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S. Marco Project and the Italian Equatorial Launch Site

by

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THE SAN MARCO PROJECT

Generalities

The San Marco Project (SMP), has been created the 30th of May, 1962 by the signature of a "Memorandum of Understanding" between the University of Rome (UR) "La Sapienza" and the "National Aeronautics and Space Administration" (NASA), approved by the Governments of Italy and USA (7th September 1962), in order to cooperate in Space Research Programs.

The originator and Director of the Project, Prof. Luigi Broglio, promoted and initiated space researches in Italy through the University of Rome. The related activities took place both in Rome (where the research and study centers, laboratories and test facilities for satellites design, integration and flight acceptance are located) and abroad, particularly in Kenya where the UR has established the San Marco Equatorial Range (SMER) for space launches and satellite telemetry support (fig. 1).

The Government of Italy funds the Project. As a Government entity, the UR is solely responsible of the SMP and avails itself of a high degree of autonomy in selecting and implementing space research programs at national and international level.

Since the beginning, the SMP has developed and maintained active fruitful and mutually advantageous cooperative programs mainly with NASA and, in due time, with several Italian and foreign organizations such as European Space Agency (ESA), Italian Air Force (AMI), National Council of Research (CNR), Italian Space Agency (ASI), American and European Universities (Dallas, Michigan, New Hampshire, Max Planck Institut, etc.).

Facilities

The SMP established in Kenya since 1964 the SMER for launch operations and satellites support. The SMER is equipped with launch facilities capable to accomplish orbital and sub-orbital (sounding rockets) launches for scientific payloads.

The location of the range is close to the Equator, in the Indian Ocean (Ngwana Bay) at 2.9 degree South and 40.2 degree East, close to Malindi Town (fig. 2).

The SMER consists of two segments: sea segment and land segment. The sea segment is composed of three mobile "off-shore type platforms (fig. 3), namely: The "San Marco", where vehicle assembling, testing and launching operations are performed, the "Santa Rita" where communication, vehicle telemetry, command-control and meteo station equipment are located, the "Santa Rita II" for Radars equipment (surveillance and tracking).

Other two small platforms contain the electrical power generation plant. All platforms are standing on their own steel legs above the sea level (10 to 14 meters, depending on tides), and are connected by submarine cables (power and signals).

The distance between Santa Rita and San Marco Platforms (about 1 Km) is enough to provide the proper safety conditions at rocket ignition and lift-off. Each platform is self sufficient and fully equipped with personnel accommodation and services.

The land segment (Base Camp) (fig. 4) is the main support to the SMER and is located at about 45 minutes boat-ride from the platforms and 60 minutes car-ride from the Malindi airport. At the base camp are also located the S,L,X bands and VHF-band telemetry stations.

The Equatorial location of the range offers to the users unique and remarkably advantageous features such as:

> <u>the equatorial position</u>, where the Earth spinning rate gives the maximum contribution to the due-East launches while the equatorial position allows to achieve any orbit inclination (from equatorial to polar), provided they are complying with the flight safety regulation,
>
> <u>the mobility</u>, very important and useful capability because puts the range in an autonomous condition with respect to the local situation, furthermore the platforms steel structure life has been recertified up to 2014,
>
> <u>the environment</u>, being always temperate, this allows to launch almost all year around,
>
> <u>the flight safety</u>, due to the geographic position the ground path of the initial trajectory of the rocket, being on the ocean, has no limitations for due East launches concerning populated areas, some limitations apply for highly inclined orbits,
>
> <u>the accessibility</u>, the ship can off-load directly on board the platforms avoiding road transportation,
>
> <u>the cost reduction</u>, is assured by the skills, which includes studying, designing, testing, assembling, checking and launch operations,

The SMER with its powerful telemetry station, together with a satellite, in equatorial orbit, equipped with a recorder, constitute an autonomous space system.

At the present time the SMP is making all possible effort to undertake a program to upgrade the launch capability.

History

The first San Marco spacecraft (San Marco 1) was launched from Wallops Island (15 December 1964) by an Italian crew while the first launch operation from SMER occurred the 26th of April, 1967 (San Marco 2). Since 1964, a number of sounding rockets launches have been performed, often in cooperation with other scientific organizations and for world wide interest type of missions (such as 1980 solar eclipse). After San Marco 1, nine satellites have been put into equatorial orbits, some of them as international cooperation, particularly with USA, UK and Germany.

Four NASA satellites (for x and γ rays astronomy) have been launched from SMER. One of these satellites (Uhuru) led to the discovery of the black holes in the Cygnus-X1 constellation. Also the UK5 satellite for x-rays astronomy was launched from SMER.

One of the reasons why the USA and UK selected SMER for these launches is because of its particularly favorable position with regard to the lower Van Allen Belt. These spacecraft were all put successfully into orbit and the data collected have been of great importance to the scientific world, in the field of astronomy.

The SMP has designed, fabricated and launched 5 scientific satellites. All launches have been entrusted to and performed by the Italian launching team consisting of highly skilled engineers and technicians many of them coming from the Italian Air Force. There have been no failure during these 30 years of the SMP activities.

The SMP vehicle programs

Up to now, the vehicle used has been the standard Scout rocket which achieves a reference orbit (equatorial, circular at 550 Km) with a payload of about 210 Kg.

Presently no space vehicles are available in Europe and in USA for covering the intermediate weight range (from 400 to 800 Kg) which is considered the optimum for scientific missions and survey and also for the future telecommunication system based on many satellites of medium weight.

Italy is now studying and pursuing the possibility to acquire an autonomous launch capability for small/medium size payloads; this target can be reached in two different ways: to build a completely new vehicle or to built one which utilizes well proven standard subsystems coming from Scout G1 or from other highly reliable vehicles.

The UR has proposed the second solution that seems particularly attractive and, if accordingly funded and sustained by the Italian government, in medium terms Italy will be able to offer to the national and international scientific space research community, complete launch services at low cost.

To this intent the SMP has studied and proposed a new vehicle called "San Marco Scout" (SMS) with 4 or 5 stages. The SMS with 4 stages (fig. 5) consists of a standard Scout without the fourth stage motor (Altair III) and with the addition of four Algol IIIA rocket motors which will function as its first stage.

This configuration is fully guided. The 5 stage version (fig. 8) differs from the 4 stages one since it foresees the utilization of the Altair III as the fifth spin-stabilized stage motor.

The 4 stages SMS can be conveniently utilized for low altitude orbits (figs. 6 and 7) for payloads ranging from 400 to 800kg, while the 5 stages is suitable for high elliptical orbits (multistationary, transfer orbit for geostationary satellites, etc.) for 170kg. 10 Earth radii apogee payloads (figs. 9, 10).

The SMS vehicles will have a reliability very close to the standard Scout, since they are based on the assembly of existing and well proved parts. The accuracy will be very high since the first four stages are fully guided and controlled. These satellites will increase the performances of the applications for remote sensing, scientific research and telecommunication.

Orbits and missions possible from SMER

It seems that the market is moving to commercial small satellite application with the addition of "revisited" approach for small scientific payloads. In other words, SMP shall be ready for a new line of flight demands.

The fast growing technical capability, keyed on more and more miniaturized systems, makes small satellites very attractive for Low-Earth-Orbit (LEO) communications, remote sensing, technology demonstration and scientific missions. In order to cover the above items of general interest, small and medium mass satellites would be the best choice due to the economic convenience, the shorter design and accomplishment time (call up time).

The SMER location and facilities allow the achievements of type of orbits, which hold significant importance in the above mentioned field of application, particularly for astronomical research (i.e. solar physics) because the experiments are not affected by the Van Allen lower belt disturbing effects; furthermore the LEO (500-600km circular) telecommunication mission needs less RF transmission power and reduces the time delay of traveling waves.

The orbit plane inclination and the kind of commercial payloads which can be lifted off from the SMER, with a S. Marco Scout class rocket, are indicatively reported below:

Orbit: Equatorial LEO (600 Kg) - small satellite -

Communication: Two ways messaging and vehicle tracking services; mobile phone services to be integrated with the major global systems, etc.

Remote sensing: Agro-meteorological survey of tropical zones; rainfall and atmosphere monitoring; multitemporal/multispectral Earth surface observation; agro/meteo/climatological model validation and studies; environmental monitoring; fish tracking, off-shore engineering, etc.

Technology demonstration: New high resolution sensor for remote sensing; ocean-color sensor for real time sea current; navigation accuracy tests; any new lighter and cheaper subsystems such as memory units, gyros, computers and increased-area solar cells, etc.

Scientific: Any university-based proposal for low cost science mission; aeronomy, multispectral sky observation; trapped particle radiation-free measurements; Thermosphere - Ionosphere - Mesosphere energetics and dynamics; high energy solar physics, etc.

Low inclination circular (< 10 degree) LEO (500 Kg)

Remote sensing, communication, science: As for the equatorial LEO but with the necessary compromise between the repetition cycles and the larger coverage needs.

Multistationary, equatorial elliptical (400-29000 Km) (250 Kg)

Communications: A system of 4 satellites can meet all the communication requirements for world-wide coverage (polar areas excluded), etc.

Technology demonstration: Radiation effect on electronic devices and components; navigation, etc.

Equatorial, elliptic (apogee at 10 Earth radii) (170 Kg)

Scientific: Plasma and magnetosphere measurements, etc.

Low inclination elliptic

Scientific: Global solar-terrestrial physics, etc.

For the above said reasons it is obvious that in the near future the need of the small and medium mass satellites will increase. SMER is optimized (therefore convenient) and finalized for this kind of requirements.

SMP missions proposal

The SMP proposed some satellites which, through remote sensing, perform land survey. This would help the emerging nations for economic planning and for a better knowledge of their own natural resources (agriculture, minerals, census, environment, etc.). One of the most important final purpose of this satellites is aimed at achieving better and more reliable weather prediction models by atmosphere sensing techniques. Data would concern the carbon dioxide, humidity and ozone distribution along the critical and important equatorial area. The SMP proposed two equatorial missions very significant for their current importance and utility, respectively called Tropical Agro-metereological Mission (TAM) (fig. 11) and Clover System (CS) (fig. 12).

The first one (TAM) is based on the fact that the present global climatological model is considered not adequate because the orbits of the existing remote sensing satellites have a very high inclination to the equatorial plane and allow a rather poor repetitive cycle of observation over the tropical region; on the other hand a circular LEO remote sensing satellite slightly inclined (< 10 degree) to the equator plane will give a very satisfactory repetitive observation cycle.

The mission objective is mainly humanitarian and will be accomplished through:

To obtain information for land use in terms of multitemporal thematic inventories, monitoring of vegetative growth and stress phenomena,

To develop new techniques for measuring rainfall by combining the measurement from several instruments,

To estimate vegetation index and surface temperature for large areas as tropical regions with an improved ground and temporal resolution,

To develop data sets for studies of weather forecast models,

To develop data sets for studies of production forecast and crop yield estimate models,

To monitor drought conditions in remote locations.

The second one (CS) is based on the possibility to obtain in a more economical way the complete continuous coverage of the Earth surface (with exception of the polar zones) monitoring, survey and communications.

This system is composed of four satellites in equatorial elliptical orbits 90 degree apart - multistationary - with 8 hours period so that each satellite will remain on the vicinity of the apogee over an Earth point for 6 hours (quasi-geostationary position). The CS is equivalent to a geostationary system that utilizes 3 satellites at 120 degree, but much less expensive.

SMER mission support and data handling

The SMER is equipped and fully capable of the operational support of spacecraft tracking, command-control, data acquisition and evaluation. In particular, the tracking of the "transfer orbit" of the geostationary satellites launched from Kourou, is one of the most useful and important support to ESA.

Due to the transfer orbit period (12 hours) and to the about 90 degree difference in longitude between Kourou and Malindi, the SMER ground station is the first one to acquire the above mentioned satellites in their transfer orbit and, moreover, to have them at their apogee for long time over SMER.

The SMER land segment (Base Camp) is equipped with a telemetry station capable to support satellite in L-band and in S-band, while in X-band the station is equipped only with a tracking chain; in S-band the station is capable to receive and preprocess data (ESA standard) up to 1 Mb/sec.

The SMP is now upgrading the station to give the same possibility to the X-band and, moreover, to receive, record, preprocess, and control the quality by a quick-look system, to generate a CCT (Computer Compatible Tape), to generate pictures coming from any remote sensing satellite up to 120 Mb/sec, or special scientific satellites with a very high bit rate.

The SMP is also increasing the capability of the communication system - voice/data - with a new 30ch 64 kb/sec digital microwave radio link between the Base Camp and Santa Rita platform and between the Santa Rita platform and Kenya network in Malindi KPT (Kenya Post and Telecommunication) through which the SMER can communicate with any location in the world. Furthermore in the near future, a direct satellite communication system will be available.

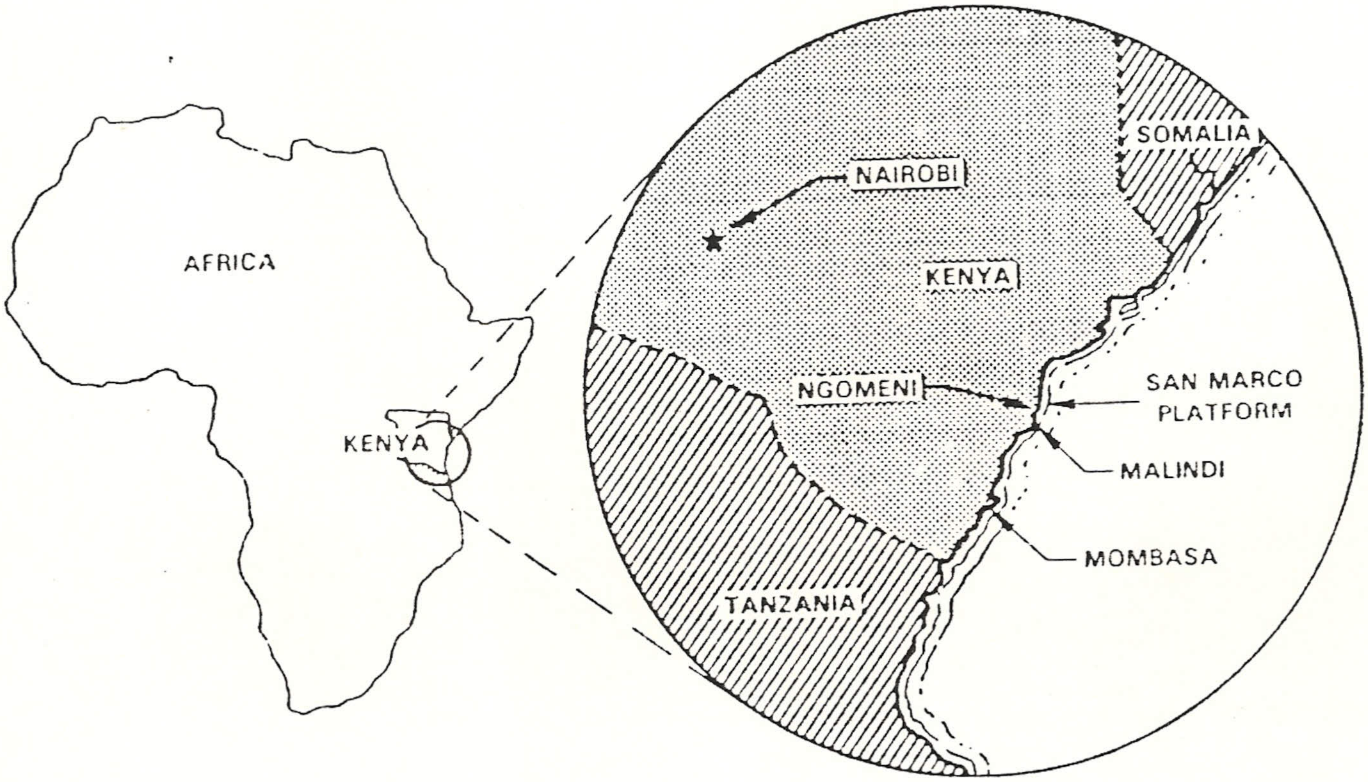


FIG. 1 San Marco Range Launch Site Map

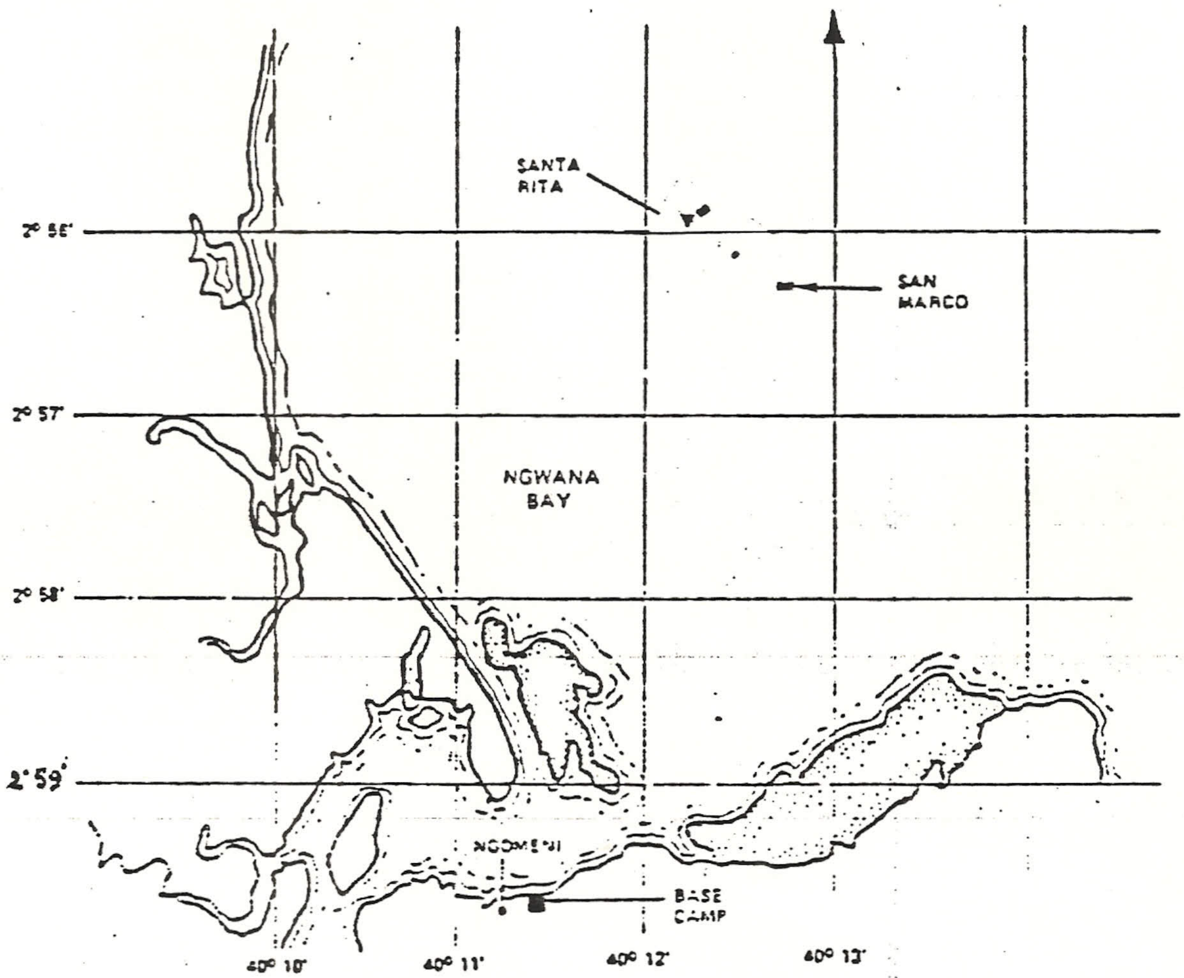


FIG. 2 LAUNCH SITE LAYOUT IN NGWANA BAY

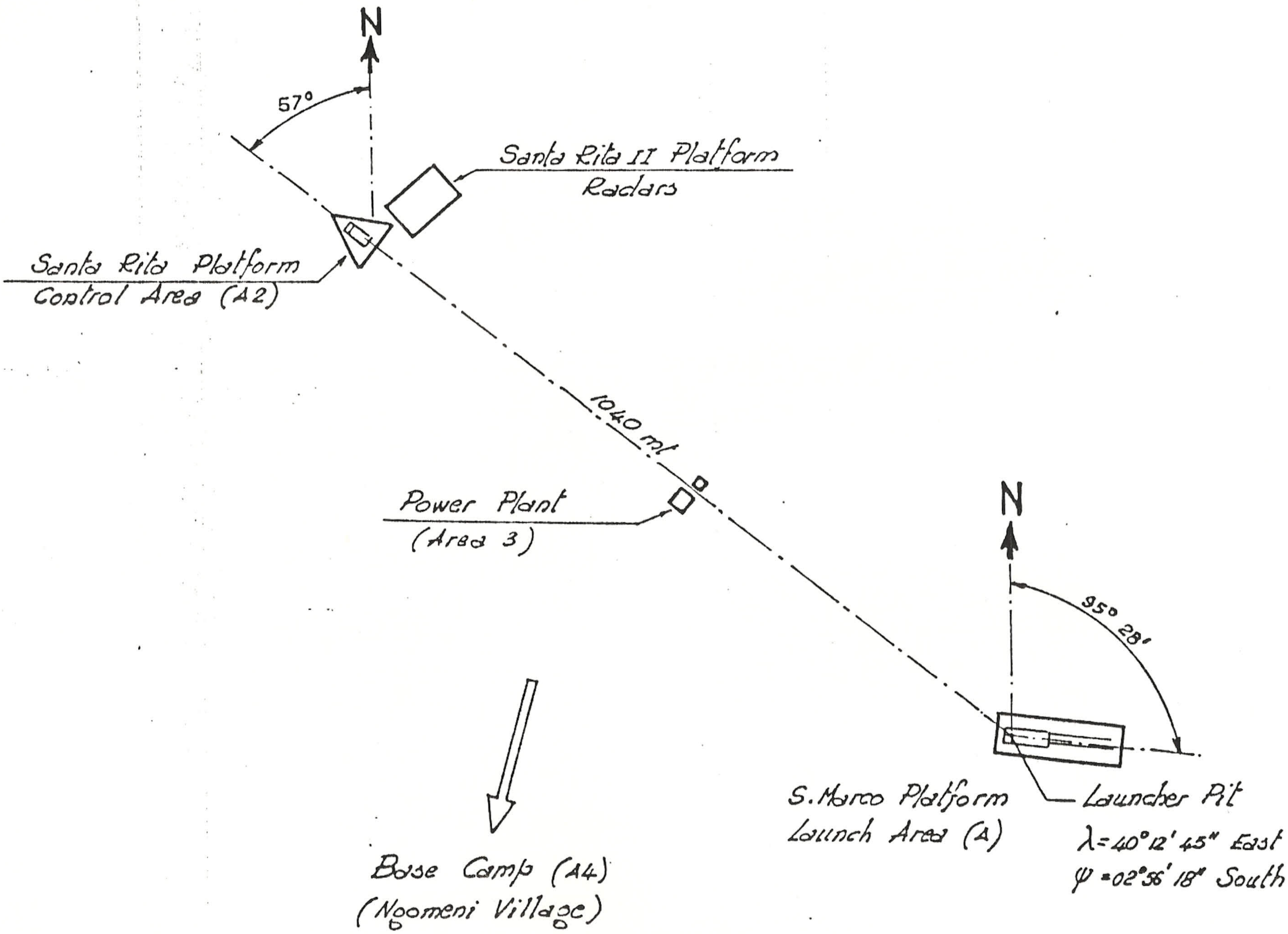


FIG. 3 S. MARCO RANGE CONFIGURATION (new)

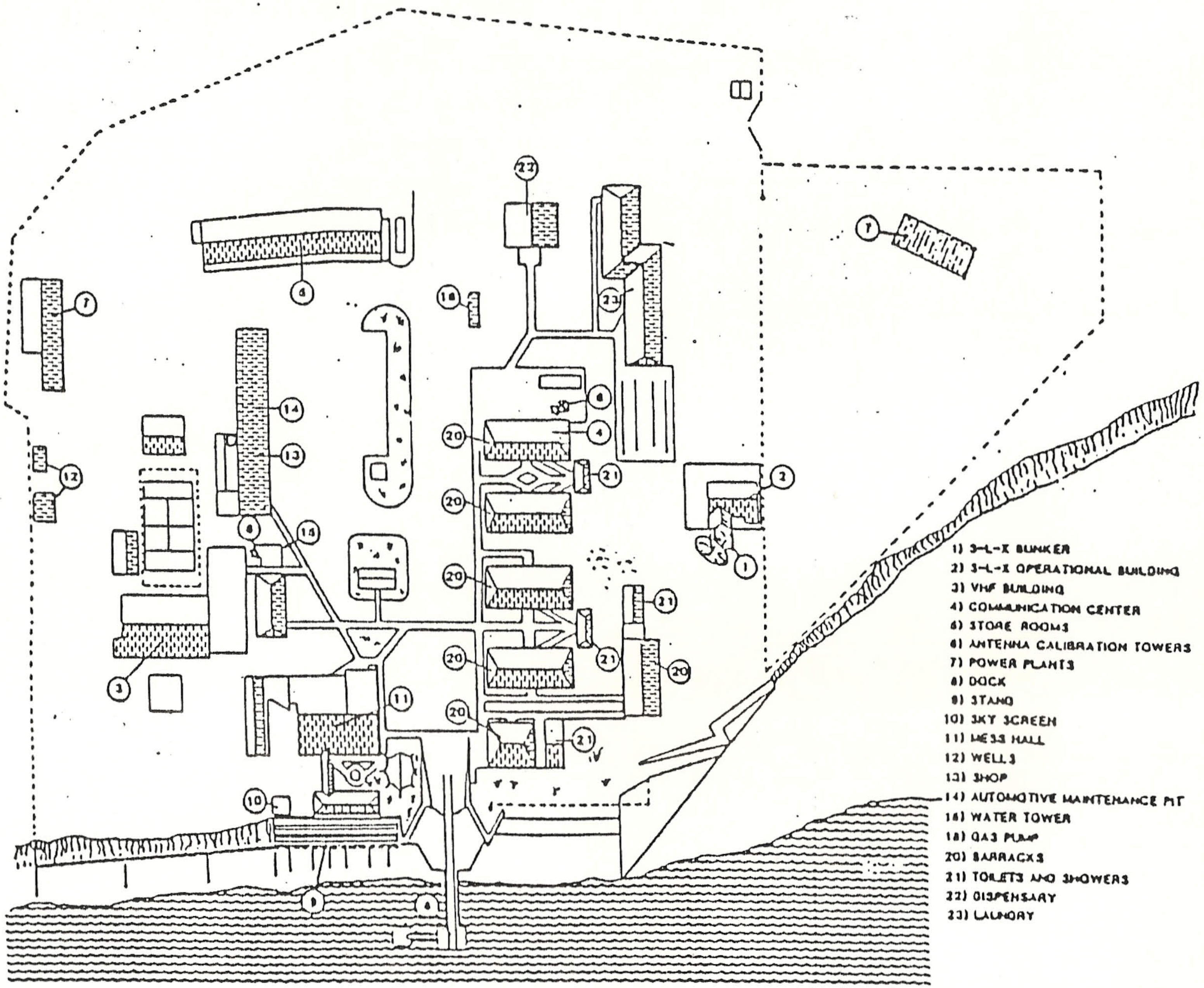


FIG. 4 - Base Camp Layout

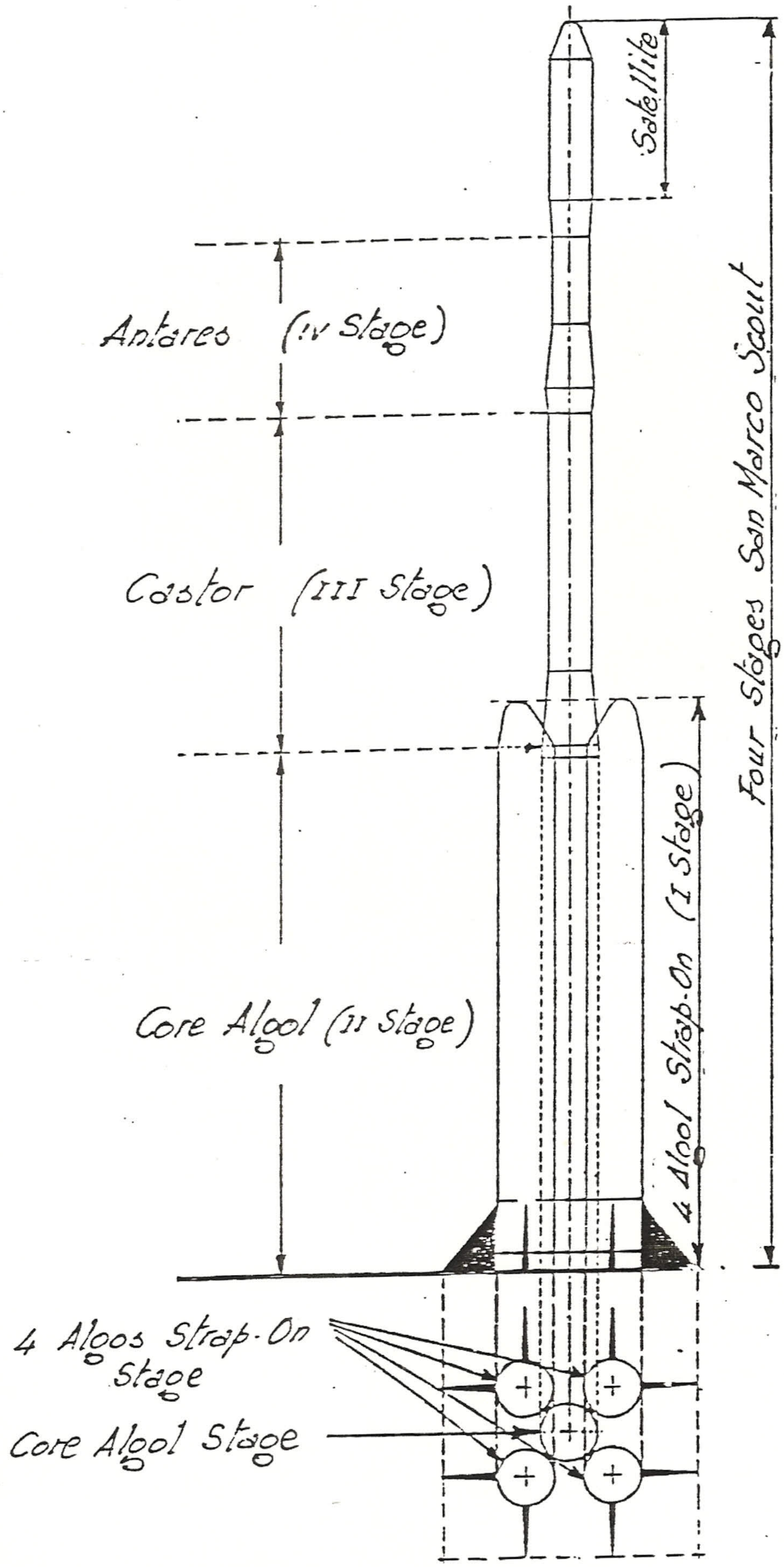
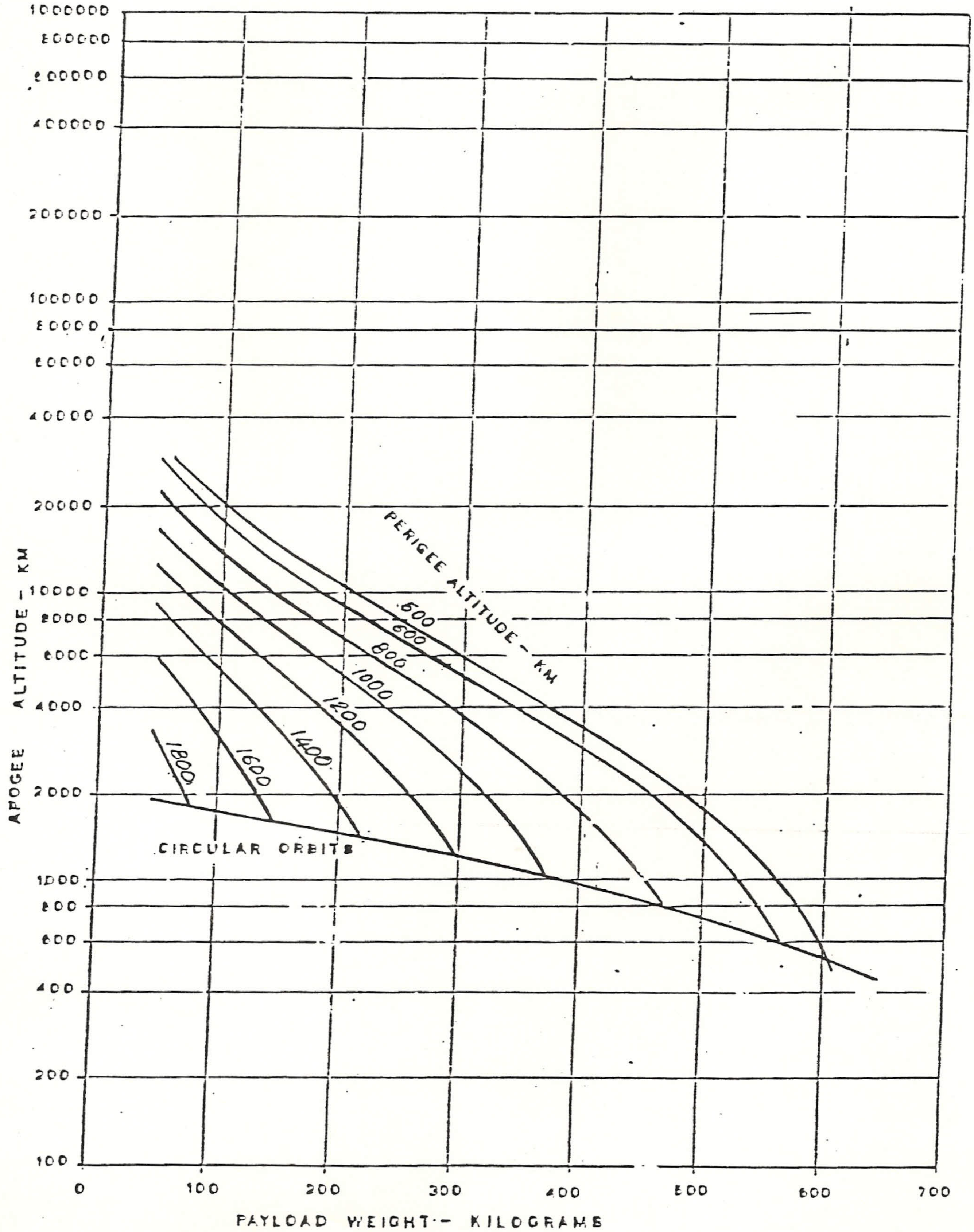

Satellite
Antares (IV Stage)
Castor (III Stage)
Core Algol (II Stage)
4 Algol Strap-On (I Stage)
Four Stages San Marco Scout
4 Algos Strap-On Stage
Core Algol Stage

FIG. 5



SMS 4 STG

FIG. 6 ELLIPTICAL LOW ORBIT PERFORMANCE

SAN MARCO SCOUT VEHICLE (SMS)
(FOUR STAGES)

- VEHICLE DESCRIPTION

  - 1st STAGE - 4 ALGOL III A MOTORS
  - 2nd STAGE - 1 ALGOL III A MOTOR
  - 3rd STAGE - 1 CASTOR II A MOTOR
  - 4th STAGE - 1 ANTARES III A MOTOR

- SMS PERFORMANCE (LOW ORBIT)

- PERIGEE (km)	500	800
- APOGEE (km)	500	800
- INCLINATION (deg)	2.9	2.9
- PAYLOAD (kg)	600	470

FIG. 7

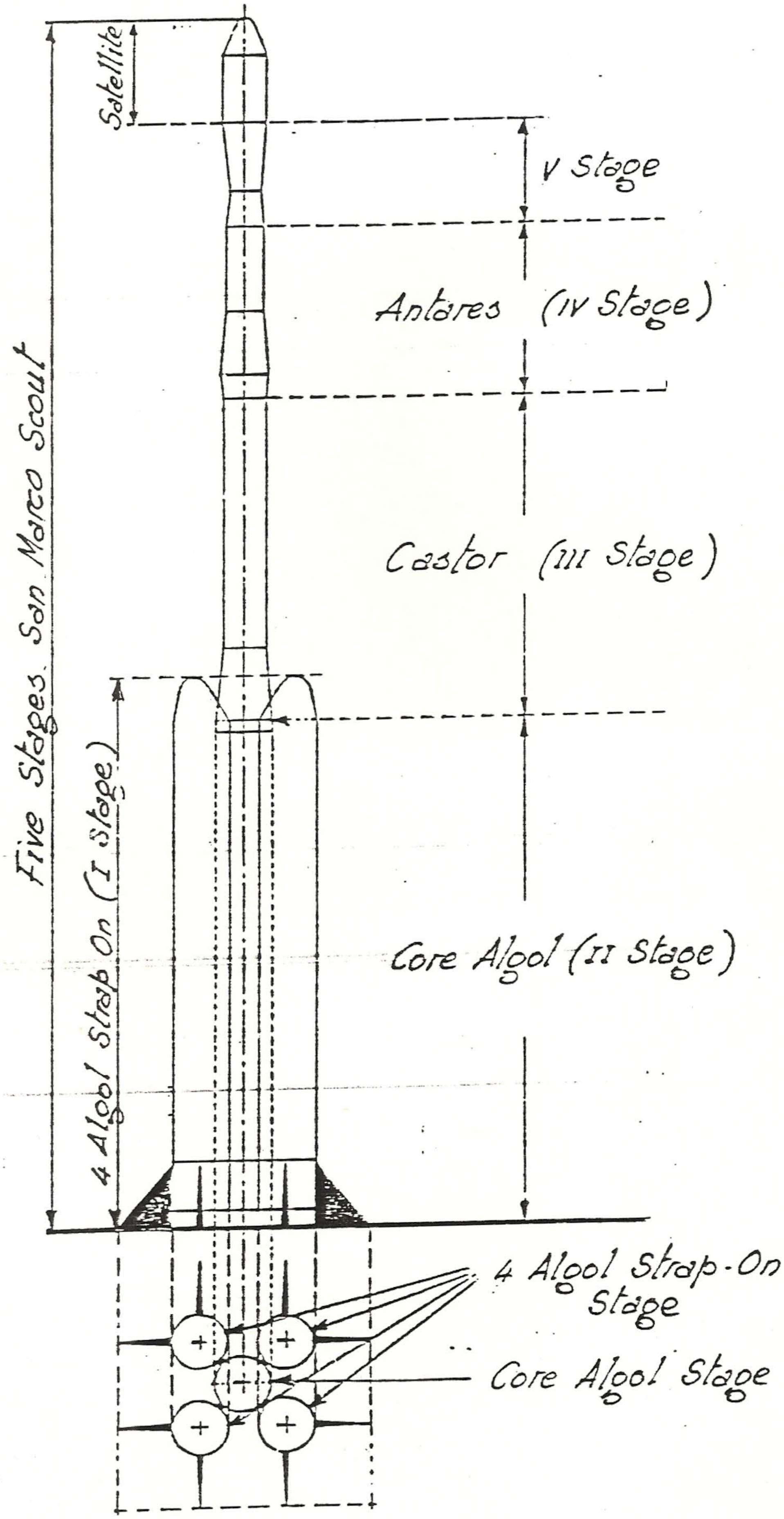
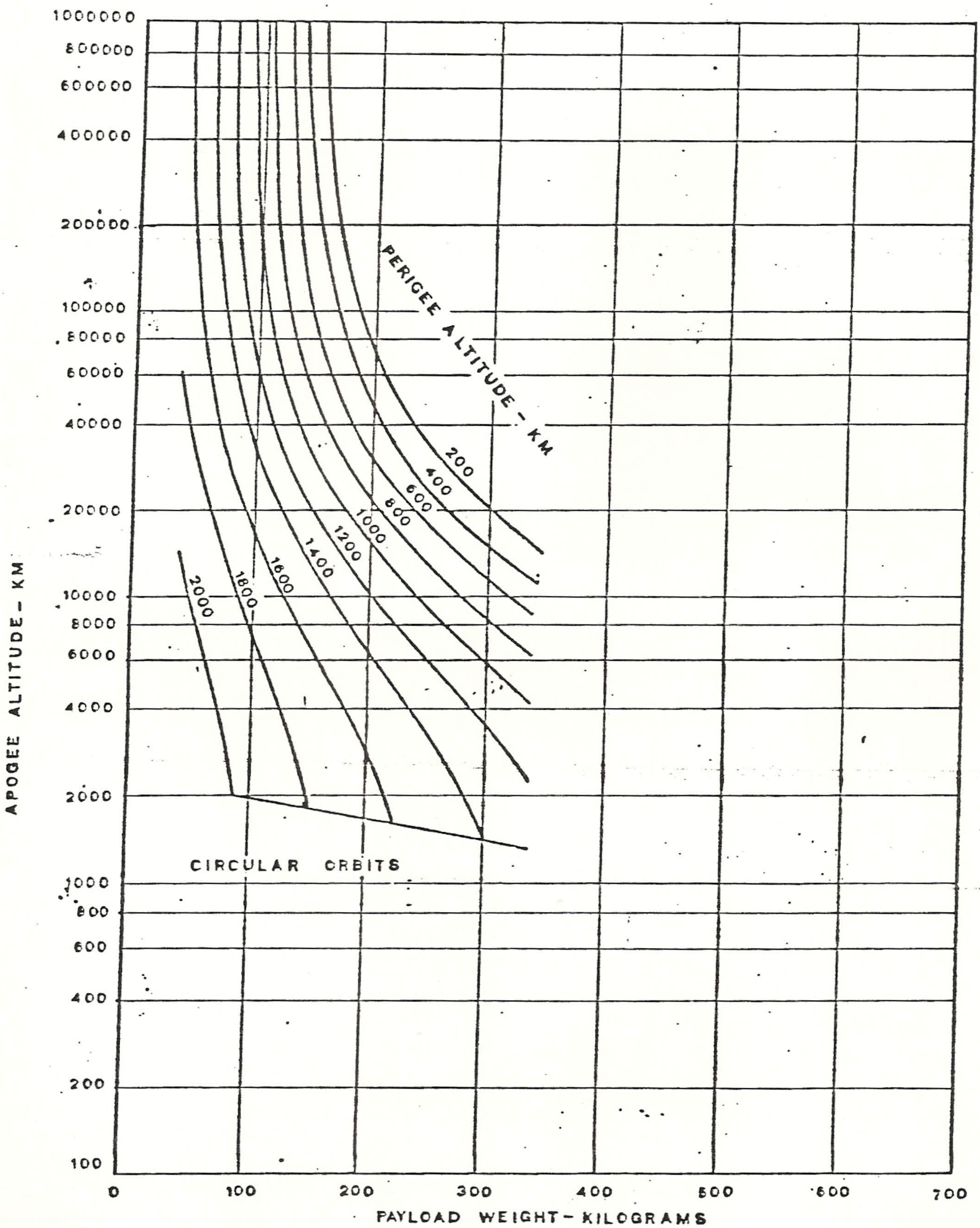

Satellite
V Stage
Antares (IV Stage)
Castor (III Stage)
Core Algol (II Stage)
Five Stages. San Marco Scout
4 Algol Strap On (I Stage)
4 Algol Strap-On Stage
Core Algol Stage

FIG. 8



ELLIPTICAL HIGH ORBIT PERFORMANCE

SMS 5 STG

FIG. 9

SAN MARCO SCOUT - 1 VEHICLE (SMS-1)
FIVE STAGES CONFIGURATION

- VEHICLE DESCRIPTION

  - 1st STAGE - 4 ALGOL III A MOTORS
  - 2nd STAGE - 1 ALGOL III A MOTOR
  - 3rd STAGE - 1 CASTOR II A MOTOR
  - 4th STAGE - 1 ANTARES III A MOTOR
  - 5th STAGE- - 1 ALTAIR III A MOTOR

- SMS PERFORMANCE (ELLIPTICAL ORBIT)

APOGEES	PERIGEES	
	500 Km	800 Km
6 Re = 38268	210 Kg	170 Kg
7 Rc = 44646	200 Kg	160 Kg
8 Re = 51024	195 Kg	150 Kg
9 Re = 57402	190 Kg	145 Kg
10 Re = 63780	180 Kg	140 Kg

FIG. 10

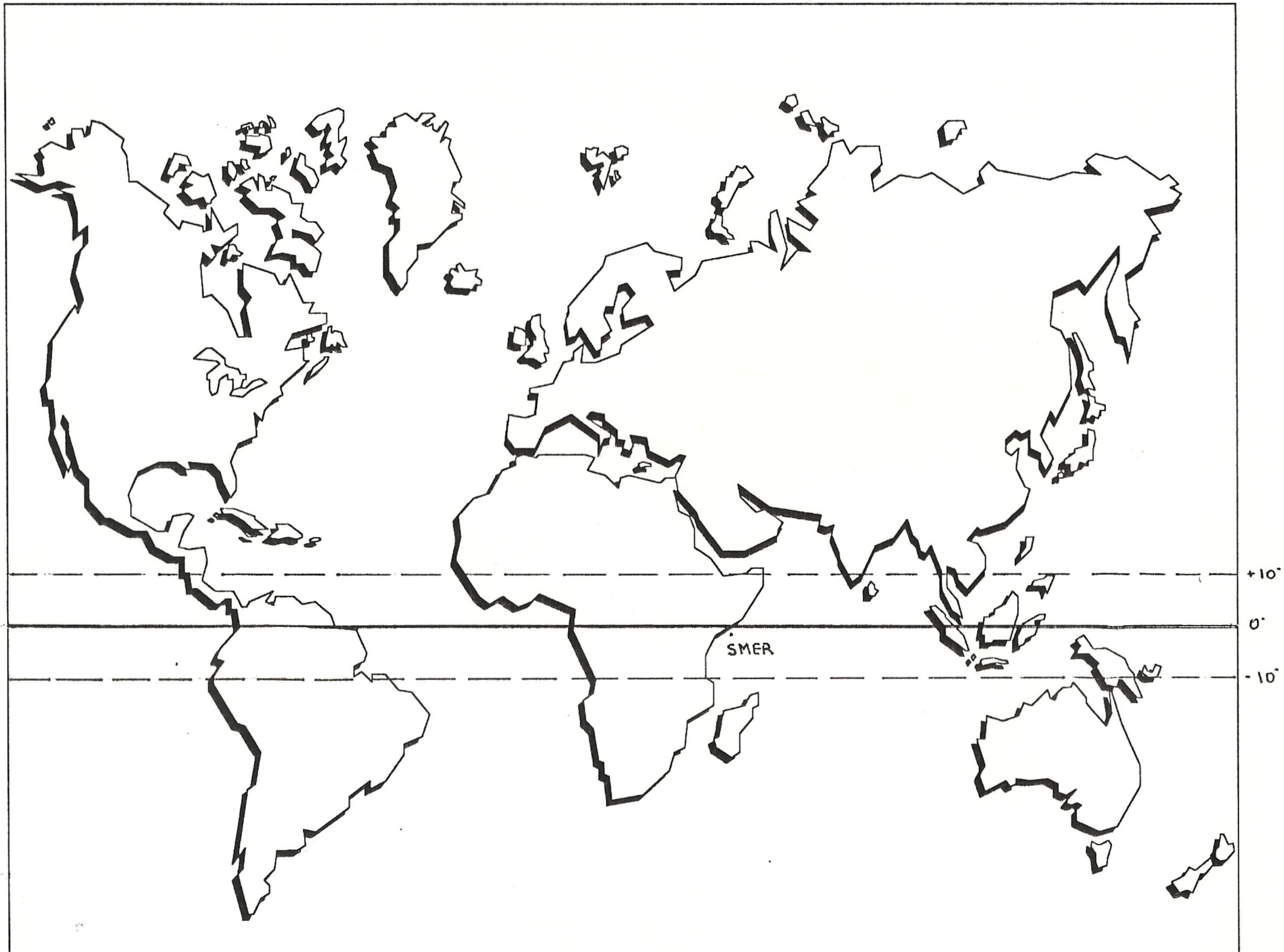


FIG. 11 T.A.M.

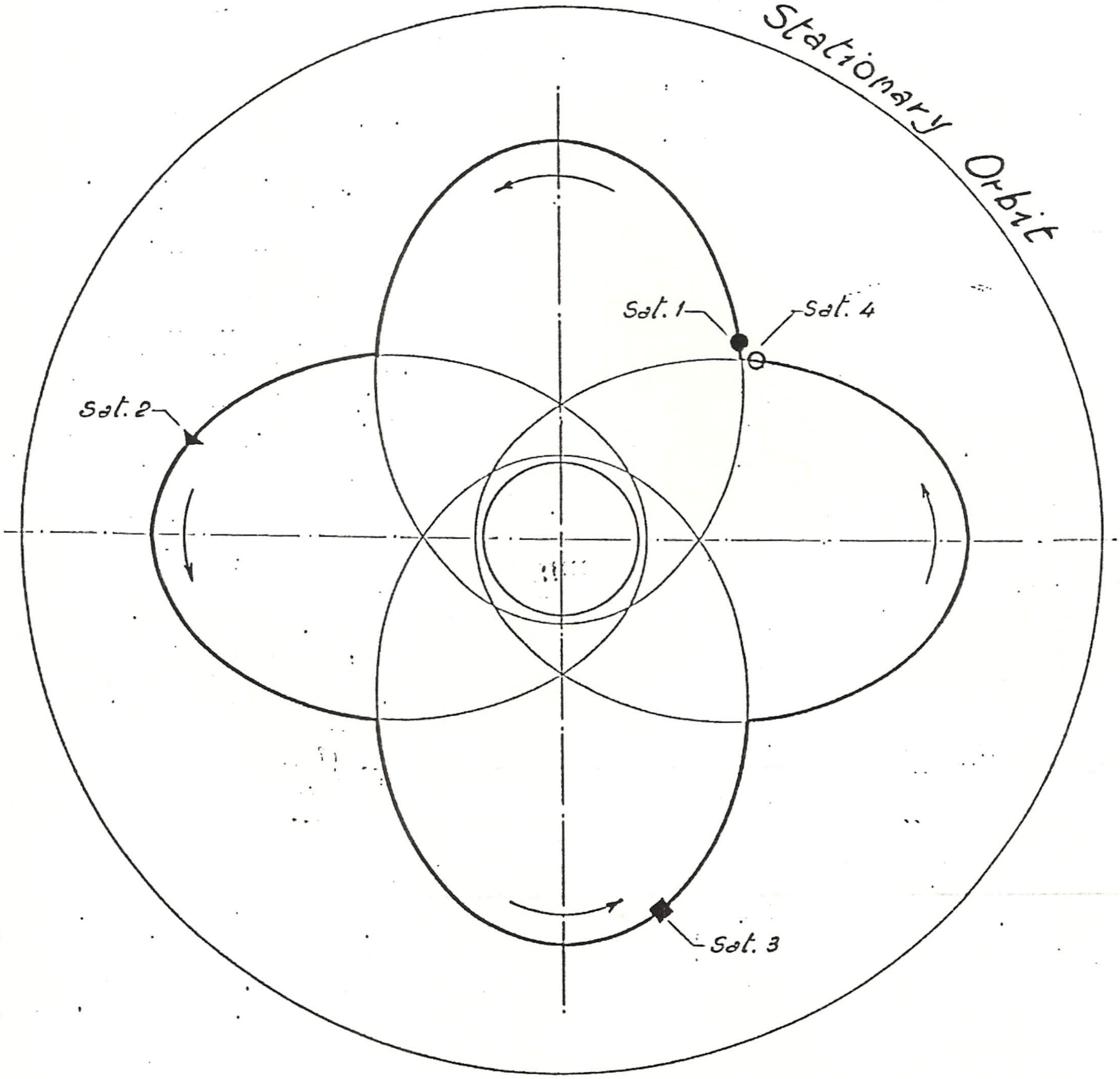


Fig 12 – Satellite phase distribution