Pre-Launch
Mission Operation Report
No. S-894-71-03

9 April 1971

MEMORANDUM

TO : A/Acting Administrator

FROM : S/Associate Administrator for
Space Science and Applications

SUBJECT: San Marco-C Explorer

On or about 24 April 1971, the San Marco-C spacecraft will be launched from the San Marco Range located off the coast of Kenya, Africa, by a Scout launch vehicle. The launch will be conducted by an Italian crew. The San Marco-C is the third cooperative satellite project between Italy and the United States. The first such cooperative project resulted in the San Marco-I satellite which was launched into orbit from the Wallops Island Range with a Scout vehicle on 15 December 1964. The successful launch demonstrated the readiness of the Italian Centro Ricerche Aerospaziali (CRA) launch crews to launch the Scout vehicle and qualified the basic spacecraft design. The second in the series of cooperative satellite launches was the San Marco-II which was successfully launched into orbit from the San Marco Range on 26 April 1967. This was the first Scout launch from the San Marco Range. The San Marco-II carried the same accelerometer as San Marco-I, but the orbit permitted the air drag to be studied in detail in the equatorial region. The successful launch also served to qualify the San Marco Range as a reliable facility for future satellite launches, and has since been used for the successful launch of SAS-A (Explorer 42). This cooperative project has been implemented jointly by the Italian Space Commission and NASA.

The CRA provided the spacecraft, its subsystems, and an air drag balance; Goddard Space Flight Center (GSFC) provided an omegatron and a neutral mass spectrometer, technical consultation and support. In addition, NASA provided the Scout launch vehicle.

The primary scientific objective of the San Marco-C is to obtain, by measurement, a description of the equatorial neutral-particle atmosphere in terms of its density, composition, and temperature at altitudes of 200 km and above, and to obtain a description of variations that result from solar and geomagnetic activities.

The secondary scientific objective is to investigate the interdependence of three neutral-density-measurement techniques from one spacecraft: direct particle detection, direct drag, and integrated drag.

The spacecraft will be launched into an orbit with the following approximate orbital elements:

Perigee -	215 km
Apogee -	800 km
Inclination -	2.9 degrees
Period -	95 minutes

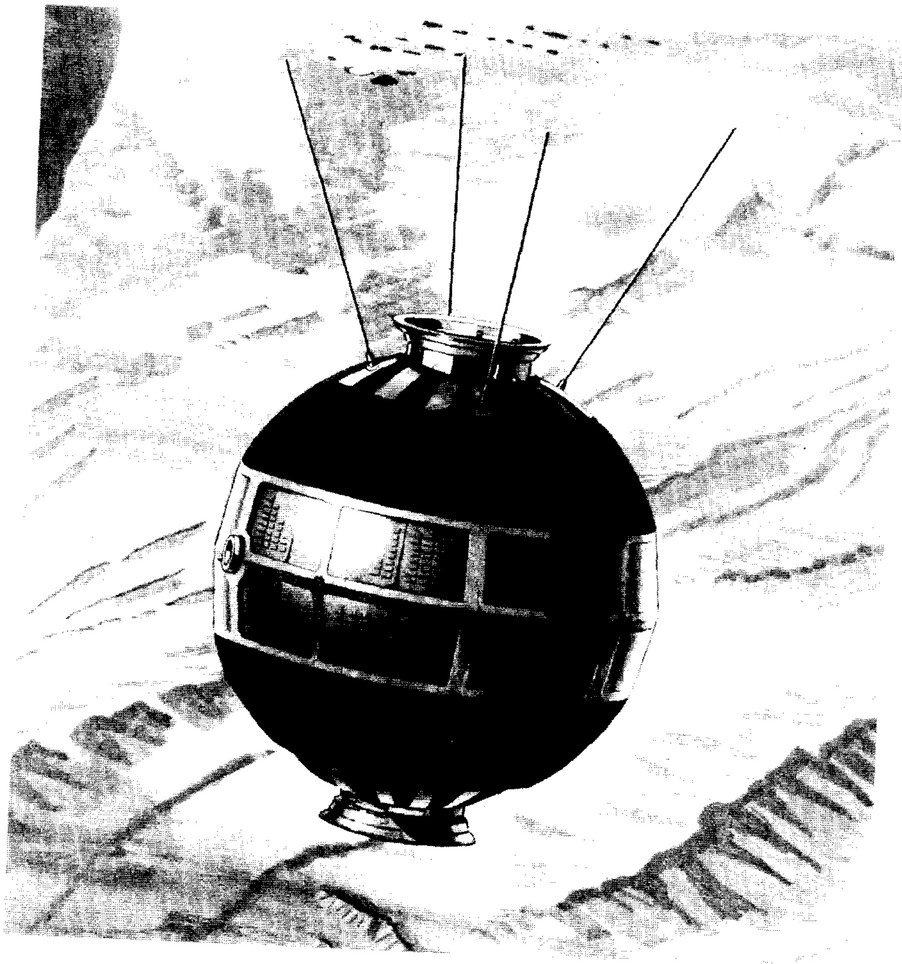
The expected orbital lifetime is 6 months.

V. L. Johnson

John E. Naugle

Report No. S-894-71-03

MISSION OPERATION REPORT



SAN MARCO-C

OFFICE OF SPACE SCIENCE AND APPLICATIONS

[redacted]

FOREWORD

MISSION OPERATION REPORTS are published expressly for the use of NASA Senior Management, as required by the Administrator in NASA Instruction 6-2-10, dated 15 August 1963. The purpose of these reports is to provide NASA Senior Management with timely, complete, and definitive information on flight mission plans, and to establish official mission objectives which provide the basis for assessment of mission accomplishment.

Initial reports are prepared and issued for each flight project just prior to launch. Following launch, updating reports for each mission are issued to keep General Management currently informed of definitive mission results as provided in NASA Instruction 6-2-10

Primary distribution of these reports is intended for personnel having program/project management responsibilities which sometimes results in a highly technical orientation. The Office of Public Affairs publishes a comprehensive series of pre-launch and post-launch reports on NASA flight missions which are available for dissemination to the Press.

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GENERAL

The Spacecraft Act of 1958 authorized the United States to conduct a program of international cooperation with other nations in aeronautical and space science activities and in the peaceful applications of the results threrof.

On 31 May 1962, the first Memorandum of Understanding concerning the San Marco program was signed by the Italian Commissione per le Richerche Spaziali (CRS) and the National Aeronautics and Space Administration (NASA).

Phase I - A suborbital launch from the Wallops Island Station and/or from an Italian platform located near the equator to flight-test the principal elements of the scientific payload.

Phase II - An orbital launch of a fully instrumented satellite utilizing a Scout vehicle from Wallops Island Station to qualify the spacecraft and to provide essential launch crew training.

Phase III - Launch of a scientific satellite into an equatorial orbit by means of a Scout booster from a platform located in Kenya to obtain air density data, and to qualify the equatorial launch complex as an operating range.

On 26 March 1964, CRA successfully launched a two-stage Nike sounding rocket from the Santa Rita launch platform off the Kenya coast concluding Phase I. It carried basic elements of the San Marco science instrumentation and served further to flight-qualify these components as well as provide a means of check-out of range instrumentation and equipment.

The second phase culminated in the launch of the San Marco-I spacecraft from Wallops Island on a Scout vehicle on 15 December 1964. This launch demonstrated the readiness of the CRA launch crews for Phase III operations and qualified the basic spacecraft design. It also confirmed the usefulness and reliability of the drag balance device for accurate determinations of air density values and satellite attitude.

Phase III was completed with the launching of San Marco-II from the San Marco platform off the coast of Kenya on 26 April 1967. The San Marco-II carried the same instrumentation as San Marco-I, but the equatorial orbit permitted a more detailed study to be made of density variations versus altitude in the equatorial region. The successful launch also served to qualify the San Marco Range as a reliable facility for future satellite launches.

The successful culmination of the first San Marco endeavor paved the way for still closer collaboration in a new effort, San Marco-C, that was begun by the signing of the second Memorandum of Understanding.

On 18 November 1967, a second Memorandum of Understanding was signed between the Italian CRS and NASA to continue their cooperation in satellite measurements of atmospheric characteristics and establish the San Marco-C project. The effort, implemented through the respective agencies, will further supplement and continue the drag balance studies of the two previous CRA and NASA cooperative projects and will initiate complementary mass spectrometer investigations of the equatorial neutral particle atmosphere. This project offers a unique scientific advantage of permitting the simultaneous measurement of atmospheric density by three different techniques: direct particle detection, direct drag, and integrated drag from one satellite.

In accordance with the terms of the Memorandum of Understanding, the areas of responsibility for the project have been defined as follows:

CRS will:

- Design, fabricate, and test the satellite.
- Integrate the U. S. Instrumentation.
- Establish, equip, maintain, and operate range facilities, including platforms, range equipment and Scout vehicle checkout and launch equipment.
- Assemble, checkout, and launch the satellite using a Scout vehicle.
- Be responsible for range safety.
- Be responsible for tracking and data acquisition facilities and operations except as provided by NASA.
- Analyze data from Italian experiments and participate with NASA in comparison of data and analysis of total results.
- Support Italian personnel in any training or requalification mutually agreed on as necessary to accomplish this program.
- Furnish all support, logistics, spare parts, and transportation costs (other than those specifically assumed by NASA) and all other costs peculiar to the project.
- Establish and maintain communication circuits required between the Kenya Range and NASA.

NASA will:

- Provide the mass spectrometers, including their transportation costs and participate in their integration checkout with the satellite.

- Provide the Scout launch vehicle (and back-up, if required), including heat shield, spacecraft tie-down and separation mechanisms, vehicle spare parts, and transportation.

- Provide training or requalification for Italian personnel as may be mutually agreed upon.

- Provide tracking and data acquisition services of suitably located STADAN stations and communications support at other locations as may be mutually agreed upon.

- Analyze data from U.S. instrumentation and participate with CRS in comparison of data and analysis of total results.

NASA MISSION OBJECTIVES FOR SAN MARCO-C

To investigate Earth's equatorial atmosphere in terms of neutral density, composition, and temperature, and its response to diurnal or sporadic changes in atmospheric heat input.

Jesse L. Mitchell
Physics and Astronomy Programs Director

Date: 4/8/71

John E. Naugle
Associate Administrator for
Space Science and Applications

Date: 4/8/71

SPACECRAFT DESCRIPTION

GENERAL

The San Marco-C spacecraft is a 28-inch diameter sphere with four canted 19-inch monopole antennas for telemetry and command (Figure 1). The structure of the spacecraft forms an integral part of the air density balance. The drag balance configuration (Figure 2) consists of a light external shell connected through the elastic elements of the air-drag measuring balance to the heavier internal structure (drum) of the spacecraft. Figure 3 shows the inner body general arrangement.

The outer shell of the spacecraft and the arms which connect the shell to the air-drag balance constitute the movable structure of the spacecraft. A series of mica windows is provided on the equator of the shell for the solar cells which are located on the periphery of the inner structure.

The power supply, consisting of three battery packs, the NACE, and the omegatron, are located inside the drum. The spacecraft's electronic instrumentation is mounted on the upper and lower sides of the drum.

The orbital design weight of the San Marco-C is approximately 378 pounds.

The spacecraft is thermally controlled by passive means to maintain the instrumentation within a safe temperature range. Satellite attitude data are provided by a triaxial magnetometer and by a digital sun sensor. The power system consists of a solar array, two nickel cadmium (NiCad) batteries, a mercuric oxide (HgO) battery pack, and associated voltage conversion and control electronics. The main components of the command system are the command receiver, the tone decoder, the command decoder, and the command combiner. The completely redundant system affords a capacity of 42 commands. The telemetry system is a 10-channel frequency-multiplexed system with three channels using PAM/FM/PM modulation and seven channels using FM/PM modulation. The link frequency is 136.74 MHz.

EXPERIMENTS

Drag Balance

The drag balance investigator is Professor Luigi Broglio, of CRA. The balance, which is an integral part of the satellite, consists of an inner mass, an elastic element, and an outer shell.

The drag balance (Figure 4) is the connecting elastic element between the outer light shell and the inner heavy body. The center of the balance is located at the satellite geometric center, or that point which is the geometric center both of the inner body and the shell.

SAN MARCO-C SPACECRAFT

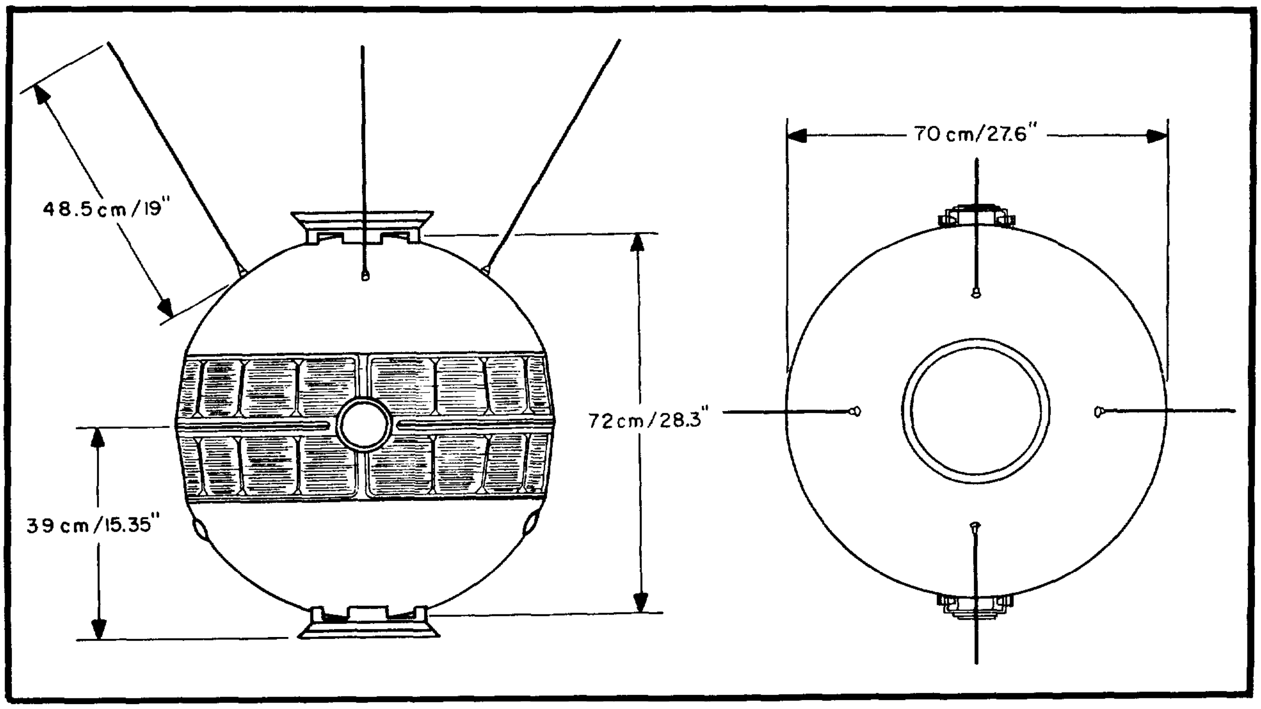

Fig. 1

DRAG BALANCE

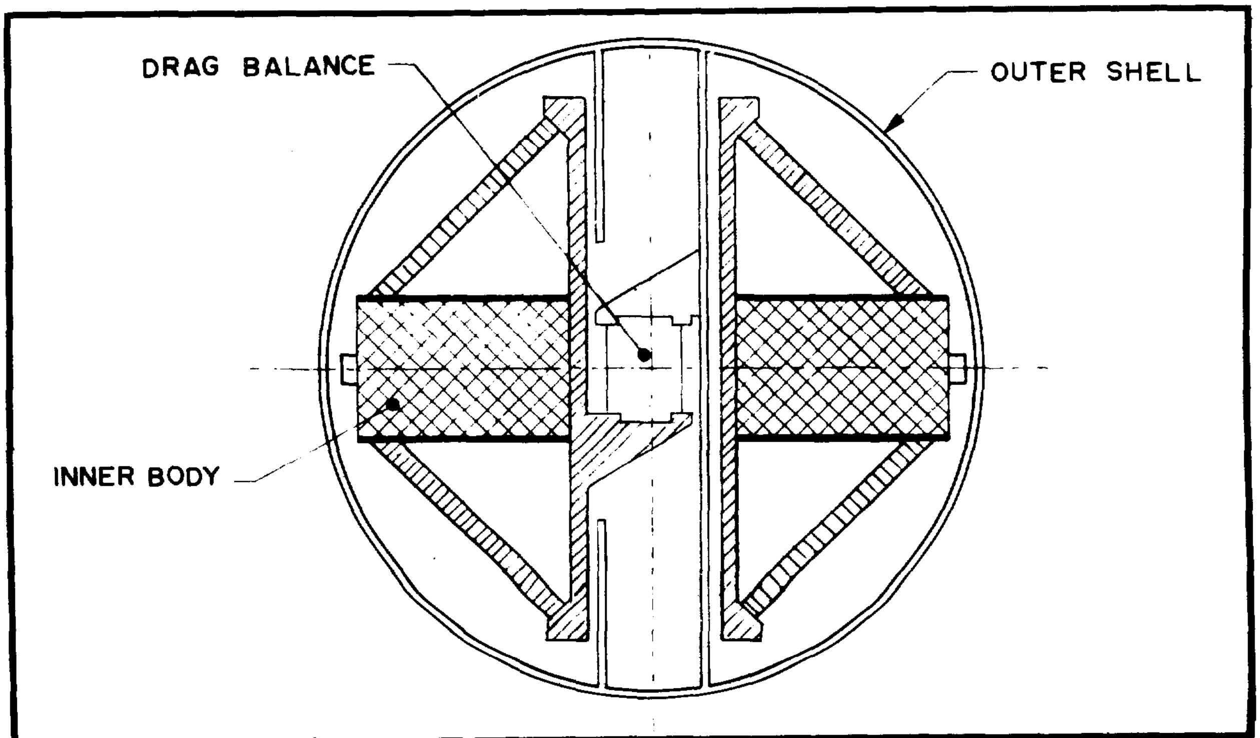

Fig. 2

SAN MARCO-C GENERAL ASSEMBLY (Inner Body)

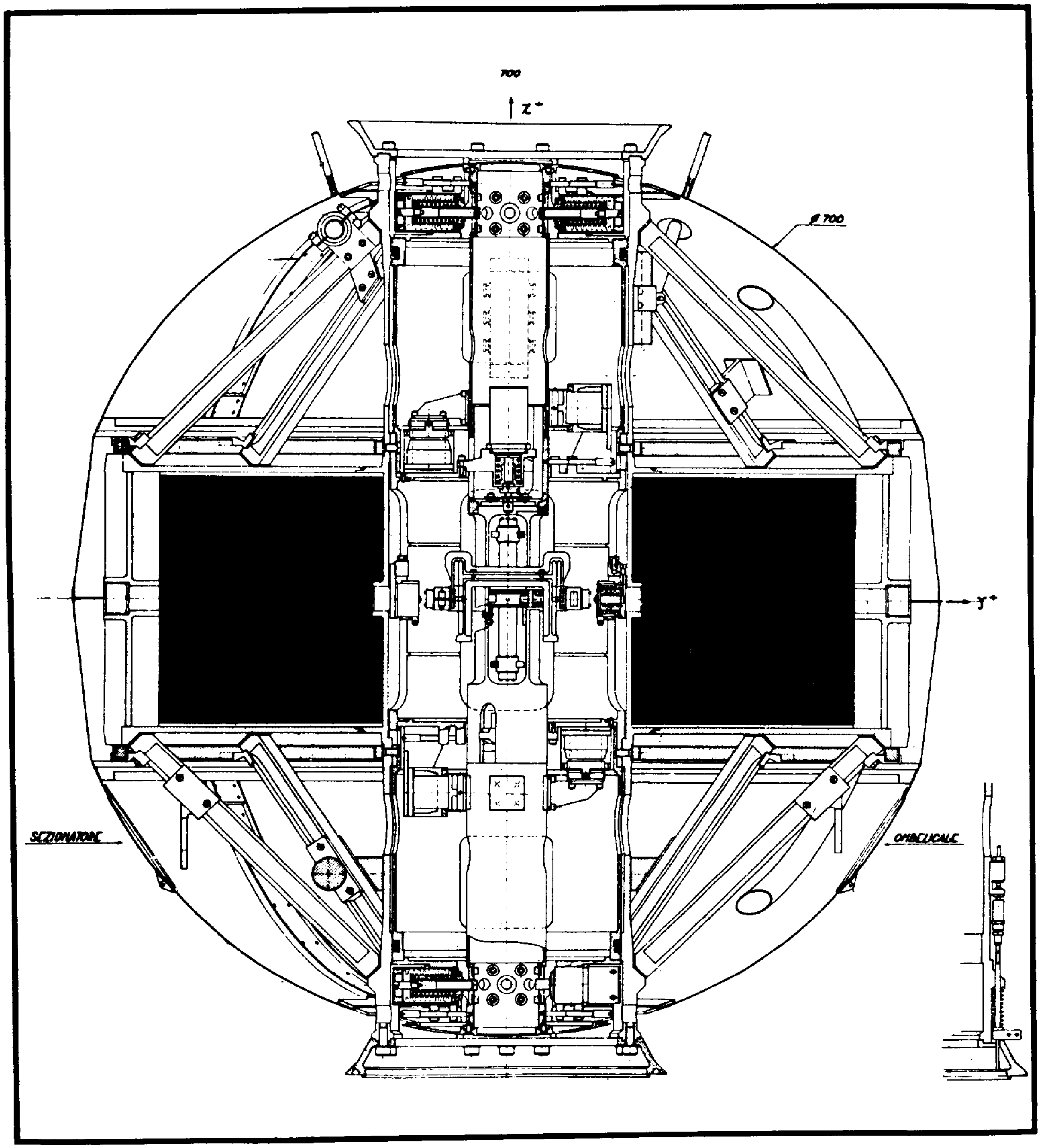

Fig. 3

BALANCE ASSEMBLY

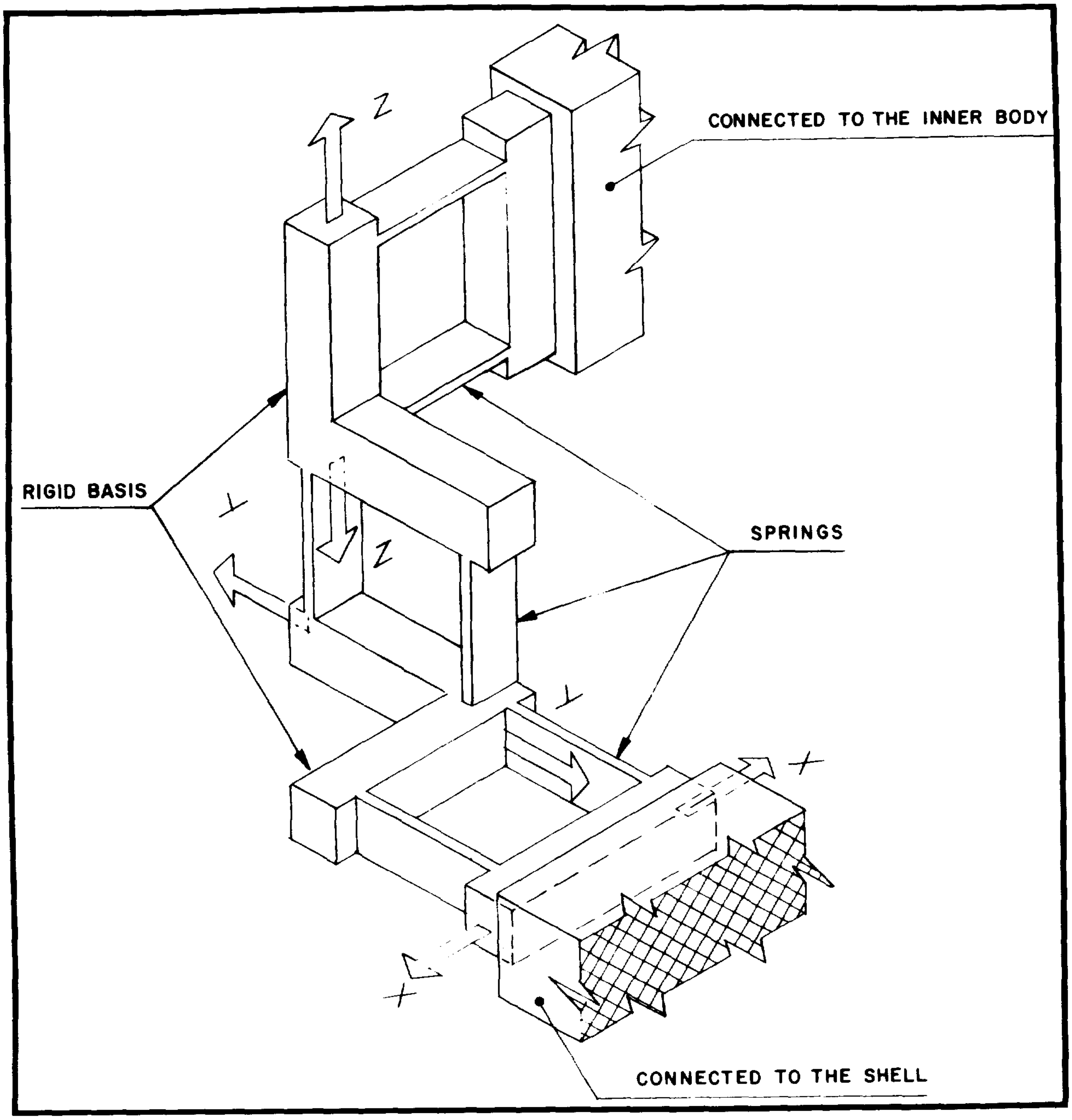

Fig. 4

While preventing any relative angular displacement, the connecting element, which is the balance, allows the relative translation of the outer shell with respect to the inner body in any direction. Any force acting on the shell in any direction causes a relative displacement (translation) of the shell with respect to the internal body only in the direction of the applied force, which is displacement linearly proportional to the force.

The San Marco balance measures the relative translations between the shell and the inner body both in value and direction, resolving any relative translation along three mutually orthogonal axes. These three axes are fixed to the body, one of them being coincident with the polar symmetry axis of the satellite. Being fixed to the satellite, the axis rotates with it in the free precession motion around the center of gravity. The balance is designed in such a way that the maximum translation between the shell and the drum is generally of the order of 0.01 millimeter. At the orbit apogee, in most cases, the drag force is negligible. As a consequence, the apogee data are used to get an inflight calibration of the balance. Thus, the translation of the elastic system is changed into voltages which are amplified and demodulated to obtain dc signals proportional to the force components.

The sensitivity of the balance ranges from 1 gram full scale to 35 grams full scale generally corresponding to the range of altitude from 400 km to 130 km, respectively.

Omegatron

The omegatron experimenters are Nelson W. Spencer of the GSFC and George Carignan of the University of Michigan. The omegatron is designed to provide direct measurements of the temperature and density of thermosphere molecular nitrogen. The omegatron mass spectrometer (Figure 5) is fixed or automatically (on command) tuned to molecular nitrogen. The sensor elements are enclosed in a special orificed spherical chamber whose center line lies in the equatorial plane of the satellite. The motion of the chamber during satellite roll causes a variation of pressure in the chamber from which one can derive the nitrogen concentration and particle energy distribution. Differentiation of the output current provides signals which are proportional to the density and the temperature of the gas. The useful range of the instrument is approximately 210 km to about 400 km, the high altitude limitation being imposed primarily by signal-to-noise ratio. The complete unit weighs 32.7 pounds and requires 2-1/2 watts of power. In addition, the omegatron requires three telemetry channels (one shared with housekeeping data) and six commands.

Neutral Mass Spectrometer (Neutral Atmospheric Composition Experiment (NACE))

The NACE experimenters are George P. Newton and David T. Pelz of the GSFC. The NACE is a closed-source neutral mass spectrometer, designed to measure the concentrations of the primary constituents of the neutral atmosphere. These data will be combined with the neutral thermosphere temperature and total density measured by the drag balance and omegatron to investigate the heating mechanisms of the equatorial thermosphere.

The NACE employs a double focusing, magnetic sector type mass spectrometer and associated electronics to perform the measurements. The instrument is located such that the orifice normal of the specially designed enclosed ion-source is in the spin-equatorial plane of the satellite. The spin modulation of the mass spectrometer ion-source

OMEGATRON SCHEMATIC

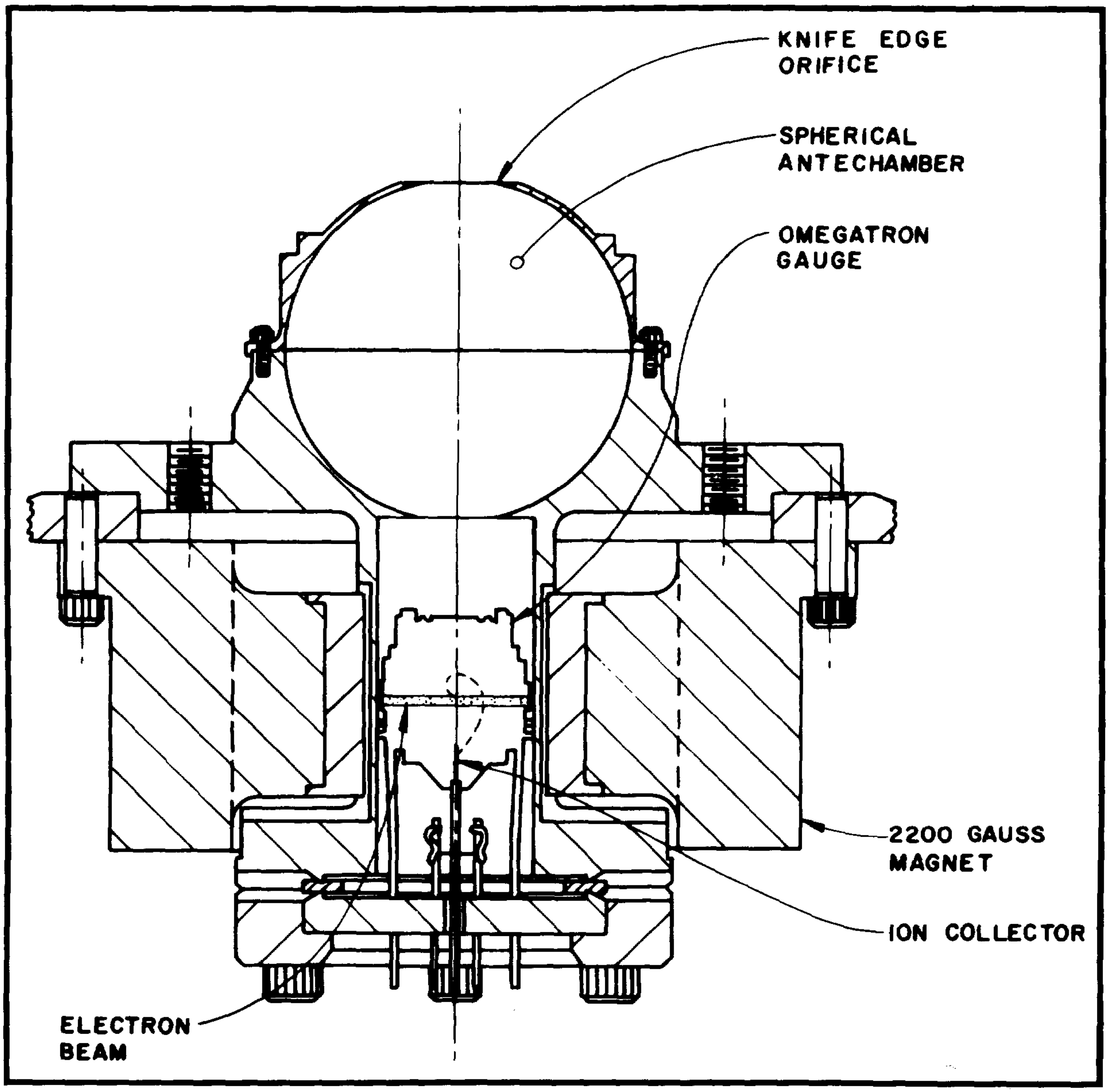

Fig. 5

pressure is proportional to the atmospheric neutral particle densities and this fact is used to relate the measured ion-source pressure to the atmospheric partial densities.

The instrument weighs 31 pounds and requires 12 watts, three elementary data channels, and seven commands.

The mass spectrometer, similar to those flown on Explorers 17 and 32, employs a spectrograph type display of ions of different mass-to-charge ratios, (m/e) (Figure 6). The concentrations of these different ions can thus be simultaneously measured. For the NACE, these m/e are 4, 14, 16, 28, 32, and 40, corresponding to He^+, N^+, O^+, O_2^+, N_2^+ and A^+, respectively. These ions are generated in the ion-source by electron bombardment of the neutral gas which enters the antechamber from the atmosphere. Once the ions are generated, the electric and magnetic sectors in the analyzer separate the ions according to their m/e. From knowledge of the mass spectrometer calibration and the satellite attitude, these ion currents are converted to atmospheric constituent concentrations.

NEUTRAL MASS SPECTROMETER SENSOR SCHEMATIC

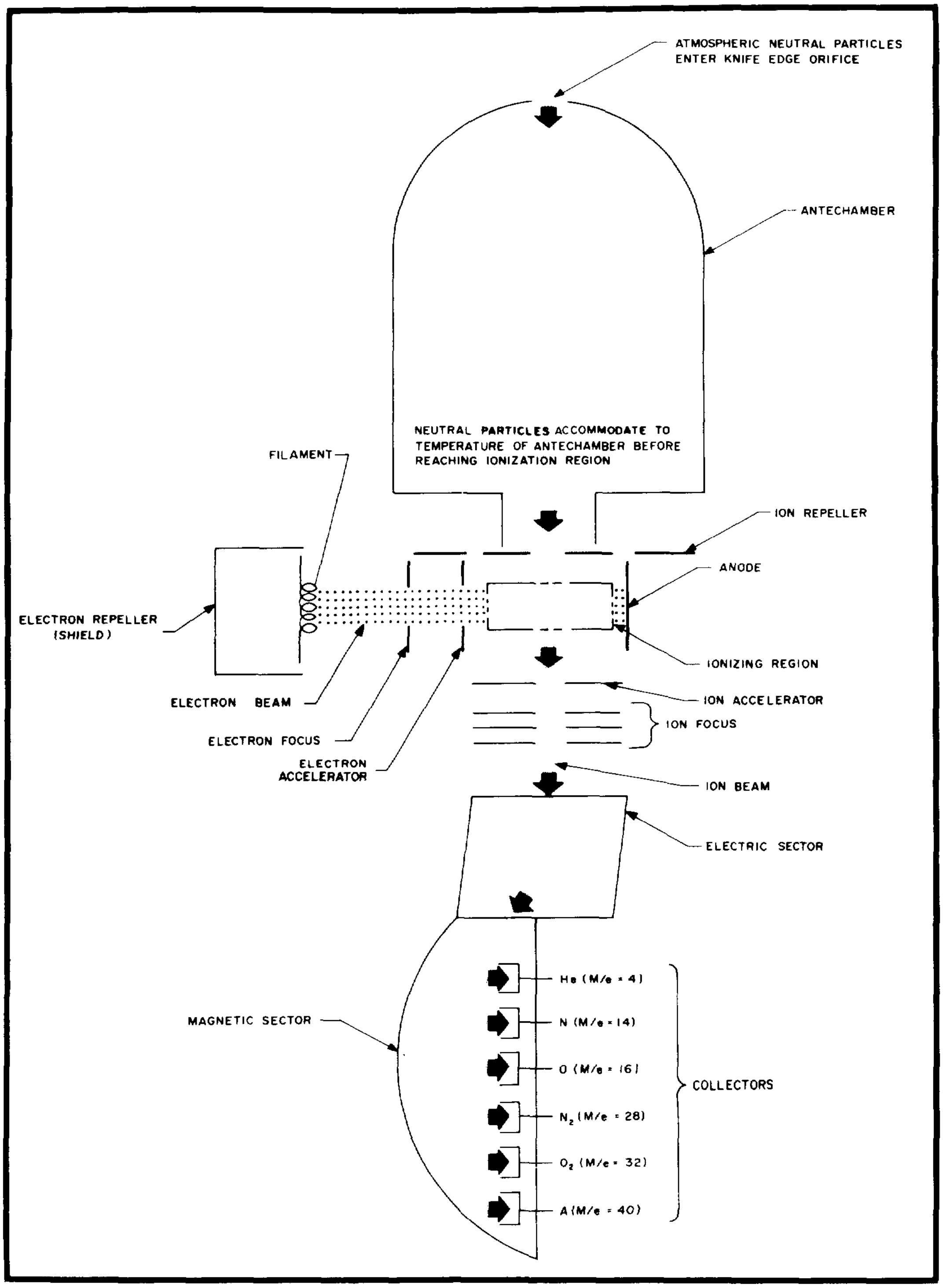

Fig. 6

LAUNCH VEHICLE DESCRIPTION

SCOUT LAUNCH VEHICLE

The launch vehicle for the SM-C is NASA Scout vehicle S-173C. The Scout is a solid-propellant, four-stage vehicle which is guided through the flight of the first three stages, as shown in Figure 7. The guidance system consists of a strapped-down three-axis gyro system for attitude and rate control. Control is provided by hydraulically actuated jet vanes and aerodynamic tip controls on a common shaft for the first stage and by a system of peroxide reaction jets for the second and third stages. The fourth stage is not guided, but is spin-stabilized. The four stages are described briefly in the following table.

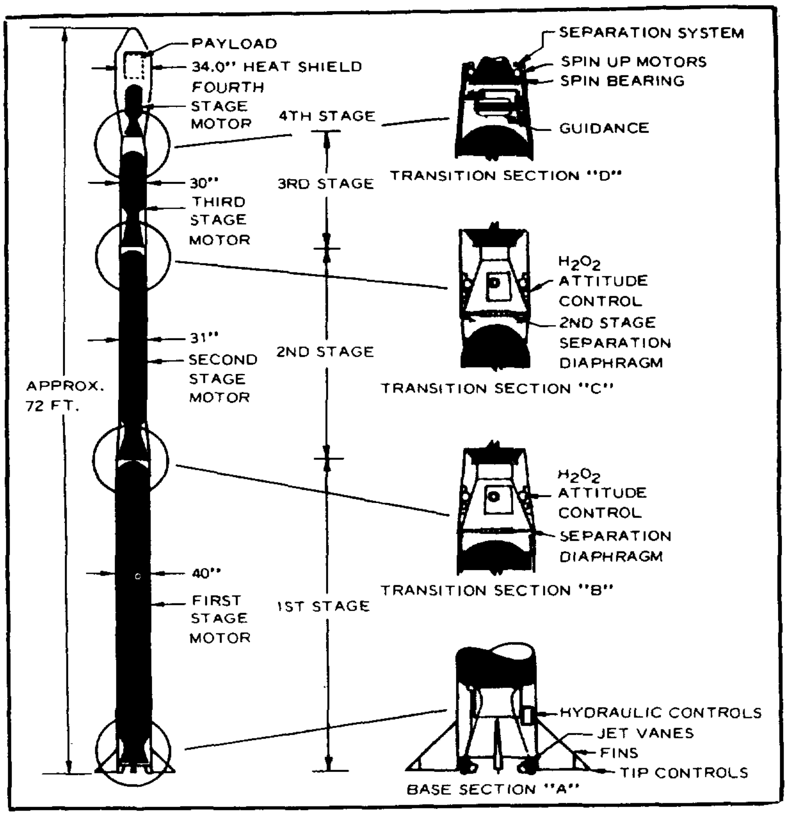

Fig. 7

Motor Designation	Total Impulse (lb-sec vacuum)	Avg. Web Thrust (lb-ft vacuum)	Burn Time (sec)	Total Weight (lb mass)
First Stage: ALGOL IIB	5, 481, 859	98, 147	76.08	23, 799
Second Stage: CASTOR IIA TX-354-3	2, 315, 115	61, 839	38.97	9, 760
Third Stage: ANTARES II X259-B3	724, 673	20, 931	35.90	2, 812
Fourth Stage: FW-4S XSR-57-UT-1	172, 243	5, 857	31.47	664.3

SEQUENCE OF EVENTS

The sequence of events is shown in the following table:

Time after Lift-off (seconds)	Events
	Lift-off
77.22 83.56	Stage 1 burn-out, stage 1 separation, Stage 2 ignition
123.97	Stage 2 burn-out
146.26	Heat shield separation
147.96	Stage 3 ignition, stage 2 separation
189.65	Stage 3 burn-out
379.70	Spin-up, stage 4 squib ignition
381.20	Stage 3 separation
386.05	Stage 4 ignition
421.13	Stage 4 burn-out
698.20	Despin
711.20	Payload separation

MISSION SUPPORT

LAUNCH FACILITIES

The spacecraft will be launched from the San Marco equatorial range. The range, located in the Formosa Bay, 3 miles off the coast of Kenya, Africa, was established by the Italian Government as an independent operating range. Its location was influenced by the desire to launch scientific satellites into equatorial orbits from international waters. Figure 8 shows the relative location of the launch site in Kenya. The Centro Ricerche Aerospaciali (CRA), University of Rome, is responsible for the management and direction of the San Marco Equatorial Range.

SAN MARCO RANGE LOCATION

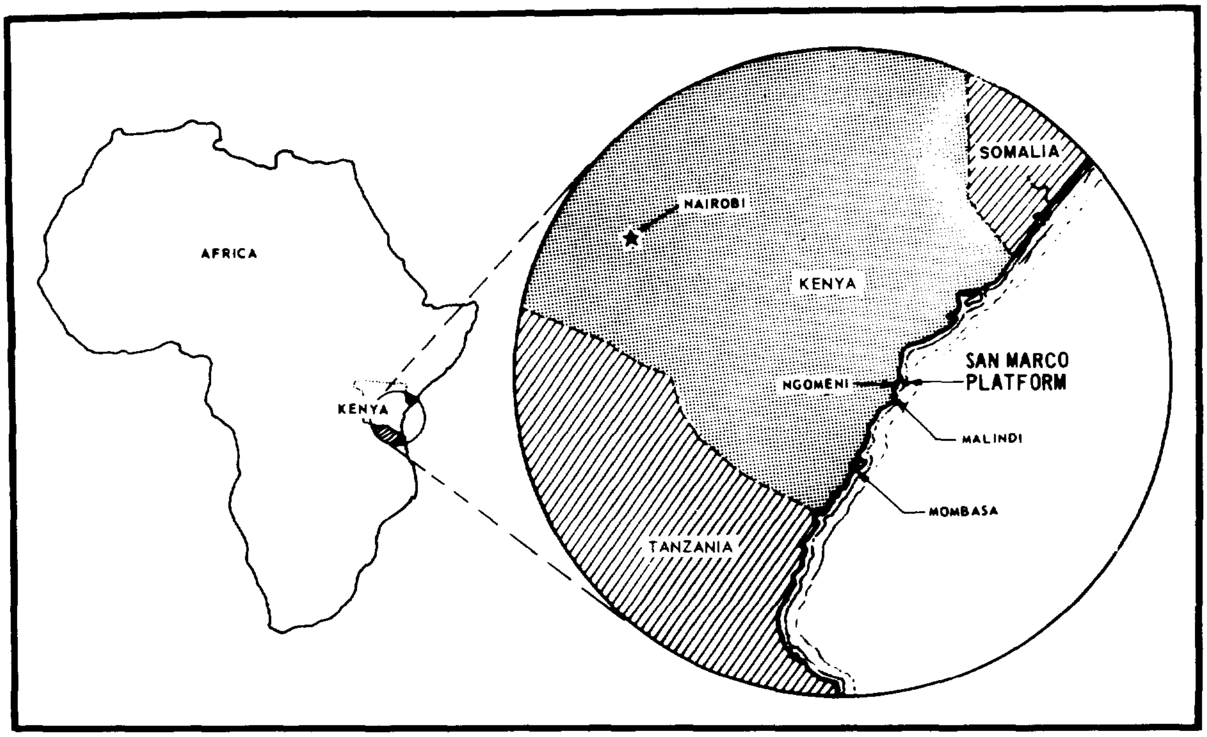

Fig. 8

The main components of the San Marco range are the launch, control and radar platforms, the logistic support center, and a ground telemetry and command station. The launch platform, containing the launcher and ground support equipment for assembly and checkout of the vehicle and payload, bears the name of San Marco. The control platform, containing equipment for remote control of vehicle launch, trajectory tracking, and data acquisition is named Santa Rita. One small platform, adjacent to the Santa Rita, supports the motor generators that supply power to the Santa Rita platform and, during countdown, to the San Marco platform. Another small platform, also adjacent, houses both the S-band and C-band radars. The logistic support center is referred to as the Base Camp and is located on the mainland. Figure 9 shows the range platform.

TRACKING AND DATA ACQUISITION

Tracking data during the launch and early orbit phases will be obtained by the following stations:

- Santa Rita Station (STS) at the San Marco site - S-Band and C-Band radar tracking
- Mobile Italian Telemetry Station (MITS) in Kenya - Doppler tracking
- Quito, Ecuador (QUITOE) STADAN Station - Interferometer tracking
- Kourou, French Guiana CNES Station (KRUFUG) - Interferometer tracking

The North American Air Defense Command (NORAD) stations also will provide early orbit tracking where possible. Figure 10 shows the spacecraft orbital path and tracking and data acquisition stations. After the spacecraft orbit has been determined at GSFC, updated orbital predictions will be forwarded to MITS, QUITOE and KRUFRG. The normal phase of operations will begin. The above stations then will have tracking and data acquisition responsibilities as follows:

Tracking - Normally, the San Marco-C will be a silent spacecraft. For a tracking pass, QUITOE and KRUFRG will command the spacecraft transmitter on two minutes before the spacecraft crosses station meridan and OFF one minute after.

Data Acquisition - Telemetry data acquisition will be the responsibility of QUITOE and MITS. QUITOE will be scheduled for 2 or 3 passes per day of telemetry data; and, MITS will acquire data from 8 or 9 passes per day.

SAN MARCO LAUNCH PLATFORM

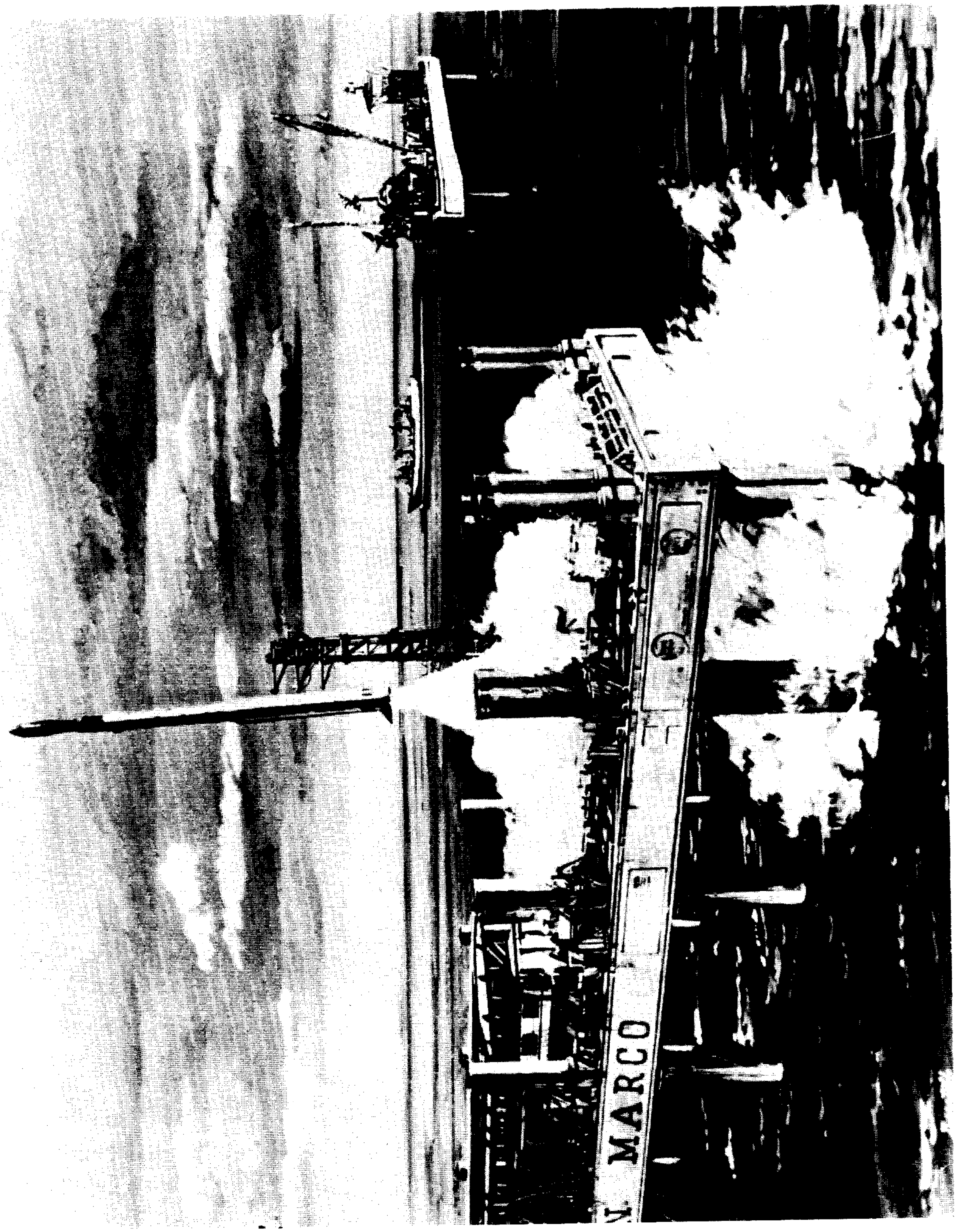

Fig. 9

NOMINAL SUBSATELLITE PLOT

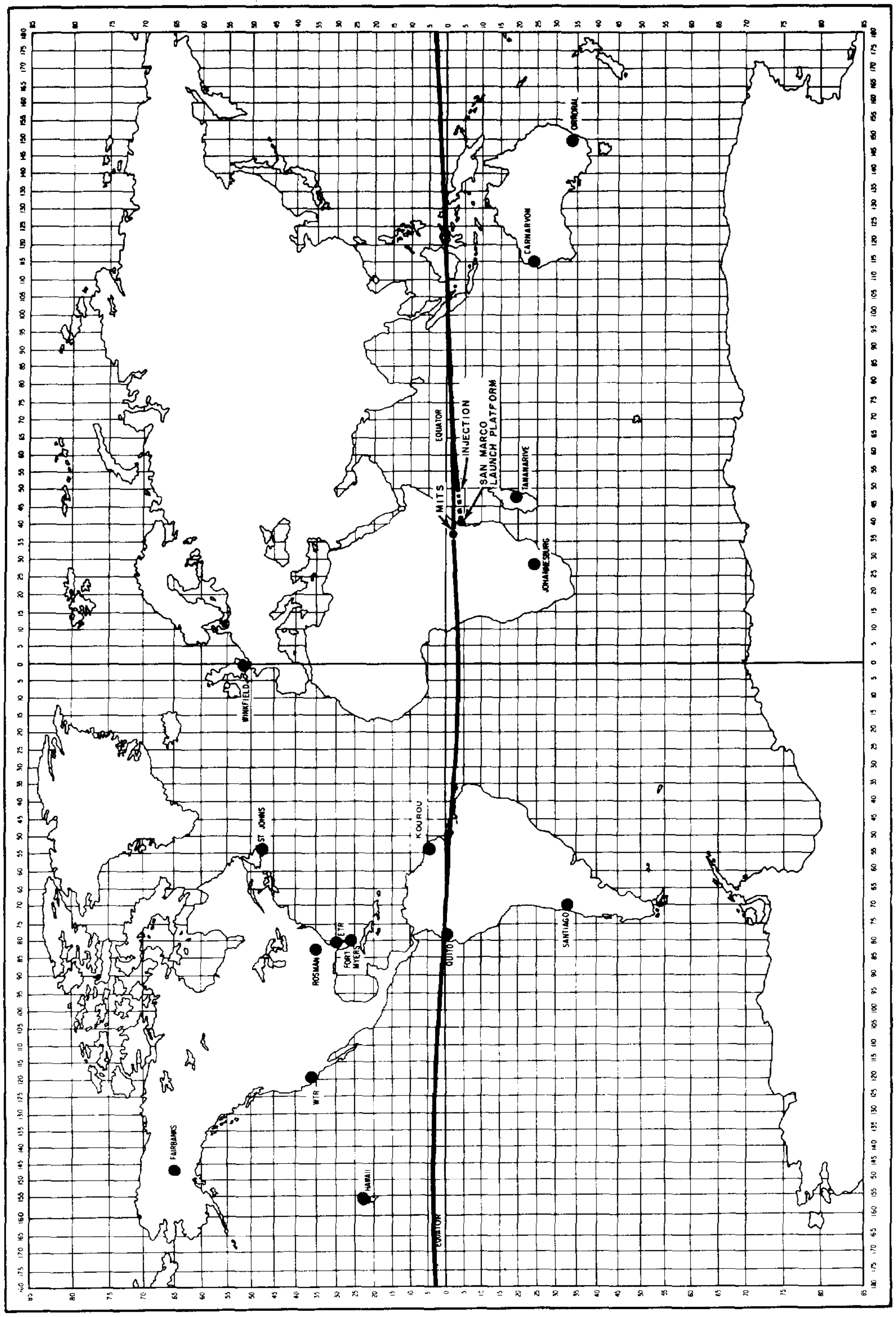

Fig. 10

Command - The MITS will be the primary station for commanding the spacecraft. QUITOE will provide back-up commanding of the experiments and other commands as required.

GODDARD DATA ACQUISITION STATION IN KENYA

The GSFC experimenter's facility located at the base camp, near MITS serves as the primary control center, and the data acquisition center for the two GSFC instrument packages. The primary omegatron data will be digitized in the ground station and recorded in a PCM format on the same tape with the raw telemetry data. Experimenter personnel, who man the facility, will analyze the status of the GSFC instrumentation and request the MITS to transmit the necessary commands to put their instruments in the correct mode.

OTHER SUPPORT FACILITIES

The Smithsonian Astrophysical Observatory stations in Addis Ababa, Ethiopia and Natal, Brazil has been requested to track San Marco-C visually. The French facility at Kourou, French Guiana has agreed to provide tracking service.

DATA REDUCTION AND ANALYSIS

CRA and GSFC will each be responsible for processing and analyzing their respective science data.

ORBIT COMPUTATION

All orbit computations will be performed by GSFC.

PROGRAM MANAGEMENT

The Office of Space Science and Applications, NASA Headquarters, is responsible for the overall direction and evaluation of the San Marco-C Program. Program management responsibilities have been delegated to the Director of Physics and Astronomy Programs. The Goddard Space Flight Center has been assigned Project Management responsibilities. The Office of Tracking and Data Acquisition, NASA Headquarters, has overall tracking and data acquisition responsibility. The Scout launch vehicle management is the responsibility of the Langley Research Center. The responsible personnel within these areas are:

Title	Name	Organization
Program Manager Explorers & Sounding Rockets	John R. Holtz	NASA Headquarters
Deputy Program Manager Explorers & Sounding Rockets	Raymond Miller	NASA Headquarters
Program Scientist	Dr. E. R. Schmerling	NASA Headquarters
Scout Program Manager	Paul E. Goozh	NASA Headquarters
Tracking & Data Acquisition Program Manager	R. R. Stephens	NASA Headquarters
San Marco-C Project Manager	A. J. Caporale	Goddard Space Flight Center
San Marco-C Project Scientist	G. P. Newton	Goddard Space Flight Center
San Marco-C Project Coordinator	M. D. Handegard	Goddard Space Flight Center
Scout Project Office Manager	R. D. English	Langley Research Center

PROJECT COSTS

Fiscal Year	Spacecraft Support	Science Support	Scout Vehicle	Total
1967	-	100	300	400
1968	21	416	800	1237
1969	25	301	100	426
1970	42	222	-	264
1971	20	120	-	140
1972	13	87	-	100
1973	-	82	-	82
Total	121	1328	1200	2649

GPO 909-503

Post Launch
Mission Operation Report
No. S-894-71-03

MEMORANDUM

17 May 1971

To: A/Administrator

From: S/Associate Administrator for Space Science and Applications

Subject: San Marco-C Post Launch Mission Operation Report #1

The San Marco-C (now designated San Marco-3) was successfully launched on 24 April 1971 at 2:32 a.m. EST from the San Marco Range off the east coast of Africa by a Scout vehicle.

The orbital elements are:

	ACTUAL	PLANNED
Apogee (km)	723	800
Perigee (km)	222	214
Inclination (degrees)	3.23	2.9
Period (minutes)	94.1	94.6

All spacecraft systems are performing nominally. All experiment instrumentation has been turned on and is operating satisfactorily. Expected satellite lifetime is 280 days, approximately 100 days longer than planned.

John E. Naugle

Post Launch
Mission Operation Report
No. S-894-71-03

MEMORANDUM

21 December 1971

TO: A/Administrator

FROM: S/Associate Administrator for Space Science

SUBJECT: San Marco-3 Post Launch Report #2

San Marco-3 is declared a success based upon the results of the mission with respect to the approved prelaunch objectives. On 24 April 1971 San Marco-3 was launched from the San Marco Range off the east coast of Africa into a slightly elliptical orbit with a payload of three scientific instruments designed to obtain direct measurements of the equatorial neutral atmospheric density, composition, and temperature.

After more than 7 months in orbit (exceeding the anticipated 6 month lifetime) the satellite reentered the atmosphere on 28 November. Good measurements were taken by the on-board instruments during the reentry phase. During the satellite's lifetime the scientific instruments performed as designed and produced excellent data on the equatorial neutral-particle atmosphere in terms of density, composition, and temperature at altitudes of 222km to 723km.

The only failure experienced was in the sun sensors, which were not essential to the mission.

John E. Naugle

NASA MISSION OBJECTIVES FOR SAN MARCO-C

To investigate Earth's equatorial atmosphere in terms of neutral density, composition, and temperature, and its response to diurnal or sporadic changes in atmospheric heat input.

Jesse L. Mitchell
Physics and Astronomy Programs Director

Date: 4/8/71

John E. Naugle
Associate Administrator for
Space Science and Applications

Date: 4/8/71

ASSESSMENT OF SAN MARCO-3 MISSION

Based upon a review of the assessed performance of San Marco-3, launched 24 April 1971, this mission is declared a success in accordance with the prelaunch mission objectives stated above.

Jesse L. Mitchell
Director of Physics and Astronomy
Office of Space Science

Date: 12/17/71

John E. Naugle
Associate Administrator for
Space Science

Date: 20 Dec 71