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THE AGENA SATELLITE

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WHAT IT HAS DONE

WHAT IT CAN DO . . .

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1 JULY 1960

M/E-22
16 sheets

THE AGENA SATELLITE

WHAT IT HAS DONE

WHAT IT CAN DO ...

Agena development is conducted under the direction of the Ballistic Missile Division of the USAF Air Research and Development Command.

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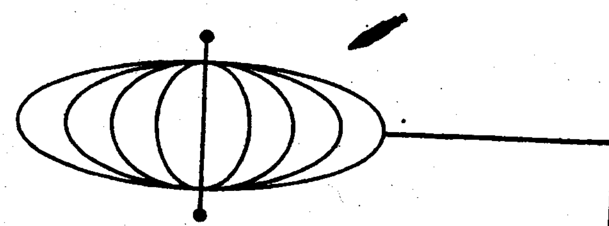

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The Agena is a satellite vehicle capable of placing a variety of payloads into precisely determined orbits in space for scientific research and military purposes. The Agena satellite can be oriented to and maintained in any attitude with respect to the earth. The capability of the Agena has been proven over the past year and a half. Substantial increases in Agena performance will be gained through advances in design already developed and ready for flight testing - advances which will make the Agena the most versatile and useful space vehicle yet produced.

AGENA

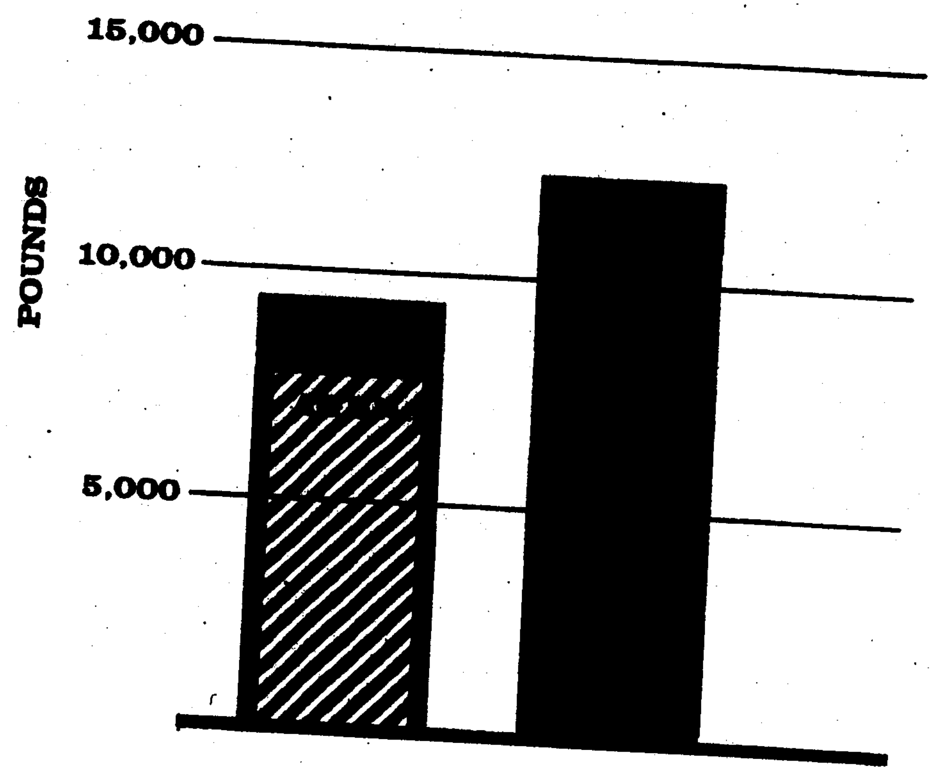
MOST PAYLOAD PLACED IN ORBIT OF ALL U.S. SATELLITES

On 1 June 1960, total payload* weight of satellites sent into orbit by the USA and USSR was 21,800 pounds. The USSR had orbited 12,300 pounds, the USA 9,500 pounds. Of the USA payload weight orbited, the Agena represented 7,800 pounds. (Agena-Discoverer, 4,200 pounds, and Agena-MIDAS, 3,600 pounds).

The Agena then represents approximately:

- 36 percent of world payload
- 82 percent of USA payload
- 63 percent of USSR payload

(As shown in graph at right)



RAPID DEVELOPMENT— ACCELERATED LAUNCH SCHEDULE

The first Agena in the Discoverer program was launched 13 months after the USAF Thor was designated as the booster for that program.

Within 14 months 11 Agenas had been launched, with 7 placed successfully in polar orbit.

*Payload defined as equipment needed for orbital operation (and capsule re-entry when applicable)

USED IN THESE MAJOR PROGRAMS:

USAF	Discoverer MIDAS Samos
NASA	Lunar Probes Scientific Satellites

An Agena-Discoverer Satellite Goes Into Orbit From Vandenberg AFB

Agena-MIDAS Infrared Detection Reconnaissance Satellite Lifts From AFMTC

AGENA

MAJOR CONTRIBUTOR TO U.S. SPACE PROGRAMS...

FIRST TO ACHIEVE...

- Earth-Referenced Attitude Control
- Ejection of Recovery Capsule

HAS DEMONSTRATED...

- Dependable Propulsion
- Ground Command of Satellite Functions
- Ample Electrical Power
- Effectiveness of Unitized Telemetry
- High Reliability

ADVANCED AGENA WILL FEATURE...

- Engine Restart in Orbit
- Double the Original Burning Time
- Increased Specific Impulse
- Greater Payload Capability
- Orbital Period Adjustment

IN ADDITION...

- Complete Satellite Support Facilities
- Contributions to Scientific Research

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AGENA

FIRST TO ACHIEVE EARTH-REFERENCED ATTITUDE CONTROL

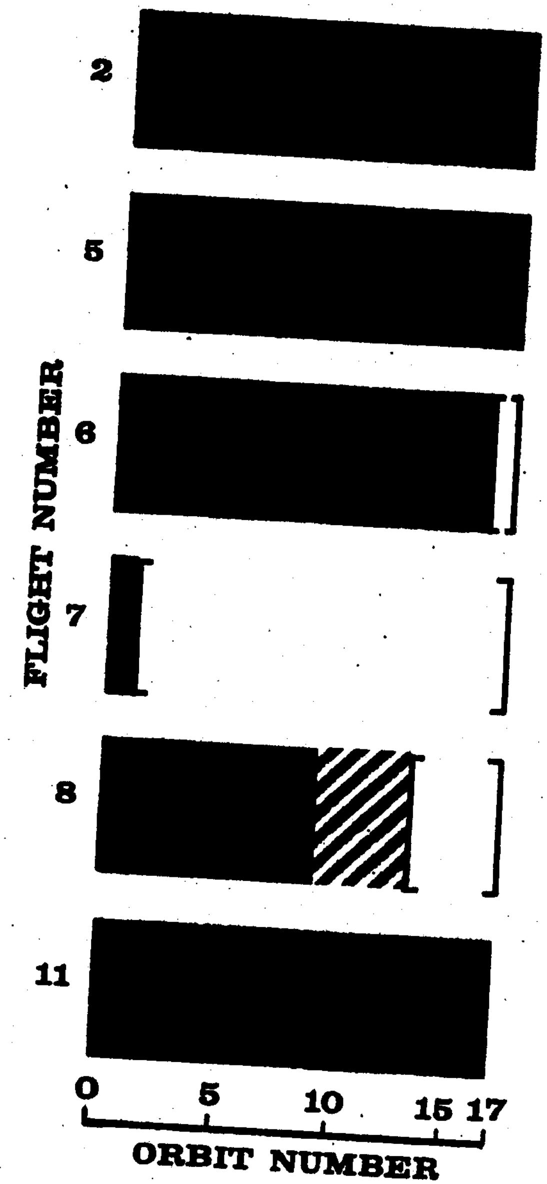
THIS MAKES POSSIBLE:

Missions requiring a stabilized satellite, such as:

- Mapping
- Recovery of orbital payload
- Communications
- Navigation
- Reconnaissance

Continuous communication between satellite and ground stations (signal blanking due to tumbling is eliminated)

Lighter, more efficient communications system through use of directional antenna



ORBIT ATTITUDE CONTROL PERFORMANCE
ON DISCOVERER FLIGHTS

SATISFACTORY CONTROL

UNCERTAIN

LOSS OF CONTROL [ ]

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Agena-Discoverer flights have demonstrated that the combination of horizon sensor, inertial reference package (IRP) and gas jet control maintain vehicle attitude within two degrees while in orbit. This first application of an infrared device for sensing the horizon has proven the soundness of its principle. Both day and night it provides a continuous master reference to correct inertial reference gyro drift on orbit. Discoverer flights also demonstrated the system's reliability for attitude positioning of the satellite to meet specific mission requirements. An example of this is the 180-degree yaw and 60-degree vehicle pitch-down successfully accomplished for in-orbit capsule ejection. Separate from the control system, a sun position indicator is being used to measure vehicle attitude.

For future Agena attitude control, the prime reference is a pair of continuously operating horizon sensors. The combination of horizon sensor and IRP will be used on short duration missions; however, the IRP will be turned off to conserve electrical power on long flights. Minor disturbances or oscillations in the vehicle will be damped out by control moment gyros and an inertial wheel system. If large disturbances should cause the wheel system to become saturated, the gas jet control system will be activated until the vehicle oscillations are reduced enough to allow inertial wheel stabilization to resume. In this back-up role, the gas consumption is between 15 and 20 pounds per year, and the electrical requirement 50 watts average power. The attitude control system permits the vehicle to operate in any attitude at orbital altitudes from 200 to 6,000 nautical miles. The system allows ±0.1 degree control in pitch and roll, and ±1.0 degree control in yaw. Maximum body rates are reduced to 4 degrees per hour.

System reliability remains high even when equipment failures occur. If one of the horizon sensors, control moment gyros or the inertial wheel system fails, the system will continue to function. If one of the control moment gyros fails, a 2-degree degradation of control results. If the inertial wheel system fails, attitude will still be maintained by the gas jet control system. This means of control, however, can last but three weeks because of increased demands on the gas supply.

FIRST TO ACHIEVE EJECTION OF RECOVERY CAPSULE

Agena is the first satellite to eject a recovery capsule after several orbits. In the Discoverer program, the capsule was ejected five times.

CAPSULE EJECTION MAKES POSSIBLE:

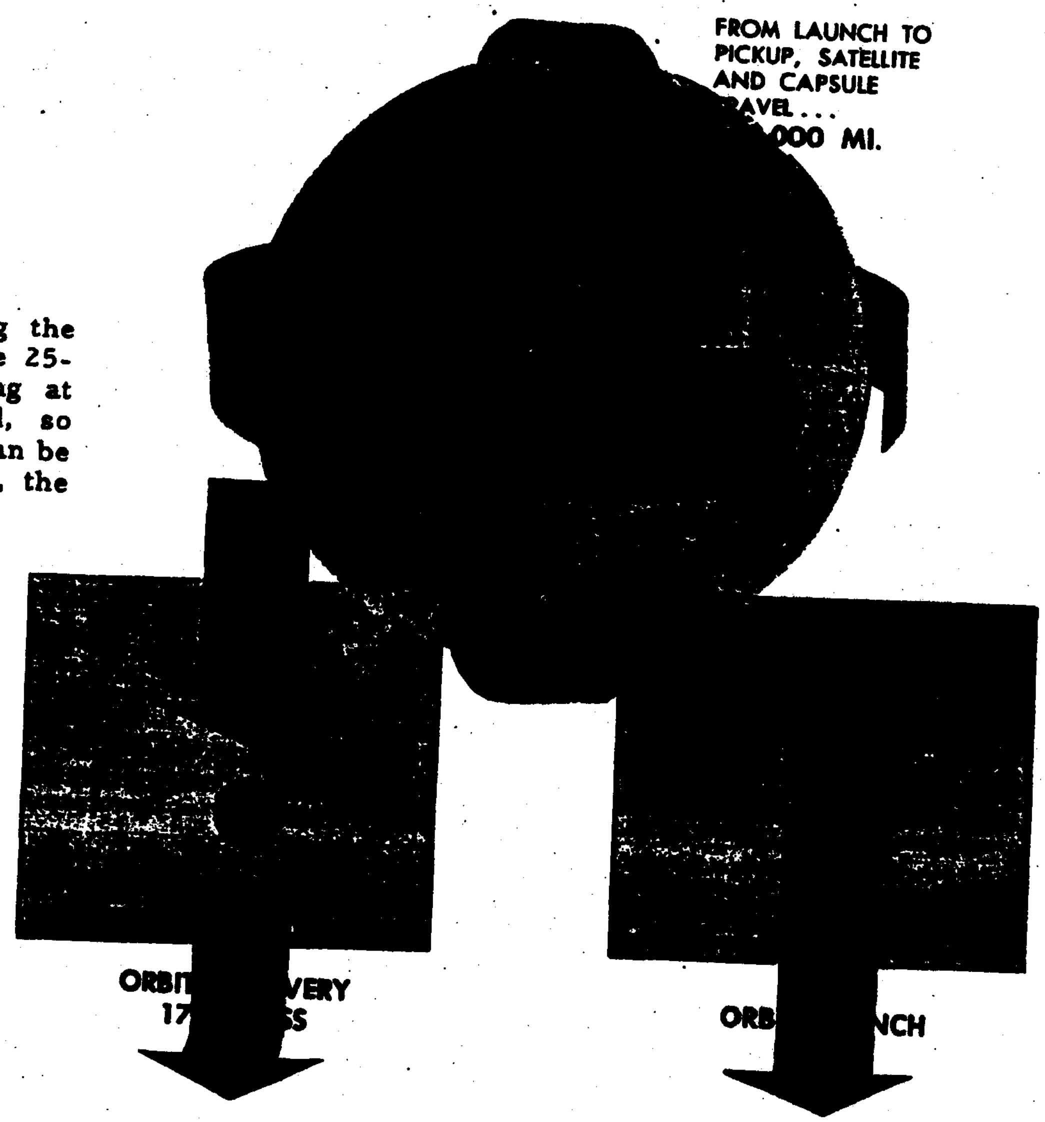
- Return to earth of experimental payloads
- Experiments leading to "man-in-space"
- Consideration of special tactical missions

The sequence of events during capsule ejection and recovery is initiated by a timer in the satellite adjusted by ground command on previous passes. The timer actuates the control system which places the vehicle in the proper attitude for capsule ejection.

The capsule is ejected from the satellite by springs after explosive separation bolts are fired. Almost immediately, two small rockets fire and spin the capsule for stability during the firing of a larger retro-rocket. The retro-rocket reduces velocity below that required to maintain the orbit. De-spin rockets then stop the spinning and the entire thrust cone is jettisoned.

During re-entry the capsule is protected from heat by an ablative shell. When the capsule has reached a deceleration of 5 g's, a switch activates the deployment sequence. A parachute is deployed and chaff ejected at about 50,000 feet. At the same time, the ablative shell is jettisoned, a radio beacon begins transmission and a brilliant light begins flashing. The capsule may be recovered by air snatch or from the sea. The capsule will float for several hours with beacon and flashing light operating.

Many factors are involved in recovering the capsule. As the satellite goes through the 25-hour period of 17 polar orbits, traveling at 17,600 mph, it must be precisely tracked, so that its orbital path, apogee and perigee can be computed accurately. From these data, the exact time is determined for the initiation of the recovery sequence. This information is transmitted to the satellite so that the capsule is ejected at the predetermined point. From this point the capsule speed is reduced so that re-entry occurs. Just before and during re-entry, a series of equipment operations must occur precisely at correct times and within required limits. For example, separation spring forces, possible misalignment of the retro-rockets, and variation in retro-rocket impulse must be within a small percent of nominal value. When these and other functions occur within operating limits, dispersion of the capsule will be within an area approximately 50 n.m. wide and 120 n.m. long. When any of the events occur outside operating limits, or fail to occur, the impact area becomes larger, and the difficulty of recovering the capsule is increased.



- FROM TIMER INITIATION OF RECOVERY CYCLE TO AIR OR SEA CAPSULE PICKUP, APPROX. 15 EVENTS OCCUR.
- UNITS OF AIR-SEA CAPSULE PICKUP TEAM MUST BE IN POSITION OVER A 6000 SQ. MI. RECOVERY AREA.

AGENA — HAS DEMONSTRATED DEPENDABLE PROPULSION

In the Discoverer program, the Agena propulsion subsystem has had the opportunity to function on 10 out of 11 flights. The subsystem started and operated on all ten. This high reliability can be attributed to design based upon proven principles and a thorough development, testing and checkout program.

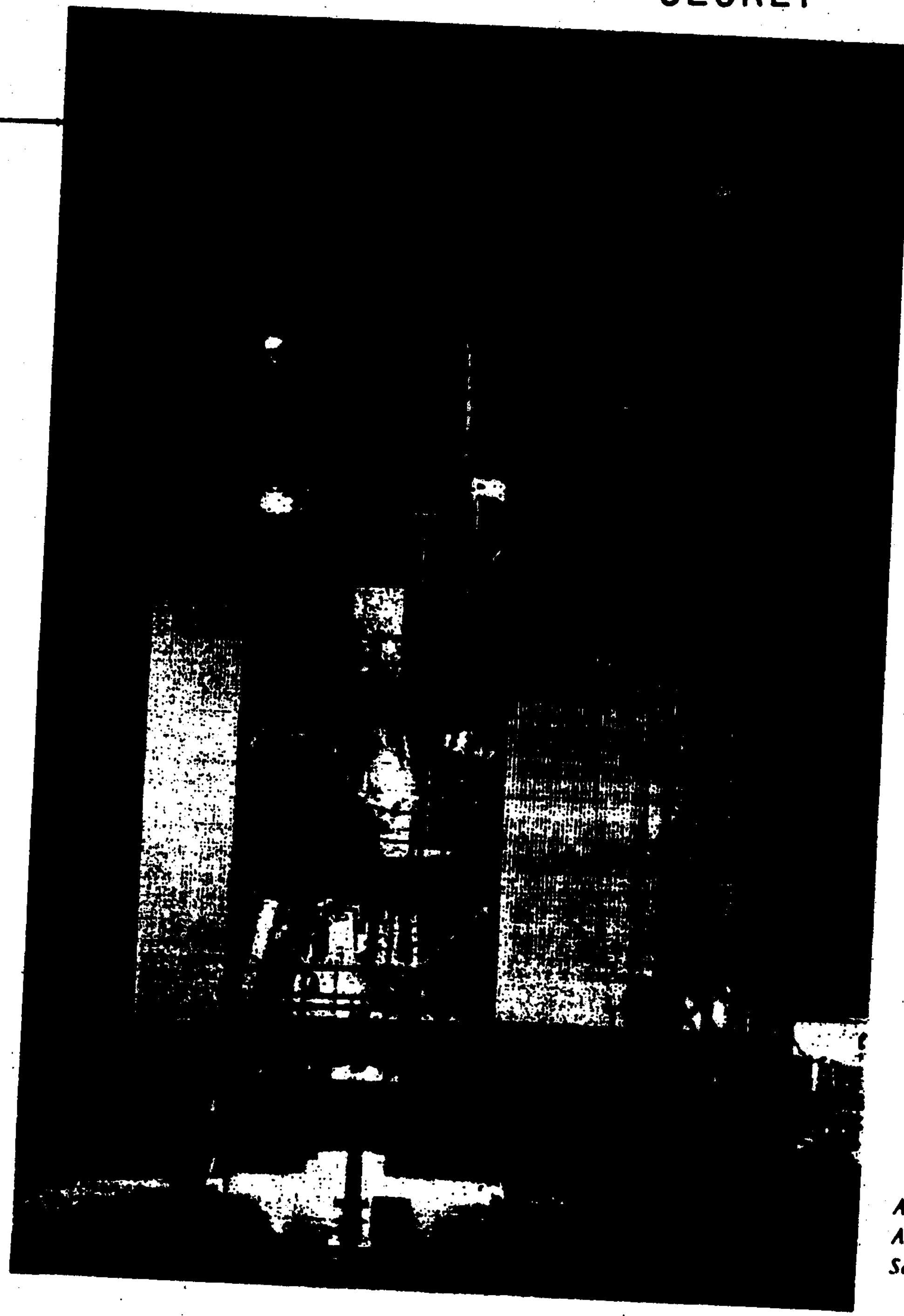
Supporting the Agena power plant, which consists of a conventional turbopump-fed, gimbal-mounted, storable propellant liquid rocket engine burning UDMH and IRFNA, are:

- A helium propellant pressurization assembly with necessary safety devices
- A trouble-free propellant loading and feed assembly consisting of umbilical disconnects plus connecting lines
- A propellant orientation assembly consisting of two solid propellant rocket motors for zero gravity engine starting.

Behind the successful performance of the Agena propulsion subsystem lies a program of close engineering control, such as:

- A comprehensive ground and altitude test program (the Agena engine was the first large full-scale engine to be tested in an altitude facility)
- Close monitoring of vendor and subcontract development and production to secure strict and constant quality control
- Maintenance of close controls on subsystem cleanliness and humidity when installed in the test vehicle
- Close engineering support to the using agencies and strict adherence to checkout and test procedures.

To further guarantee successful performance in future Discoverer flights, the propulsion subsystem with its components is being further simplified.



An Agena Satellite is Acceptance-Tested at Santa Cruz Test Base

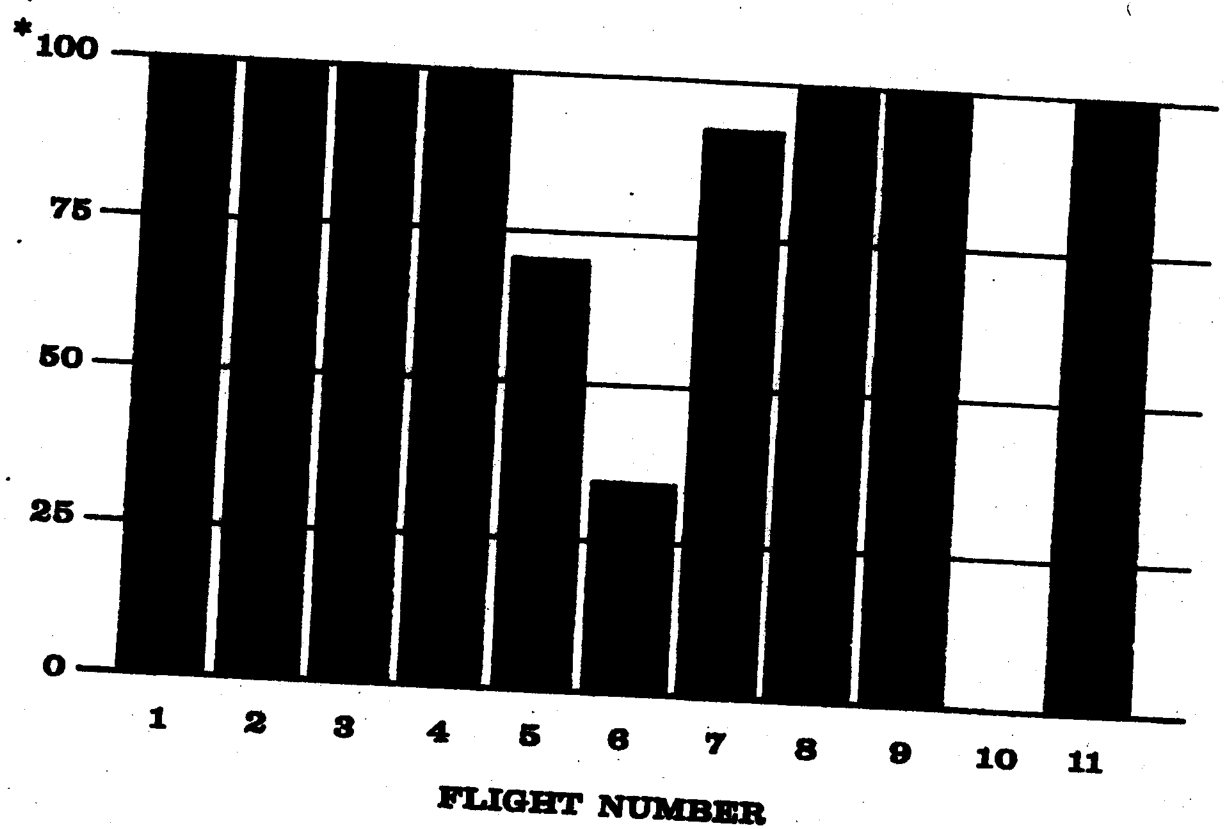
HAS DEMONSTRATED GROUND COMMAND OF VEHICLE FUNCTIONS

Execution of these commands permits:

More accurate injection into orbit by adjusting time-of-ignition and velocity-to-be-gained

Adjustment of vehicle timer to program telemetry readout over tracking stations

Control of start of ejection sequence to accommodate variation in orbital period



No. 3, 4, & 9: did not orbit

No. 5 & 6: operational and equipment difficulties

No. 7: vehicle tumbled, blanking some transmissions after control gas exhaustion

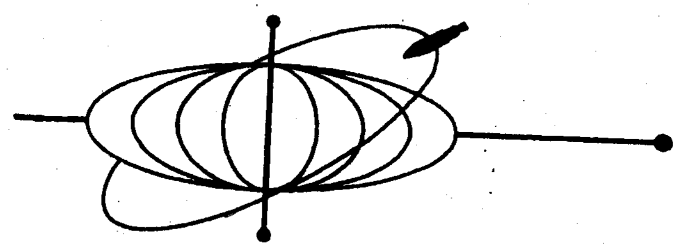
No. 10: booster and vehicle destructed at T + 57 sec

* Percent of commands sent that were received and verified.

Discoverer flights show an extensive history of successful satellite command. This success has been scored with a space-ground communications loop presenting a highly sophisticated capability. Not only programmed but "real-time" commands are transmitted when the satellite is within range of a ground station.

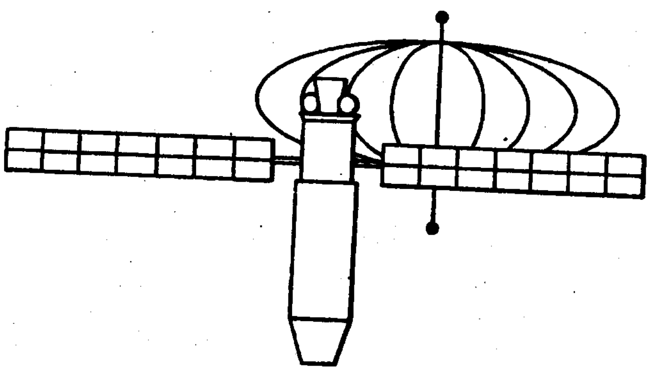
Programmed satellite commands, using an on-board sequencer, are available for orbital operations when the satellite has passed beyond range of systems ground stations. In this manner, for instance, capsule ejection is carried out.

Real-time commands are performed with the ground station tracking radar (VERLORT). For command purposes, the two-pulse "tracking" group is modified with an additional pulse. Tone modulation of this pulse varies the command. Six commands are possible. The radar beacon in the satellite functions in the dual role of conventional receiver and conventional transponder. In the latter function, it responds to command type signals. Commands received by the satellite are verified by transmitting a signal to the ground station. Up to a total of forty-one commands have been sent to one satellite and verified.



HAS DEMONSTRATED AMPLE ELECTRICAL POWER (Supported by solar APU in the advanced Agena)

Agena has achieved a very good record with electrical power supply operation. The power supply, consisting of a 28v dc battery source feeding 400-and 2000-cycle inverters, functioned normally on all 11 Discoverer flights, with one exception; during the first orbit of flight 7, an element of the 400-cycle system failed.



The advanced Agena will provide:

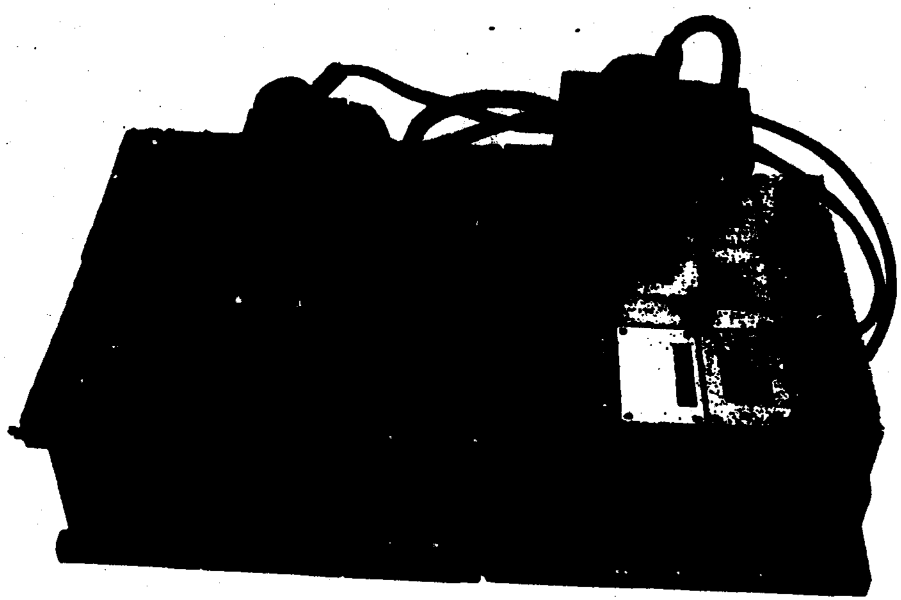
Longer operating life

Secondary batteries will be recharged by solar cell arrays extended after the satellite is in orbit. The cells are oriented for maximum exposure to the sun by a motor driving unit controlled by solar radiation sensing devices.

Lightweight system

0.6 pounds per watt, 28v dc
3.0 watts per square foot in direct solar radiation (including all losses)

HAS DEMONSTRATED EFFECTIVENESS OF UNITIZED TELEMETRY



In the Discoverer program, this equipment has achieved 90-95 percent recovery of all telemetered data.

Advantages of the telemetry design:

Flexible FM/FM system for a variety of mission needs

Modular "building block" construction permits easy assembly of a telemetering system tailored to the needs of a particular mission.

Lightweight equipment

Thirty percent lighter than other comparable systems

Weight with 15 channels and an 8-watt transmitter is 35 pounds.

PAM/FM to be used in the MIDAS program will give better quality transmission with one-third the equipment space and one-sixth the power requirements.

HAS DEMONSTRATED HIGH RELIABILITY

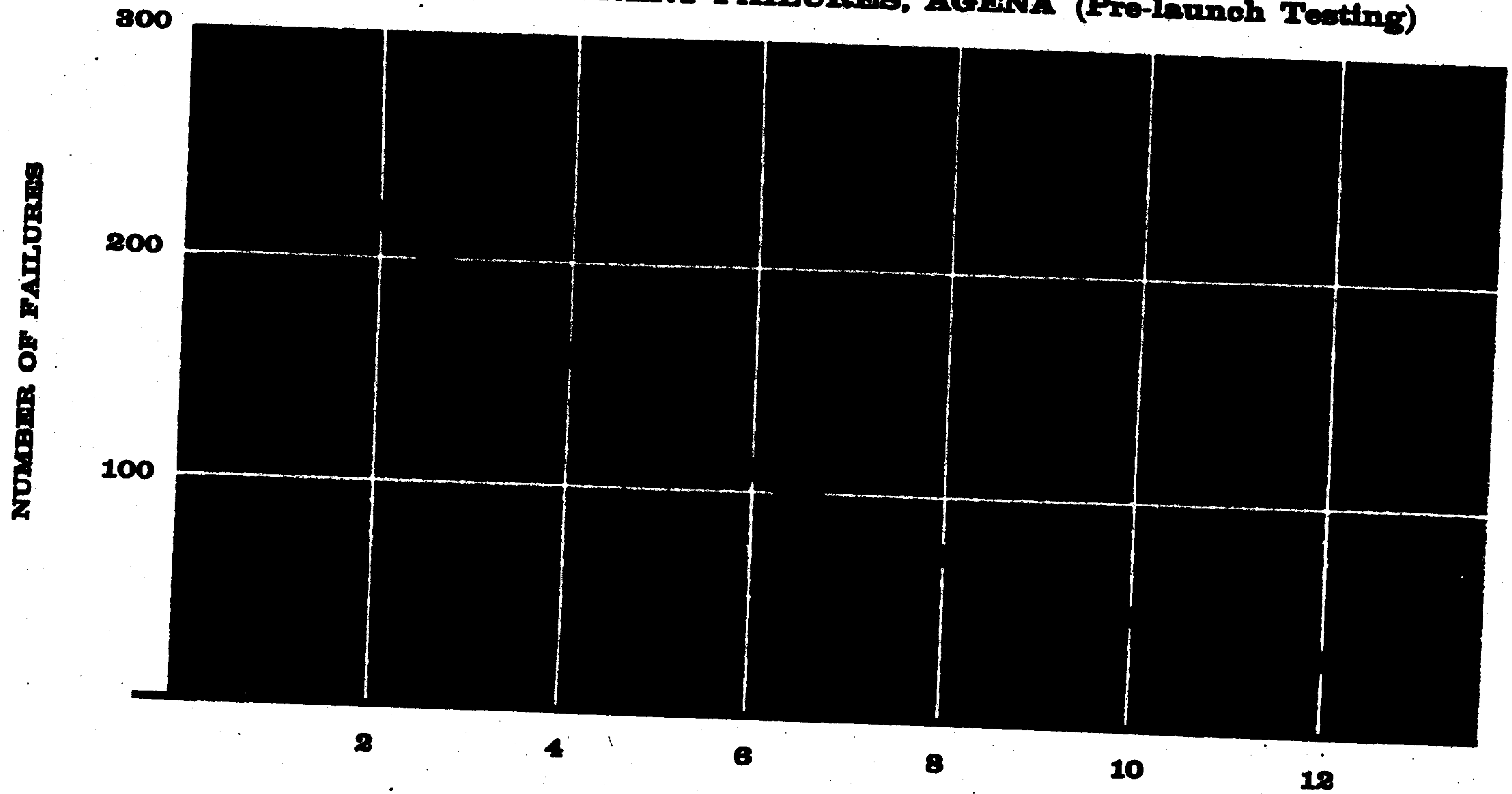
THE AGENA SATELLITE IN THE DISCOVERER PROGRAM:

- Achieved separation during ascent on 10 of 11 flights
- Achieved engine ignition on 10 of 11 flights
- Maintained orbital attitudes within 0.25 degree in pitch and roll and 1.0 degree in yaw
- Provided 90-95 percent recovery of telemetered data
- Received and executed 80-85 percent of all commands transmitted
- Achieved satisfactory performance from the power supply system on all but one flight
- Achieved orbit velocity on 7 of 11 flights
- Demonstrated structural integrity on all flights.

The success achieved by the Agena in the Discoverer and MIDAS projects has resulted from careful design and engineering. Components, subsystems and complete systems are designed with reliability in mind. As the systems develop, they are constantly reviewed to assure compliance with reliability standards.

Through the entire development of the Agena, components, subsystems and systems are rigorously tested to make sure they are reliable. Standards for reliability of the Agena are constantly revised in the light of new experience derived from space programs.

DROP IN COMPONENT FAILURES, AGENA (Pre-launch Testing)



PRODUCTION SEQUENCE VEHICLE NUMBER

ADVANCED AGENA WILL FEATURE ENGINE RESTART IN ORBIT

ADVANCED AGENA ENGINE RESTART CAPABILITY, A MAJOR STEP IN PROPULSION:

- Permits either a higher circular orbit or an increase in payload weight
- Allows varying of point of injection into orbit to meet the particular need of a mission
- Eliminates need for separate recovery propulsion

A series of engine ground tests has conclusively shown that the Agena engine can be restarted at orbital altitude. The restart technique for orbital injection means greater altitudes and heavier payloads with substantially the same equipment. After the engine has finished the first burn, the satellite coasts to the desired apogee altitude on a transfer ellipse. Here the engine is ignited briefly to inject the satellite into a circular orbit.

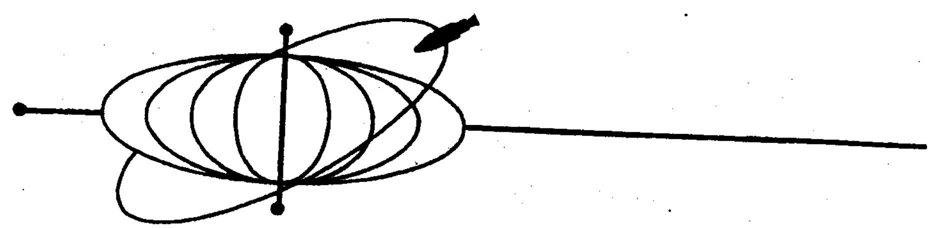
Because of basic energy relationships, the restart technique permits either a higher circular orbit or an increase in payload weight. That is, a fixed payload weight can be carried to a higher orbital altitude, or if the orbital altitude is fixed by the mission, a heavier payload may be carried.

Restart permits selection of the injection point, a factor important for scientific missions. Restart also permits use of the main propulsion system for recovery, eliminating the need for a separate recovery propulsion system.

DOUBLE THE ORIGINAL BURNING TIME

THE DESIGN OF THE ADVANCED AGENA ENGINE HAS ALLOWED A 100 PERCENT INCREASE IN FLIGHT BURNING TIME

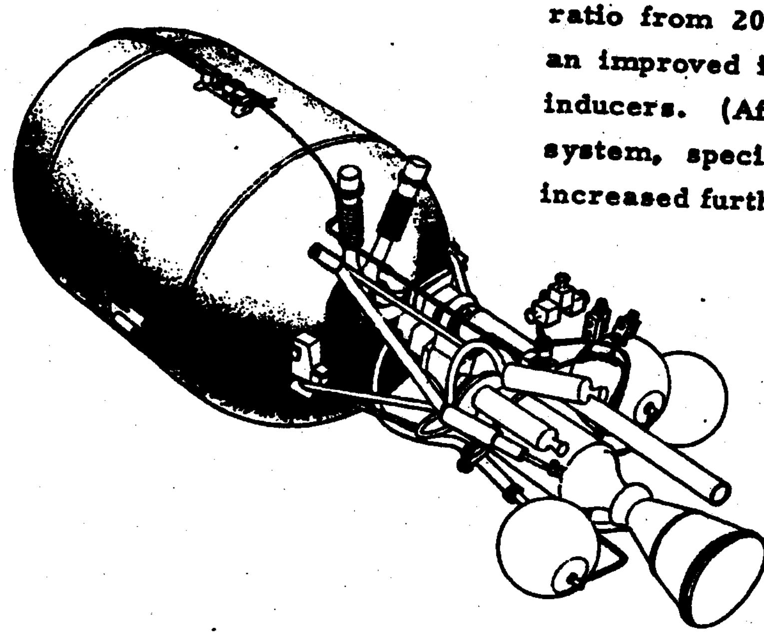
Test firings of the Agena engine showed that it can burn for extended periods. As a result of these tests, flight burning time was increased 100 percent. The satellite and propulsion system design allowed an additional 6,500 pounds of propellants to be added with only an approximate 19 percent increase in Agena structural, pressurization system and tank weight. The ratio of impulse propellant weight to total burnout weight, including guidance and control, propellant residuals and ascent telemetry (excluding payload that is functional only in orbit), is over 0.90. This is achieved from the development of a propulsion system with a ratio of impulse-propellant-to-system-weight (excluding residuals) of 0.945.



INCREASED SPECIFIC IMPULSE

THE SPECIFIC IMPULSE OF THE ADVANCED AGENA ENGINE IS BEING INCREASED TO 292 ± 2 POUND-SECONDS PER POUND

This performance increase in the advanced Agena engine of 14 pound-seconds per pound in specific impulse (278 to 292) is primarily achieved by increasing the nozzle expansion ratio from 20:1 to 45:1. Other changes include an improved injector system and turbo-pump inducers. (After flight demonstration of the system, specific impulse is expected to be increased further.)



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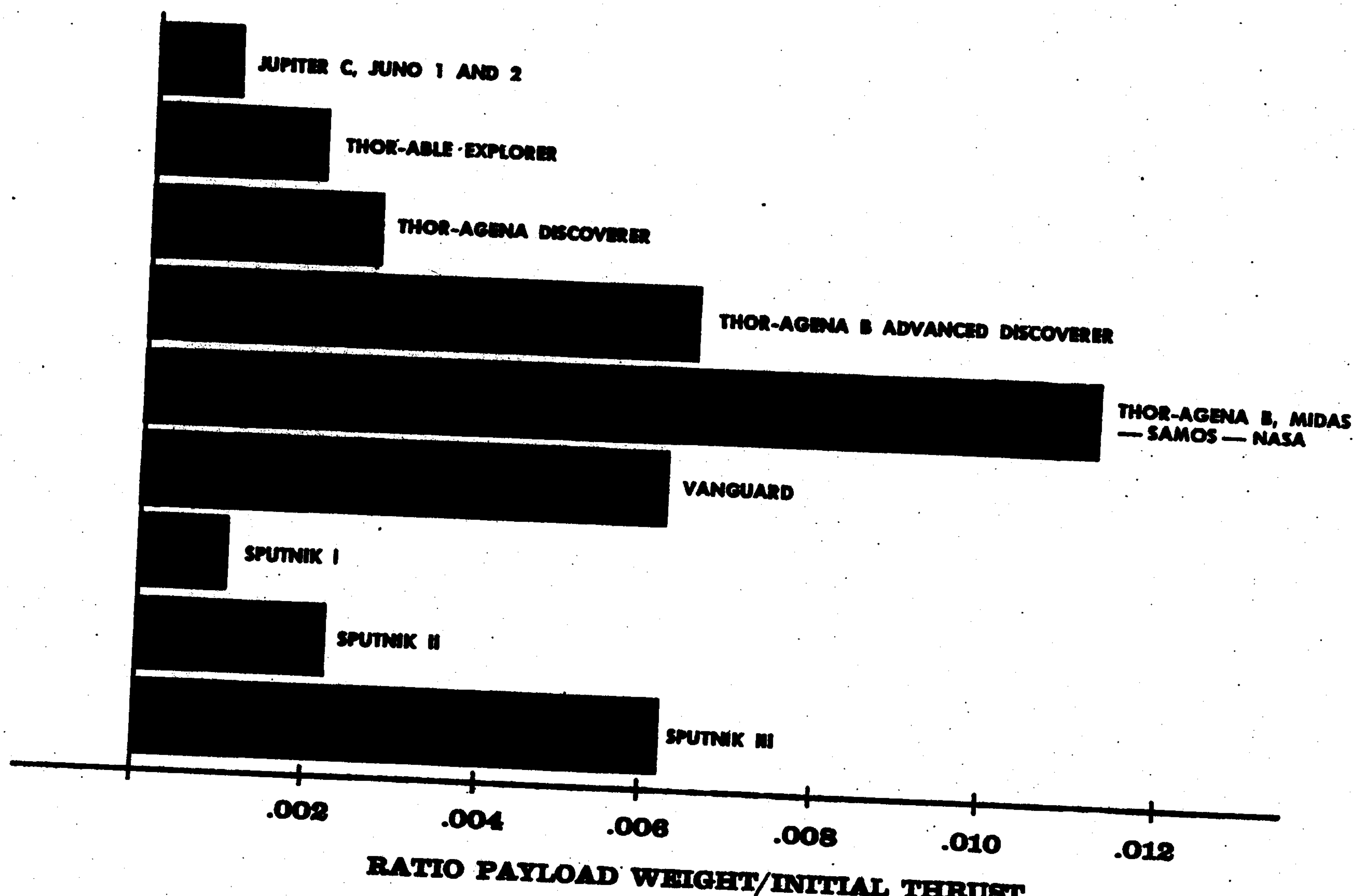
RESULT: INCREASED PERFORMANCE

RELATIVE SATELLITE EFFICIENCY



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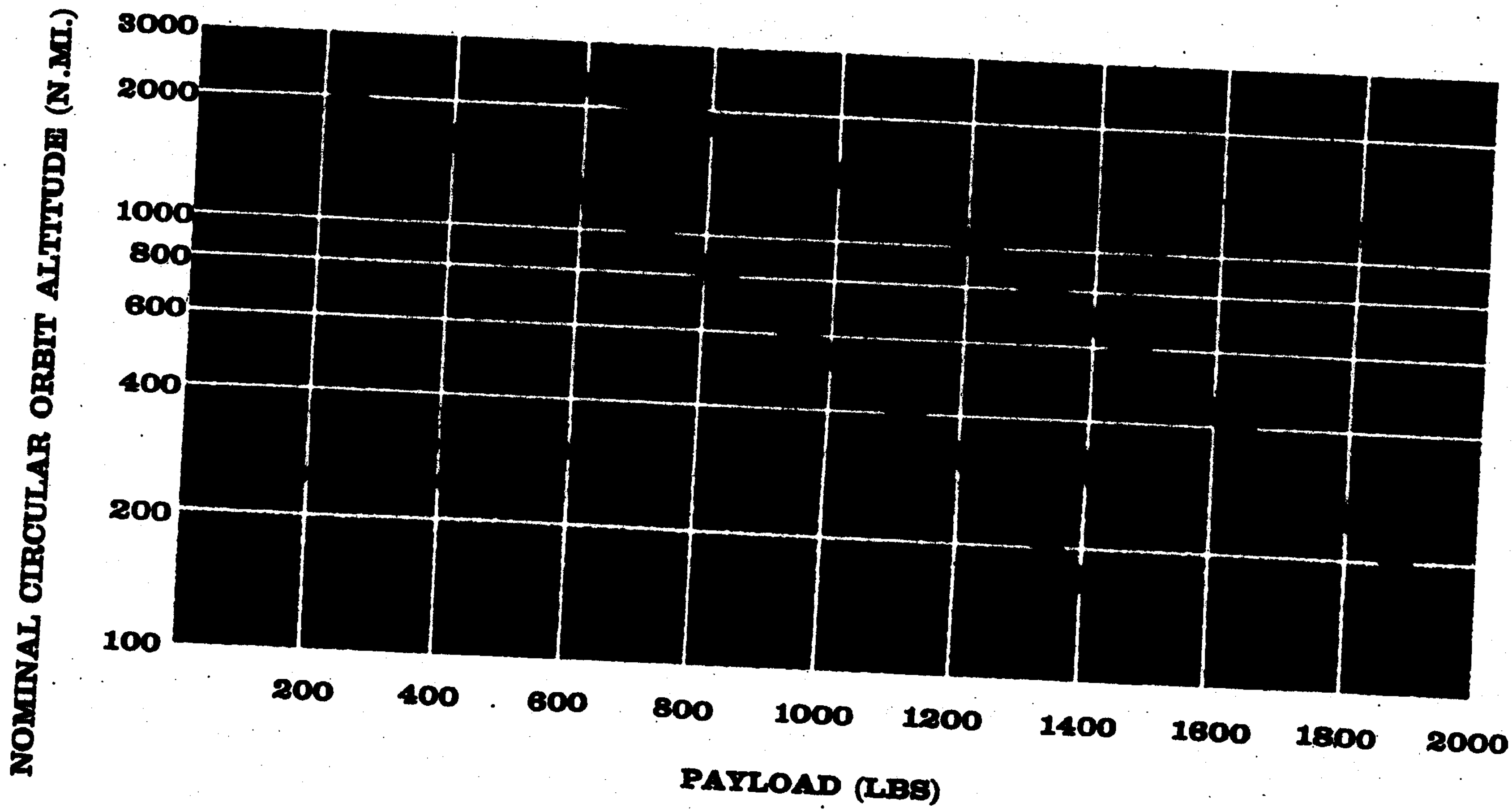
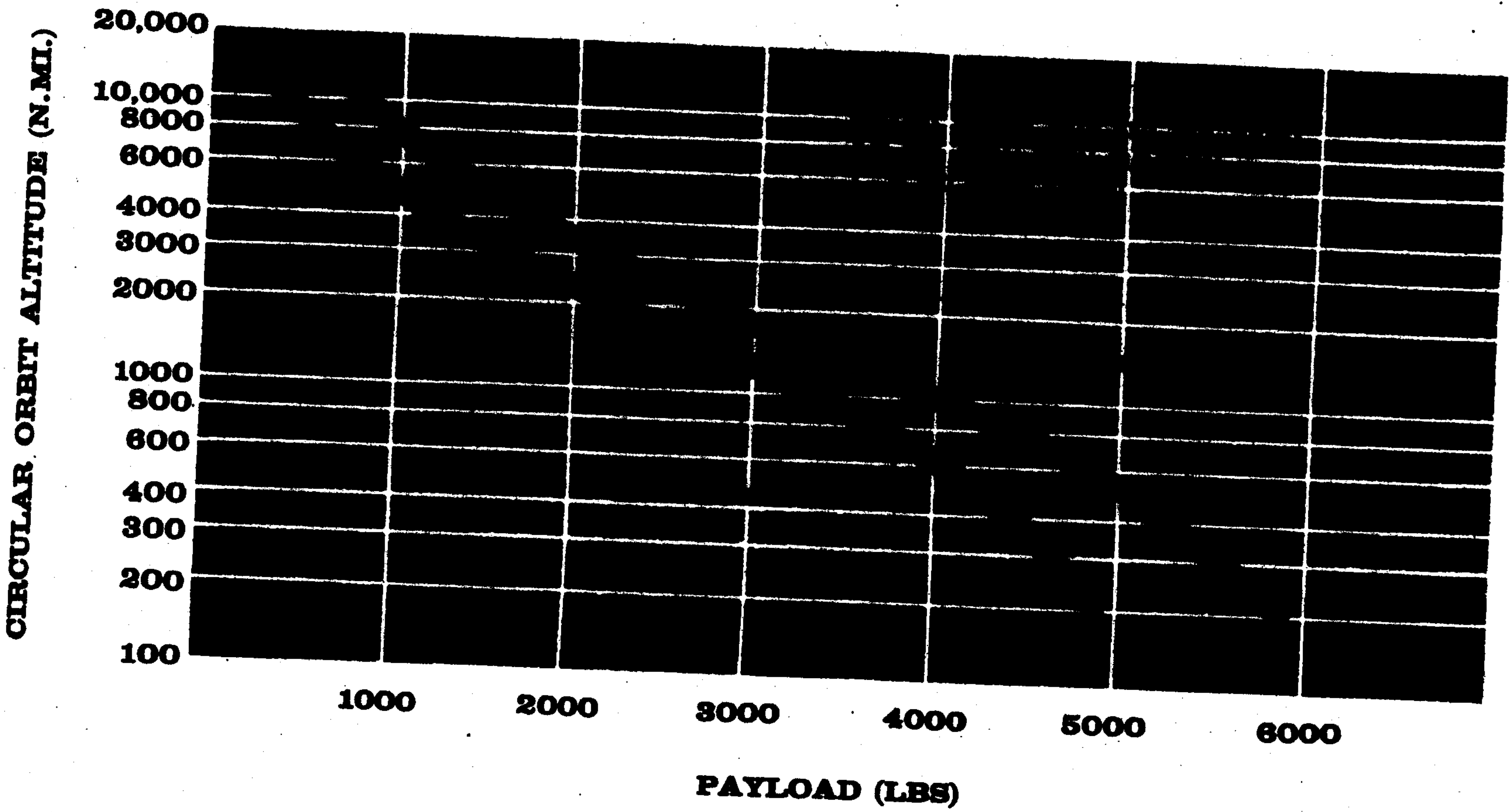
ADVANCED AGENA WILL FEATURE GREATER PAYLOAD CAPABILITY . . . WITH USAF DM-21 THOR BOOSTER



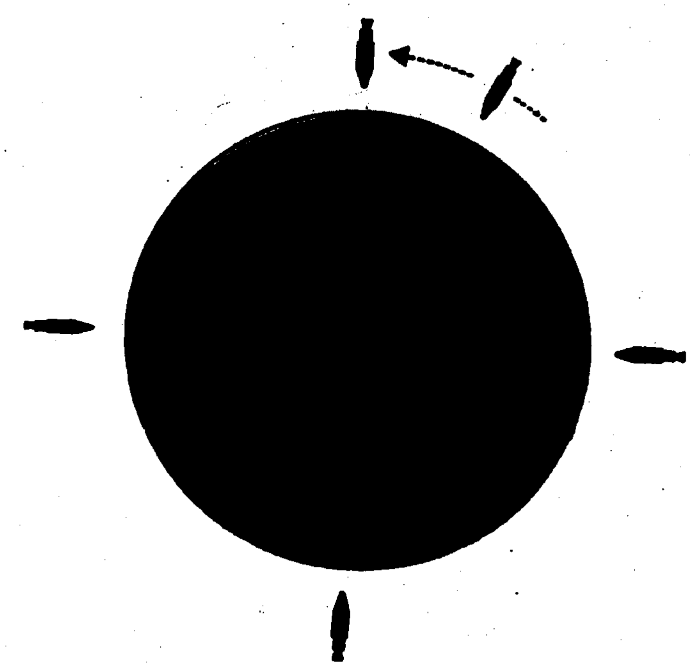
. . . WITH USAF ATLAS BOOSTER



ADVANCED AGENA WILL FEATURE ORBITAL PERIOD ADJUSTMENT

The advanced Agena will be the first satellite designed to adjust its position while in orbit. This provides for:

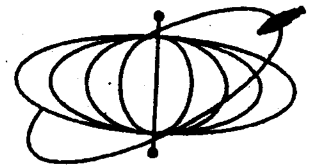
> Maintenance of orbital vehicle position for operational systems such as MIDAS
>
> More precise control of ejection point in space so that ground recovery location can be more accurately predicted



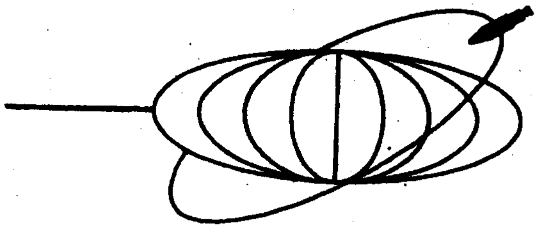
A program of global coverage could be maintained with fewer satellites if they were placed precisely into planned orbits. A system for such precise placement is under development by the Lockheed Missiles and Space Division. The system incorporates control jets that can make small velocity vector changes. This auxiliary thrust system will contain a pair of 200-pound-thrust nozzles, a pair of 20-pound-thrust nozzles, and approximately 110 pounds of propellants within a system weight of approximately 200 pounds.

WEIGHT

TYPICAL ADVANCED AGENA SATELLITE

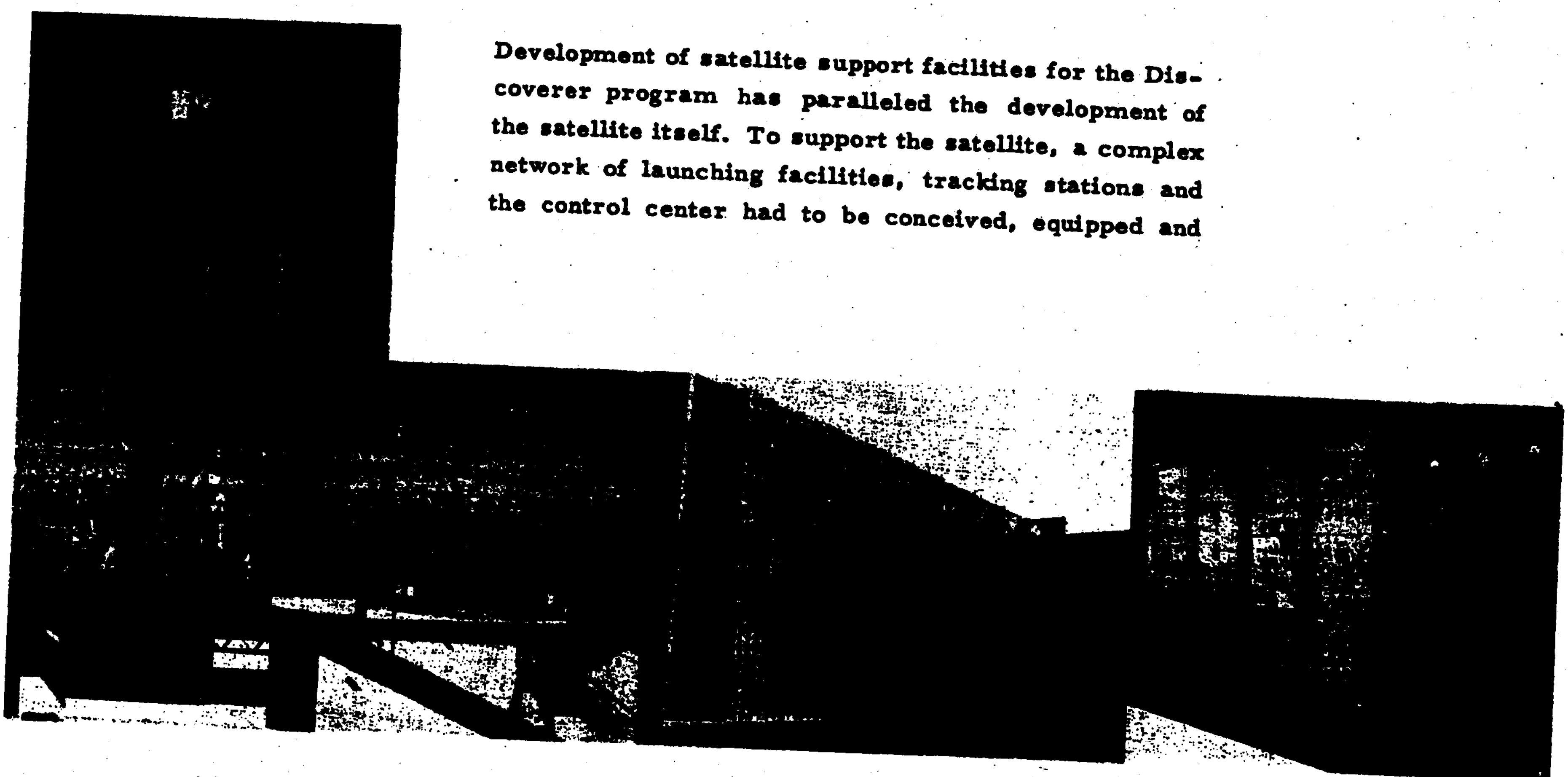


			POUNDS SUB-TOTAL	TOTAL
"A"	STRUCTURE		250	
	NOSE FAIRING (86 LBS), THOR ADAPTER (259 LBS), DESTRUCT-CHARGE AND RETRO-ROCKETS (23 LBS), ULLAGE ROCKETS (76 LBS)			
"B"	PROPULSION		444	
	INCLUDING: ROCKET MOTOR		656	
	PROPELLANT PRESSURE SYSTEM WITH HELIUM BOTTLES AND GAS	(297)		
	PROPELLANT TANK	(79)		
"D"	GUIDANCE AND CONTROLS	(280)		
"C"	AUXILIARY POWER		188	
"H"	COMMUNICATIONS (COMMAND AND TRACKING)		146	
	WEIGHT EMPTY (LESS PAYLOAD)		32	
	PROPELLANTS			1,716
	GROSS WEIGHT (LESS PAYLOAD)		13,117	
	LESS: NOSE FAIRING, ADAPTER, ETC. AND CONTROL GAS			14,833
	IGNITION WEIGHT (1st BURN)		-378	
	LESS: IMPULSE PROPELLANT			14,455
	LESS: OXIDIZER PRE- AND POST-FLOW, ULLAGE ROCKETS (2nd BURN), START CHARGE, CONTROL GAS		- 12,950	
	BURNOUT WEIGHT (LESS PAYLOAD)		-140	
				1,365



IN ADDITION . . .

COMPLETE SATELLITE SUPPORT FACILITIES



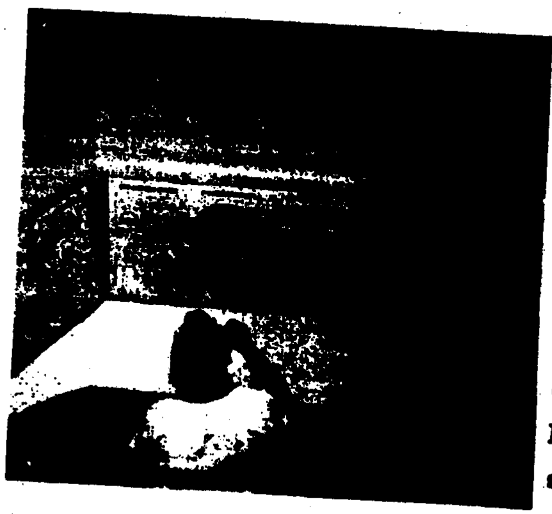
Development of satellite support facilities for the Discoverer program has paralleled the development of the satellite itself. To support the satellite, a complex network of launching facilities, tracking stations and the control center had to be conceived, equipped and

Atlas-Agena Launch Complex Under Construction at Point Arguello

The Control and Command Center for the Satellite Network is Located in Sunnyvale, California

Tracking Station Transmitting Equipment for Commanding Agena Satellites put into operation. The design, fabrication of equipment and testing of this network was a major task. The training of personnel and successful operation of the network are in themselves very significant technological accomplishments.

The Pacific Missile Range (PMR) Agena-Thor launch complex at Vandenberg AFB includes two launch pads. By mid-1960 two launch pads for Atlas-Agena flights will be available at the Point Arguello (PMR) facility.



Angle Tracker Control Console at Vandenberg AFB

At AFMTC in the Atlantic Missile Range (AMR), a pad and its support equipment for Atlas-Agena flights is available.

The Agena tracking and control network for satellite tracking, data acquisition and ground-to-space capability has been well-tested in the Discoverer program. This network includes the Vandenberg AFB facility for launch and orbital tracking, stations for orbital tracking in Alaska and Hawaii, and the Air Force Satellite Test Center at Sunnyvale, California.

Supporting the Satellite Test Center is a UNIVAC 1103A computer. Procedures and programs have been perfected for computing ephemerides from tracking data. From the ephemeris, acquisition and command information has been accurately computed and retransmitted to all tracking stations on all of the Agena flights.

The Data Processing and Reduction facility at Sunnyvale receives and processes all telemetry data pertinent to mission accomplishment. Analog and digital records of the vehicle parameters are available for analysis 8 to 10 hours after they have been recorded at the tracking station. Improvements in processing techniques and computer programs have meant a 40 to 50 percent saving in data reduction time.

CONTRIBUTIONS TO SCIENTIFIC RESEARCH

Biomedical Data

In one Discoverer flight, a biomedical research capsule containing four live mice was monitored for 791 seconds. Physiological data was obtained on reactions of the specimens during the boost phase and 510 seconds of weightlessness. Such information is of use for man-in-space experiments like Project Mercury.

Temperature Data

Approximately 500 ascent and orbital temperature measurement channels have been provided on Agena flights. In early flights, temperature instrumentation was mainly adapted to study of ascent heating. Actual measurements were not as high as predicted. As a result, the method of computing ascent temperatures was revised. The ability to more accurately predict peak temperatures encountered during ascent will permit weight-saving in structural designs. Orbital temperature measurements have confirmed the present methods of prediction.

High Precision Satellite Position Measurement

As a simultaneous means for tracking the Agena, an optical method was devised. Satellite lights were tracked by various sites equipped with Baker-Nunn cameras. Discoverer 11 was optically tracked in Spain (other stations had cloud cover). Data from such experiments contribute to precise determination of the geoid.

Special Planned Geophysical Measurements

Its stabilization in polar orbit makes the Discoverer satellite particularly useful for a number of orbital geophysical experiments. Equipment planned for these experiments includes (1) magnetic spectrometers for measuring the spectrum of auroral electrons and their angular distribution, (2) integrating dosimeters for measuring total radiation, (3) nuclear emulsions for cosmic ray experiments, (4) an x-ray diffraction camera, and (5) an absorption spectrometer for measuring the intensity and energy of gamma and x-rays in the range between 1 and 100 Kev.

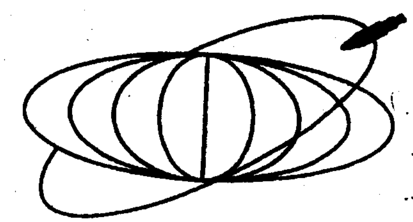
Satellite Internal Pressure Measurements

To check the rate of pressure decay in orbit, a Phillips ion gage was flown in the forward equipment section of Discoverer 11. Pressures of about 10^{-4} mm Hg were recorded in this area for many hours. This data discloses that thermal conduction paths may exist temporarily in satellites on orbit.

Other Contributions

Routine tracking of the Discoverer satellite gives rise to additional scientific data. For example, atmospheric density is determined from tracking measurements of satellite orbits. Because of the polar orbit of the Discoverer, it is possible to determine density as a function of altitude over a wide range of geographical positions. Such measurements yield valuable information about the motion, ionization and heating of the upper atmosphere and the manner in which it is influenced by the various kinds of incident solar radiation.

The contributions from these experiments and others to come are helping the Discoverer to earn the reputation of the space age "Test Bed."



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... *Prepared by Dept. 61-10*