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SUMMARY

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Meteorological satellites collect infrared data and video pictures of the earth's cloud cover and store it on board for transmission while in the vicinity of a ground station. The most economical and efficient method of data storage is achieved through the use of an on-board magnetic tape recorder, and continuous-loop magnetic tape cartridges. Advantages of this combination are that the most recent data always transmitted to the ground stations and multiple interrogations are possible. A satellite tape recorder is subjected to a severe environment during its lifetime, and its mechanical design must be adequate to withstand this environment. It also must have a sophisticated electrical design which will serve the data storage requirements of a meteorological satellite.

This paper describes the recorder design concepts and products evolved, and their utilization in meteorological satellites.

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INTRODUCTION

Meteorological satellites collect infrared data and video pictures of the earth's cloud cover and store it on board for transmission while in the vicinity of a ground station. The most economical and efficient method of data storage is through the use of an on-board magnetic tape recorder, with a continuous-loop magnetic tape cartridge. Advantages of this combination are that the most recent data are always transmitted to the ground station, and that multiple interrogations are possible.

A satellite tape recorder is subjected to a severe environment during its lifetime, and it requires a mechanical design which will withstand the rigors it will be subjected to. It must also have a sophisticated electrical design which will serve the data storage requirements of a meteorological satellite. This paper will trace the development of the continuous-loop magnetic tape recorder from its inception in 1956 as a part of the Vanguard program, to its use in the Tiros and Nimbus meteorological satellite programs; and it will outline projected lines of development of present design concepts.

The continuous-loop recorder has several advantages over other types of magnetic tape recorders, and among these are: (1) the single tape reel provides compact storage; (2) reversal mechanisms are not required for record and playback functions; (3) the tape can drive beyond one pass without requiring safety cutoff devices for the motors; and (4) momentum compensation is simple when required. It also has two main disadvantages: (1) frictional wear on the tape surfaces within the pack during operation, and (2) snubbing devices are necessary to maintain stability in tape packs of 1200 feet or more, during vibration testing and during the launch environment.

Designing, fabricating, and testing magnetic tape recorders for satellite applications is unique.

Satellite recorders must operate and perform under unattended conditions in a spacecraft and periodic maintenance is impossible. Once the recorder is in orbit magnetic heads and tape cannot be cleaned, bearings cannot be relubricated or replaced, and components cannot be adjusted or changed. Thus, it becomes necessary to design the recorder to survive the launch and space environment and then to perform satisfactorily without maintenance.

The result is a rigorous test program which qualifies the design and workmanship on a prototype and on flight models. The program includes random and sinusoidal vibration tests to simulate the rocket launch phase, vacuum and thermal tests for the orbit environment, humidity tests for storage and transportation conditions before launch operational and life performance tests to ensure a maintenance-free capability, and electro-mechanical interface checkouts. Finally, the design must consider the effects resulting from its integration with the spacecraft system.

During the launch phase, the combination of steady state acceleration, sinusoidal vibrations, and random vibrations, is transmitted from the rocket to the satellite and subsequently to the recorder. These vibrations are the result of rapid changes in vehicle behavior due to fuel consumption, attitude correction maneuvers, engine pulsation, erratic burning of fuel and acoustical noise. Of extreme importance is consideration of magnification factors of vibration during resonant modes. In orbit it must perform satisfactorily under zero gravity and wide temperature changes as the satellite passes from the sunlit to the dark portion of the orbit.

To eliminate space vacuum effects on bearings, rotating parts, and dynamic surface contacts, the recorders are pressure sealed. The effects of thermal radiation and heat transfer in a vacuum must also be considered in the design.

A satellite orbit is a function of vehicle thrust and total vehicle weight and payload. In the earlier meteorological programs, it was necessary as a result to design each component with strong emphasis on minimum weight with the least sacrifice in performance and reliability.

Power consumption has always been a significant factor in spacecraft electronics design. Power availability is determined by the batteries and solar cells contained on the spacecraft. Although the total number of systems flown on a single spacecraft has increased, the unit power availability is now greater and has alleviated what were once stringent power constraints on recorders.

THE VANGUARD RECORDER

The design and development of continuous loop recorders for meteorological satellites originated in the Vanguard II program, part of the United States' space program for the International Geophysical Year. The Vanguard II was a 21 inch diameter satellite (Figure 1), designed to contain an infra-red system for observing the cloud cover of the earth. The design of such an IR system was a challenging task when initiated in 1956. The objective was a total satellite weight of less than 21 pounds, consisting of approximately 7 pounds of batteries, 8 pounds of structure and sensors and 6 pounds of electronics. An endless-loop recorder was required which could store 50 minutes of data, reproduce it in 1 minute, survive the vehicle steady state accelerations and vibrations during launch, be designed for minimum power and weight, and survive the temperature variations in outer space.

There was at that time no experience in industry or government, in the design of endless-loop recorders to survive the various rocket launch and orbital environments. In addition, no established testing procedures existed for evaluation of equipment performance during launch conditions. As a result of this, there were no established design techniques such that satellite tape recorders would withstand the random vibrations which they would probably be subjected to. Therefore testing of units was rigorous and empirical. Success could only be assured by a painstaking quality selection of a few samples which underwent extreme environmental and performance tests. For example, the recorder was tested through a temperature range of 0° to 60°C and underwent random vibration of 30 G's rms from 20-2000 cps. As a result 9 recorders were tested in order to yield 3 which could be considered as flight hardware. The performance of the three units selected, however, remained consistent throughout tests and proved adequate for the intended mission.

The Vanguard II was launched on 17 February 1959 and its tape recorder was the first endless-loop recorder designed to be flown in an earth orbiting meteorological satellite. Although the satellite was to be spin-stabilized it went into a tumbling mode; and the result was an extremely difficult data analysis task. However, the highly successful operation of the system itself for its full two-week life substantiated the design and test approach which had been taken, and was a significant step forward in the design of endless-loop tape recorders for satellites.

The Vanguard recorder was packaged as part of a cylindrical instrumentation package (Figure 2), consisting of batteries, the recorder, and an electronics deck. The entire package slipped into a cylindrical can which was part of the satellite structure. The recorder (Figure 2) contained 75 feet of lubricated tape, had a record speed of 0.3 in./sec., and a reproduce

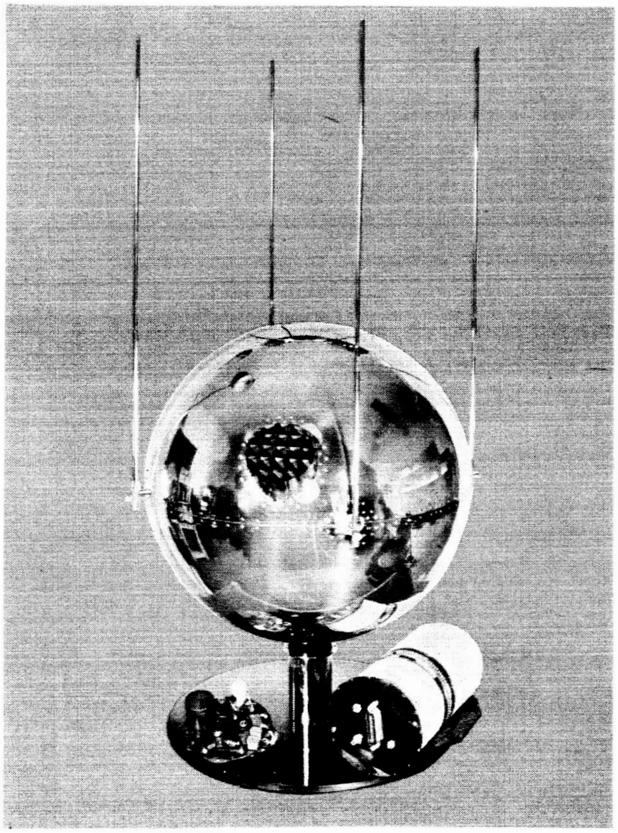

Figure 1—Vanguard II satellite.

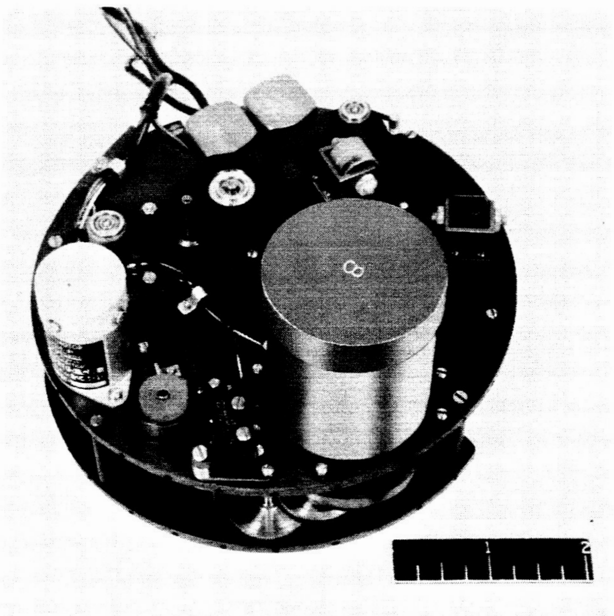

Figure 2—Vanguard II magnetic tape recorder.

speed of 15 in./sec. Because the recorder was not vibration isolated, the recorder was placed at the bottom of the instrumentation package and secured under a slight compressive force, to minimize amplification factors. Spring preloading of recorder bearings was used wherever possible. To avoid the detrimental effects of space vacuum on the recorder components the entire instrumentation package was pressurized and sealed.

Because the booster used had a relatively low thrust it was necessary to minimize weight wherever possible in order to obtain the desired orbit. Magnesium was used extensively throughout the recorder. It weighed 1.5 pounds and was 3 inches high and 5.5 inches in diameter. In addition, the only power source was a non-rechargeable storage battery unit. Therefore to conserve power the recorder utilized two high efficiency low power dc motors without speed regulators. The record motor utilized .09 watts and the reproduce motor utilized 2.0 watts of power. Flutter was about 6% P-P.

This recorder was designed for minimum power consumption and weight rather than for accurate performance.

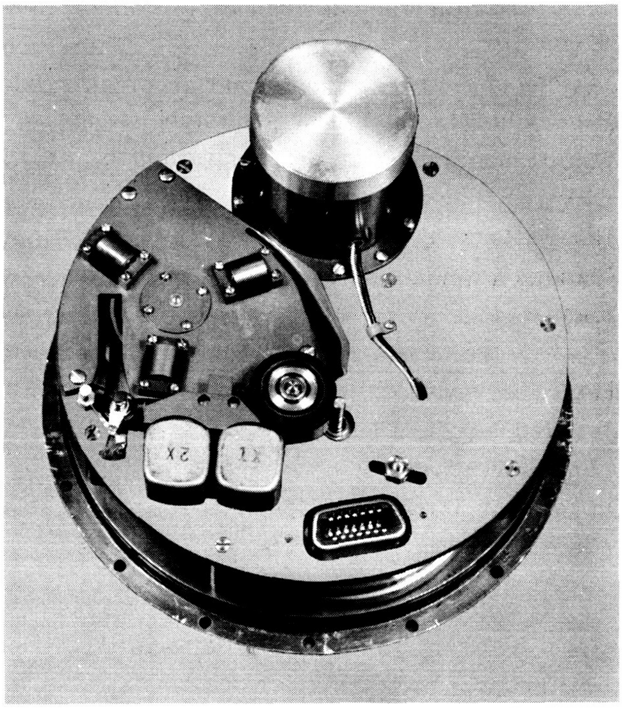

Figure 3—Courier tape recorder, top view.

THE SCORE RECORDER

A modified version of this recorder (Figures 3 and 4) was flown in a communications satellite in December 1958, before Vanguard was launched. This satellite was part of the Atlas-Score project and is believed to be the first known endless-loop tape recorder flown in an earth-orbiting satellite. The instrumentation package is shown in Figure 5. Although the Vanguard recorder was completed and qualified before the modified Score recorder, delays in the Vanguard launch schedule resulted in the Score satellite being launched first. This recorder proved highly successful during its lifetime.

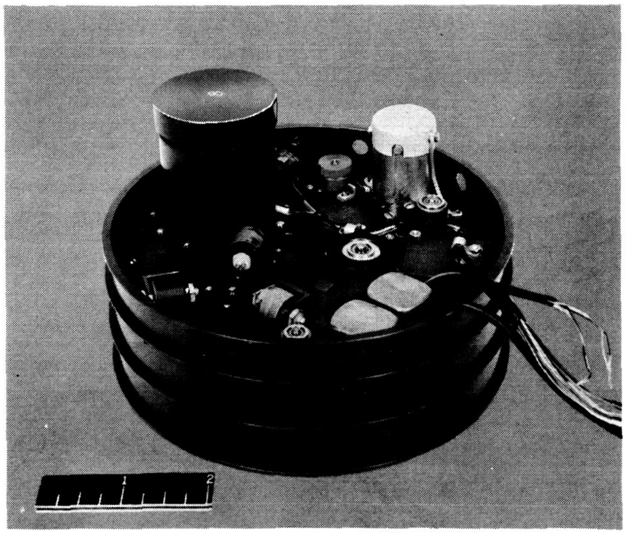

Figure 4—Courier tape recorder, side view.

THE TIROS RECORDER

The Tiros (Television infra-red observation satellite, Figure 6) program produced the 2nd generation of endless-loop tape recorders for meteorological satellites (Reference 1). Such a recorder was included as part of the infra-red system in this spin-stabilized satellite series. For the Tiros program performance requirements were more stringent and considerable design changes were necessary in the recorder. Orbit life of 6 months rather than two weeks was required; wow and flutter requirements were reduced to 2.5% P-P from 6%, and 200 feet of 1/4 inch lubricated tape were needed, a substantial increase over the Vanguard requirement. In addition, it was necessary to have a record speed of 0.4 in./sec., and a reproduce speed of 12 in./sec.

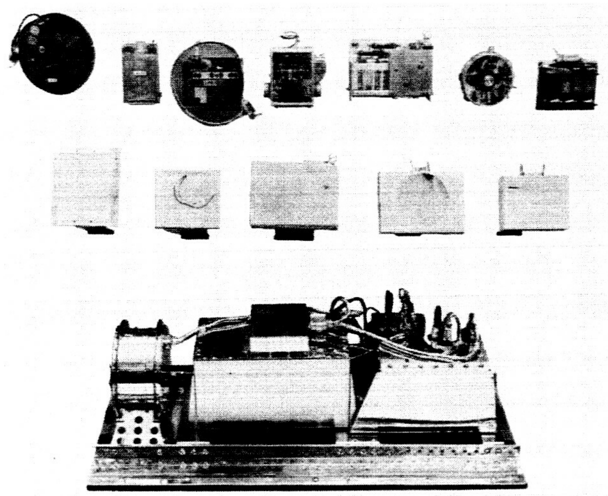

Figure 5—Courier instrument package.

Experience gained in the test program of Vanguard II and the increased knowledge of rocket launch environments enabled a more thorough design analysis to be utilized. More design emphasis had to be applied to the preloading of ball bearings, to the use of polyester film belt drives (Reference 2), and to the precision fabrication of the recorder components, to obtain the required life and performance and to survive the environmental conditions. Low power and weight requirements combined with accurate performance and high reliability demanded much greater precision fabrication techniques than those used for the Vanguard recorder.

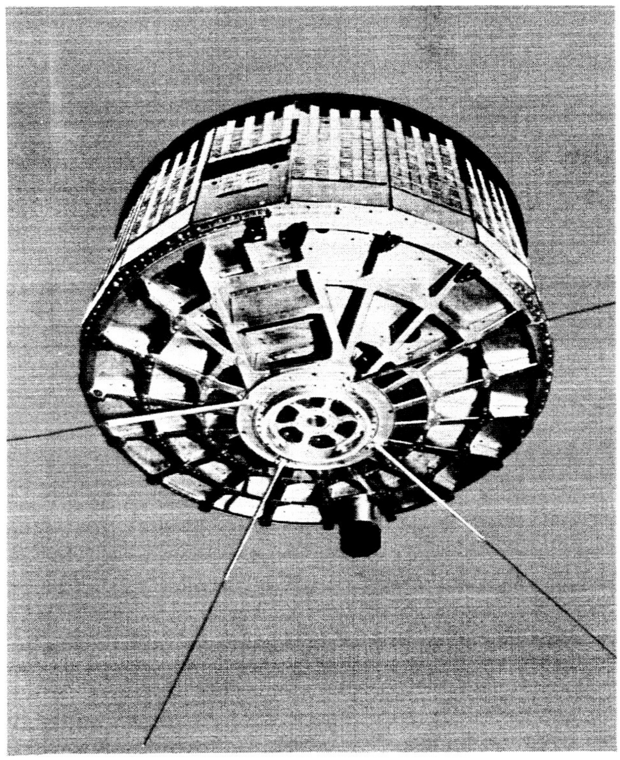

Figure 6—Tiros satellite.

The basic packaging technique for Tiros placed the tape recorder and the electronic components in a cylindrical pressurized can, (used successfully in Vanguard II), shown in Figure 7. These components were sealed under atmospheric pressure to prevent oil loss from bearings and prevent other detrimental effects on components and materials due to outgassing. The recorder was "hard-mounted" in the bottom of the instrumentation can under a slight

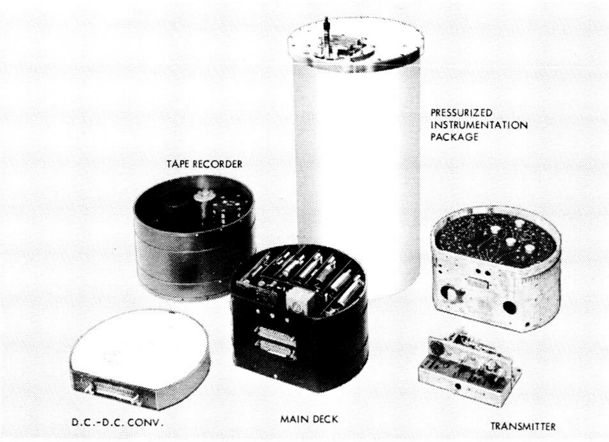

Figure 7—Tiros instrumentation package and components.

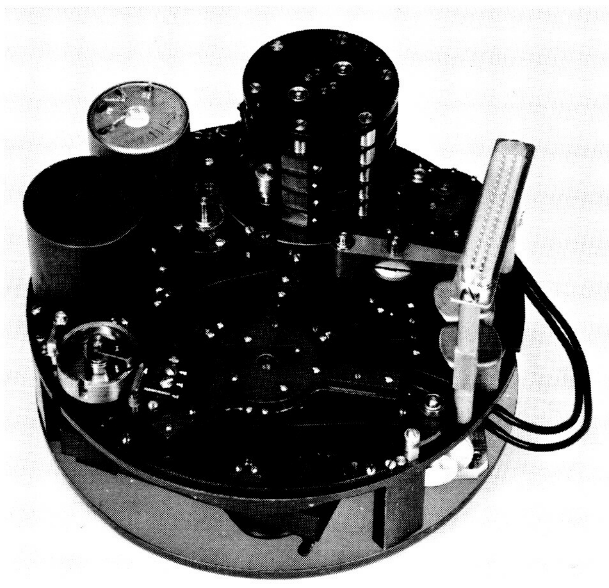
Figure 8—Tiros tape recorder.

compressive force. The tape recorder (Figures 8 and 9) was a two-speed recorder utilizing an endless-loop tape cartridge which stored the 200 feet of tape.

The low power requirement imposed on this recorder resulted in a special motor development which produced a hysteresis synchronous motor with about 25% efficiency for the record mode. Because of higher power required for the playback mode a high efficiency dc motor was used with a speed control circuit.

The record system employed a 2 phase 137.5 cps, 14 vac hysteresis loop synchronous motor requiring less than .300 watts. The recorder utilized a 5000 RPM playback motor requiring less than 1 watt running power. A transistorized dc speed control unit maintained better than 1% regulation of this motor. Speed reduction of the motors to the capstan drive were obtained through reduction pulleys incorporating polyester film belts. Frictional drag from components not being used during certain operating cycles was minimized by using spring clutches. This prevented a power drain on the motors during the normal operating cycles.

Because it was desired that the record motor operate continuously, the use of spring clutches allowed the motor to be over-ridden during the playback mode. Flutter and wow were maintained below 2.5% peak-to-peak from 0 to 1000 cps bandwidth. This exceptional performance is made possible by use of an extremely accurate gyro-type capstan assembly. The capstan has a maximum runout of 50 microinches and the assembly utilized a duplex bearing and integral race technique. The bearings in this assembly were preloaded by a fixed center distance which required very accurate measuring and machining.

Special precautions had to be taken in the duplex preloading arrangement to prevent damage due to temperature extremes during environmental testing. Wherever thermal expansion due to differences in materials caused preloading inconsistencies it was necessary to use materials which

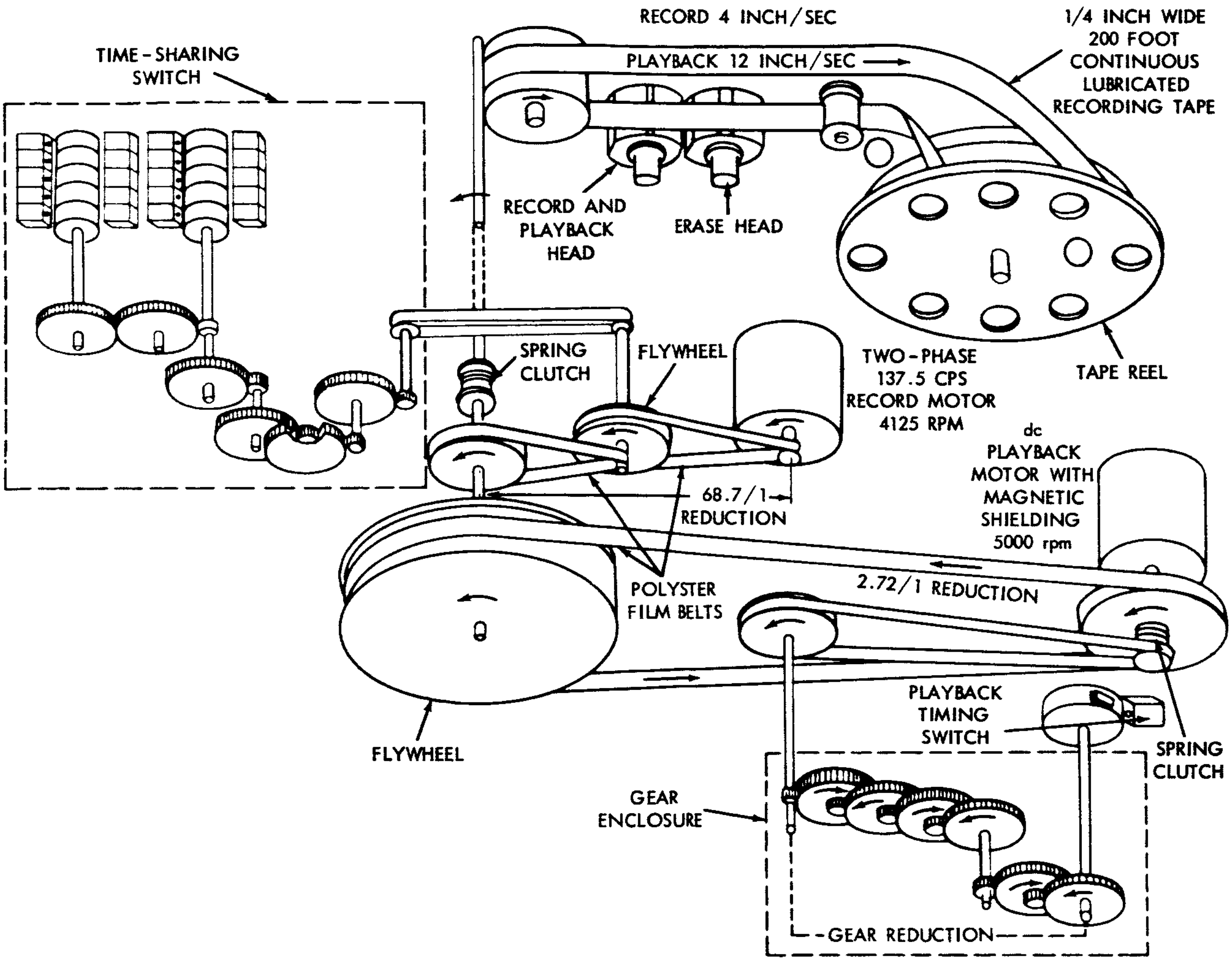

Figure 9—Mechanical assembly of Tiros tape recorder.

had the same expansion coefficient as the bearings. Usually this resulted in compromising the weight requirements. This method of preloading was also used in the motor assemblies where shaft torque output had to be a maximum while still obtaining the advantages of preloaded bearings.

Magnesium was used extensively for weight reduction. Type K-1A magnesium was used for the main plate because of its high internal damping characteristics. This reduced the drumming effect due to rocket vibrations and reduced the mechanical vibrations transmitted to the magnetic heads due to motor and shaft rotations. The resultant recorder weighed 4 pounds and was 2.3 inches high and 6.25 inches in diameter.

These recorders have flown in Tiros II, Tiros III, and Tiros IV. At the time of the last complete interrogation of Tiros II on May 2, 1962 when it had been in orbit for over 17 months (launched on November 23, 1960), the entire IR electronic package with the tape recorder was performing perfectly. The only degradation noticed occurred on the tape which had run continuously for the 17 months. The Tiros II battery pack (not part of the IR package) had degenerated so that further interrogations of the satellite were no longer possible.

In Tiros III, the electronic package was functioning perfectly at the time of its last interrogation 7 months after launch (July 12, 1961). The successful launch of Tiros IV with a new IR system resulted in the stopping of interrogations on Tiros III.

In Tiros IV, the electronic package performed perfectly up to its latest interrogation on September 24, 1962, more than 7 months after launch (February 8, 1962). The failure of a tape recorder mechanism caused the data acquisition to be stopped at that time, however.

While the recorders survived more than six months in an orbital environment, there is still a question of shelf life. Although only a single example, the IR package flown in Tiros IV was built at the same time as that for the Tiros II and survived on a shelf for more than a year before launch, plus seven months in orbit.

THE NIMBUS RECORDER

The successful performance of the recorders in the Tiros satellites influenced the decision to use this same design for the PCM telemetry system of the yet-to-be-launched Nimbus spacecraft* (Reference 3 and Figure 10). The Nimbus spacecraft is an earth-oriented 800 pound advanced meteorological satellite to be launched in a near-polar orbit by a Thor-Agena B rocket. It contains an active control system to maintain the satellite orientation towards the earth, a solar cell array, and a doughnut-type sensory ring structure (Figure 11) to house modular

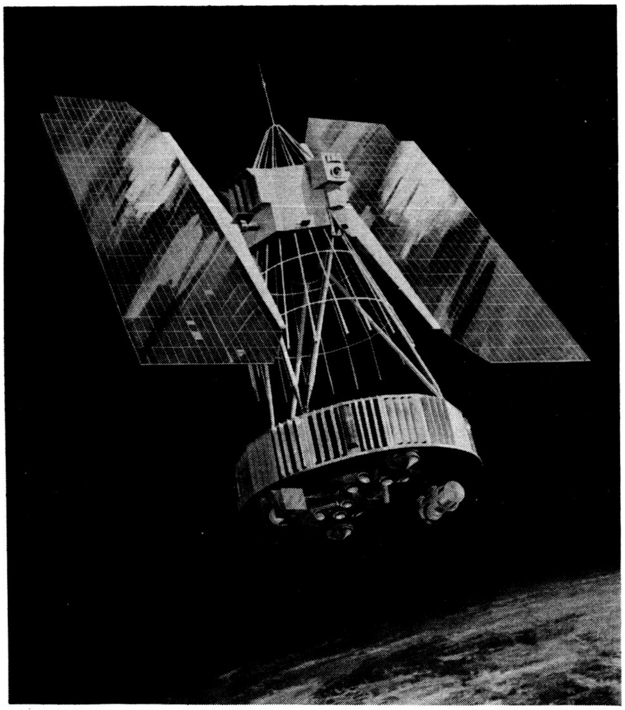

Figure 10—Nimbus satellite.

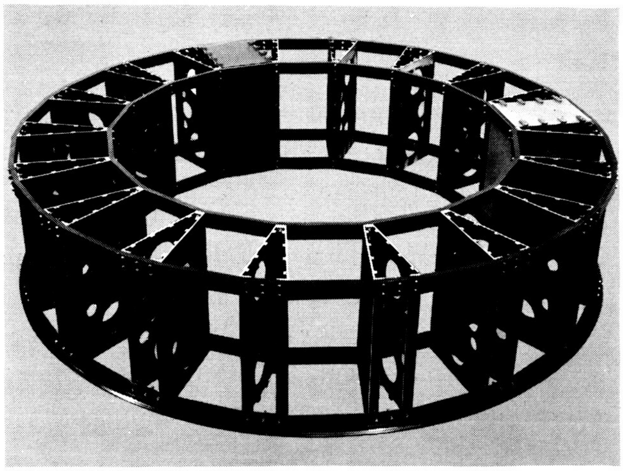

Figure 11—Nimbus sensory ring.

*Nimbus I (1964 52A) was successfully launched on 28 August 1964 from Vandenberg AFB, Calif.

instrumentation packages. The resultant tape recorder was limited in size to 8 inches by 6 inches by 6-1/2 inches. In addition a momentum compensation flywheel system was added to counteract momentum effects induced into the spacecraft as flywheel speeds varied in a change from record mode to playback mode and vice versa.

Most design changes were of a routine nature and the primary effort was directed toward building recorders into rectangular packages. However, serious vibration problems arose when packaging the recorder and considerable effort was expended in designing an isolation system to solve the vibration problems without major redesign of the tape transport.

When the design of the endless-loop recorder (Figure 12) had been proven out, it was packaged into a box-structure and was applicable for the Nimbus PCM telemetry system and the Tiros IR system. This latest design on Tiros VII is considered the best IR system flown by the experimenters. It was flown on Tiros VII, launched on June 19, 1963, and is still operating after more than a year in orbit.*

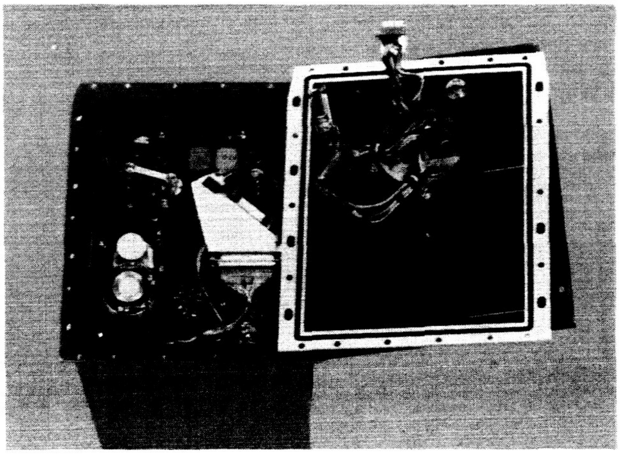

Figure 12—Nimbus tape recorder.

ADVANCED DEVELOPMENT

As a result of the meteorological satellite programs, the technology in endless-loop recorder design has increased significantly. Although flight experience has been limited to endless-loop recorders capable of up to 300 feet of tape storage, a significant breakthrough has been made in the design and fabrication of large endless-loop recorders (Reference 4) capable of containing 1200 feet of 1/4 and 1/2 inch wide tapes (Figures 13 to 15).

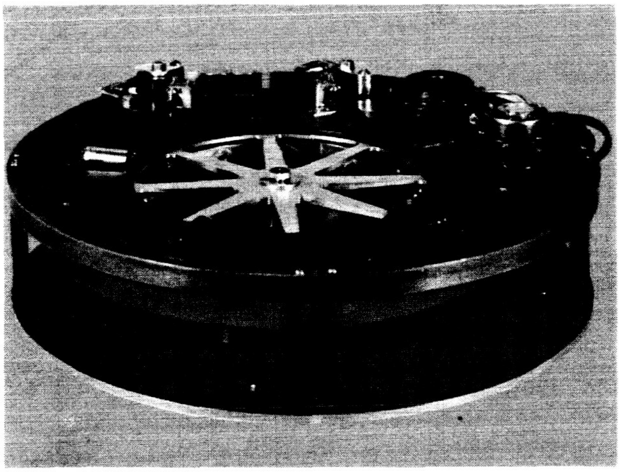

Figure 13—Quarter-inch 1200-ft. advanced tape recorder.

Interplanetary capsules and large satellites, in which endless-loop recorders are required, utilize large capacity endless-loop tape cartridges for data storage, and recorders with tape storage capacities of 300 feet are no longer entirely satisfactory. The new requirement of 1200 feet of tape on an endless-loop cartridge means that a rigid set of design

*This tape recorder has been in continuous operation for 18 months as of December 19, 1964.

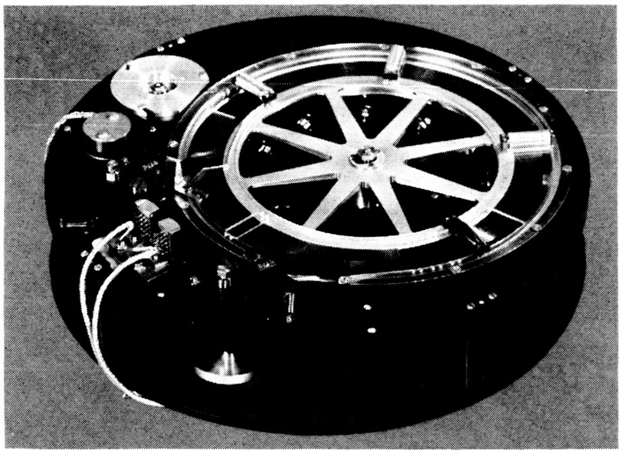

Figure 14—Half-inch 1200-ft. advanced tape recorder, side view.

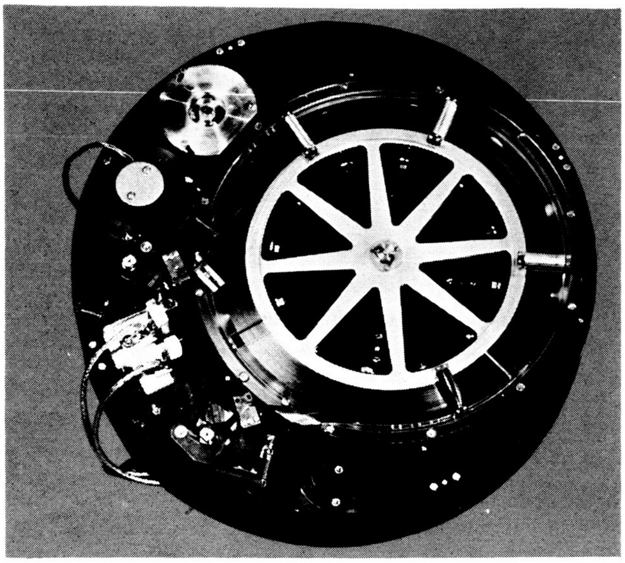

Figure 15—Half-inch 1200-ft. advanced tape recorder, top view.

specifications must now be employed to assure long life and reliability. New design considerations, with respect to obtaining a functionally operational recorder, are required to achieve the low flutter, low power consumption, long life and low weight limitations. As a recorder's storage requirement is increased, many new design problems must be taken into consideration.

Tape life is one design parameter that must be investigated. This includes deterioration of magnetic properties, abrasion loss of the lubricant, edge wear and the behavior of the mylar base material and oxide binder. Each one of these factors may be affected by temperature, tape velocity, mean pack diameter (which determines the slippage between outer and inner tape diameters), and recorder operational lifetime. Because of these problems, it is not just a simple matter of making a larger cartridge to accommodate the larger tape requirement.

Another consideration is the selection of the proper motor. Again, this is not simply the utilization of existing motors in other tape recorders. Power requirements are different and motors must be matched to the recorder to prevent undesirable hunting which produces detrimental flutter and wow.

The methods by which capstans are made (e.g., bearing preload techniques, machining tolerances, material and assembly and mounting arrangements) determines to a great extent how performance (flutter and wow, skew, and amplitude variations) will be affected.

The 1200-foot endless-loop tape recorder is a lightweight, low power, multi or single speed system. The overall external dimensions are 13-3/8 inches in diameter, 3-1/2 inches in depth, and weighs 10 pounds.

A maximum mechanical power of 1.29 watts is required to drive the transport at 30 inches per second at 0°C. At a tape speed of 3-3/4 in./sec., only .083 watts of mechanical power are required at 0°C to operate the transport. These values vary slightly for the 1/2" wide tape and the type of tape used. Speed reductions are obtained by the use of accurately machined pulleys and seamless polyester film belts. Although the optimum motor has not been obtained as of this writing, wow and flutter measurements have been obtained at 1.14% P-P from 0-1000 cps bandwidth.

Tape Cartridge

The item which required the longest development time was the tape cartridge. At the time, the only cartridges in common usage had tape capacities from 200 to 300 feet. To attempt to design a cartridge for 1200 feet of tape, many design considerations had to be taken into account such as tape life, as defined earlier in the Introduction, transport operational life, performance requirements, and environmental testing. A design life of 9 months allowed approximately 3 months of satellite ground testing and 6 months of operation in orbit. The life requirement and environmental testing was most severe on the tape.

The tape cartridge had to be designed to allow 1200 feet of magnetic tape to function properly. Parameters such as power, flutter, signal to noise ratio, and operation at two speeds (record and playback) had to be considered in addition to the life requirement. The 9 months of continuous operation necessitated that the cartridge design must impose minimum wear on the tape.

The first approach to cartridge design was to obtain an optimum mean diameter of the cartridge with minimum pack thickness. It is important to have a narrow pack thickness to minimize tape wear induced by the angular velocity difference between inner and outer tape layers. In addition, the mean tape diameter should be within reasonable limits to prevent an excessively heavy and large recorder design. From a curve of mean tape pack diameter versus pack thickness for various lengths of tape an optimum mean diameter of 8 inches was chosen for a pack thickness of 0.8 inches for 1200 feet of tape.

After the basic size of the cartridge was determined, there were two possibilities for a design. One was to expand the Tiros type into a larger size. As a result of conducting some preliminary tests, it was found that flutter was appreciably reduced when the tape was supported on rollers during operation. Thus the second design consisted of utilizing rollers to support the tape in the cartridge.

A large Tiros type cartridge (Figure 16) was built and tested extensively. Although the cartridge appeared to function well, there were severe tape pulsations which increased in magnitude with tape speed, and eliminated this cartridge from further consideration. The pulsations resulted from excessive tape friction between layers, and between the tape edges and reel flange. This caused accelerated tape wear and would have been detrimental to overall recorder reliability. Because of the magnitude of the pulsations, filtering could not be easily accomplished with simple devices, and the result would have been large periodic flutter and wow disturbances.

At this point, the roller-reel tape cartridge (Figure 17) was put into the testing phase. The main development problem concerned the tape support rollers. The original rollers were straight

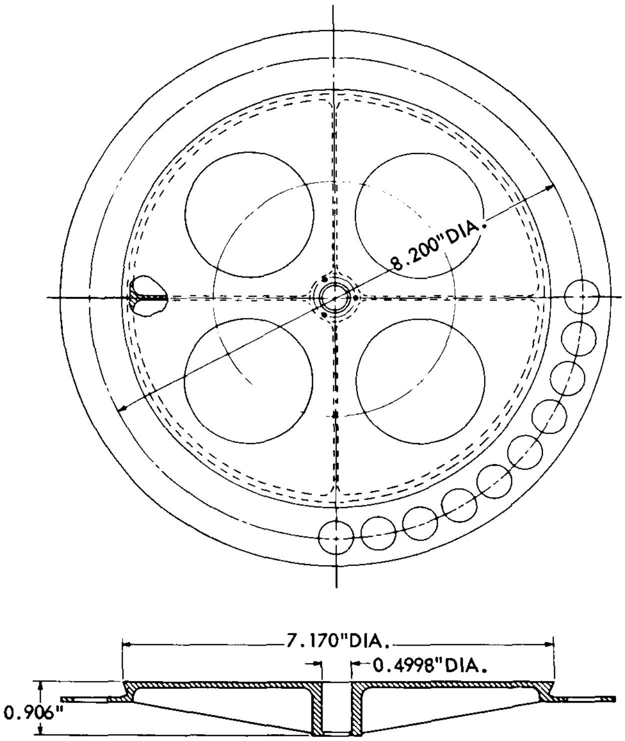

Figure 16—Tape reel, 1200-ft., top view and cross-section.

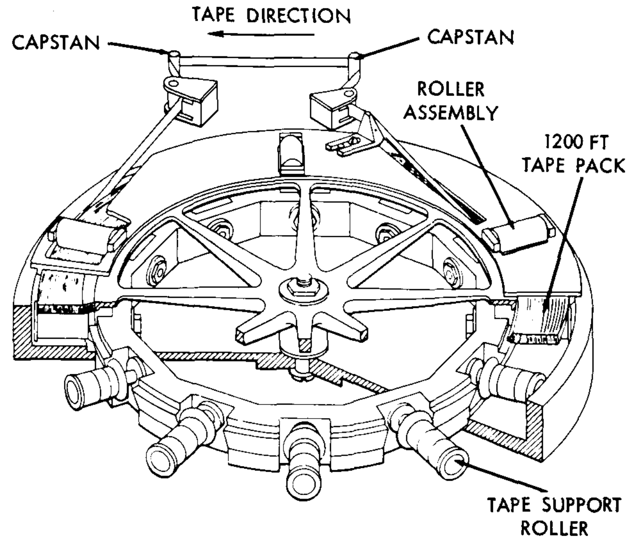

Figure 17—Tape cartridge, 1200-ft.

cylinders. During testing, it was observed that upon acceleration the tape would form a loop on the return side which would not pull in and which remained at a constant length. This situation resulted because there was no friction between the outer layers of tape and the tape rollers as existed between the outer layers of tape and the flange of the larger Tiros reel. With the Tiros type cartridge, the flange which supports the tape has higher linear velocities at every point than the tape itself; therefore, there is a constant frictional force pulling the tape into the cartridge on the return side. This effect is absent with the rollers. To correct this situation, a series of tests were conducted which resulted in two cylindrical steps being added to the straight roller section. It was found that the RPM of the rollers was determined at the smallest diameter which provides a higher circumferential velocity at the two larger steps. The resultant relative velocity between the roller and tape edge was sufficient to prevent the tape from forming and maintaining a loop on the return side of the cartridge.

With this problem solved, the cartridge functioned well and it was decided that further development would be centered around this cartridge modification.

The cartridge consists of a tape reel, 12 tape support rollers, a roller mounting ring, a tape guide plate, a tapered guide, cover plate rollers, and 1200 feet of lubricated mylar base magnetic tape.

Tape Life

Although the problem of obtaining a functionally operating endless-loop tape cartridge for 1200 feet of tape was solved, there still were difficulties with the magnetic tape itself. The tape which was used for smaller endless-loop cartridges on the Tiros and Nimbus recorders was not satisfactory for use on the larger cartridge, since the more rigorous tests of this program revealed deficiencies in the mechanical stability of the tape during temperature testing. There were two primary temperature problems, (a) the oxide binder became soft at 70°C, and (b) the tape had a very high shrinkage rate.

Temperature tests were run on the 1200-foot endless-loop cartridge using type LR 1220 tape at a speed of 30 inches per second and at temperatures of 0°C, 25°C, and 60°C. At 0°C, the transport operated if the recorder was first placed in a plastic bag, flushed with dry air, and sealed before being brought down to temperature. This was necessary to prevent the cartridge from jamming. This occurrence is attributed to the possibility of ice condensing on the transport and tape.

At 25°C the cartridge performed satisfactorily. However, at 60°C, problems arose when the tape exhibited properties of excessive interlayer friction. This friction caused the cartridge to tighten up and eventually to jam. A series of tests were conducted to determine whether the oxide, the lubricant, or both were causing the trouble. At about 70°C, it was noted that the sliding friction of oxide against oxide increased; but that the sliding friction of lubricant against lubricant remained constant. At 100°C, the same effect was noted. This fact was brought to the attention of the tape manufacturer. The manufacturer conducted his own tests and found that the oxide binder was stable only up to about 80°C.

Although the recorder temperature test is run at 60°C, it is possible that the tape angular velocity difference in the inner layers causes a localized heating effect which raises the tape surface temperature above 70-80°C.

As a result of these tests, the manufacturer provided new samples of tape (LR 1259 and 8943), which were considered identical in magnetic and lubrication properties to the LR 1220 but with a higher temperature binder on the oxide side. The LR 1259 was tested at 60°C for a considerable length of time, and the results showed that the new binder was the solution to this problem.

However, at this point the second problem arose. When using the LR 1220 tape, the cartridge never operated long enough at the high temperature to observe other characteristics.

As the LR 1259 continued to run at 60°C, it was observed that the tape pack was gradually tightening up. Finally, the point was reached where the pack became so tight that the cartridge jammed. This tightening process was attributed to the shrinkage of mylar at high temperatures. Although this characteristic of mylar is well known, the exact rates of shrinkage were not as well known for various temperatures. Tests were run on LR 1220, LR 1259, 8943, and a tensilized tape sample to determine their shinkage rates.

The longitudinal shrinkage for LR 1259 tape at 60°C is 0.13%; however, if localized heating raises the temperature to 80°C, the shrinkage becomes 0.34%. For 1200 feet of tape, 0.34% longitudinal shrinkage reduces tape length by 49 inches, thus increasing tape tension excessively.

The longitudinal shrinkage for LR 1220 tape at 60°C is 0.075% and at 80°C it becomes 0.19%. For 1200 feet of tape, 0.19% longitudinal shrinkage causes the tape to lose 27.4 inches (about one-half that of LR 1259). The 8943 tape had a longitudinal shrinkage of 0.13% and base mylar (.001" thick) had a longitudinal shrinkage of .284%.

Because these results showed large amounts of shrinkage as well as a variation with tape type, it was decided to preshrink the LR 1259 tape at 100°C for one hour and then repeat the test in the cartridge at 60°C. When this was done, the tape ran continuously at 60°C without any indication of tightening or jamming. During life testing, however, a wear problem became apparent with the lubricant. Again the manufacturer studied the problem and supplied NASA with a new sample which passed the required 9 month accelerated life test. There were not enough samples to determine the recording characteristics although it was specified that the oxide should have the same magnetic properties as the tape it replaced. This new tape has a designation of LR 1353.

Environmental Testing

Performance measurements were taken at room temperature with the 1/4" and 1/2" 1200-foot preprototype recorders and are shown in Table 1.

This transport has survived operation at 0°C and 60°C. However, during vibration testing, a problem of tape spew and tightening arose. This problem was solved by snubbing the tape, against its edges, so that the layers of tape could not move during vibrations. In addition the recorder was mounted on vibration isolators.

Of equal importance in the design is an ability to hold up under environmental testing. A 1200-foot endless-loop recorder is much more sensitive to temperature and vibration testing than a small unit. The large loop tends to act very erratically under random and sinusoidal vibration tests if left in a free condition in a cartridge.

Table 1

Performance Measurements.

	1/4" Preprototype		1/2" Preprototype
Length of tape (feet)	1200	1200	1200
Temperature (°C)	25	25	25
Record Speed (in./sec.)	3-3/4	30	30
Reproduce Speed (in./sec.)	30	30	30
Flutter (% P-P) 0-1000 cps	1.14	.64	.7
Mechanical Power to Drive Entire System (watts)	.0717 record .897 reproduce	.897	.88
Signal to Noise Ratio (db)	40	-	26.6
Tape Type	LR 1220	LR 1220	LR 1353

The following specifications are the vibration levels to which the recorder was tested:

a. Sinusoidal

10 g's (limit to 1/4 inch single amplitude)

5 to 2000 cps

18 minute duration

b. Random

20 g's RMS

20 to 2000 cps

.2 g^2/cps spectral density

4 minute duration

A third type endless-loop cartridge (Figures 18 and 19) utilizing 1200 feet of 1/4 inch wide tape was built and demonstrated good performance characteristics with respect to power consumption and smoothness of tape motion. The uniqueness of this cartridge is that the tape can be stored in a recorder approximately 1/2 the recorder diameters of those previously mentioned. However, this cartridge will have to be incorporated into a transport system to obtain more complete performance and operating specifications.

A complete tabulation of recorder performance for all meteorological satellite endless-loop tape recorders is shown in Table 2.

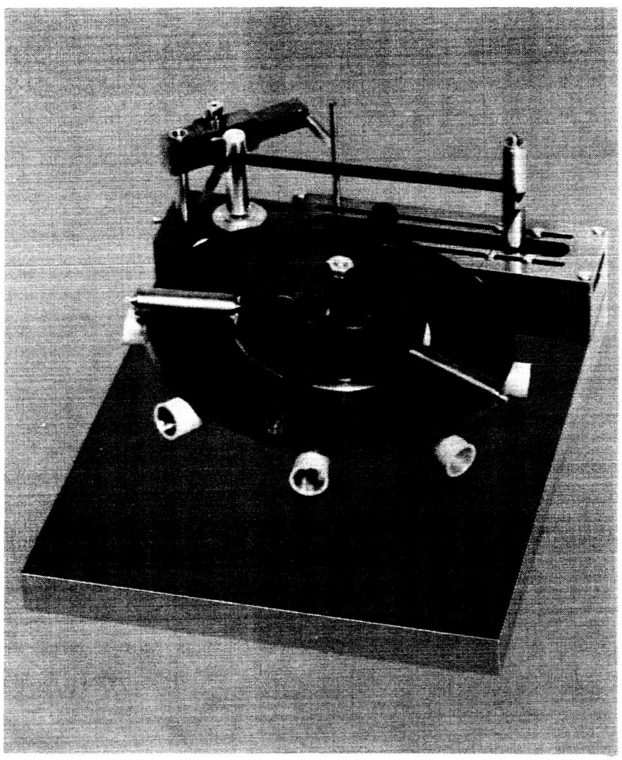

Figure 18—Quarter-inch 1200-ft. compact advanced tape recorder, front view.

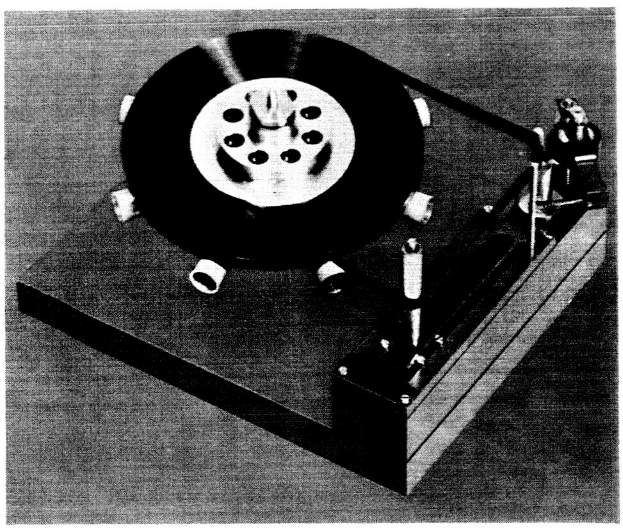

Figure 19—Quarter-inch 1200-ft. compact advanced tape recorder, side view.

Table 2

Performance Characteristics of Various
Meteorological Satellite Endless-Loop Tape Recorders at 25°C.

Satellite	Vanguard II	Tiros	Nimbus	Advanced Recorder
Weight (lbs)	1.5	4.0	8	10
Size (in. dia.)	5.5	6.0	8 x 6	13.375
Height (in.)	3	2.3	6.5	3.5
Tape Speed (in./sec.)				
Record	0.3	0.4	0.4	33
Reproduce	15	12	12	33
Power Req. (watts)				
Record	0.09	0.3	1.0	0.88 (Mech.)
Reproduce	1.0	1.0	4.0	0.88 (Mech.)
Percent Flutter (P-P)*	6	2.5	2.5	0.7
Analog or Digital Data	A	A	A & D	A
Amplitude Modulation				
(Percent P-P)	—	7	7	4.0
Data Packing Density				
(bits/in.)	—	—	250	—
Tape Length (feet)	75	200	200	1200
Maximum Life	2 weeks	17 mos.	13 mos.	—

*0-1000 cps

CONCLUSION

The 1/2" 1200-foot tape recorder has shown the greatest promise for solving large data storage needs. On the basis of performance tests, this recorder was recently selected for testing the recording and reproduction of television pictures utilizing the Nimbus meteorological satellite camera system. Having passed this test successfully, this tape recorder will figure in plans for large endless-loop recorders in future meteorological satellite programs.

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REFERENCES

1. Falwell, R. C., Stark, K. W., and White, A. F., "A Precision Endless Loop Magnetic Tape Recorder for Space Application," NASA Technical Note D-1542, February 1963.

2. Licht, J., and White, A., "Polyester Film Belts," NASA Technical Note D-668, May 1961.

3. Stampfl, R. A., "The Nimbus Spacecraft and its Communication System as of September 1961," NASA Technical Note D-1422, January 1963.

4. Stark, K. W., "Development of a 1200 Foot Endless-Loop Tape Transport for Satellite Applications," NASA Technical Note D-2316, June 1964.