Prelaunch
Mission Operation Report
No. S-894-74-04

MEMORANDUM

15 February 1974

TO: A/Administrator

FROM: S/Associate Administrator for Space Science

SUBJECT: San Marco C-2 Explorer

The San Marco C-2 spacecraft will be launched no earlier than 18 February 1974 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-2 is the fourth cooperative satellite project between Italy and the United States. The purpose of the mission is to obtain measurements of the diurnal variations of the equatorial neutral atmosphere density, composition, and temperature and to use these data for correlation with AE-C (Explorer 51) data for studies of the physics and dynamics of the thermosphere.

The San Marco C-2 project is a joint undertaking of the National Aeronautics and Space Administration (NASA) and the Italian Space Commission officially initiated with a Memorandum of Understanding in August of 1973. Project management responsibility for the Italian portion of the project has been assigned to the Centro Ricerche Aerospaziali (CRA) while the Goddard Space Flight Center (GSFC) has responsibility for the United States portion.

In accordance with the Memorandum of Understanding the CRA has provided the spacecraft, its subsystems, and an air drag balance while NASA has provided an omegatron, a neutral mass spectrometer, technical consultation and support as well as the Scout launch vehicle.

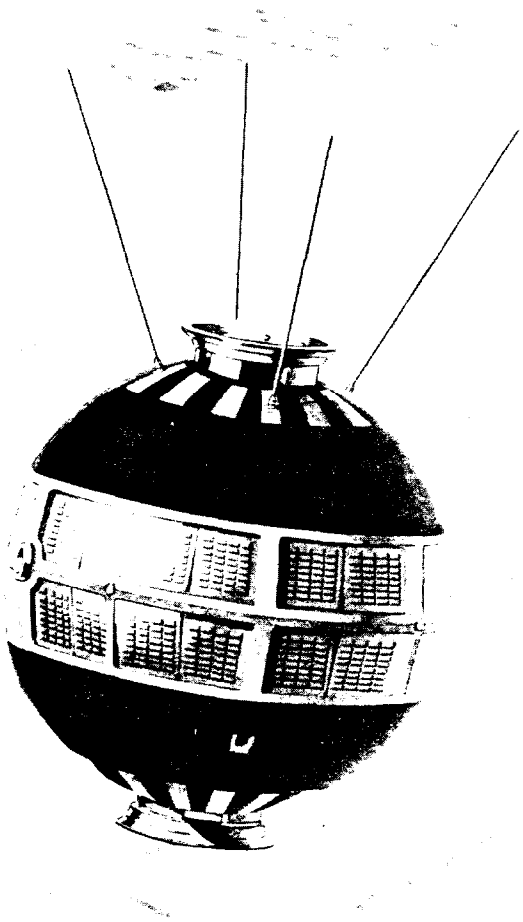
Tracking and data acquisition support will be provided by the Spaceflight Tracking and Data Network (STDN) as well as Italian and other foreign ground stations.

The spacecraft will be launched into an orbit with the following nominal orbital elements: Perigee — 228 km, Apogee — 850 km, Inclination — 2.9 degrees, Period — 95 minutes. The expected orbital lifetime is 9 months.

f V. L. Johnson
John E. Naugle

Report No. S-894-74-04

MISSION OPERATION REPORT



SAN MARCO C-2

OFFICE OF SPACE SCIENCE AND APPLICATIONS

[redacted]

CONTENTS

	Page
General	1
NASA Mission Objectives for San Marco C-2	4
Spacecraft Description	5
Launch Vehicle Description	13
Mission Support	15
Program Management	20
Project Costs	21

LIST OF FIGURES

Figure Number	Title	Page
1	San Marco C-2 Spacecraft	6
2	Drag Balance	6
3	San Marco C-2 General Assembly (Inner Body)	7
4	Balance Assembly	8
5	Omegatron Schematic	10
6	Neutral Mass Spectrometer Sensor Schematic	12
7	Scout Launch Vehicle	13
8	San Marco Range Location	15
9	San Marco Launch Platform	17
10	Nominal Subsatellite Plot	18

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. This effort, implemented through the respective agencies, supplemented and continued the drag balance studies of the two previous CRA and NASA cooperative projects and initiated complementary mass spectrometer investigations of the equatorial neutral particle atmosphere. This project offered the 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.

On 6 August 1974, a Third Memorandum of Understanding was signed between the Italian CRA and NASA to continue and extend their cooperation in satellite measurements of atmospheric characteristics and to establish the San Marco/Atmosphere Explorer/Cooperative Project. This effort will make possible the measurements of diurnal variations of the equatorial neutral atmosphere density, composition, and temperature for correlation with AE-C (Explorer 51) data for studies of the physics and dynamics of the thermosphere.

In accordance with the terms of the Memorandum of Understanding, each agency will use its best efforts to carry out the following responsibilities:

- Refurbishment of the second flight unit of the San Marco III satellite, including ground testing and integration of the satellite with the Scout vehicle;
- Provision of a "drag balance" for the satellite;
- Shipment of the satellite to the NASA Goddard Space Flight Center (GSFC) for integration of the two NASA-supplied spectrometers and temperature measurement package;
- Travel and per diem support for CRA personnel at GSFC for integration activities and subsequent data correlation;
- Assembly, check-out and launching of the Scout vehicle including range safety;
- Operation of the Italian control center for real time data coverage following launching;
- Maintenance of the San Marco Range facilities and their modifications as required by the San Marco C-2 launch;
- Tracking and data acquisition from the Italian MITS station in Kenya and possibly an ESRO station at Singapore;

- Long distance communications from MITS to GSFC and for MITS and Singapore operations and for a quick look data exchange system for comparison with Atmosphere Explorer data.

- Logistics, spare parts, materials cost and shipment from the US (or Italy) to Kenya of all materials including transport of the Scout vehicle from the US to the San Marco Range.

- Analysis of the data from the CRA "drag balance" and participation with NASA in correlative analysis between data from San Marco and the neutral atmosphere measurements made from the Atmosphere Explorer satellite.

- Provision of spacecraft attitude data and provision of these for use by NASA.

NASA will:

- Provision of a neutral mass spectrometer and a temperature and density measurement package for the San Marco C-2 spacecraft;

- Provision of a Scout launching vehicle including heat shield, spacecraft tie-down and separation mechanism and vehicle spare parts, and, transport to US port of embarkation;

- Tracking and data acquisition support of suitably located STDN stations and at other locations for telemetry support as may be required and mutually agreed;

- Technical consultation as mutually agreed upon by CRA and NASA;

- Analysis of data from the US spectrometer and temperature measurement package and participation with CRA in correlative analysis between data from San Marco and the neutral atmosphere measurements made from the Atmosphere Explorer satellite.

NASA MISSION OBJECTIVES FOR SAN MARCO C-2

PRIMARY OBJECTIVE

- To obtain measurements of the diurnal variations of the equatorial neutral atmosphere density, composition, and temperature.

SECONDARY OBJECTIVE

- To utilize these data for correlation with AE-C (Explorer 51) data for studies of the Physics and dynamics of the thermosphere.

John R. Holtz for / N L Johnson

Alois W. Schardt	John E. Naugle
Director, Physics and Astronomy Programs	Associate Administrator for Space Science
Date: 2/13/74	Date: 2/13/74

SPACECRAFT DESCRIPTION

GENERAL

The San Marco-C spacecraft is a 70 cm. diameter sphere with four canted 48.5 cm. 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 170 kg.

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-2 SPACECRAFT

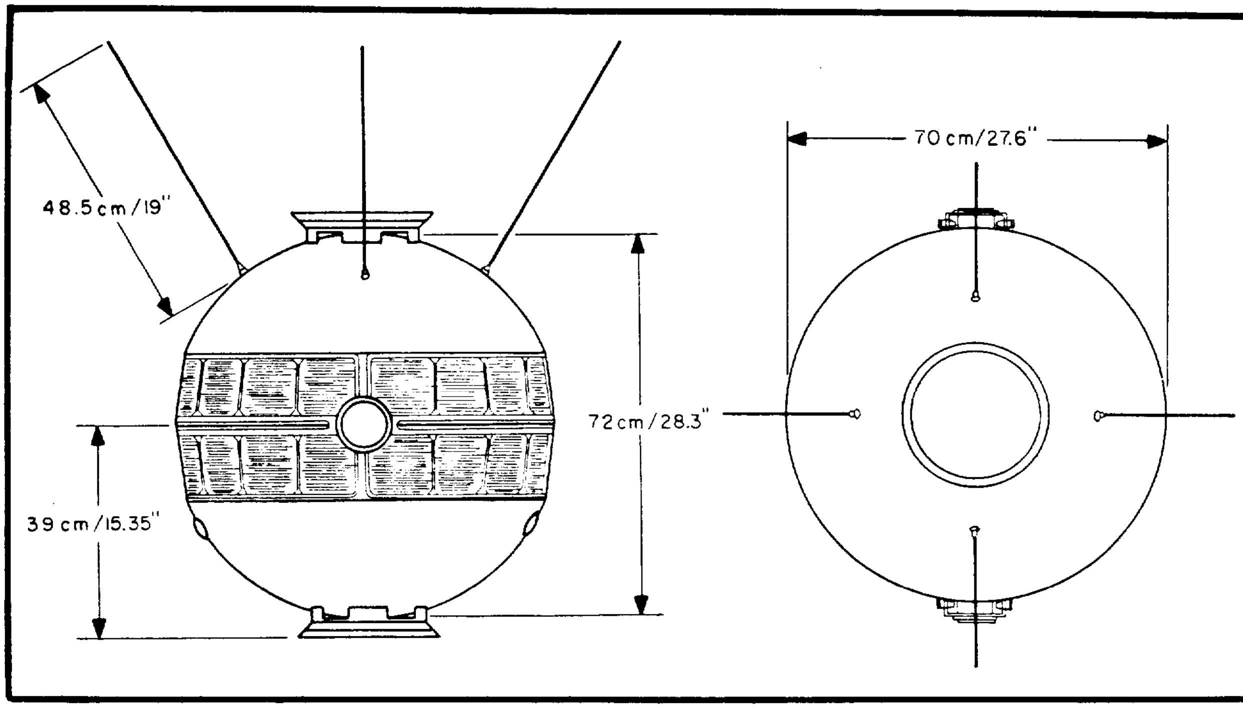


Fig. 1

DRAG BALANCE

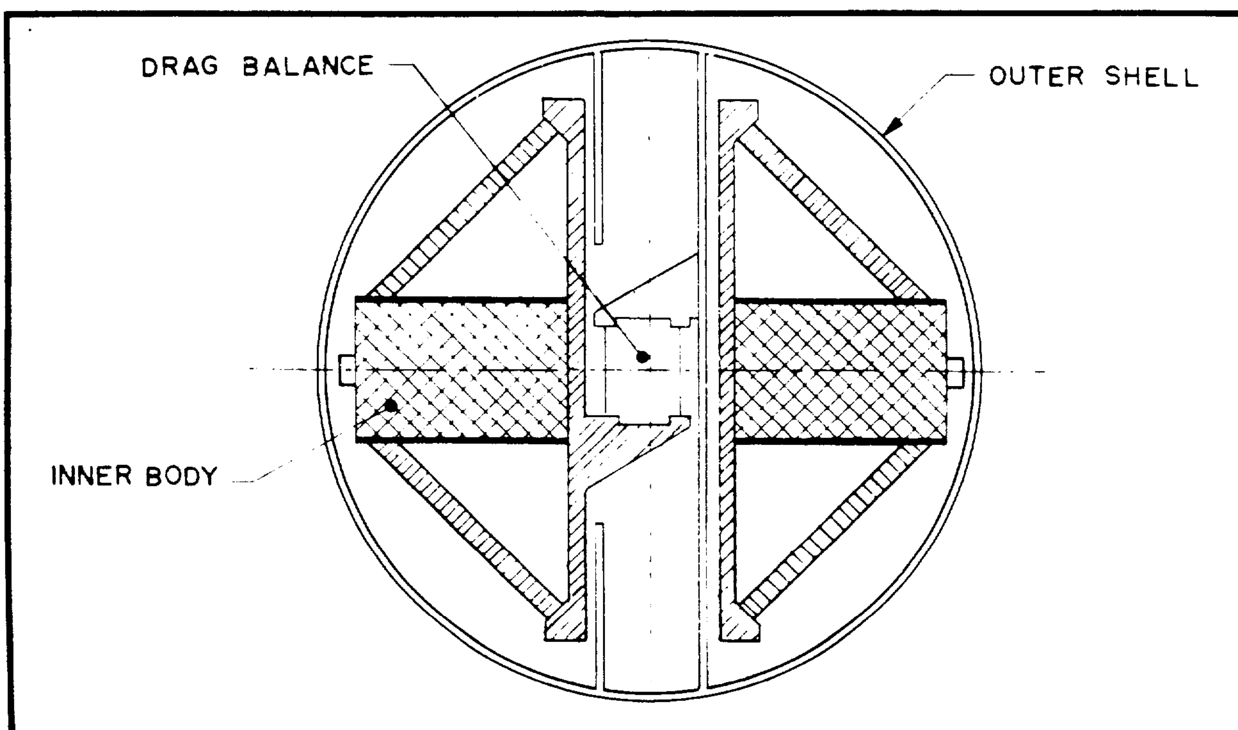


Fig. 2

SAN MARCO C-2 GENERAL ASSEMBLY (Inner Body)

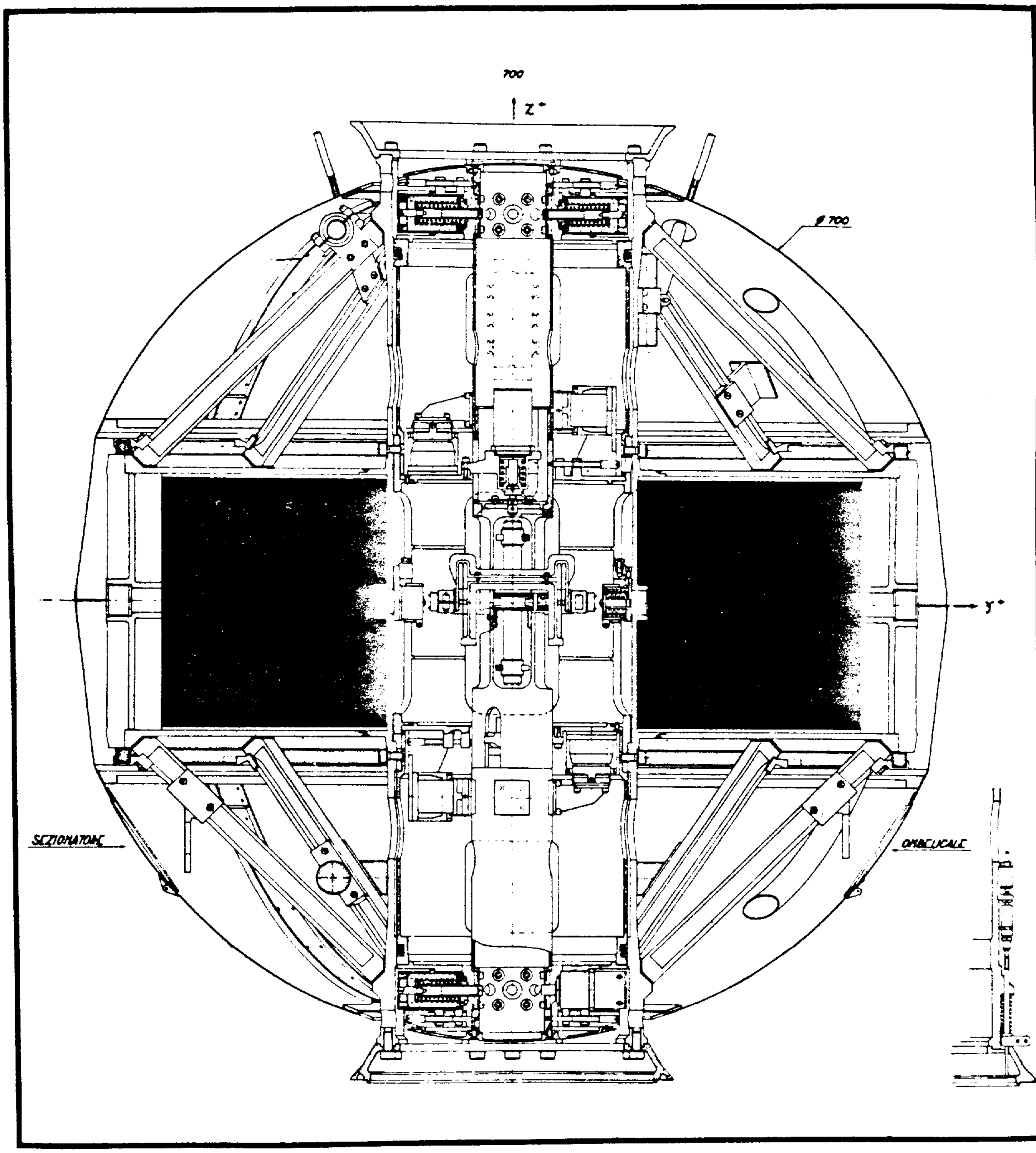


Fig. 3

BALANCE ASSEMBLY

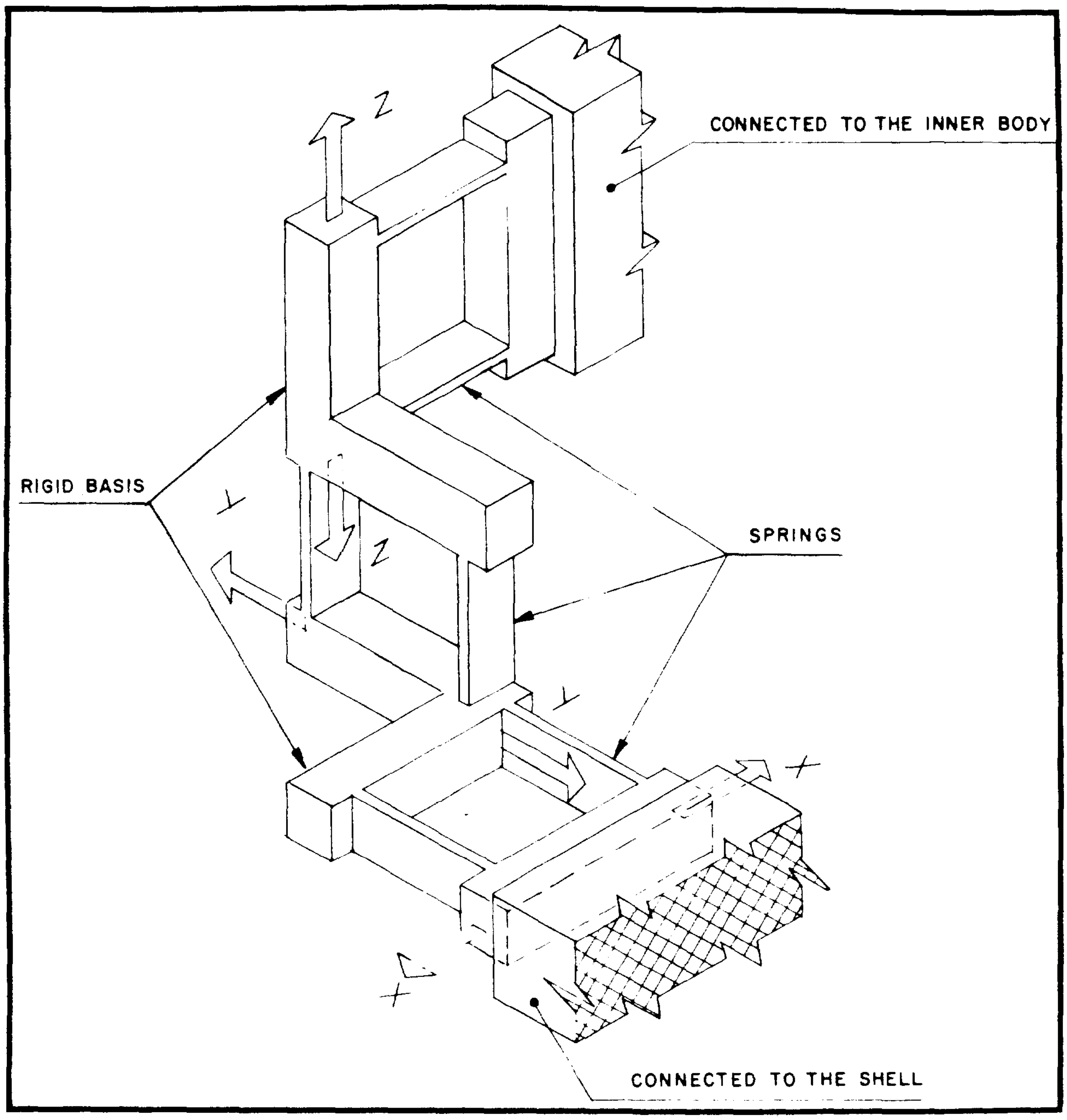


Fig. 4

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 14.7 kgs. 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

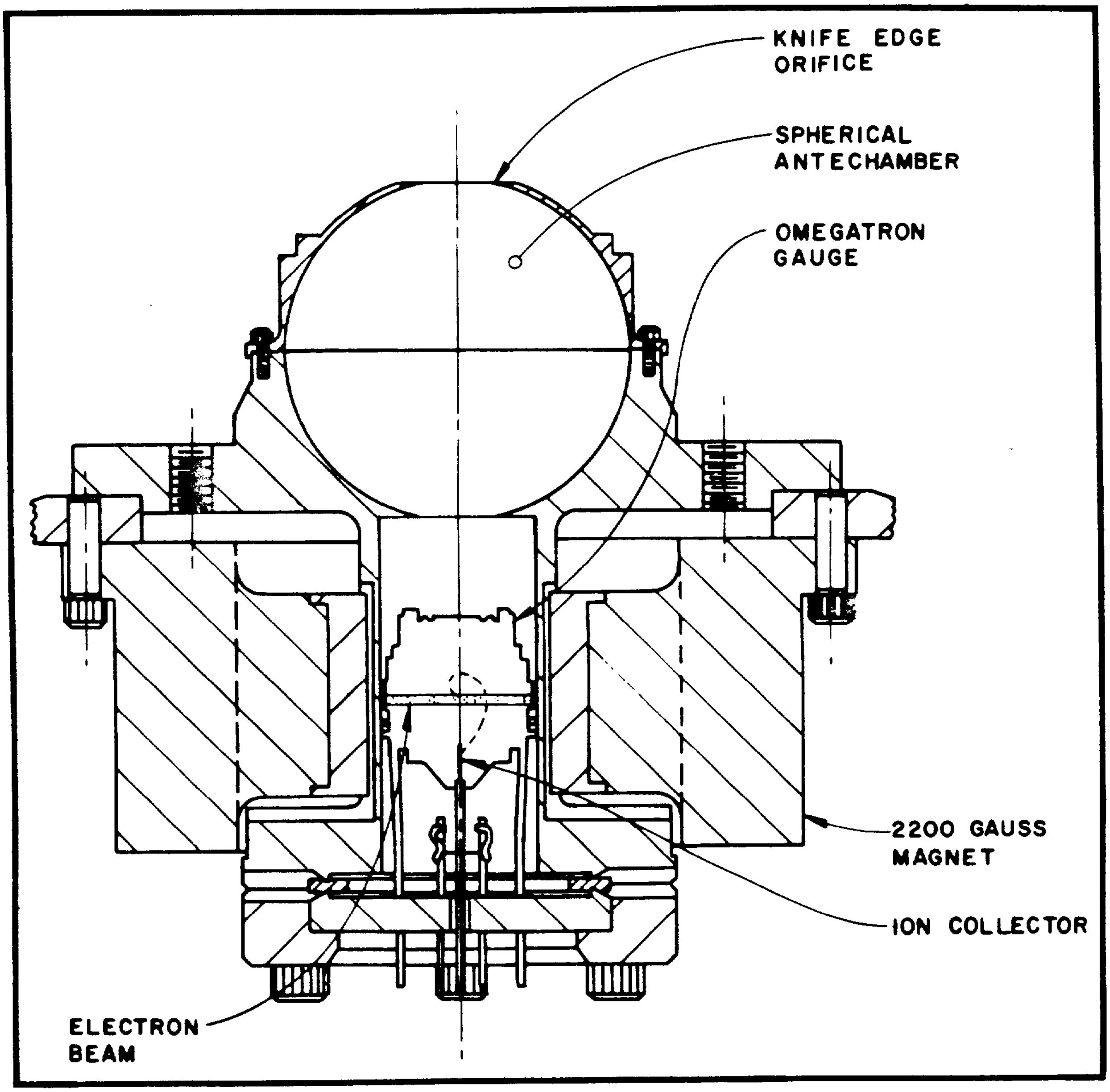


Fig. 5

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 14 kg and requires 12 watts, three elementary data channels, and seven commands.

The mass spectrometer, similar to those flown on Explorers 17, 32, and 51 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

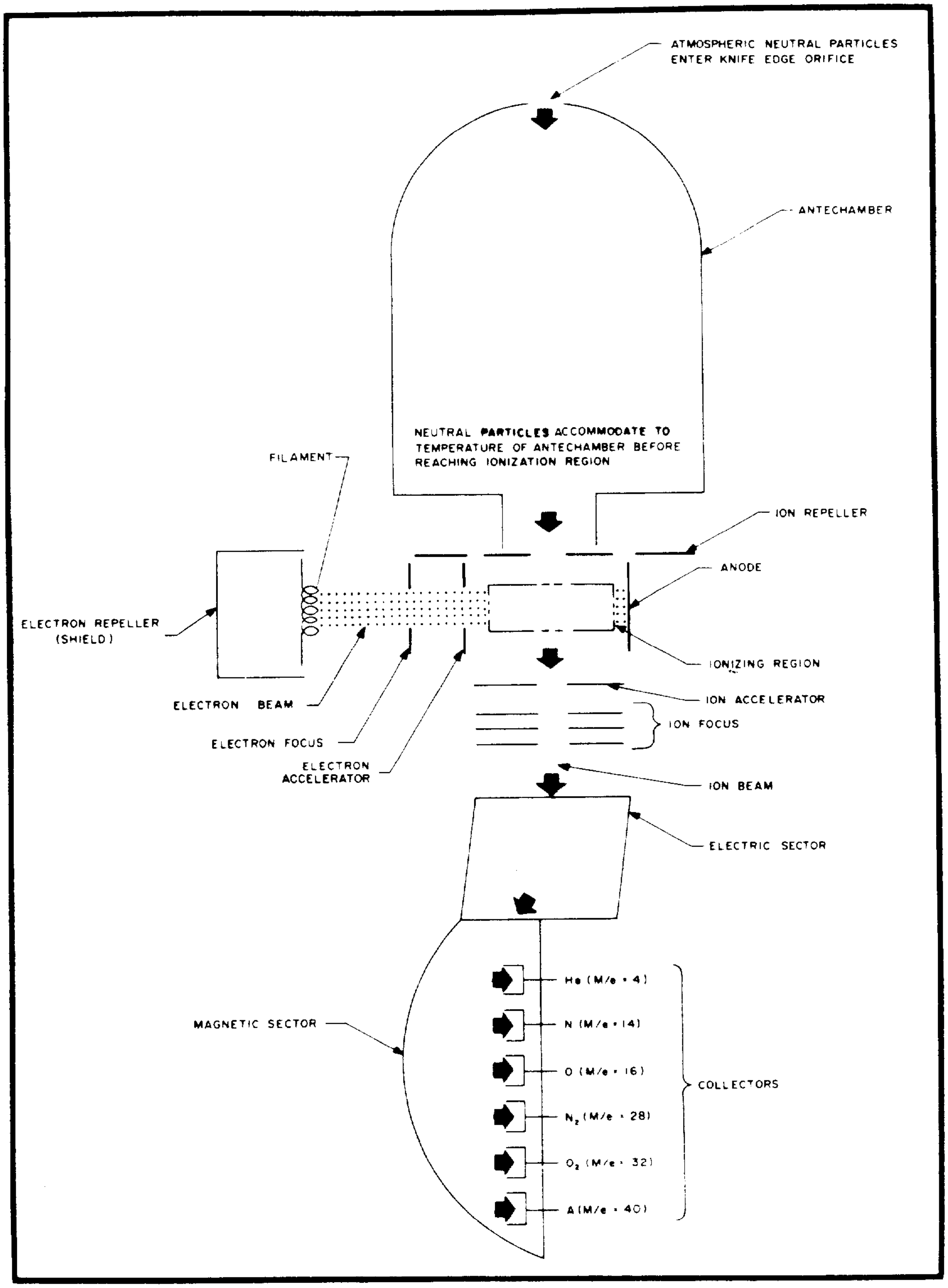


Fig. 6

LAUNCH VEHICLE DESCRIPTION

The launch vehicle for the SM-C is NASA Scout vehicle S-190C. 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.

SCOUT LAUNCH VEHICLE

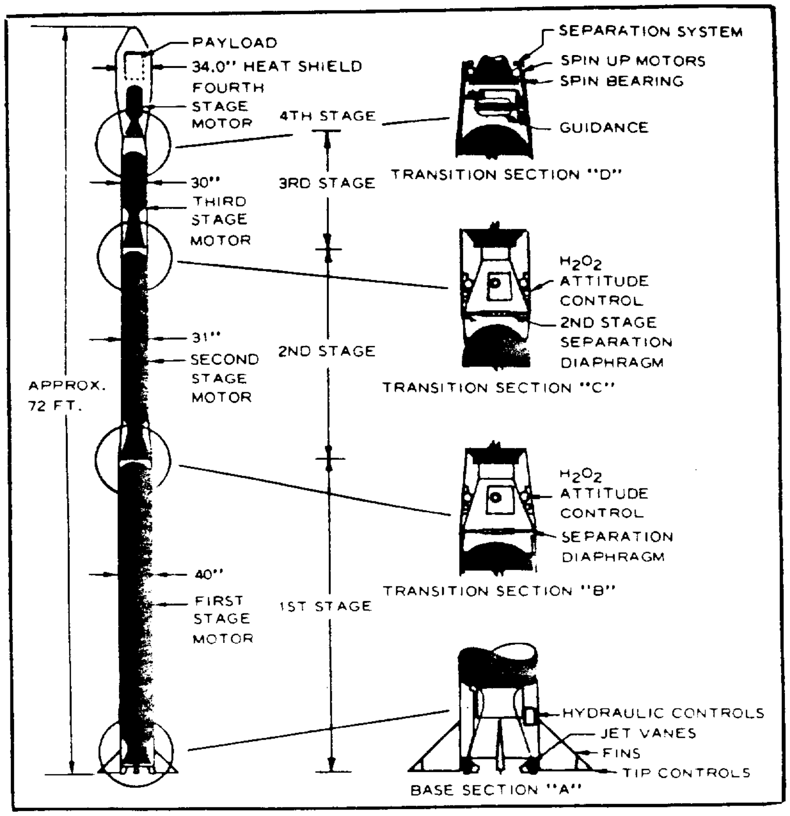


Fig. 7

Motor Designation	Total Impulse (lb-sec vacuum)	Avg. Web Thrust (lb-ft vacuum)	Burn Time (sec)	Total Weight (lb mass)
First Stage: ALGOL 111A	7,268,578	107,168	80.26	31,406
Second Stage: CASTOR 11A TX-354-3	2,308,231	61,839	40.00	9,808
Third Stage: ANTARES 11A X259 - B3	719,202	22,024	36.65	2,802
Fourth Stage: ALTAIR 111A	172,049	5,349	30.97	664.1

SEQUENCE OF EVENTS

The sequence of events is shown in the following table:

Time after Lift-off (seconds)	Events
	Lift-off
80.13 86.28	Stage 1 burn-out, stage 1 separation, Stage 2 ignition
126.27	Stage 2 burn-out
184.57	Heat shield separation
186.27	Stage 3 ignition, stage 2 separation
222.92	Stage 3 burn-out
324.05	Spin-up, stage 4 squib ignition
325.55	Stage 3 separation
330.40	Stage 4 ignition
361.37	Stage 4 burn-out
395.55	Despin
625.55	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

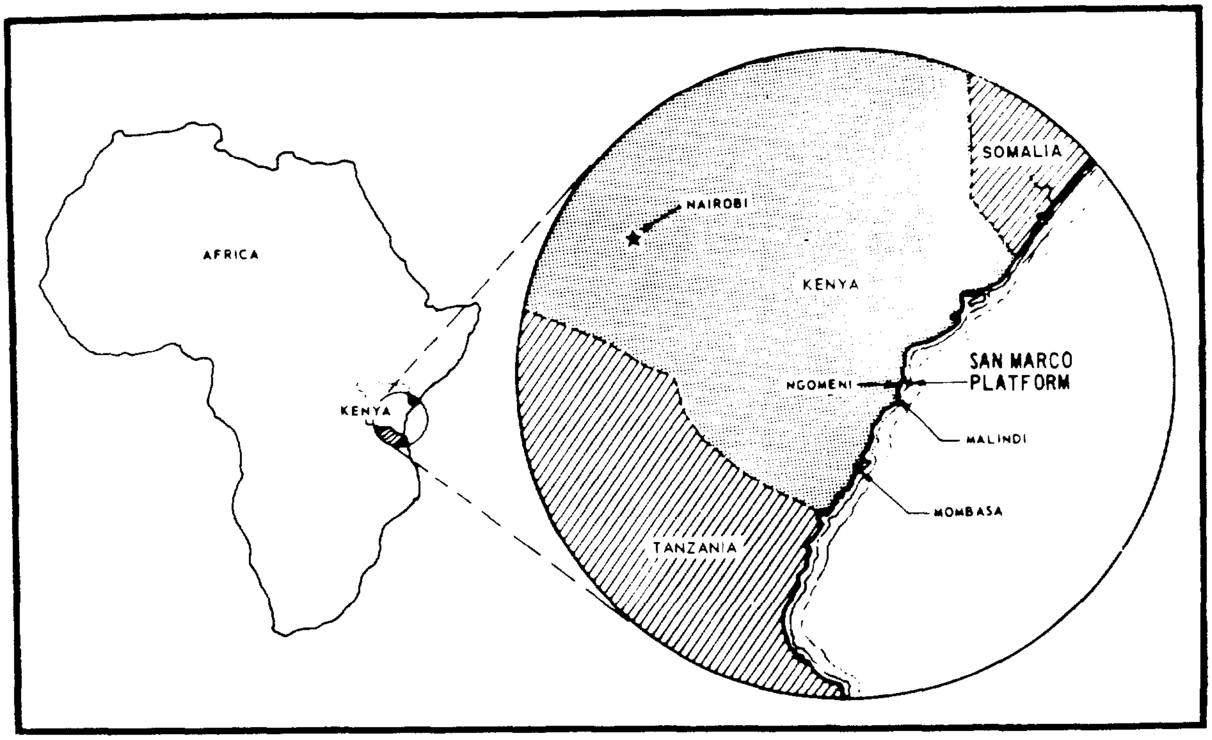


Fig. 8

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

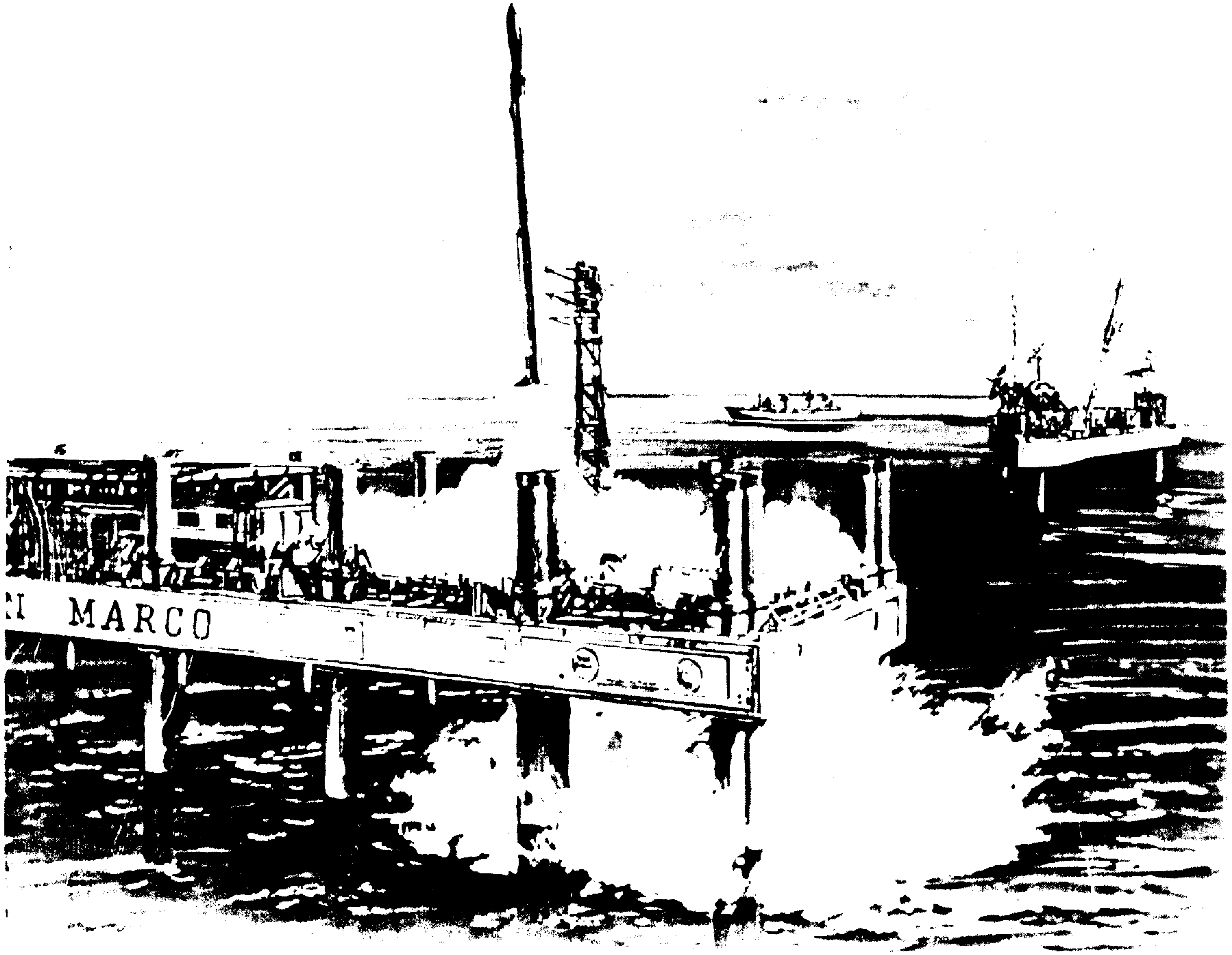


Fig. 9

S-894-74-04

NOMINAL SUBSATELLITE PLOT

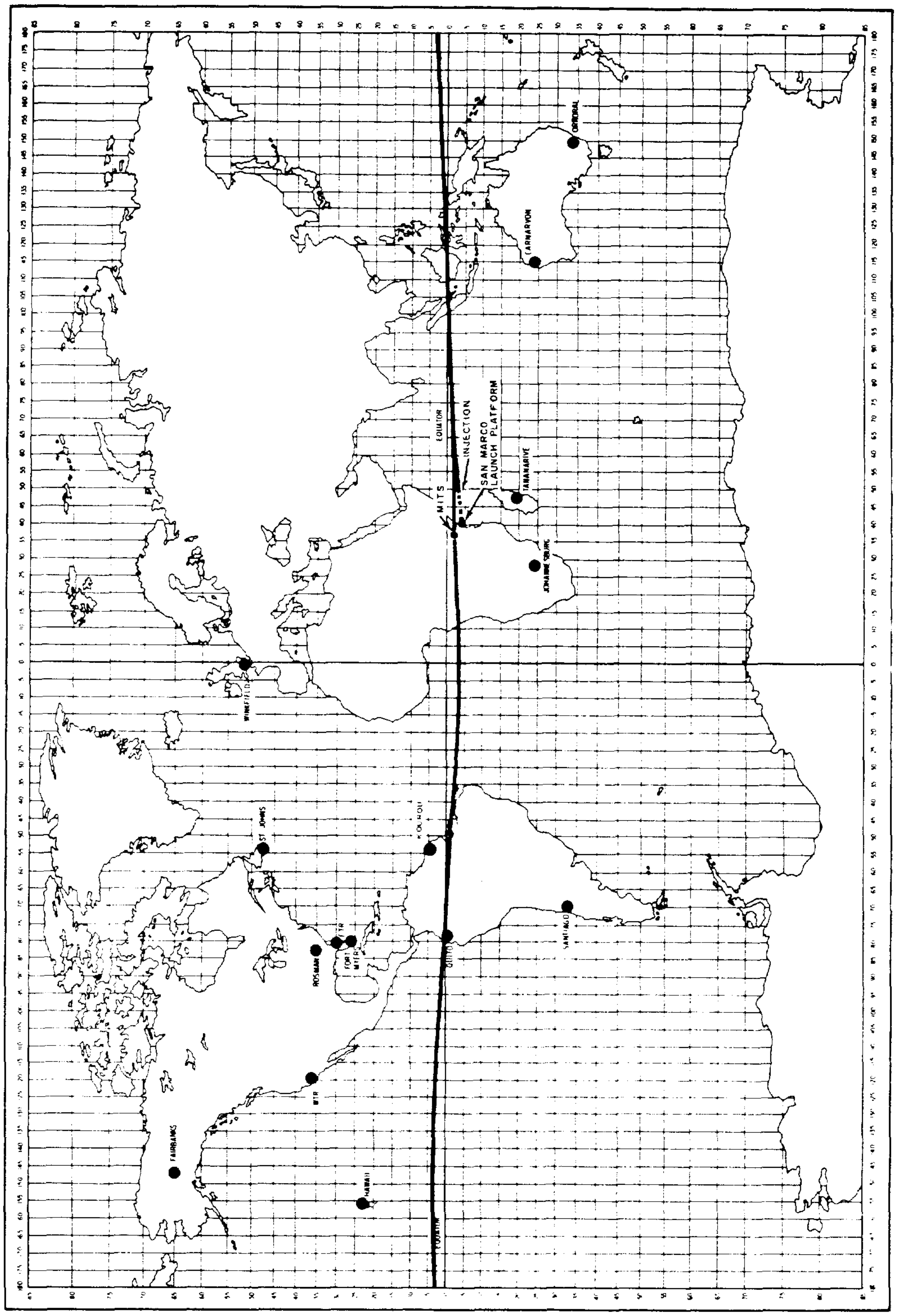


Fig. 10

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-2 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-2 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
Director, Physics and Astronomy	Dr. A. Schardt	NASA Headquarters
Program Manager Atmosphere Explorer/San Marco	Frank W. Gaetano	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-2 Project Manager	A. J. Caporale	Goddard Space Flight Center
San Marco C-2 Project Scientist	G. P. Newton	Goddard Space Flight Center
Scout Project Office Manager	R. D. English	Langley Research Center

SAN MARCO C-2 PROJECT COSTS

(in thousands)

Fiscal Year	Spacecraft Support	Science Support	Scout Vehicle	Total
1974	10	60	1,300	1,370

GPO 871-779