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THE EVOLUTION OF ELECTRONIC TRACKING, OPTICAL, TELEMETRY, AND COMMAND SYSTEMS AT THE KENNEDY SPACE CENTER

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INTRODUCTION

The following is a history of the major electronic tracking, optical, telemetry, and command systems used at ETR in support of Apollo-Saturn and its forerunner vehicles launched under the jurisdiction of the Kennedy Space Center and its forerunner organizations.

1. ELECTRONIC TRACKING SYSTEMS

1953 SCR-584 Radar-Mod II: The first Redstone was tracked by the SCR-584 which was already in use at the ETR. This radar is a modified and rehabilitated World War II system designed to provide azimuth, elevation and slant range. All data is referenced to targets of known position. The antenna is of the nutating scan type. Tracking with the aid of an airborne S-Band (2900 MHz, 10 cm) beacon, Mod II can provide unambiguous radar line of site coverage to 740 km. This radar can be used to skin track as well as beacon track. Accuracy is about 30 meters in range and 3 minutes in angle. (References 1 and 2)

1954 AZUSA: The Redstone began carrying the AZUSA transponder in 1954. The name AZUSA is a code word originally applied to the system and is taken from the name of the town, Azusa, California, near where the system was developed. The position of the vehicle (transponder) is determined at the AZUSA ground station by measuring range (R) and two direction cosines (1, m) with respect to the antenna baselines. The antenna layout of the AZUSA station consists of two crossed baselines (at right angle) with three antenna pairs each. The transmitter antenna radiates a CW signal at 5 GHz to the vehicle. This signal is offset by 60 MHz in the transponder and retransmitted to the ground station receiving antennas. The direction cosine, with respect to a baseline, is obtained from the measurement of the phase difference between signals received at spaced antenna pairs along this baseline. The range to the transponder is found by measuring the phase difference between transmitted and received signal. For range ambiguity resolution, the transmitted carrier is modulated with several low frequencies. Accuracy is about 3 meters in range and $1X10^{-5}$ in cosine data. AZUSA can track to 1800 kilometers. (References 1 and 2)

1954 DOVAP: Redstone (RS-3) was the first to make use of the DOVAP system which was adapted from a similar system in use at White Sands. DOVAP (Doppler Velocity and Position) is a velocity measuring system which can provide three loop distances by velocity integration, thereby determining a position in space. The system makes use of the well known Doppler principle wherein the apparent frequency of a signal emitted by a moving object varies as the object moves toward or away from the observer. In practice a transponder is installed on the missile and excited by a ground transmitter. The transponder receives the reference frequency (36 MHz) plus a Doppler shift. The transponder retransmits a doubled frequency plus a doubled Doppler shift which is received by a receiving station on the ground. By beating against a reference frequency, an audio frequency Doppler resultant is obtained which is proportional to the rate of change of the total distance from transmitter to transponder to receiver. This distance may be found by integration with a suitable tie-in point to supply the constant of integration. DOVAP is a range sum or ellipsoid system. At any instant of time, the missile lies on an ellipsoid of which the transmitter and the receiver constitute the foci. If three receivers are used, then the position of the missile in space may be found as the point of intersection of the three ellipsoids. Position accuracy is about 10 meters at 30 kilometers. (References 3 and 4)

1954 BEAT-BEAT (DOVAP): This system began to support the Redstone launches during 1954. The BEAT-BEAT system determines the deviation of a missile from a predetermined flight path. It derives its name from the fact that the two receivers involved in the system compare, or beat, two beat frequencies against each other. The system consists of a pair of DOVAP (which see) receiver stations placed symmetrically about the flight line and modified to indicate the angle of the missile off course in real time. As long as the missile remains in a plane equidistant from the two stations, the Doppler beat frequency is exactly the same. When the missile deviates to the left or right, one beat frequency will increase and the other will decrease. The difference between these two beats, or the "beat-beat" is an indication of lateral velocity. The total number of cycles of the difference is directly proportional to the difference between the slant distances from the missile to the two stations. The system is designed to detect angular deviations of about 3 minutes. (Reference 3)

1955 MILS: The Redstone program utilized the Missile Impact Location System beginning in 1955 to locate the missile impact points in the Atlantic Ocean target area. The MILS is an underwater sound detection and location system which uses hydrophones to detect the sound created by either falling objects impacting on the ocean surface or underwater explosions of bombs released by an object on impact. The arrival times of these sounds at a number of known locations in the ocean are recorded. The geodetic position of the hydrophones together with the velocity of propagation of sound in the ocean and the time of arrival of the sound at the hydrophones provide the data required to determine the location of the impact point. (References 4 and 6)

1956 MICROLOCK: This system was first used with the Jupiter C No. 27 on September 20, 1956. The MICROLOCK system allows a low level signal, varying in frequency, to be acquired and tracked automatically at line of sight distances of several thousands of miles. An interferometer antenna system is used to determine the angular position of the transmitter to an accuracy of 1 mil. The sensitivity of the MICROLOCK system to low level signals (-150 dbm) allows the use of a minimum-weight, low-power transmitter in a missile or satellite vehicle. The missile-borne transmitter consists of a 108 MHz oscillator that is phase-modulated by telemetering signals. The oscillator radiates three milliwatts, weighs approximately one pound, and will operate for several months on battery power. The heart of the ground station is a phase-locked loop receiver, designed to detect the beacon signal and to provide automatic tracking of Doppler shift as the missile or satellite transits the station. The simple phase-locked-loop is a servo system which locks a voltage-controlled oscillator (VCO) in phase synchronism with the signal input, in spite of large amounts of signal noise that might be present. (Reference 8)

1957 ELSSE: The Redstone and Jupiter first used the Electronic Skyscreen Equipment (ELSSE) during 1957. It was used to determine angular deviations of the missile from the flight line. The system consists of two ELSSE receivers placed behind the missile equidistant on either side of the backward extended flight line. A phase comparison is made on the signal received from the telemetry transmitter. If the missile remains on the flight line, the phase of the signal received at each ELSSE station is the same. Deviations from the flight line cause a measurable phase change which is proportional to the deviation. The output signal from the equipment has a phase directly related to the phase difference between the signals from the two receivers. This signal develops an output which produces an indication on the recording equipment. Angular deviations can be measured to about 1.5 minutes. (Reference 5)

1957 UDOP: The Jupiter vehicles began carrying the UDOP transponder during 1957. UDOP, which means Ultra High Frequency Doppler, is very similar to the DOVAP system except that the transmitter operates at a frequency of 440 MHz. The higher frequency results in greater resolution, less ionospheric refraction effects, and less rocket flame attenuation. As in DOVAP, the target position is at the intersection of three ellipsoids. (References 1 and 2)

1958 BEAT-BEAT (Telemetry): This system was used in support of the Redstone and Jupiter launches and was also used on Juno II Pioneer III (Jupiter AM-11). It is very similar to the conventional beat-beat Doppler system described previously except that it uses the telemetry transmitter instead of the DOVAP transponder.

1958 EXTRADOP: This system was used in support of the Redstone and Jupiter launches and was used on the Juno I Explorers I, II and III, and the Juno II Pioneer III. Its name is derived from "extended range Doppler" utilizing as it does, an extended baseline. EXTRADOP utilizes basic DOVAP techniques but uses a common coherent, reference frequency for both uprange and downrange stations. As the vehicle moves downrange, the distance from the transponder to the uprange receiver stations becomes very much greater than the distance between stations. This results in poor system geometry and dilutes the precision of measurement. Therefore, additional receivers are also required at downrange locations. However, if the receivers are not sufficiently near the transmitter for the reference frequency to be received, no frequency comparison is possible and therefore, no Doppler shift can be detected. In EXTRADOP, the following situation is utilized. There is submarine cable running from the launch site to points downrange. From the central timing generation station a 32 kHz sine wave is propagated down the cable for synchronization of all downrange timing stations. This signal is used as the common coherent reference frequency for the EXTRADOP system and is sent to all downrange receiving stations and converted to the proper comparison frequency at the stations. This system needs only one transmitter and has continuous coverage so long as the vehicle is within line of sight to the transmitter and three or more receiver stations.

1958 AN/FPS-16 Radar: This radar was in general use on all programs during 1958 and subsequent years. The AN/FPS-16 is a high precision, C-band (5700 MHz, 5.2 cm) monopulse radar designed specifically for missile tracking. Monopulse radar differs from scanning radar in that angle error information is derived on each pulse, thus shortening the acquisition time and facilitating missile tracking. This is accomplished in the monopulse system by employing four horns in a square and comparing return signals as to phase and/or amplitude from each horn for each pulse. The radar ground stations determine the position of the vehicle by measuring range, azimuth angle, and elevation angle. Range is derived from pulse travel time, and angle tracking is accomplished by amplitude-comparison. As many as four radar stations may track the beacon simultaneously. Accuracy in range is about 5 meters. Coverage extends to 1800 km. (The FPQ-6 and TPQ-18 radars are improved versions of the FPS-16.) (References 2 and 6)

1958 MINITRACK: This system was used in support of the Juno I Explorer I launch (RS-29). MINITRACK is a continuous-wave radio frequency system which determines angular direction to the vehicle. It consists of a vehicle-borne beacon, tracked by a world-wide network of stations arranged such that at least one station is in line of sight of the vehicle on each orbit. The MINITRACK beacon radiates at a frequency of 140 MHz with an output power of 20 milli-watts. The beacon may be modulated for telemetry purposes. Each MINITRACK station has an antenna pattern on crossed baselines (similar to AZUSA). A direction cosine with respect to each baseline is computed from measurement of phase difference in the reception of radio frequency energy at separated antennas along the baseline. Each station computes two direction cosines, with respect to its space-fixed antenna baselines, as a function of time. The vehicle orbit is computed from angle measurements made at a series of ground stations. (Reference 2)

1963 MISTRAM: The first use of MISTRAM by the Saturn program was on vehicle SA-4. The MISTRAM (Missile Trajectory Measurement) system uses an 8000 MHz continuous wave phase comparison technique to measure range and range differences. A central station at the vertex of an L-shaped array is connected to remote stations along the legs by cable, waveguide, and microwave links. Range is measured by counting the number of wavelengths traveled by the signal to the vehicle transponder and back to the central station. Range difference is measured by counting the difference of the number of wavelengths traveled by the signals from the vehicle to each end of the baselines. Vehicle position is then fixed by the range and range differences.

An external computer is used to compute trajectory and the rates at which the range and range differences are varying to determine velocity. From the range measurement, it will be known that the vehicle lies on the surface of an imaginary hemisphere whose center lies at the central station and whose radius is equal to the range. The range differences between the central station and two remote stations define two hyperboloids whose intersections with the sphere define the vehicle's position in space. Accuracy is about 0.5 meter at 110 km. (References 2 and 5)

1964 GLOTRACK: The Saturn I vehicle began receiving support from the GLOTRACK system in 1964. GLOTRACK (GLObal TRACKing) was originally planned as a global tracking system, but changes in programs restricted the number of ground stations. GLOTRACK uses the AZUSA transponder in the vehicle. GLOTRACK ground stations are equipped with either a transmitter or a receiver or both. Existing AZUSA stations may be considered as part of GLOTRACK. The transponder in the vehicle is interrogated by an AZUSA ground station or by a GLOTRACK transmitter site. The transponder offsets the received frequency and retransmits the signal to GLOTRACK receiving sites where the Doppler shift is measured by comparing the received signal with the transmitter signal (if receiver is located near the transmitter) or with a local frequency source. The measured Doppler shift provides the range sum similar to DOVAP. At GLOTRACK stations equipped with both a transmitter and receiver, the range to the transponder is measured by phase comparison between the transmitted and received signals. The AZUSA transponder can also be interrogated by C-band radars for range and angle determination. Position accuracy of GLOTRACK is about 30 meters. (Reference 1)

1964 ODOP: The ODOP transponder was first carried on the Saturn I vehicle in 1964. The ODOP (Offset Doppler) tracking system is essentially the same as the UDOP system (which see), but ODOP operates at different frequencies. Whereas the UDOP system uses a transmitter frequency of 450 MHz which is doubled in frequency to 900 MHz, ODOP uses a transmitter frequency of 890 MHz which is offset to 960 MHz. The higher transmitter frequency in ODOP is less affected by ionspheric perturbations, resulting in increased tracking accuracy. Moreover, the ODOP geometry is so arranged as to provide data immediately after liftoff. UDOP does not provide data until after 100 seconds of flight time. Tracking accuracy is about 1.5 meters. (Reference 1)

1964 Radar Altimeter: This device was first carried by the Saturn I vehicles in 1964. The Saturn high altitude altimeter has been developed for on-board instrumentation to supply tracking data for vehicle trajectories not completely covered by earth-based tracking stations (e.g. over long stretches of ocean). The altimeter determines range from vehicle to earth by accurate measurement of the time interval between its transmitted pulse and the return echo. This range information is digitally encoded and transmitted through the vehicle telemetry link to ground receiving stations for support of the tracking function. The heart of the altimeter is a stable crystal oscillator which controls the radar pulse repetition rate and supplies timing intervals for the counting circuit. Transmission of the radar pulse gates the counter "on" reception as the return pulse gates the counter "off". The number of counts between each pulse and its return represents a number of timing intervals which is analogous to vehicle altitude. The altimeter operates at a frequency of 1610 mc. A single antenna (Model 502) serves both transmitting and receiving functions and is mounted on the exterior of the instrument unit. (Reference 2)

1967 USB: The Unified S-Band began to support the Saturn IB launches in 1967. The USB system employs a single carrier frequency for both tracking information and communications with the spacecraft. This system employs a variation of the classical radar ranging method of measuring the round trip propagation time of a signal from a ground transmitter to a vehicle transponder and back to a ground station. An S-Band (2102 MHz, 14 cm) carrier, phase modulated by a pseudo-random code, is radiated to the airborne transponder and retransmitted to the ground at 2282 MHz where it is received by the same antenna used for transmitting. A pseudo-random code is a pulse code format which statistically resembles random noise, but which repeats itself and therefore can be distinguished from true noise.

If, in a conventional pulsed ranging system, the repetition period of the pulse is less than the time required for the signal to travel to the target and return, there will be ambiguity in the range measurement. Since the USB ranging system is designed to be compatible with the goals of the complete Apollo program, it must provide unambiguous ranging to lunar distances. At lunar distances, the ambiguity can be avoided only if the pulse repetition period is greater than 2.6 seconds.

The pseudo-random code uses a pulse repetition rate which is less than the total pulse transit time; however, the code train does not repeat itself for 5.4 seconds. As a result, the range information rate is constant and independent of the measured range without ambiguity. The ground station is also capable of detecting the Doppler shift in the carrier frequency and accumulating Doppler cycle counts as a function of changing range. Given an initialized range by the pseudo-random code technique, the station can continue to produce updated ranging by the Doppler technique. Angle information can be obtained directly from the antenna mount position.

Figure 1 summarizes the use of these electronic systems as applied to the various ABMA/NASA programs at KSC from 1953 to present.

AJOR LECTRONIC RACKING YSTEMS AND ERIOD USED OR KSC / EHICLE/ ROGRAM ND URATION	54-68 AZUSA	54-61 BEAT BEAT DOVAP	58-61 BEAT BEAT TELEMETRY	54-61 DOVAP	57-69 ELSSE	58-60 EXTRADOP	64-68 GLOTRACK	56-61 MICROLOCK	55-61 MILS	58-65 MINITRACK	63-65 MISTRAM	64-69 ODOP	53-62 RADAR S BAND	58-on RADAR C BAND	64-65 RADAR ALTIMETER	57-64 UDOP	67-on USB
edstone (53-68)	x	x	x	x	x	x			x				x	x			
upiter (R&D) (57-60)	x	x	x	x	x	x			x				x	x		x	
upiter C (56-57)		x		x	x			x					x				
uno I Expl. (1958)		x		x	x	x		x		x			x	x			
ardtack (1958)		x	x	x													
uno II Pioneer (58-59)		x	x	x	x	x		x					x	x		x	
uno II Expl. (59-61)	x	x	x	x	x	x		x		x			x	x		x	
ershing (60-61)	x		x		x								x	x		x	
ercury-Redstone (60-61)	x		x	x	x				x				x	x			
anger (61-62)	x				x								x	x			
ariner (1962)	x				x									x			
aturn I (63-65)	x				x		x			x	x	x	x	x	x	x	
aturn IB (66-68)	x				x		x					x		x			x
aturn V (67-72)	x				x		x					x		x			x
kylab (73-)														x			x

FIGURE 1

2. OPTICAL TRACKING SYSTEMS

1953 CZR: The first Redstone launch (RS-1) was tracked by the CZR cameras. These fixed metric (ribbon frame) cameras are used at AMR to provide vehicle position data of high order accuracy during the first few seconds after launch. The ribbon frame cameras record images on strips of film 5.5 inches wide at rates of 30 fps, 60 fps, 90 fps, or 180 fps. Timing is recorded in code along the edge of the film. The camera is mounted on a three-axis precision gimbal mount which allows the camera to be centered on a precisely surveyed camera pad, and oriented in azimuth and elevation so that the missile will traverse through the field of view of the camera. The camera is locked in position and started by signal from the remote sequencer. The angular orientation of the camera is determined by using surveyed target boards. Two or more cameras photographing the same point on the vehicle will provide the information required to determine the position of the vehicle by triangulation. (References 4, 6 and 7)

1953 Cinetheodolite: These devices were also used to track the first Redstone (RS-1) launch. The cinetheodolite is a theodolite equipped to record photographically the field of view of the theodolite, and a coded time of frame exposure simultaneously. Precise surveys have been performed to locate the geodetic position of each instrument. The shutters of all theodolites are opened and closed simultaneously by pulses from a central timing station. The position of the launch vehicle in space may be found by triangulation using two or more cinetheodolites. The cinetheodolite has a random error of 9 seconds of arc with a corresponding systematic error of 21 seconds of arc.

Optimum accuracy acquisition requires that a well-defined point of track be resolved on the film exposed by each of the cameras. Lack of a well-defined point of track on the surface of the vehicle will degrade the metric fixed camera data. Random error (due largely to reading error and image quality) under average conditions is approximately 30 seconds of arc. Systematic error (due largely to camera orientation) may vary from 139 seconds of arc to 194 seconds of arc depending on the method of orientation. (References 4, 6 and 7)

1955 Ballistic Cameras: The Redstone program first began using these cameras on vehicle RS-9 launched at 0151, April 20, 1955. A ballistic camera is a fixed camera which obtains a vehicle trajectory by recording a series of images on one photographic plate. Ballistic cameras are considered to be the most accurate data acquisition systems for determining vehicle position. The use of ballistic cameras is usually restricted to nighttime operations in which the vehicle carries a flashing light source which records on the photographic plate as a series of dots. Alternately, the rocket flame may be "chopped" by a fast acting shutter which is opened and closed at predetermined times. The star background is also recorded and the position of the camera is determined by geodetic survey. The survey of the camera and the star background provide the information necessary for precise fixing of the angular and spatial position of the camera. Two or more cameras photographing the same light sources allow the position of the light sources to be determined by triangulation. Ballistic cameras with focal lengths of 115 mm, 210 mm, 300 mm, 600 mm, and 1,000 mm have been used. Angular accuracies of 3 seconds from the camera to the vehicle may be obtained. Vehicle reentry trajectories can also be obtained in the daytime by chopping the image of the reentry flow. The star background can be photographed on the same plate either before or after the vehicle data acquisition.

1957 ROTI: The Recording Optical Tracking Instrument (ROTI) was first used to support Redstone and Jupiter C launches in 1957. The ROTI is essentially an engineering sequential camera with an inherent angle readout capability with the use of auxiliary equipment. The optical system employs a 24 inch aperature reflecting telescope in a Newtonian mounting. The focal length is basically 100 inches with an amplifying system giving a choice of effective focal lengths of 100, 200, 300, 400, or 500 inches, thus providing long-range photographic ability with high definition. A Mark 30, 5 inch Naval gun mount provides support for the instrument which can be operated by remote or local control. The ROTI can be tracked in elevation and azimuth. Automatic focus and exposure control are incorporated into the optical system. The camera portion takes 70 mm film with frame rates of 10, 20, 30, 40 and 60 frames/sec. At the usual running rate of 10 frames/sec, the exposure time can be varied from 1/30 to 1/800 sec. (References 6 and 7)

1958 IGOR: The Intercept Ground Optical Recorder (IGOR) was used by the Juno I Explorer series during 1958. The IGOR is somewhat similar to the ROTI in that it is also a two-man operated engineering sequential camera employing reflecting telescopic optics in a Newtonian mounting. There is no provision for radar control or angle readout. The optical system has an 18 inch aperature with a basic focal length of 90 inches which is variable in steps of 90, 180, 360, or 500 inches. The instrument has automatic focus and exposure control. Either a 35- or a 70-mm film size camera can be used with the instrument. Both the IGOR and ROTI are in use at the present time (1973) in support of NASA launches.

Figure 2 summarizes the use of these optical tracking systems on the various ABMA/NASA programs from 1953 to present.

MAJOR OPTICAL TRACKING SYSTEMS AND PERIOD USED FOR KSC / VEHICLE/ PROGRAM AND DURATION	BALLISTIC CAMERA 55-61	CZR CAMERA 53-69	CINE THEODOLITE 53-69	IGOR 58-on	ROTI 57-on
Redstone (53-68)	x	x	x		x
Jupiter (R&D) (57-60)	x	x	x		x
Jupiter C (56-57)	x	x	x		
Juno Explorer (1958)	x	x	x	x	x
Hardtack (1958)					
Juno II Pioneer (58-59)	x	x	x		x
Juno II Explorer (59-61)	x	x	x	x	x
Pershing (60-61)	x	x	x	x	x
Mercury-Redstone (60-61)		x	x	x	x
Ranger (61-62)		x		x	x
Mariner (1962)		x	x	x	x
Saturn I (63-65)		x	x	x	x
Saturn IB (66-68)		x	x	x	x
Saturn V (67-72)		x	x	x	x
Skylab (73-)				x	

FIGURE 2

3. EVOLUTION OF SPACE VEHICLE TELEMETRY

1930: First successful flight of a radio-telemetry equipped weather balloon was made in Germany. Humidity, temperature and pressure were telemetered as the balloon rose.

1940's: The early 1940's saw the development of telemetering systems to transmit information as to the state of flight of remotely controlled aircraft and to transmit data such as vibration, strains, flutter, etc.

1947-50: PPM/AM: The V-2 (launched at White Sands) used Pulse Position Modulation (PPM) to transmit data on an Amplitude Modulated Carrier (AM). The principal advantage of this type of modulation is that the AM transmitter is on only a small fraction of the time.

1953 PAM/FM/FM: The Redstone vehicle used Pulse Amplitude Modulation (PAM) to frequency modulate (FM) baseband subcarriers which in turn were used to frequency modulate (FM) an RF carrier. The PAM data stream was generated by commutating the output of multiple transducers to a single FM/FM channel. Two channels per transmitter were usually commutated. Transducers which generated data that varied too rapidly to commutate were used to frequency modulate separate subcarrier oscillators. These FM signals were summed and used to frequency modulate the RF carrier thus producing an FM/FM signal. The Redstone telemetry transmitter (AN/DKT) was subsequently used on development flights of Pershing, Saturn I, and Saturn V vehicles and on the lunar module (LM).

1958 PDM/FM/FM: The earliest Vanguard telemetry equipment called "MINITRACK" used 48 channels of commutated data applied as Pulse Duration Modulation (PDM) to frequency modulate (FM) a sub-carrier which in turn frequency modulated (FM) the RF carrier.

1959 PCM/FM: The Explorer VI satellite used Pulse Code Modulation (PCM) to biphase modulate a 1024 Hz signal which in turn was used to frequency modulate (FM) a UHF carrier. PCM's importance lies in the fact that the use of binary techniques allows superior noise immunity as compared to the previously mentioned systems. This PCM encoding scheme may be utilized as PCM/AM, PCM/FM, PCM/PM, PCM/FM/FM, PCM/PSK, etc. PCM encoding is in general use today, i.e., Saturn V, Titan III, Centaur, and nearly all of the most recent satellites.

1962 PCM: Saturn SA-3 flew the first experimental PCM transmitter designed by NASA. Transitional design packages were flown on SA-4, 5 and 6 culminating in the final design first flown on SA-7.

1964 SS/FM: Single Sideband Frequency Modulation (SS/FM) was used on the Saturn I development flights to transmit vibration and other high frequency data. Separate wideband channels are transposed in frequency to their baseband position. These single sideband signals are then summed and the composite is used to frequency modulate an RF carrier. Since the single sideband signals can be spaced relatively close together, a very large quantity of data can be efficiently transmitted over their system. For example, the Saturn I system is capable of transmitting 15 channels of 3 kHz data in a bandwidth of 80 kHz.

1967 Unified S-Band (USB): The lunar orbiter used an S-Band (2200-2300 MHz) transponder to down-link telemetry channels and to transmit television video in the form of vestigial sideband amplitude modulation of a phase modulation sub-carrier. The USB could also handle uplinks command data with the same transponder. Prior to this system the majority of telemetry transmissions were in the VHF region (200-300 MHz).

4. EVOLUTION OF SPACE VEHICLE COMMAND SYSTEMS

Early Range Safety History at Eastern Test Range: The present site of the Eastern Test Range for flight test of rocket-thrust vehicles was selected primarily for its favorable safety factor in minimizing the danger to population centers from malfunctioning guidance systems aboard vehicles undergoing flight test. From the very first test of "Bumper 8" in 1950, every flight was made under the mandatory stipulation that a trajectory outside pre-set guidelines called for the destruct in flight of the test vehicle. The decision to destroy rested with the Range Safety Officer, who could close a switch that would activate a ground radio transmitter.

The destruct system technique first incorporated at the ETR was developed by the Navy and the Air Force. It was a radio remote control system for experimental pilotless aircraft. The airborne control system was comprised of an aircraft type radio receiver in the 400 MHz band and a Model KY-55/ARW decoder to sort out commands from pairs of audio tone modulations. The receiver handled all combinations of pairs from ten audio tones. The commands from the ground provided the stage firing and maneuvering signals for the early model remotely controlled test vehicles and, when required, the destruct signal to terminate an erroneous flight. Each powered stage of a multistage vehicle had its own safety receiver. A powerful transmitter at Cape Kennedy (then Cape Canaveral) provided the control signals for the early short flights. More transmitters were added at downrange islands as the length of the flights was extended.

Many of the early vehicles to undergo flight test were missiles of aerodynamic type which were launched for horizontal flight. The Snark was turned around at the end of its planned flight-run to land back at its starting point on the Skid Strip. The Snark touched down on skis instead of wheels. To destruct the Matador, its wings were blown off to cause it to fall into the Atlantic. To terminate the flight on other missiles, simple fuel cutoff sufficed; on others, the fuel tanks were ruptured by means of exploding primacord. The first control frequency used was 408 MHz. This was raised to 420 MHz for Mercury Redstone, and finally to 450 MHz for Apollo.

Chronology of NASA Usage of Range Safety and Other Command Systems at KSC:

1953/Present Range Safety: Unmanned launch vehicles use a command receiver/decoder (AN/DRW-13) with a frequency range of 405 to 240 MHz. The commands are transmitted by the AN/FRW-2A transmitter as a combination of audio tones which serve to shutoff propellants and to activate destruct circuitry.

1965/Present Digital Range Safety Command System (DRSCS): The DRSCS on both the Saturn and Skylab programs required the transmission of an "Address" word and a "Command" word and the subsequent decoding of each before the command could be executed. The "Address" is a 9 character word and the "Command" is a 2 character word. Each character is made up of two audio-frequency tones. The commands may be used to arm the destruct circuitry, shutoff propellants, disperse propellants, and/or switch the DRSCS off. The system operates in the 450 MHz region and the same AN/FRW-2A is utilized to transmit commands as in the unmanned case.

1958-63 Mercury Spacecraft Command System: The Mercury Spacecraft UHF (406-500 MHz) Command System employed a RF carrier that was frequency shift keyed (FSK) with 20 tones. Primary use was for range safety and provided engine cutoff and fuel dispersion capabilities.

1964-66 Gemini Spacecraft Command System: The Gemini Spacecraft UHF (406-500 MHz) Command System employed a RF carrier that was phase shift keyed/frequency modulated (PSK/FM) with 20 tones. Primary use was to update maneuver thrust calculations, fuel requirement calculations, and reentry calculations.

1966/Present Command Uplink: Apollo (Saturn IB) and Skylab updata command is a UHF (406-500 MHz) carrier FM modulated with 1 and 2 kHz phase shift keying with approximately 200 commands (450 for Skylab) used.

1966/Present Apollo (Saturn V Vehicle): Launch Vehicle and Spacecraft Updata Command is an S-Band (2200-2300 MHz) carrier frequency modulated by a 70 KHz subcarrier in turn phase shift keyed by 1 and 2 kHz command modulation. S-Band was selected for its higher overall bandwidth capacity than UHF since other modulation (ranging, communications, telemetry and TV) is also applied to the Unified S-Band.

APPENDIX 1

TELEMETRY INSTRUMENTATION DEVELOPMENT

Figure 1 is indicative of technological progress in increasing the number of measurements per telemetry transmitter.

Figure 2 represents the number of measurements telemetered per vehicle type and indicates the increasing complexity and sophistication that occurred with each new program.

Figure 3 compares the number of measurements for the various vehicles with the number of telemetry transmitters required to transmit the data.

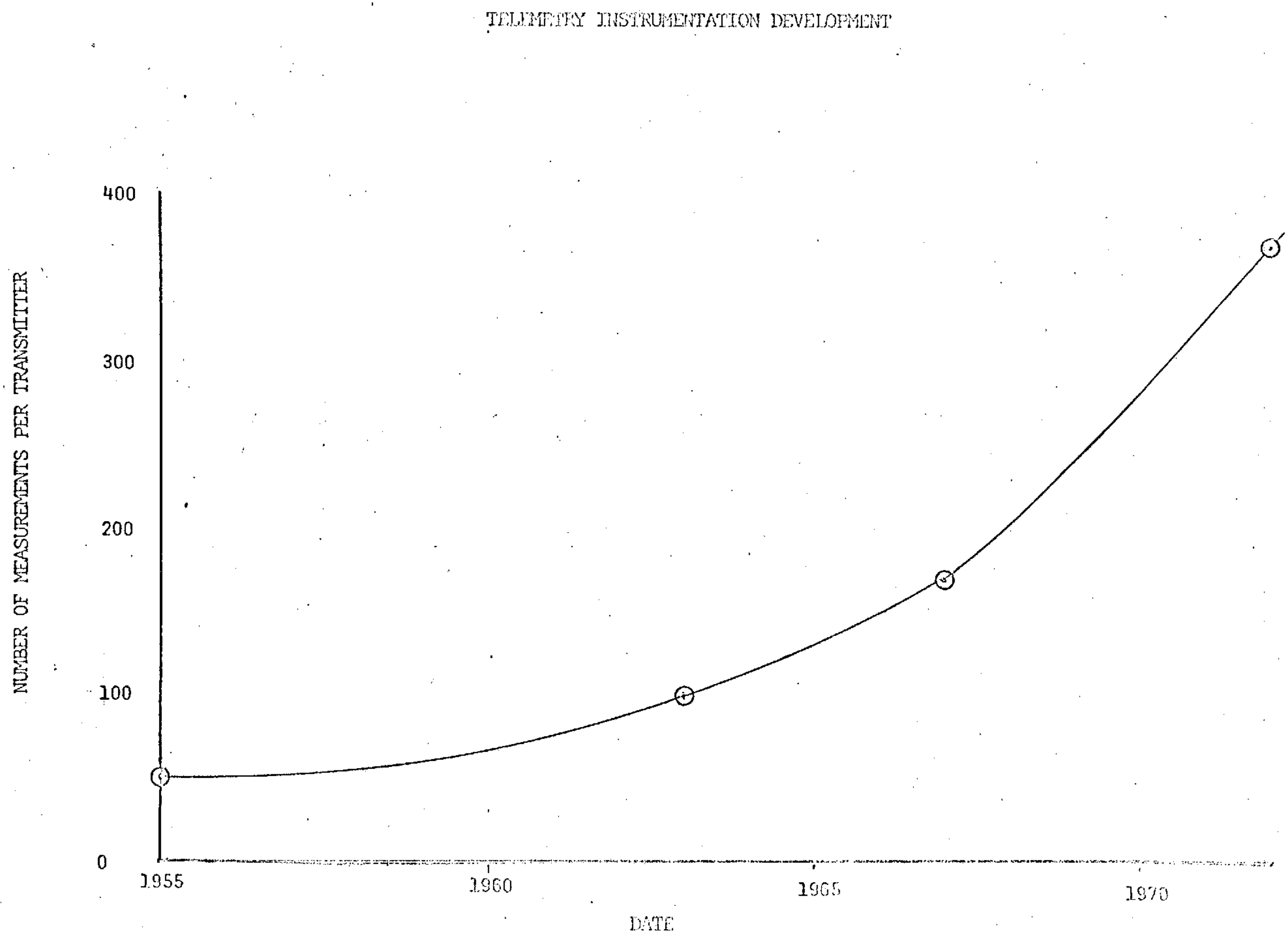
TELEMETRY INSTRUMENTATION DEVELOPMENT
400
300
200
100
0
NUMBER OF MEASUREMENTS PER TRANSMITTER
1955
1960
1965
1970
DATE

FIGURE 1

TELEMETRY INSTRUMENTATION DEVELOPMENT

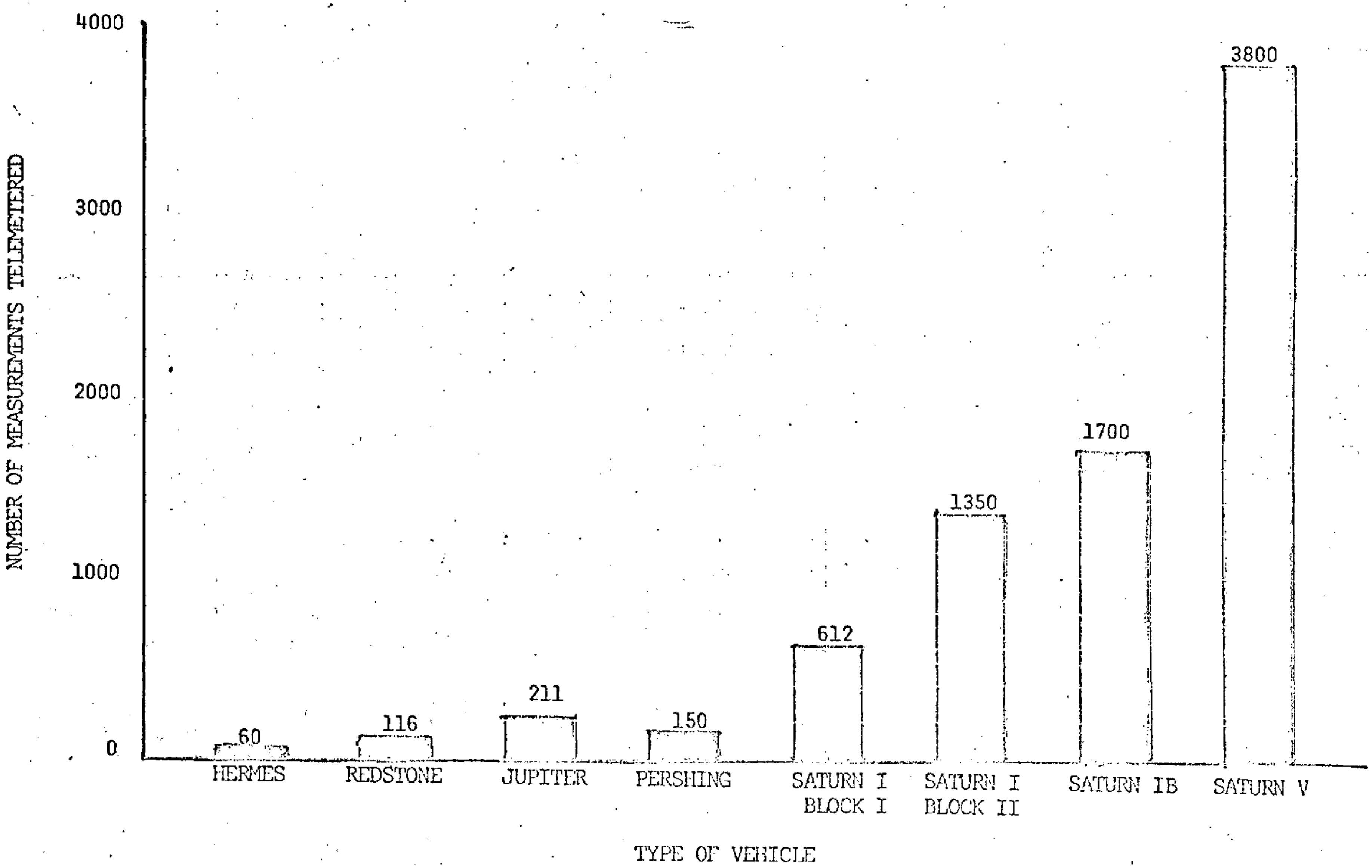

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FIGURE 2

TELEMETRY INSTRUMENTATION DEVELOPMENT

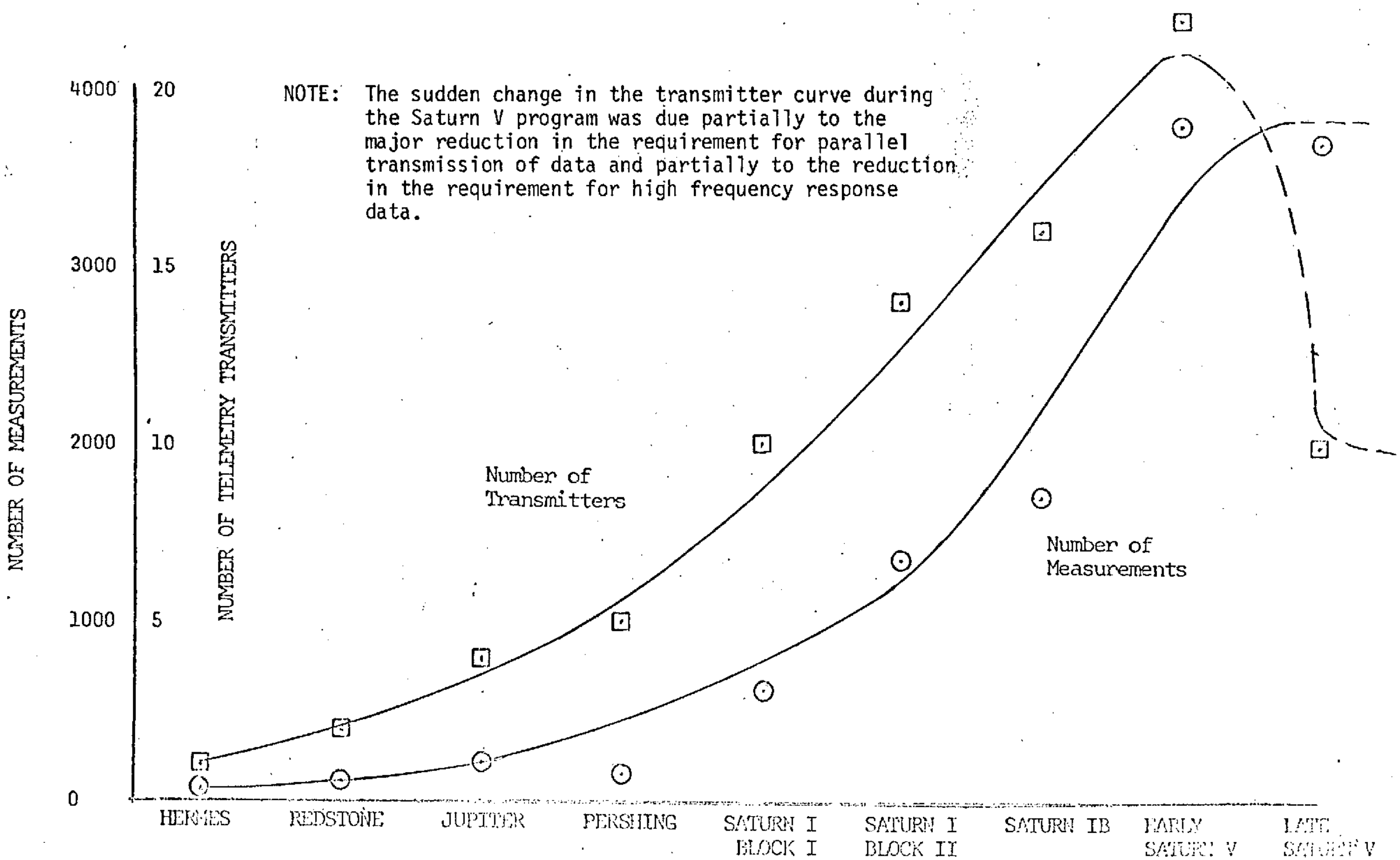

FIGURE 3

APPENDIX 2

REDSTONE TELEMETRY SYSTEM

The Redstone missiles launched between August 1956 and February 1958 with the exception of those used for the first deep penetration of space (RS-27) the nosecone recovery tests (RS-34 and RS-40) and Explorer 1 (RS-29 carried two telemeters which transmitted a total of approximately 90 flight measurements. Enclosure #1 is a typical measuring program for these missiles. Each telemeter weighed approximately 110 pounds and radiated a frequency modulated (FM) signal of 30 to 35 watts through an antenna system consisting of 3 antennas spaced 120^{o} apart around the missile. Each telemeter transmitted 15 FM/FM channels of "continuous" data and one pulse amplitude modulated/FM/FM (PAM/FM/FM) channel of time division multiplexed data. Twenty-seven data channels were time division multiplexed (each data channel was sampled 10 times per second) and transmitted via the PAM/FM/FM channel. The time division multiplexing was performed by a motor-driven mechanical commutator switch. Redstone missiles RS-27, RS-34, RS-40 and RS-29 each carried one telemeter of the type described above. Approximately 45 flight measurements were transmitted. Enclosure #2 is a typical measuring program for these missiles. Enclosure #3 is the Firing Test Report of the first Redstone Missile (RS-1) launch at the ETR.

ENCLOSURE #1

MEASUREMENT PROGRAM

TYPICAL OF

1956-1957 REDSTONE MISSILES

(TWO TELEMETERS PER MISSILE)

MEASURING PROGRAM

Issue No. 2 — Sheet 1 of 10

Total Meas. Points 92

Measuring Group Propulsion System — REDSTONE MISSILE NO. 22 — Date 24 Sept 1956 — Rev. 9 Oct. 1956

MEAS. No.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	No.	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
1 (95)	[illegible]	10/sec	A-1/BR	Pressure, Air in Pressure Bottle	0-3500 psi	27	1,2	5	Prop Unit	Stripling	Yes
2 (55)	O-12	10/sec	A-2/BR	Pressure, Air Controlled	0-1000 psi	26	1,2	5	Prop Unit	Stripling	See Note 1
3 (61)	P-2	10/sec	A-3/BR	Pressure, Top Lox Container	0-50 psi	26	1	5	Prop Unit	Stripling	Yes
4 (19a)	O-10	10/sec	A-4/BR	Pressure, Top Alc Container	0-50 psi	26	1	5	Prop Unit	Stripling	See Note 1
5 (62)	O-3	10/sec	A-5/BR	Pressure, Top H_2O_2 Container	0-600 psi	26	1	5	Prop Unit	Stripling	Yes
6 (63)	P-4	10/sec	A-6/BR	Pressure, Lox at Pump Inlet	0-50 psi	26	1	5	Prop Unit	Stripling	Yes
7 (64)	O-9	10/sec	A-7/BR	Pressure, Lox at Injector	0-400 psi	26	1	5	Prop Unit	Stripling	See Note 1
8 (65)	O-6	10/sec	A-8/BR	Pressure, Alc at Pump Inlet	0-50 psi	26	1	5	Prop Unit	Stripling	Yes
9 (66)	O-7	10/sec	A-9/BR	Pressure, Alc at Injector	0-400 psi	22	1	5	Prop Unit	Stripling	See Note 1
10 (19b)	O-11	10/sec	A-10/BR	Pressure, Steam at Inlet Turbine	0-600 psi	26	1	5	Prop Unit	Stripling	See Note 1
254	10 J1-7.35	7.35 KC 2)	COUNTER	ADAPT #2 Pressure, Combustion Chamber	0-350 psia	32	1,2	0.5	Tail Unit	Mack	No
11 (85)	9 I2-5.4	80 cps	BR-1	RPM of Turbine	0-5000 RPM	27	1,2	Dir Cnt	Prop. Unit	CC	No
14 (87)	B2-[illegible]	11 cps 3)	BR-2	Flow Rate Lox	0-25 gal/sec	27	1,2	0.3	Center Unit	Stripling	No
15 (89)	B1-[illegible]	11 cps 3)	BR-3	Flow Rate Alc	0-25 gal/sec	27	1,2	0.3	Center Unit	Stripling	No
232 (172)	[illegible]	8 cps 4)	BR-4	Flow Rate H_2O_2	0-7 lbs/sec	27	1,2	1.0	Prop Unit	Stripling	No
59	O-25	10/sec	D-1	Temperature Alcohol	-30° to $+50^\circ$C	32	1	5	Center Unit	Paludan	Yes
60	O-26	10/sec	D-2	Temperature Lox	-185° to -170°C	32	1	5	Center Unit	Paludan	Yes

REMARKS-1. Special Calibration as follows. - No calibration from take-off minus 6 seconds to take-off plus 3 seconds and from take-off plus 100 seconds to impact.

2. Subcarrier oscillator not required on this channel.
3. 60 cps output filter required on this channel.
4. 35 cps output filter required on this channel.

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ENCLOSURE #1

RSA FORM 17, 23 AUG 55 REPLACES GMDO FORM 101

Army-Redstone Arsenal, Alabama

MEASURING PROGRAM

Issue No. 2 Sheet 2 of 10

Total Meas. Points ____

Measuring Group Prop. System Cont. REDSTONE MISSILE NO. 22 Date 24 Sept. 1956 Rev. 9 October 1956

MEAS. No.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT		RANGE		FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
D 502	0-23	10/sec	D-3	#33Z Temp. Air to Vib. Gauge		0-300° C	32	1,2	5	Prop Unit	Paludan	Yes
17(91)	0-8	10/sec	A-11/BR	#5119(91) Press. Combustion Chamber		0-400° [illegible]	27	1,2	5	Prop Unit	Stripling	See Note

REMARKS- 1. See Note 1 Sheet 1.

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MEASURING PROGRAM

Issue No. 2 Sheet ___ of 10
Total Meas. Points [illegible]

Measuring Group Expulsion System REDSTONE MISSILE NO. 22 Date 24 Sept 1956 Rev. 9 Oct. 1956

MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDED	MEASUREMENT	RANGE	DWG PG NO	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
18 (79)	P-5	10/sec	A-11/E-9	Press. in Expulsion Cylinders	0-3500 psi	26	1.2	5	Prop Unit	Stripling	Yes
19a (4)	O-10	10/sec	A-4/BR	Bursting of Diaphragm Cyl. U	------	26	2	--	Center Unit	cc	See Note 1
19b (10)	O-11	10/sec	A-10/BR	Bursting of Diaphragm Cyl. D	------	26	2	--	Center Unit	cc	See Note 1
61 (3)	P-2	10/sec	A-3/BR	Explosive Screw No. 1	------	26	2	--	Center Unit	cc	Yes
62 (5)	O-3	10/sec	A-5/BR	Explosive Screw No. 2	------	26	2	--	Center Unit	cc	Yes
63 (6)	P-4	10/sec	A-6/BR	Explosive Screw No. 3	------	26	2	--	Center Unit	cc	Yes
64 (7)	O-9	10/sec	A-7/BR	Explosive Screw No. 4	------	26	2	--	Center Unit	cc	See Note 1
65 (8)	O-6	10/sec	A-8/BR	Explosive Screw No. 5	------	26	2	--	Center Unit	cc	Yes
66 (9)	O-7	10/sec	A-9/BR	Explosive Screw No. 6	------	26	2	--	Center Unit	cc	See Note 1

REMARKS- 1. See note 1 sheet 1.

MEASURING PROGRAM Issue No. 2[illegible] Sheet 1 of 10

Total Meas. Points [illegible]

Measuring Group Struct Temp REDSTONE MISSILE NO. 22 Date 24 Sept 1956 Rev. 9 Oct. 1956

MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT		RANGE	DWG REF NO	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
194	P-13	10/sec	D-4	[illegible] ~~Temp. Instr. Compartment~~	/	0-60°C	31	1,2,3	5	Instr. Gr.	Paludan	Yes
22	P-14	10/sec	D-5	#31Z Temp. Top Skin Loc. 1	/	0-500°C	31	1,2,3	5	Nose Unit	Paludan	Yes
~~23~~	~~P-15~~	~~10/sec~~		CANCELLED PER AS 414 ~~Temp. Top Skin Loc. 2~~	/	~~0-500°C~~		~~1,2,3~~	~~5~~	~~Nose Unit~~	~~Paludan~~	~~Yes~~
295	P-16	10/sec	D-6	#31Z Temp. Top Skin	/	0-500°C	31	1,2,3	5	Aft Unit	Paludan	Yes
234	0-13	10/sec	D-7	#32Z Temp. Flame Shield	/	0-1200°C	32	1,2	5	Tail Unit	Paludan	Yes
241	0-14	10/sec	D-8	#32Z Temp. Rudder Drive Bracket-Fin	/	0-900°C	32	1,2	5	Tail Unit	Paludan	Yes
242	0-15	10/sec	D-9	#32Z Temp. Rudder Drive Housing No.	/	0-900°C	32	1,2	5	Tail Unit	Paludan	Yes
243a	0-16	10/sec	D-10	#32Z Temp. Rudder Drive Housing No.	/	0-900°C	32	1,2	5	Tail Unit	Paludan	Yes
244	0-17	10/sec	D-11	#32Z Temp. Antenna Support Fin 1	/	0-900°C	32	1,2	5	Tail Unit	Paludan	Yes
21	0-18	10/sec	G-1	#33Z Temp. Air Rudder No. 4	/	0-300°C	32	1,2	5	Tail Unit	Paludan	Yes
25	0-19	10/sec	G-2	#33Z Temp. Fin No. 4 Upper Point	/	0-300°C	32	1,2	5	Tail Unit	Paludan	Yes
26	0-20	10/sec	G-3	#33Z Temp. Fin No. 4 Lower Point	/	0-300°C	32	1,2	5	Tail Unit	Paludan	Yes
356	0-21	10/sec	G-4	#32Z Temp. End Frame Skin	/	0-900°C	32	1,2	5	Tail Unit	Paludan	Yes
71	P-17	10/sec	G-5	ADAPT. #31Z Temp. Air Vane No. 4	/	0-500°C	31	1,2,3	5	Aft Unit	Paludan	Yes
297	P-18	10/sec	G-6	#31Z Temp. Inside Aft Unit	/	0-400°C ~~0-600°C~~	31 AS 4[illegible]	1,2,3	5	Aft Unit	Paludan	Yes
418	P-15	10/SEC	G-7	#31Z TOT. TEMP ON NOSE BOOM	/	0-1200°C	31	1,2,3	5		MACK PALUDAN	Yes

REMARKS- NOTE:
MEAS #418 ADDED AS PER MEMO AS 414

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Army-Redstone Arsenal, Alabama

MEASURING PROGRAM

Issue No. 2 Sheet 5 of 10

Total Meas. Points 17

Measuring Group Struct Press. and Vib. REDSTONE MISSILE NO. 22

Date 24 Sept 1956 Rev. 9 Oct. 1956

MEAS. No.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT		RANGE	DWG PG NO	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
72	P-11	10/sec	B-2	Press. Inst. Compartment	/	0-18 psia		1,2,3	5	Aft Unit	Stripling	Yes
73	P-22	10/sec	B-3	Press. in Tail Section	/	0-15 psia	31	1,2	5	Tail Unit	Stripling	Yes
180(439)	13 M2-52.5	790 cps	F-1	ADAPT #10 #9M 9W2 Vibration Air Rudder No. 4	/	≤ 5 g's 100cps	30	1,2	5	Tail Unit	Downs	No
439(180)	13 M2-52.5	790 cps	F-1	ADAPT #9 (B) 9M 9W2 Vibration Air Vane No. 4	/	≤ 5 g's 100cps	30	3	5	Aft Unit	Downs	No

REMARKS-

MEASURING PROGRAM

Issue No. 2 — Sheet 6 of 10

Total Meas. Points 84

Measuring Group Flight Mechanics — REDSTONE MISSILE NO. 22 — Date 24 Sept 1956 — Rev. 9 Oct. 1956

MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT		RANGE		FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
~~35~~	~~P1-2.3~~	~~35 cps~~		CANCELLED PER MS 407 ~~Angle of Attack - Pitch~~		~~∠ 10°~~		~~1,2,3~~	~~5~~	~~Nose Unit~~	~~Mack~~	~~Yes~~
~~38~~	~~G2-3.0~~	~~45 cps~~		CANCELLED PER MS 407 ~~Angle of Attack - Yaw~~		~~∠ 10°~~		~~1,2,3~~	~~5~~	~~Nose Unit~~	~~Mack~~	~~Yes~~
370	4 D1-1.3	20 cps	G-8	Angle of Attack - Pitch α Contro		∠ 10°	30	1,2,3	5	Nose Unit	Mack	Yes
371	3 70RC C2-0.95	14 cps	G-9	Angle of Attack - Yaw α Contro		∠ 10°	30	1,2,3	5	Nose Unit	Mack	Yes
383	13 M1-52.5	790 cps	C-1	Local Angle of Attack - Loc No.	X	∠ 4°	25	1,2,3	2	Aft Unit	Mack	Yes
384	7 G1-3.0	45 cps	C-2	Local Angle of Attack - Loc No.	Y	∠ 10°	25	1,2,3	2	Aft Unit	Mack	Yes
385	P-23	10/sec	C-3	Local Angle of Attack - Loc No.	Z	∠ 10°	25	1,2,3	2	Aft Unit	Mack	Yes
185	12 L1-14.5	14.5 KC 2)	COUNTER	V. ADAPT #1 Pitot Pressure		0-15 and 0-140 psia	1) 28	1,2,3	0.3	Nose Unit	Mack	No
186	11 K1-10.5	10.5 KC 2)	COUNTER	V. ADAPT #1 Static Pressure		0-3 and 0-15 psia	1) 28	1,2,3	0.3	Nose Unit	Mack	No
41(41a)	P-10	10/sec	C-4	Acceleration of Missile Longt.		∠ 1 to /2 g's	27	1	5	Instr. Gr.	Mack	Yes
41a(41)	P-10	10/sec	C-4	Acceleration of Missile Longt.		∠0.5 to -1 g's	27	2,3	5	Instr. Gr.	Mack	Yes
36	0-2	10/sec	F-2	Angular Velocity - Pitch		∠ 10°/sec	28	1,2,3	5	Instr. Gr.	Dománi	Yes
39	5 E2-1.7	25 cps	F-3	Angular Velocity - Yaw		∠ 10°/sec	28	1,2,3	5	Instr. Gr.	Dománi	Yes
40	3 C1-0.96	14 cps	F-4	Angular Velocity - Roll		∠ 10°/sec	28	1,2,3	5	Instr. Gr.	Dománi	Yes
94(227)	5 E1-1.7	25 cps	RR-5	Speed Contact?		----		12,3	Dir Cnt	Instr. Gr.	Gyro Sec	No
77(77a)	P-12	10/sec	C-5	Acceleration of Missile - Yaw		∠ 1.2 g's	32	1,2	5	Inst. Gr.	Mack	Yes
77a(77)	P-12	10/sec	C-5	Acceleration of Missile - Yaw		∠ 6 g's	32	3	5	Instr. Gr.	Mack	Yes

REMARKS- 1. Range changes at separation - Two gauges used.
2. Subcarrier oscillator not required on this channel.

EASURING PROGRAM) Issue No. 2 Sheet _ of 10

Total Meas. Points [illegible]

Measuring Group Steering Control [illegible] REDSTONE MISSILE NO. 22 Date 24 Sept 1956 Rev. 9 Oct. 1956

MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	DWG Pt	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
43(226)	6 F2-2.3	35 cps	BR-6	Tilting Program Lev 3	0-180° 1°/Step	29	1,2,3	Dir Cnt	Inst. Gr.	Gyro. Sec.	No
226(43)	6 F2-2.3	35 cps	BR-6	Input to Step Motor	----	29	1,2,3	Dir Cnt	Inst. Gr.	Gyro. Sec.	No
227(94)	5 E1-1.7	25 cps	BR-5	Input to Step Switch	----	29	1,2,3	Dir Cnt	Instr. Gr.	Network Section	No
44	P-1	10/sec	F-5	Gyro Pitch Position - Minus Pr	∠ 15°	27	1,2,3	5	Instr. Gr.	Gyro Sec Downs	Yes
45	P-3	10/sec	F-6	Gyro Yaw Position	∠ 15°	27	1,2,3	5	Instr. Gr.	Gyro Sec Downs	Yes
46	1 A27-.56	20 cps	F-7	Gyro Roll Position	∠ 10°	27	1,2,3	5	Instr. Gr.	Gyro Sec Downs	Yes
218(200)	O-4	10/sec	C-6	Deflection Jet Vane No. 1	∠ 27°	29	1,2	5	Tail Unit	Beltran	Yes
219(201)	O-5	10/sec	C-7	Deflection Jet Vane No. 2	∠ 27°	29	1,2	5	Tail Unit	Beltran	Yes
220(202)	P-6	10/sec	C-8	Deflection Jet Vane No. 3	∠ 27°	29	1,2	5	Tail Unit	Beltran	Yes
221(203)	P-7	10/sec	C-9	Deflection Jet Vane No. 4	∠ 27°	29	1,2	5	Tail Unit	Beltran	Yes
200(218)	O-4	10/sec	C-6	Deflection Air Vane No. 1	∠ 27°	29	3	5	Aft Unit	Beltran	Yes
201(219)	O-5	10/sec	C-7	Deflection Air Vane No. 2	∠ 27°	29	3	5	Aft Unit	Beltran	Yes
202(220)	P-6	10/sec	C-8	Deflection Air Vane No. 3	∠ 27°	29	3	5	Aft Unit	Beltran	Yes
203(221)	P-7	10/sec	C-9	Deflection Air Vane No. 4	∠ 27°	29	3	5	Aft Unit	Beltran	Yes
78	8 H1-3.9	60 cps	BR-7	Frequency of Inverter No. 1	399.75 to 400.25 cps	28	1,2,3	10^{-5} ABS	Instr. Gr.	Downs	No
84	P-8	10/sec	B-4	Tank Press Air for Top Jets	0-3500 psi	26	1,2,3	5	Aft Unit	Stripling	Yes
85 (11)	9 I2-5.4	80 cps	BR-1	Top Jet Operation I2 and I4	Off-On	27	3	---	Aft Unit	Stripling	No

REMARKS-

MEAS #78: OSC. FREQ. = 39971.8 CPS

BEAT FREQ. @ 400 cps = 28.2 cps 27

$$\text{INV. FREQ.} = \frac{\text{OSC. FREQ.} + \text{BEAT FREQ.}}{100}$$

REPLACES GMDD FORM 101 | Army-Redstone Arsenal, Alabama

MEASURING PROGRAM

Issue No. 2 Sheet 1 of 10

Total Meas. Points

Measuring Group Steering Control Cont' REDSTONE MISSILE NO. 22 Date 24 Sept 1956 Rev 9 Oct. 1956

MEAS. No.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	DWG PG No	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
87(14)	B2-0.73	11 cps 1)	BR-2	Top Jet Operation II and II_1	Off - On	27	3	--	Aft Unit	Stripling	No
89(15)	B1-0.73	11 cps 1)	BR-3	Top Jet Operation III_2 and III_4	Off - On	27	3	--	Aft Unit	Stripling	No
91(17)	O-8	10/sec	A 11 BR.	Top Jet Operation IV_1 and IV_3	Off - On	27	3	--	Aft Unit	Stripling	See Note 2
51a	P-9	10/sec	F-8	Voltage Servo Battery	0-30 Volts	29	1,2,3	5	Instr. Gr.	Downs	Yes
79(18)	P-5	10/sec	F-9 B-1	Torque on Air Vane 1	± 40 MKG	26	3	5	Aft Unit	Beltran	Yes
172(232)	A1-0.56	8 cps 3)	BR-4	Dive Phase Control Switch Point	Off - On	27	3	--	Nose Unit	Mack	No
483	J2-7.35	110 cps	BR-8	CS 1,5,8,12,15,19,22,26	0-5 VDC	23	1,2,3	5	Aft Unit	Control Section	No
484	K2-10.5	160 cps	BR-9	CS 2,6,9,13,16,20,23,27	0-5 VDC	23	1,2,3	5	Aft Unit	Control Section	No
485	R1-22	330 cps	BR-10	CS3,7,10,14,17,21,24,28	0-5 VDC	23	1,2,3	5	Aft Unit	Control Section	No
486	I1-5.4	80 cps	BR-11	Cs,4,4,11,11,18,18,25,25	0-5 VDC	23	1,2,3	5	Aft Unit	Control Section	No

REMARKS-
1. 60 cps output filter required on this channel.
2. See note 1 sheet 1.
3. 35 cps output filter required on this channel.

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Army-Redstone Arsenal Alabama

EASURING PROGRAM

Issue No. 2 Sheet [illegible] of 10

Total Meas. Points [illegible]

Measuring Group Signals

REDSTONE MISSILE NO. 22

Date 24 Sept 1956 Rev. 9 Oct. 1956

Meas. No.	Telemeter Channel	Telemeter Response	Meas. Recorder	Measurement		Range	Dwg Pg No	Flight Period	% Acc'y	Location	In Charge	On Flight Calib
55(2)	0-12	10/sec	A-2/BR	Cutoff Signal		---	26	1	--	Instr. Gr.	Fichtner	See Note 1
95(1)	0-1	10/sec	A-1/BR.	Emergency Cutoff	/	---	27	1	--	Instr. Gr.	Fichtner	Yes
161	R2-22	330 cps	BR-12	Daisy Flash Pulses		---	31	1,2,3	--	Aft Unit	Downs	NO

REMARKS- 1. See note 1 sheet 1.

2. Separation signal may be observed from switching over measurements 218 to 200, 219 to 201, 220 to 202 and 221 to 203. Separation point may be observed on those channels which are disconnected from the telemeter at separation. Takeoff signal may be observed on those channels which are switched with recorder transfer - Measurement nos. 1, 4, 18, 84 and 194.

MEASURING PROGRAM

Issue No. 2

Measurements Recorded in Blockhouse REDSTONE MISSILE NO. 22 Date 24 Sept 1956 Rev. 9 Oct. 1956

MEAS. No.	MEAS. RECORDER	MEASUREMENT	RANGE	IN CHARGE	REMARKS
A		Press. Air in Pressure Bottles	0-3500 psi	Stripling	Same gauge used for Meas. #1
B		Press. Top Lox Container	0-50 psi	Firing Lab	
C		Press. Top Alc Container	0-30 psi	Firing Lab	
D		Press. Expulsion Cylinders	0-3500 psi	Stripling	Same gauge used for Meas. #18
E		Tank Press. Air for Top Jets	0-3500 psi	Stripling	Same gauge used for Meas. #84
F		Press. Lox Topping Device	0-50 psi	Firing Lab	
G		Temp. Instr. Compartment	0-60° C	Paludan	Same probe used for Meas. #194
H		Temp. H_2O_2	10° -100°C	Firing Lab	
K		Measuring Voltage	0-5 volts	Firing Lab	

GENERAL NOTES- 1. Straight channels are denoted by center frequency in KC and also by letters A thru N and R. A1 refers to channel A of telemeter no. 1 and A2 refers to channel A of telemeter no. 2. Channel O is included in telemeter no. 1 and channel P is included in telemeter no. 2. Both O and P are commutated and samples are given at the rate of 10/sec on both channels. The center frequency of both O and P is 30 KC.
2. Flight period no. 1 = take-off to propulsion cut-off. No. 2 = Propulsion cut-off to separation. No. 3 = separation to impact. 3. Measurements no. 43, 44, 45 and 46 are presented at central control on LINK No. 1 (218.5) MC

LAST SHEET 30

ENCLOSURE #2

MEASUREMENT PROGRAM

TYPICAL OF

SCIENTIFIC REDSTONE LAUNCHES

(RS-27, RS-29, RS-34, RS-40)

(ONE TELEMETER PER VEHICLE)

Encl. 2

AB FORM 94, 1 Oct 56

MEASURING PROGRAM

Army-Redstone Arsenal, Alabama

Issue No. 1 Sheet 1 of 8

Total Meas. Points 45

Measuring Group Prop. System REDSTONE MISSILE NO. 40 Date 8 Nov 1956 Rev.

MEAS. No.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
1(95)	0-1	10/sec	A-1	Press Air in Press Bottles	0-3500 psi	1	5	Prop Unit	Stripling	Yes
254	10 J-7.35	7.35 KC 1)		Press. Combustion Chamber	0-350 psia	1	0.5	Tail Unit	Mack	No
11(54)	11 K-10.5	160 cps	BB-1	RPM of Turbine	0-5000 RPM	1	Dir Cnt	Prop Unit	Stripling	No
14(55)	2 B-0.73	11 cps 2)	BB-2	Flowrate Lox	0-25 gal/sec	1	0.3	Cent. Unit	Stripling	No
15(347)	7 G-3.0	45 cps	BB-3	Flow Rate Alc	0-25 gal/sec	1	0.3	Cent. Unit	Stripling	No
232	1 A-0.56	8 cps 3)	BB-4	Flow Rate H_2O_2	0-7 lbs/sec	1	1.0	Prop Unit	Stripling	No
60	0-2	10/sec	2-1	#45 Temp. Lox at Pump Inlet	-185° to -170°	1	5	Cent. Unit	Paludan	Yes
6	0-12	10/sec	A-2	Press. Lox @ Pump Inlet	0-50 psi	1	5	Prop Unit	Stripling	Yes

REMARKS- 1. Subcarrier Oscillator not required on this channel.
2. 60 cps filter required.
3. 35 cps filter required.

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ENCLOSURE #2

AI FORM 94, 1 Oct 56

MEASURING PROGRAM

Issue No. 1 Sheet 2 of 8

Total Meas. Points ____

Measuring Group Struct. Temp. REDSTONE MISSILE NO. 40 Date 8 Nov 1956 Rev. 1(4/10/57)

MEAS. No.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	DWG FIG NO	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
277	0-3	10/sec	D-2	Temp. Inst. Compt. Skin	0-300°C	13	1	5	Instr. Gr.	Paludan	Yes
278	0-4	10/sec	D-3	Temp. Inst. Compt. Skin	0-300°C	[illegible]	1	5	Instr. Gr.	Paludan	Yes
279	0-5	10/sec	D-4	Temp. Inst. Compt. Skin	0-300°C	[illegible]	1	5	Instr. Gr.	Paludan	Yes
280	0-6	10/sec	D-5	Temp. Inst. Compt. Skin	0-300°C	[illegible]	1	5	Instr. Gr.	Paludan	Yes
234	0-7	10/sec	D-6	Temp. Flame Shield	0-1200°C	13	1	5	Tail Unit	Paludan	Yes
356	0-8	10/sec	D-7	Temp. End Frame Skin	0-900°C	13	1	5	Tail Unit	Paludan	Yes
243	0-9	10/sec	D-8	Temp. Rudder Drive Housing nt	0-900°C	13	1	5	Tail Unit	Paludan	Yes
242	0-10	10/sec	D-9	Temp. Rudder Drive Housing	0-900°C	13	1	5	Tail Unit	Paludan	Yes
244	0-11	10/sec	D-10	Temp. Ant Support-Fin 1	0-900°C	13	1	5	Tail Unit	Paludan	Yes

REMARKS-

ABMA FORM 94, 1 Oct 56

MEASURING PROGRAM

Issue No. 1 Sheet 3 of 8

Total Meas. Points

Measuring Group Struct Vib and Press REDSTONE MISSILE NO. 40 Date 8 Nov 1956 Rev. 1(5/22/57)

	MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
	450	M-52.5	790 cps		Vibration, Base of Rotational Launcher - Pitch	±1g 100 cps	1	10	Nose Unit	Downs	No
	451	N-70	1050cps		Vibration, Base of Rotational Launcher - Yaw	±1g 100 cps	1	10	Nose Unit	Downs	No
(1)	72	0-15	10/sec		Press. Inst. Compartment	0-38 psia	1	5	Instr. Gr.	Stripling	Yes

REMARKS-

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A) FORM 94, 1 Oct 56) MEASURING PROGR.) Army-Redstone Arsenal, Alabama

Issue No. 1 Sheet 4 of 8

Total Meas. Points

Measuring Group Flight Mechanics REDSTONE MISSILE NO. 40 Date 8 Nov. 1956 Rev. 1(4/10/57)

	MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE		FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
	36	0-16	10/sec	F-3	Angular Velocity - Pitch	± 10°/sec	12	1	5	Inst. Gr.	Downs	Yes
	39	H-3.9 (8)	60 cps	F-4	Angular Velocity - Yaw	± 10°/sec	12	1	5	Inst. Gr.	Downs	Yes
	40	I-5.4 (7)	80 cps	F-5	Angular Velocity - Roll	± 10°/sec	12	1	5	Inst. Gr.	Downs	Yes
(1)	524	0-17	10/sec	C-1	Accel. of Missile - Longt.	+1 to +6 g's	12	1	5	Inst. Gr.	Mack	Yes
(1)	528	0-18	10/sec	C-2	Accel. of Missile - Yaw	±6 g's	12	1	5	Inst. Gr.	Mack	Yes
(1)	527	0-19	10/sec	C-3	Accel. of Missile - Pitch	±6 g's	12	1	5	Inst. Gr.	Mack	Yes

REMARKS-

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ABMA FORM 94, 1 Oct 56

Army-Redstone Arsenal, Alabama

MEASURING PROGRAM

Issue No. 1 Sheet 5 of 8

Total Meas. Points ____

Measuring Group Steering Control REDSTONE MISSILE NO. 10 Date 8 Nov 1956 Rev. 1(5/22/57)

	MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	PKG NO.	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
	43(226)	6 F-2.3	35 cps	[illegible]	Tilting Program - LEV-3	---	12	1	--	Inst. Gr.	Mueller	No
	226(43)	6 F-2.3	35 cps	[illegible]	Input to Step Motor	---		1	--	Inst. Gr.	Mueller	No
(1)	44	3 C-0.96	14 cps	E-6	Gyro Pitch Position-Minus Pr.	± 15°		1	5	Inst. Gr.	Mueller	See Note 1
(1)	45	4 D-1.3	20 cps	E-7	Gyro Yaw Position	± 15°		1	5	Inst. Gr.	Mueller	See Note 1
	46	5 E-1.7	25 cps	E-8	Gyro Roll Position	± 15°		1	5	Inst. Gr.	Mueller	Yes
	47	O-20	10/sec	C-4	Deflection of Jet Vane 1	± 27°	11	1	5	Tail Unit	Beltran	Yes
	48	O-21	10/sec	C-5	Deflection of Jet Vane 2	± 27°	11	1	5	Tail Unit	Beltran	Yes
	49	O-22	10/sec	C-6	Deflection of Jet Vane 3	± 27°		1	5	Tail Unit	Beltran	Yes
	50	O-23	10/sec	C-7	Deflection of Jet Vane 4	± 27°		1	5	Tail Unit	Beltran	Yes
	227(94)	17 R-22	330 cps	[illegible]-6	Input to Step Switch	---	14	1	--	Inst. Gr.	Fichtner	No
	94(227)	17 R-22	330 cps	[illegible]-6	Speed Contacts	---	14	1	--	Inst. Gr.	Fichtner	No

REMARKS-

1. No calibration from take-off minus 6 sec. to take-off plus 3 sec. and from take-off plus 100 sec. to impact.

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MEASURING PROGRAM

Issue No. 1 Sheet 6 of 8

Total Meas. Points

Measuring Group Cluster Unit

REDSTONE MISSILE NO. 40

Date 8 Nov 1956 Rev.

MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT	RANGE	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
324	12 L-14.5	220 cps	[illegible]-7	RPM of Rotational Launcher	0-7500 RPM	1	Dir Cnt	Top Unit	Stripling	No
326	0-26	10/sec	F-9	Battery Voltage DC Motor Supply	21-31 Volts	1	5	Inst. Gr.	Downs	Yes
325	0-25	10/sec	F-10	Current DC Drive Motor No. 1	0-300 amps	1	5	Inst. Gr.	Downs	Yes
448	0-27	10/sec	F-11	Current DC Drive Motor No. 2	0-300 amps	1	5	Inst. Gr.	Downs	Yes

REMARKS-

AE FORM 94, 1 Oct 56 — Army-Redstone Arsenal, Alabama

MEASURING PROGRAM

Issue No. 1 Sheet 7 of 8

Total Meas. Points ____

Measuring Group Signals

REDSTONE MISSILE NO. 40

Date 8 Nov 1956 Rev. ____

MEAS. NO.	TELEMETER CHANNEL	TELEMETER RESPONSE	MEAS. RECORDER	MEASUREMENT		RANGE	DWG	FLIGHT PERIOD	% ACC'Y	LOCATION	IN CHARGE	ON FLIGHT CALIB
54(11)	11 K-10.5	160 cps	BR-1	Take-off		---	10	1	--	Inst. Gr.	Fichtner	No
55(14)	2 B-0.73	11 cps 1)	BR-2	Cutoff		---	10	1	--	Inst. Gr.	Fichtner	No
95(1)	0-1	10/sec	A-1/BR.	Emergency Cutoff		---	13	1	--	Inst. Gr.	Fichtner	Yes
347(15)	7 G-3.0	45 cps	BR-3	Ignition Signal of Cluster		---	10	1	--	Inst. Gr.	Fichtner	No

REMARKS-
1. 60 cps filter required on this channel.
2. Separation of Cluster Unit may be observed on meas. nos. 324, 325 and 448.

Issue No. 1

Measurements Recorded in Blockhouse REDSTONE MISSILE NO. 40 Date 8 Nov 1956 Rev. ____

MEAS. NO.	MEAS. RECORDER	MEASUREMENT	RANGE	IN CHARGE	REMARKS
A	[illegible]	Press. Air in Press. Bottles	0-3500 psi	Stripling	Same gauge used for meas. no. 1
B	[illegible]	Press. Top Lox Container	0-50 psi	Firing Lab	
F		Press. Lox Topping Device	0-50 psi	Firing Lab	
G		Temp. Inst. Compartment	0-60°C	Paludan	Thermocouple probe B-GM 66365B used with Temp. Adapter 14. Not on Flight
H		Temp. H_2O_2	10°-100°C	Firing Lab	
K		Measuring Voltage	0-5 Volts	Firing Lab	
V		RPM of Rotational Launcher	0-7500 RPM	Stripling	Same Inst. used for Meas. no. 324
BB		Vibration, Base of Rotational Launcher - Pitch	±1g 100 cps	Downs	Same Inst. used for Meas. no. 450
CC		Vibration, Base of Rotational Launcher - Yaw	±1g 100 cps	Downs	Same Inst. used for meas. no. 451
	[illegible]	[illegible] Voltage	60V		

GENERAL NOTES- 1. Straight channels are denoted by center frequency in KC and also by letters A thru N and R. Channel "O" is commutated and samples given at the rate of 10/sec. Center frequency of O is 30 KC. Commutated channel P is not used.

2. Flight Period 1 - Take-pff to Cluster Ignition.

ENCLOSURE #3

FIRING TEST REPORT

MISSILE NO. RS-1

15 OCT 1953

INCLUDING THE MEASURING PROGRAM

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ENCLOSURE #3

SECRET
SECURITY INFORMATION
UNCLASSIFIED

MISSILE FIRING LABORATORY

GUIDED MISSILE DEVELOPMENT DIVISION

FIRING TEST REPORT, MISSILE NO. RS-1

15 October 1953

This report contains a summary of the firing activities conducted by Redstone Arsenal personnel in preparation and firing of REDSTONE Missile No. RS-1. The missile was fired at AFMTC, Cape Canaveral, Florida, at 0937 EST, 20 August 1953.

1. FABRICATION

At the time of firing the missile was as specified in the following drawings:

Drawing No.	Title	Manu-facturer
J-GM-55000	XSSM-A-14 Redstone Missile Ass'y	RSA
J-GM-55001 A1	Booster Ass'y	RSA
J-GM-55002 A1	Power Unit Ass'y	RSA
J-GM-55003 G	Center Unit Ass'y	RSA
J-GM-55004 J1	Tail Unit Ass'y	RSA
J-GM-55005 A	Top Ass'y	RSA
J-GM-55006 C1	Nose-Unit Ass'y	RSA
J-GM-55007 D	Aft-Unit Ass'y	RSA
J-GM-55008-I	Instrument Group Ass'y	RSA
Rocket Engine	NAA 75-110 (001)	NAA

The aft end of the missile was protected from heat by a sandwich type insulator consisting of sheet asbestos between sheet metal. This insulator covered all exposed parts of the missile aft end, including the servomotor housing. Also, a circular flame shield of the dented design with 4 graphite blocks was mounted at the exhaust nozzle.

2. MISSILE EQUIPMENT SPECIFICATIONS

The following equipment was installed in the missile:

Telemetering: Raymound Rosen, 16-channel.

Gyros: Waldorf-Kerns Company
Pitch Gyro - H-165
Yaw-Roll Gyro - K-156

Integrator: #038 (A. Ott Kempten).

Command Receivers: ARN-59 with KY-55 Decoders (two each).

UNCLASSIFIED

SECRET
SECURITY INFORMATION

FIRING TEST REPORT, MISSILE NO. RS-1

Radar Beacons: DPN-17 (two).

Pre-flight Cooler: Blower circulated air over dry ice (RSA Design and Fabrication).

Decomposer Screen Pack: Silver-plated screen activated with potassium permanganate.

Expulsion Tube Assembly: Drawing No. GM 63117 (two cylinders with air storage).

Helium High Pressure System.

Rudder Drive (aluminum casting).

3. OBJECTIVES

RS-1 was launched for the purpose of testing:

a. The power plant.

b. The missile structure.

c. Booster control system.

d. Action of missile at low take-off acceleration.

e. Operation of roll control system after cut-off.

f. Automatic separation.

4. MEASURING PROGRAM

Following is a list of all flight measurements used on Missile No. RS-1. For detailed information regarding these measurements, see Measuring Program (REDSTONE Missile Instrumentation System A).

GROUP	MEASUREMENT	RANGE
Propulsion Unit	Press. HE. in Pressure Bottles	0-3000 psig
	Press. HE Controlled	0-1000 psig
	Press. Top LOX Container	0-50 psid
	Press. Top Alc. Container	0-30 psid
	(Cont'd)	

FIRING TEST REPORT, MISSILE NO. RS-1

GROUP	MEASUREMENT	RANGE
Propulsion Unit	Press. Top Peroxide Container	0-600 psig
	Press. LOX at LOX Pump Inlet	0-50 psid
	Press. LOX at Injector	0-400 psig
	Press. Alc. Pump Inlet	0-50 psid
	Press. Alc. at Injector	0-400 psig
	Press. Steam at Inlet Turbine	0-600 psig
	RPM of Turbine	0-5000 RPM
	Pressure of Exhaust Steam	0-30 psid
	Position Main LOX Valve	0-90°
	Flow Rate LOX	0-25 gal/sec
	Flow Rate Alc.	0-25 gal/sec
	Pressure Combustion Chamber	0-400 psig
Structure Temperatures	Skin Temperature Location #1	260°-700°K
	Skin Temperature Location #2	260°-700°K
	Skin Temperature Location #3	260°-700°K
	Skin Temperature Fin #4 - Upper Point	260°-550°K
	Skin Temperature Fin #4 - Lower Point	260°-550°K
	Temperature of Jet Vane Bracket	260°-750°K
	Temperature of Flame Shield Between Fin 1 & 2	260°-1400°K
	Temperature of Flame Shield Between Fin 3 & 4	260°-1400°K
	Temperature of End Frame Between Fin 1 & 2	260°-1000°K
	Temperature of End Frame Between Fin 3 & 4	260°-1000°K
	Temperature of Antenna Cover	260°-1400°K

FIRING TEST REPORT, MISSILE NO. PS-1

GROUP	MEASUREMENT	RANGE
Structure Vibrations	Vibration Instrument Compt. Longt.	± 50g-150 cps
	Vibration Instrument Compt. Pitch	± 5g-150 cps
	Vibration Thrust Frame Longt.	± 250g-1200 cps
	Vibration Thrust Frame Pitch	± 250g-1200 cps
	Vibration Booster Fin #4	± 5g-50 cps
	Vibration Servomotor #1 - Longt.	± 250g-1200 cps
	Vibration Servomotor #1 - Lat.	± 250g-1200 cps
Force	Lateral Force - Air Vane #1	± 1200 kg
Flight Mechanics	Angle of Attack Pitch	± 7°
	Angular Velocity Pitch	± 5°/sec
	Angular Acceleration Pitch	± 20°/sec
	Angle of Attack Yaw	± 7°
	Angular Velocity, Roll	± 5°/sec
	Acceleration Booster Longt.	- 1.1 to +5.4 g
Steering Control	Tilting Program	0-180°
	Gyro Pitch Position - Minus Program	± 10°
	Gyro Yaw Position	± 10°
	Gyro Roll Position	± 10°
	Deflection Jet Vane #1	± 27° to ± 54°
	Deflection Jet Vane #2	± 27° to ± 54°

(Cont'd)

FIRING TEST REPORT, MISSILE NO. RS-1

GROUP	MEASUREMENT	RANGE
Steering Control	Deflection Jet Vane #3	± 27° to ± 54°
	Deflection Jet Vane #4	± 27° to ± 54°
	Voltage Servo Battery	0-42 Volts
	Total Torque Servomotor #1	± 60 mkg
	Torque Air Vane #1	± 60 mkg
Signals	Take off Signal	
	Speed Contacts	
	Cut off Signals	
	Emergency Cut off Signal	
	Separation Signal	
Tele-metering	Zero Measuring Voltage	
	Zero Measuring Voltage	
	(+) Measuring Voltage	
	(+) Measuring Voltage	
	Standard Voltage (+)	
	(-) Measuring Voltage (Tel.)	
	(+) Measuring Voltage	

FIRING TEST REPORT, MISSILE NO. RS-1

5. FLIGHT SAFETY PROVISIONS

Flight safety is defined as all safety measures to be taken relative to the missile when in flight. The AFMTC Flight Safety Officer had the sole responsibility over the missile during flight.

The flight safety system was based on a group of ground stations for optical and radar tracking of the missile, as well as real-time presentation of some attitude data via telemeter. For termination of flight and emergency separation, two separate command receivers and transmitter systems were provided. For further details, see

a. Missile Test Request No. 305.
b. Range Safety Plan, REDSTONE, dated 7 August 1953.
c. Flight Safety REDSTONE, dated 14 August 1953.

6. CLIMATIC DATA

The launch time observation for Cape Canaveral, 0937 EST, 20 August 1953:

Cloudiness: 2/10 low clouds bases 3,000 feet and tops estimated at 6,000 feet.

7/10 middle clouds bases 15,000 feet.

5/10 high clouds at 30,000 feet.

Visibility: 10 miles.

Station Pressure: 1013.7 mbs (29.935 in.).

Temperature: 83°F

Relative Humidity: 80%

Dew Point: 76°F

Wind: SSW at 7 knots.

ENCLOSURE #3

LAUNCH HISTORY 1953 - 1972

VEHICLE	LIFTOFF TIME/DATE	PAD
Redstone RS-1	0937 Aug. 20, 1953	4
Redstone RS-2	1020 Jan. 27, 1954	4
Redstone RS-3	1228 May 5, 1954	4
Redstone RS-4	0904 Aug. 18, 1954	4
Redstone RS-6	4310 Nov. 17, 1954	4
Redstone RS-8	1512 Feb. 29, 1955	4
Redstone RS-9	0151 April 20, 1955	6
Redstone RS-10	2324 May 24, 1955	6
Redstone RS-7	1912 Aug. 30, 1955	6
Redstone RS-11	0051 Sept. 21, 1955	6
Redstone RS-12	1946 Dec. 5, 1955	6
Redstone RS-18 (Jupiter A)	1935 March 14, 1956	6
Redstone RS-19	1121 May 15, 1956	6
Redstone CC-13 (Jupiter A)	0347 July 19, 1956	5
Redstone RS-20	0326 Aug. 8, 1956	6
Jupiter-C RTV-1 (Redstone RS-27)	0146 Sept. 20, 1956	5
Redstone CC-14	0405 Oct. 18, 1956	6
Redstone RS-25	2105 Oct. 30, 1956	6
Redstone CC-28	2105 Nov. 13, 1956	6
Redstone CC-15	0824 Nov. 29, 1956	6
Redstone CC-22	2229 Dec. 18, 1956	6
Redstone CC-16	2037 Jan. 18, 1957	6

VEHICLE	LIFTOFF TIME/DATE		PAD
Jupiter AM-1A	1657	March 1, 1957	5
Redstone CC-32 (Jupiter A)	0312	March 14, 1957	6
Redstone CC-30	2002	March 27, 1957	6
Jupiter AM-1B	1512	April 26, 1957	5
Jupiter-C RTV-2 (Redstone RS-34)	0255	May 15, 1957	6
Jupiter AM-1	1309	May 31, 1957	5
Redstone CC-31 (Jupiter A)	0609	June 26, 1957	6
Redstone CC-35 (Jupiter A)	0130	July 12, 1957	6
Redstone CC-37 (Jupiter A)	2317	July 25, 1957	6
Jupiter-C RTV-3 (Redstone RS-40)	0159	Aug. 8, 1957	5
Jupiter AM-2	1602	Aug. 28, 1957	26B
Redstone CC-38 (Jupiter A)	2142	Sept. 10, 1957	6
Redstone CC-39 (Jupiter A)	1429	Oct. 2, 1957	6
Jupiter AM-3	2007	Oct. 22, 1957	26B
Redstone 41 (Jupiter A)	2352	Oct. 30, 1957	6
Jupiter AM-3A	2111	Nov. 26, 1957	26B
Redstone CC-42 (Jupiter A)	1937	Dec. 10, 1957	6
Jupiter AM-4	1907	Dec. 18, 1957	26B
Redstone CC-45	2024	Jan. 14, 1958	6

VEHICLE	LIFTOFF TIME/DATE	PAD
Juno I Explorer I (Redstone RS-29)	2058 Jan. 31, 1958	26A
Redstone CC-46	1954 Feb. 11, 1958	6
Redstone CC-43	1500 Feb. 27, 1958	6
Juno I Explorer II (Redstone RS-26)	1328 March 5, 1958	26A
Juno I Explorer III (Redstone RS-24)	1238 March 26, 1958	5
Redstone 1002	1905 May 16, 1958	5
Jupiter AM-5	0005 May 18, 1958	26B
Redstone CC-48	2059 June 11, 1958	6
Redstone CC-54	2236 June 24, 1958	6
Jupiter AM-6B	0405 July 17, 1958	26B
Juno I Explorer IV (Redstone RS-44)	1000 July 26, 1958	5
Redstone 50 "Teak" (Operation Hardtack)	2347 July 31, 1958 (Johnston Island time)	Johnston Island Pacific Ocean
Redstone 51 "Orange" (Operation Hardtack)	2327 Aug. 11, 1958 (Johnston Island time)	Johnston Island Pacific Ocean
Juno I Explorer V (Redstone RS-47)	0117 Aug. 24, 1958	5
Jupiter AM-7	1815 Aug. 27, 1958	26A
Redstone CC-56	1300 Sept. 17, 1958	6
Jupiter AM-9	2249 Oct. 9, 1958	26B
Juno I Beacon (Redstone RS-49)	2221 Oct. 22, 1958	5
Redstone CC-57 (Last R&D firing)	1943 Nov. 5, 1958	6

VEHICLE	LIFTOFF TIME/DATE	PAD
Juno II Pioneer III (Jupiter AM-11)	0045 Dec. 6, 1958	5
Jupiter AM-13 (Bio-Flight 1; Monkey "Old Reliable")	0358 Dec. 13, 1958	26B
Jupiter CM-21	1910 Jan. 1, 1959	5
Jupiter CM-22	0049 Feb. 27, 1959	26B
Juno II Pioneer IV (Jupiter AM-14)	0011 March 4, 1959	5
Jupiter CM-22A	1934 April 3, 1959	26B
Jupiter AM-12	2047 May 6, 1959	26B
Jupiter AM-17	0052 May 14, 1959	5
Jupiter AM-18 (Bio-Flight 2 Monkeys "Able" & "Baker")	0235 May 28, 1959	26B
Jupiter AM-15	2001 July 9, 1959	26B
Juno II Explorer (Jupiter AM-16)	1237 July 16, 1959	5
Redstone EU CC-2003	2302 July 21, 1959	26A
Redstone CC-2004	2105 Aug. 4, 1959	26A
Juno II Beacon (Jupiter AM-19B)	1931 Aug. 14, 1959	26B
Jupiter AM-19	2030 Aug. 26, 1959	5
Jupiter AM-23	0645 Sept. 16, 1959	26B
Jupiter AM-24	2028 Sept. 30, 1959	6
Juno II Explorer VII (Jupiter AM-19A)	1031 Oct. 13, 1959	5
Jupiter CM-31	2200 Oct. 21, 1959	26A
Jupiter CM-33	1938 Nov. 4, 1959	6

VEHICLE	LIFTOFF TIME/DATE		PAD
Jupiter AM-25	2031	Nov. 18, 1959	26B
Jupiter AM-32	1908	Dec. 9, 1959	6
Jupiter AM-26	1903	Dec. 16, 1959	26B
Jupiter AM-28	1948	Jan. 25, 1960	26B
Jupiter AM-30	1919	Feb. 4, 1960	6
Pershing 105	1301	Feb. 26, 1960	30A
Redstone EU CC-2020	2022	March 21, 1960	6
Juno II Explorer (Jupiter AM-19C)	0835	March 23, 1960	26B
Pershing 106	1330	April 20, 1960	30A
Pershing 107	1100	May 10, 1960	30A
Pershing 108	1120	June 9, 1960	30A
Pershing 109	1100	June 30, 1960	30A
Pershing 110	1100	July 26, 1960	30A
Redstone CC-2023	2031	Aug. 9, 1960	6
Pershing 205	1438	Aug. 28, 1960	30A
Redstone CC-2037	2244	Oct. 5, 1960	6
Jupiter LST CM-217	1102	Oct. 19, 1960	26A
Juno II Explorer VIII (Jupiter AM-19D)	0023	Nov. 3, 1960	26B
Pershing 206	1325	Nov. 16, 1960	30A
Mercury-Redstone MR-1	0900	Nov. 11, 1960	5
Pershing 207	1342	Dec. 12, 1960	30A
Mercury-Redstone MR-1A	1115	Dec. 19, 1960	5
Pershing 208	1910	Jan. 5, 1961	30A

VEHICLE	LIFTOFF TIME/DATE	PAD
Redstone CC-2038	2104 Jan. 21, 1961	6
Pershing 209	1930 Jan. 25, 1961	30A
Mercury-Redstone MR-2 (Chimp "Ham")	1155 Jan. 31, 1961	5
Pershing 210	2028 Feb. 15, 1961	30A
Juno II Explorer (Jupiter AM-19F)	1913 Feb. 24, 1961	26B
Pershing 211	0007 March 2, 1961	30A
Redstone EU-CC-2040	2130 March 8, 1961	6
Pershing 212	2019 March 15, 1961	30A
Mercury-Redstone MR-BD	1230 March 24, 1961	5
Pershing 308	1050 April 4, 1961	30A
Jupiter (CTL) CM-209	0907 April 22, 1961	26A
Juno II Explorer XI (Jupiter AM-19E)	0916 April 27, 1961	26B
Mercury-Redstone MR-3 (Freedom 7 Shephard)	0937 May 5, 1961	5
Redstone CC-2042	2100 May 16, 1961	6
Pershing 310	2100 May 17, 1961	30A
Juno II Explorer (Jupiter AM-19G)	1448 May 24, 1961	26B
Redstone CC-2043	2120 June 27, 1961	6
Mercury-Redstone MR-4 (Liberty Bell 7 Grissom)	0720 July 21, 1961	5
Jupiter (CTL) CM-218	1919 Aug. 4, 1961	26A
Atlas-Agena 1 Ranger I	0504 Aug. 23, 1961	12
Saturn C-1 SA-1	1006 Oct. 27, 1961	34

VEHICLE	LIFTOFF TIME/DATE	PAD
Atlas-Agena 2 Ranger II	0312 Nov. 18, 1961	12
Jupiter (CTL) CM-115	1737 Dec. 6, 1961	26A
Atlas-Agena 3 Ranger III	1530 Jan. 26, 1962	12
Jupiter (CTL) CM-114	1346 April 18, 1962	26A
Atlas-Agena 4 Ranger IV	1550 April 23, 1962	12
Saturn C-1 SA-2 (Project Highwater)	0901 April 25, 1962	34
Atlas-Centaur F-1	1449 May 8, 1962	36A
Atlas-Agena 5 Mariner I	0421 July 22, 1962	12
Jupiter (CTL) CM-111	1346 Aug. 1, 1962	26A
Atlas-Agena 6 Mariner II	0153 Aug. 27, 1962	12
Atlas-Agena 7 Ranger V	1159 Oct. 18, 1962	12
Saturn C-1 SA-3 (Project Highwater)	1245 Nov. 16, 1962	34
Jupiter (CTL) CM-106	1927 Jan. 22, 1963	26A
Saturn I SA-4	1511 March 28, 1963	34
Saturn I SA-5	1125 Jan. 29, 1964	37B
Saturn I SA-6	1207 May 28, 1964	37B
Saturn I SA-7	1122 Sept. 18, 1964	37B
Saturn I SA-9 (Pegasus I)	0937 Feb. 16, 1965	37B
Saturn I SA-8 (Pegasus II)	0235 May 25, 1965	37B
Saturn I SA-10 (Pegasus III)	0300 July 30, 1965	37B
Saturn IB AS-201	1112 Feb. 26, 1966	34

VEHICLE	LIFTOFF TIME/DATE	PAD
Uprated Saturn I SA-203	0953 July 5, 1966	34
Uprated Saturn I AS-202	1316 Aug. 25, 1966	34
Saturn V AS-501 (Apollo 4)	0700 Nov. 9, 1967	39A (KSC)
Saturn IB AS-204 (Apollo 5)	1748 Jan. 22, 1968	37B
Saturn V AS-502 (Apollo 6)	0700 April 4, 1968	39A (KSC)
Saturn IB AS-205 (Apollo 7 Schirra-Eisele-Cunningham)	0741 Oct. 11, 1968	34
Saturn V AS-503 (Apollo 8 Borman-Lovell-Anders)	1100 Dec. 21, 1968	39A (KSC)
Saturn V AS-504 (Apollo 9 McDivitt-Scott-Schweikart)	1100 March 9, 1969	39A (KSC)
Saturn V AS-505 (Apollo 10 Cernan-Young-Stafford)	1249 May 18, 1969	39B (KSC)
Saturn V AS-506 (Apollo 11 Armstrong-Aldrin-Collins)	0932 EDT July 16, 1969	39A (KSC)
Saturn V AS-507 (Apollo 12 Conrad-Gordon-Bean)	1122 Nov. 14, 1969	39A (KSC)
Saturn V AS-508 (Apollo 13 Lovell-Haise-Swigert	1413 April 11, 1970	39A (KSC)
Saturn V AS-509 (Apollo 14 Shepard-Roosa-Mitchell)	1603 Jan. 31, 1971	39A (KSC)
Saturn V AS-510 (Apollo 15 Scott-Worden-Irwin)	0939 EDT July 26, 1971	39A (KSC)
Saturn V AS-511 (Apollo 16 Young-Mattingly-Duke)	1254 April 16, 1972	39A (KSC)
Saturn V AS-512 (Apollo 17 Cernan-Evans-Schmitt)	0033 Dec. 7, 1972	39A (KSC)

NOTES:

1. General

   a. All liftoff times and dates are local times and dates at the launch site.

   b. All liftoff times are Eastern Standard Time (using the 24-hour clock) unless otherwise noted.

   c. All launchings were from launch complexes on Cape Canaveral/Cape Kennedy (AFMTC/CKAFS) unless otherwise noted.

2. Redstone Missile Nomenclature

   a. Missile numbering indicated whether they were built at Redstone Arsenal (RS-1, etc.) or by Chrysler at the Michigan Missile Plant (CC-13, etc.).

   b. Some Redstones carried Jupiter missile components for flight testing. These missiles were given the added name of "Jupiter A."

   c. Production missiles were numbered CC-2000 and up; a few of these selected for Engineering User (qualification) testing were designated "Redstone EU."

   d. Missile numbers were painted on the sides of the early Redstones, using the following letter-coding:

H	U	N	T	S	V	I	L	E	X
1	2	3	4	5	6	7	8	9	0

   Thus, "HX" would indicate Redstone missile number 10 (or RS-10). This letter-coding is visible in many photos of launchings, and aids in identification.

3. Jupiter C and Juno I

   a. Jupiter C was a three-stage reentry test vehicle (RTV), carrying scale-model Jupiter nose cones for payloads. The Jupiter C did not have orbital capability.

   b. Juno I was a four-stage satellite launch vehicle, carrying a scientific payload in its fourth stage. The spent fourth stage casing and the payload were injected into orbit, forming the satellite.

   c. The first stages of both the Jupiter C and Juno I vehicles were elongated, modified Redstones. Therefore, the numbers of the Redstones so modified are given in parentheses in the Table.

d. Jupiter C and Juno I vehicles were identical in external appearance; hence the popular (public affairs) tendency to lump them all together as Jupiter C's. However, this is technically and historically inaccurate.

4. Jupiter Missile Nomenclature

a. Jupiter missile numbering indicated whether they were built at ABMA (AM-1, etc., for Army missile) or at the Michigan Missile Plant (CM-21, etc., for Chrysler missile).

b. Jupiter missiles used to train NATO missile crews were designated as "CTL" for "Combat Training Launch."

c. Jupiter CM-217 was a test of the operational Jupiter weapons system launching equipment. Hence the designation "LST" for "Launch Systems Test."

d. Two Jupiter missiles (AM-13 and AM-18) carried primates as secondary payloads in their nose cones. These preludes to man-in-space were designated as Bio-Flights I and II.

5. Juno II

a. Juno II space launch vehicles were composed of modified Jupiters for the first stage, with Juno I upper stages. The number of the Jupiter missile used in the modification is given in parentheses in the Table.

6. Agena and Centaur

a. From July 1960 through September 1962, MSFC had management responsibility, and LOD/LOC had launch responsibility, for Agena --- and through December 1962 for Centaur. Therefore, Agena and Centaur missions launched during this period have been included in the Table.

7. Saturn Vehicle Nomenclature

a. Saturn C-1 was designated Saturn I on February 7, 1963.

b. The Saturn IB vehicle was renamed the Uprated Saturn I on June 9, 1966. On January 15, 1968, the name was changed back to Saturn IB.

c. Saturn C-1 and Saturn I vehicles SA-1 through SA-5, and Uprated Saturn I vehicle SA-203, were used in Launch Vehicle Development missions.

d. Saturn I vehicles SA-6 through SA-10 had boilerplate Apollo spacecraft as payloads. (Pegasus spacecraft were stowed inside the boilerplate Apollos during the powered flight phase of their missions.)

e. Saturn IB AS-201 and AS-204, and Uprated Saturn I AS-202, payloads were unmanned but fully instrumented Apollo spacecraft. Saturn IB AS-205's payload was the first manned mission (Apollo 7) in Project Apollo.

f. Saturn V vehicles AS-501 through AS-512 were all flown on mainstream Project Apollo missions.

g. On April 24, 1967, Dr. George E. Mueller, Associate Administrator for Manned Space Flight, NASA, officially designated the test in which astronauts Grissom, White, and Chaffee lost their lives as Apollo 1. At the same time, he announced that the forthcoming Saturn V (AS-501) flight would be called Apollo 4, and that future Apollo missions would be numbered in the sequence in which they occurred. Thus, there have never been any missions officially designated as Apollo 2 or Apollo 3.

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(NASA TMX-881) pps 6-5 thru 6-87

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4. Gwinn, R. F. & Cooper, W. T.: Metric Tracking Instrumentation Systems used by NASA at AMB; KSC TR 4-47-1 (1964)

5. Near-In Impact Prediction Study TRW Contract NAS10-4553 (1967)

6. AFETR Instrumentation Handbook: ETR TB-71-5 (1971)

7. Handbook of Astronautical Engineering, McGraw-Hill, 1961
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8. Engineering Notes (9-J) Microlock Station; Jet Propulsion Lab (1957)