (typically over an 80-microsecond duration), rather than a fast one (Figure 2). In order to make this slow transition without carrier cancellation during the switching process, the phase difference between the off-going and the on-coming signals is kept to less than 180° of the carrier frequency. For a typical system with an 8.5-MHz FM carrier, this amounts to 60 nanoseconds.

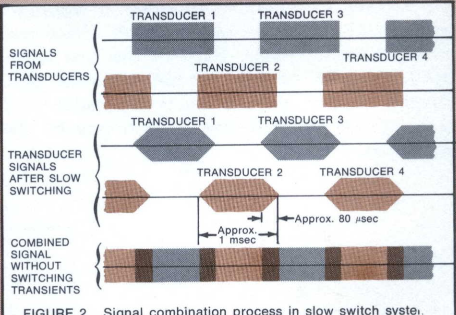


FIGURE 2. Signal combination process in slow switch syste

To bring the two signals into phase, a pilot frequency from a stable crystal-controlled oscillator is frequency multiplexed with the FM signal during recording. (This frequency is located below the useful lower sidebands of the FM carrier so it does not interfere with the data.) On playback, the pilot is compared in phase and an error signal derived to vary the amount of delay in a voltage-variable delay line through which the four playback signals pass prior to commutation. By this means, the FM information in the on-coming channel is brought to within 15 nanoseconds of that in the off-going channel before the switching begins.

ROTARY HEAD RECORDER FAMILY

Current rotary-head instrumentation recorders such as the FR-900 provide a capability of recording 6 MHz on one channel for one hour. The reproduced signal is continuous and transient free. Signal-to-noise ratio is better than 40 dB peak-to-peak signal to rms noise. Time-base error is exceptionally low, within ±15 nanoseconds of the timing reference of the recorder/reproducer over the entire duration of the recording. Besides the wideband channel, the FR-900 records two longitudinal channels for additional data or voice logging. Each has a bandwidth of 300 Hz to 30 kHz.

Other machines in this family are the FR-950, a two-channel 6-MHz recorder/reproducer with a one-half hour recording capacity; the AR-500, a record-only, single-channel airborne counterpart to the FR-900; and the AR-550, a record-only, two-channel airborne counterpart to the FR-950.

APPLICATIONS

Multiple Instrumentation Radar Recording: A typical radar application involves recording video data of approximately 1.2-MHz bandwidth from two radars plus a radar trigger. Precise time correlation is required between the two video signals. Also, azimuth information from each radar is recorded. The FR-900 6-MHz wideband channel is split into two bands. One radar video and associated trigger are recorded directly. The second radar video is first frequency modulated on a 4-MHz subcarrier, then recorded.

This approach utilizes the wide bandwidth of the 6-MHz channel for two smaller bandwidth data channels. Close interchannel timing is achieved between the two radar video signals and the radar trigger since they are all recorded on the same channel. Coarse and fine azimuth synchro information including reference frequency from a single radar is frequency multiplexed on one of the two longitudinal channels.

Airborne Search Radar Recording: One of the original requirements for an airborne rotary instrumentation recorder was to record radar and moving target indicator video, of approximately 5.5-MHz bandwidth each, from an airborne search radar. Each of the two wideband channels of the AR-550 airborne unit records a video channel from the radar. The radar trigger is multiplexed onto one of the wideband channels.

The time-base stability of the rotary-head recorders is such that ranging errors caused by signal jitter are negligible for most radar systems. The ranging time for a radar mile is approximately 12 microseconds or 6.8 nanoseconds per yard. Since the AR-500/FR-900 family has a time-base stability of ±15 nanoseconds peak-to-peak, the maximum reproduced timing error between a radar trigger and video pair of pulses is 30 nanoseconds. This corresponds to a ranging error of 4.4 radar yards. Accurate data correlation of the two radar channels is also provided because the interchannel time displacement error between the two 6-MHz channels is 25 nanoseconds or less on the AR-550/FR-950 recorders. Data reproduced from an AR-550 tape is free of any head-switching transients when operated within the recorder's rather wide environmental limits. The dynamic range of the AR-550/FR-950 allows a minimum width pulse of approximately 200 nanoseconds, half amplitude duration, to be visible above noise level when 40 dB below full-level signal.

The AR-550 for this application included a digital synchro unit which digitizes radar azimuth synchro data, and records it on one of two longitudinal tracks. Upon reproduction, the synchro information is converted back to analog form and maintains an accuracy of 0.36°

Related applications of these airborne/ground systems are reconnaissance missions, training of radar operators, radar evaluation, and data computing systems evaluation.

Predetection Recording: Another important application of rotary instrumentation recorders is their use without the internal FM modulator/demodulator for predetection recording. Picture data from the Lunar Orbiter uses this technique on an FR-900 (see *Readout*, Volume 6, No. 3). Typically, the intermediate frequency output of a receiver is used for recording frequency modulated signals directly. The usable bandwidth in the predetection mode is 1 MHz to 10 MHz. When reproduced, the predetection output is fed to a limiter stage to provide a constant amplitude output over the recorded bandwidth for demodulation by external equipment. In this mode the pilot signal from the timing reference of the recorder can be recorded with the predetection signal for transient-free reproduction.

Recording Television Signals of Any Scan Rate: A rotary-head instrumentation recorder synchronizes the rotary head and tape speed to its own internal timing reference. (A standard television recorder synchronizes to the input signal.) This means a rotary instrumentation recorder can record a television signal of any vertical or horizontal scan rate whose signal bandwidth is within the recorder bandwidth. In some applications, such as aircraft with several sensor systems (infrared, side-looking radar, television cameras), each sensor system may have different scanning rates. The AR-500 can record these singly or in any sequence on one channel. The AR-550 can record any two signals simultaneously.

Digital Data Recording up to 20 Mbit/s and Higher: In digital data recording applications, the wide bandwidth, transient-free head switching, low jitter, (as well as a proprietary redundant recording scheme) permit the FR-900 family to record up to 10 megabits per second per channel of serial NRZ digital data at very low error rates. If the digital data source is synchronized to the timing reference of the recorder this reference can be used as an error-free data clock when the data is reproduced. Error rates at 10 megabits per second are less than 1 in 10^8 bits measured on a bit-by-bit basis. Data rates in excess of 10 megabits per second can be handled by multichannel recorders, for example: 20 megabits per second on the two-channel FR-950 or AR-550. In fact, the existing technology of the FR-900 family can be extended to rates up to 20 or 30 megabits per second. The absence of head-switching transients permits recording digital data at high bit rates even during the switching period at these low error rates.

Another important consideration is that more digital data can be recorded on a given amount of tape on a rotary instrumentation recorder than on any other type of magnetic tape recorder. One roll of tape on a standard 10½-inch reel is capable of recording 10 megabits per second for one hour or 3.6×10^{10} bits. Standard longitudinal recorders with 14 tracks on 1-inch tape at 800 bits/inch can record 5×10^8 bits/roll (3600 feet). For an equivalent volume comparison, two 1-inch rolls of 1-inch tape on 10½-inch reels will hold 10^9 bits. One rotary-head recorder tape holds almost 36 times as many bits as two longitudinal recorder tapes.

Reprinted from READOUT®
Volume 7 Number 2
A magazine of Ampex Corporation

AMPEX

Ampex Corporation • 401 Broadway • Redwood City • California 94063 • U.S.A.

North Sydney, Australia • Sao Paulo, Brazil • Rexdale, Ontario, Canada • Montreal, Quebec, Canada • Bogota, Colombia • Reading, England • Boulogne, France • Frankfurt/Main, Germany • Hong Kong, B.C.C. • Tokyo, Japan • Beirut, Lebanon • Mexico City, Mexico • Sundbyberg, Sweden • Lugano, Switzerland

LITHO IN U.S.A.—G313—2-69