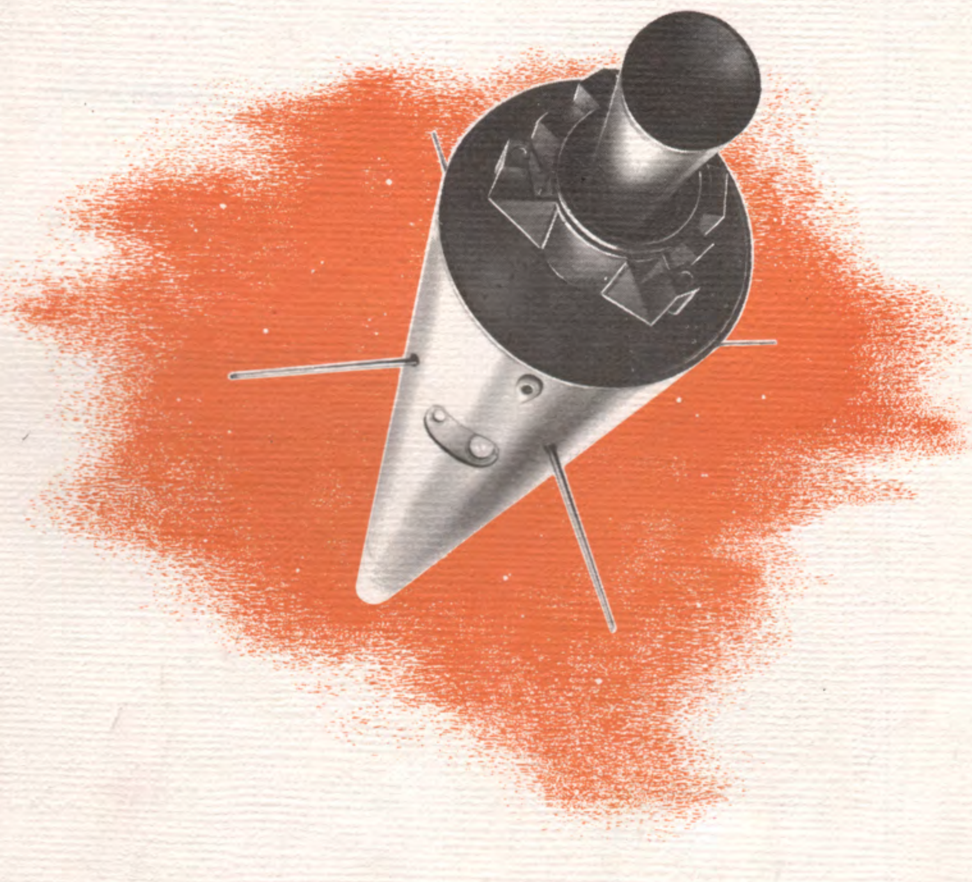
WRESAT

WEAPONS RESEARCH ESTABLISHMENT SATELLITE



AUSTRALIA

DEPARTMENT OF SUPPLY

WEAPONS

RESEARCH

ESTABLISHMENT

SATELLITE

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FOREWORD

Space has always been a realm for man's speculation, investigation and endeavour. During the last decade or so, activities associated with space have expanded so dramatically that they have become the direct concern of Governments and constitute matters for international negotiation. One or two countries have embarked upon very ambitious national space programmes while others have grouped together in co-operative ventures. Most countries in the world participate to some degree in space activities and recognise the potentialities of new technologies which are involved.

In Australia, we have become very much aware of significant achievements in this new field and of the benefits that result from active participation in attaining them. In co-operative programmes with Britain, Europe and the United States of America, Australia has become an authority for the launching of rocket vehicles and plays an important role in tracking spacecraft. This has largely come about as a result of facilities established at the Woomera Rocket Range and the supporting specialised activities of the Weapons Research Establishment of the Department of Supply. This Establishment is now able to demonstrate its interest and competance in space technology by launching a satellite of its own design from its own rocket range.

The W.R.E. satellite, WRESAT, and the space experiments installed on it have been developed in the last year jointly by W. R. E. and the University of Adelaide, following an existing programme of upper atmosphere research using sounding rockets. The three stage launching vehicle, together with the vehicle preparation teams, have been provided by the Department of Defense of the U.S.A. The NASA global tracking network will track our satellite and gather the information from the experiments it will carry. The facilities of the Joint Australia/United Kingdom Weapon Testing Project will support the launch activities at Woomera. International co-operation and goodwill which have made this endeavour possible are greatly appreciated.

The experiments on board WRESAT are intended to gain a greater understanding of the behaviour of the earth's atmosphere upon which we are so dependent. In Australia, climatology is of particular interest to our economy and means of forecasting or perhaps even controlling the weather are most important. Because of our particular geographic situation, we not only have, at the same time, special problems to solve in this area but also special features to help us do so if we take advantage of the new technologies and applications that are emerging from space research. As Minister for Supply, I am pleased to be associated with such undertakings and wish every success to Australia's first satellite.

Denham Henty

(Denham Henty)
Minister of State for Supply

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PROJECT WRESAT

BACKGROUND TO THE PROJECT

Project WRESAT (Weapons Research Establishment Satellite) involves the design, development and launching of a small scientific satellite from the Woomera Range by the end of 1967. A good example of international space research co-operation is reflected in this endeavour. The actual satellite is being developed by Australia, the launching vehicle and the vehicle preparation team are being provided by the Department of Defense of the United States of America and the actual launch operations are being supported by the United Kingdom through its association with Woomera activities. In addition the global satellite tracking and data acquisition network of the United States National Aeronautics and Space Administration will support the mission.

The Weapons Research Establishment of the Department of Supply has for many years been carrying out extensive measurements in the upper atmosphere using locally developed sounding rockets and scientific payloads. This work has been done in close association with the Department of Physics at the University of Adelaide and is primarily concerned in extending climatological studies. Close contact has been maintained with overseas experimenters in this field.

The opportunity of extending and supplementing this work was presented when, after mutual assessment by W. R. E. and the U. S. Department of Defense, arrangements were made for the provision of a SPARTA launch vehicle to orbit a small Australian scientific satellite. Project SPARTA is a tri-partite programme at present being conducted at Woomera involving the study of the physical phenomena associated with the re-entry of objects at high velocity into the earth's atmosphere. Australia, the United States and the United Kingdom are involved in this Project.

Design work on WRESAT began at W. R. E. and the University of Adelaide early in 1967 and it is planned that the launch will take place from Woomera before the end of 1967. The Adelaide University is responsible for the provision of most of the sensors for the experiment. The United States support to the Project is being provided by the Advanced Research Projects Agency of the Department of Defense through the U. S. Army Missile Command which is using Thompson Ramo Wooldridge Systems in the vehicle preparation team. These organisations are already providing the U. S. support to the existing Project SPARTA.

OBJECTIVES OF THE PROJECT

The primary object of the Project is to take advantage of this opportunity to supplement and extend the range of scientific data at present being obtained by existing Australian and other research programmes on upper atmosphere physics. Secondary objectives include assistance to the U. S. in the provision of further data of relevance to her own programmes and the development of techniques pertinent to satellite launching trials in the ELDO, Black Arrow and other possible future programmes at the Woomera Range.

A further advantage in conducting a project of this kind accrues from the development and stimulation of the wide range of scientific and technological disciplines necessary for participation in satellite programmes and which have wide application to defence science and general national technological progress. In meeting the requirements of the project, particularly those of time-scale, many parts of a complex organisation have been usefully exercised.

The work already done by W. R. E. in the study of the effects of the upper atmosphere on climatology has attracted world wide interest. A detailed understanding of the mechanism of the heat balance between the solar and terrestrial radiation within the atmosphere is vital in the study of climatology and this may, eventually, allow more accurate and extensive meteorological forcasting to be undertaken. An understanding of the whole atmosphere and the solar-terrestrial relationship are prerequesites for the long term forecasting and perhaps eventual control of weather. Southern Hemisphere regions differ markedly from those of the Northern Hemisphere - firstly in the relationship of land mass to ocean areas and secondly in the attitudes to the solar flux. Australia is in a geographically favourable position to explore the effects of these differences.

MEASUREMENTS TO BE MADE

The WRESAT experiment has been designed to provide information on the solar radiation flux in wavelengths which have a direct influence upon the temperature structure at heights above 30 km (19 miles), and will assist in the determination of the composition of the upper atmosphere above the homopause at approximately 100 km (62 miles). Direct measurement of the solar flux will provide data on solar activity.

In order to gain a better understanding of the relationship between the outer and inner layers of the atmosphere it is necessary to know the specific inputs from solar radiation. The thermal energy interchange between the outer and inner layers is influenced greatly by the presence and distribution of molecular oxygen and ozone and since these constituents affect the absorption of ultra-violet radiations measurements at ultra-violet wavelengths are essential inputs to a greater understanding of the physical processes taking place.

Specific measurements will be made at the following wavelengths:-

(a) In the ultra-violet region of 1 050 to 1 660 Å by using ion chambers.

(b) In the wavelength around 2 500 Å by the interference filter-photocell technique to determine absorption of ozone by the atmosphere.

(c) In the wavelengths of 1 050 to 1 340 Å by using an ion chamber with nitric oxide filling and a lithium fluoride window. This instrument will also be used as a telescope to determine the albedo of the earth in this waveband and to measure the resonantly scattered Lyman α (1 216 Å) radiation from the geocoronal hydrogen belts.

(d) By using X-ray counter techniques, solar flux at 8 Å will be monitored.

These measurements will form inputs to three basic experiments:-

(a) Sunset-sunrise experiment

(b) Orbital measurements in sunlight

(c) Orbital measurements towards the anti-solar point.

The sunrise-sunset experiment depends upon the viewing of the sun by the ion chambers and the ozone sensor through the atmosphere close to the earth. From this information, profiles of molecular oxygen and ozone concentration may be determined. It is a requirement that this experiment provide information at one latitude rather than cover a band of latitudes. Because the majority of telemetry stations are situated in the northern hemisphere, this experiment will be mainly confined to the high latitude northern stations in the U. K. and North America.

The orbital daylight experiment will provide measurements of solar flux in the ultra-violet and X-ray wavelengths. Solar activity will be monitored primarily by the X-ray sensor and these measurements will be correlated with the ionosonde soundings taken at Woomera, Salisbury and other world centres co-inciding with the satellite pass. The Lyman α telescope will not be viewing the sun, but will measure the albedo of the earth in this wavelength.

The orbital night experiment will measure the Lyman α radiation scattered resonantly by the geocoronal hydrogen. The Lyman α telescope will also determine the position of Lyman α sources in the night sky.

SATELLITE INSTRUMENTATION

The essential measurements of the experiment are made by a variety of sensors which are positioned either to look forward from the nose or sideways. The measurements are conveyed to the ground stations by radio-telemetry transmitting on 136.350 MHz. Additionally, the telemetry sender conveys certain satellite "house-keeping" information such as temperature and the state of charge of batteries. The radiation sensors are classified according to their response frequency. The ultra-violet ion chambers are:-

WINDOW	GAS	WAVELENGTH
Lithium fluoride	Nitric oxide	1 050 to 1 340 Å
Sapphire	Xylene	1 425 to 1 480 Å
Quartz	Triethylamine	1 560 to 1 660 Å

Measurements at wavelengths of 1 050 to 1 340 Å and 1 425 to 1 480 Å will complement and extend previous work done by Australia and U. S. A. in sounding rockets and also by the U. S. A. in satellites as far as is known. Measurements at 1 560 to 1 660 Å have not previously been made from satellite vehicles.

The X-ray counter will be collimated and have a mica window with gas filling of neon and argon. The response is of narrow width around 8 Å.

The solar aspect sensors are identical with those previously flown in Long Tom, (a W. R. E. Sounding Rocket) and rely upon the response of a photo-diode to the light collected from a flat teflon surface and a nipple of teflon. At night, the aspect will be determined by a magnetometer unit which will also provide attitude information during the daylight hours, provide a check upon the solar aspect sensors and determine the accuracy of attitude-prediction for night from the use of solar sensors only.

A magnetometer unit is installed in the satellite at least 1 inch from any conducting surface. The influence of any switch motor, the effect of any ferrous material in the satellite and the residual magnetism associated with the third-stage motor will be tested. The weight of the magnetometer unit (head + amplifier + leads) is about $\frac{3}{4}$ lb.

The ozone sensor is a photodiode sensing the solar flux after transmission through an interference filter centred around 2 500 Å in the Hartley band. This experiment, although monitoring solar flux in these wavelengths, is dependent on measurements at sunrise or sunset for ozone profile determination.

The Lyman α telescope has a field of view of 2° half angle. With such a field of view, the sun will not be seen during daylight orbiting. The amplifier will be set for maximum sensitivity to measure the resonantly scattered Lyman α radiation ($\sim 10^{-5}$ of daylight flux).

There are two positions of instrumentation in the satellite. The first position is located forward looking from the nose, the tip of which will be separated after injection, and comprises three ion chambers, the ozone sensor and aspect sensor.

The sideways looking instrumentation of three ion chambers, the Lyman α telescope and an aspect sensor is in the same rotational plane as the forward looking sensors, and orthogonal to them.

The complete satellite is powered by batteries which should provide a useful transmitting life of up to ten days; the orbital lifetime of the satellite is expected to be about 40 days.

A C-Band Radar Beacon is fitted in the satellite to provide initial trajectory information for safety tracking and subsequent data analysis purposes.

DESCRIPTION OF SATELLITE

The conical satellite including the experiment and instrumentation weighs about 100 lb and has a base diameter of about 30 inches and a height of about 5 feet. The third stage solid propellant motor will not be jettisoned after burn-out but will go into orbit attached to the satellite cone, since no performance or operational penalties are involved and less mechanical complication is introduced into the design. The total weight of the orbiting body will be approximately 160 lb.

The sensors located at the cone tip will have an 80° angle of view forward along the axis of the cone; a second set, having a similar field of view, is oriented at right angles to the cone axis.

The satellite cone is made of light alloy frames and skin, and all instrumentation units are thermally isolated from the main flight structure. The external surfaces of the cone are treated with a special high temperature black paint in order to achieve a satisfactory temperature within the cone during the orbit phase and yet withstand the aerodynamic heating effects which will be encountered during launching. The inside of the cone is painted white in order to assist in obtaining temperature equilibrium of the internal equipment.

Comprehensive environmental testing of the satellite structure and equipment has been and will be undertaken. This includes static and dynamic loading, vibration testing, impact loading and testing at elevated temperatures. In addition the complete satellite has been tested in a vacuum chamber at the

University of Adelaide at a pressure of 10^{-5} mm Hg while being cycled in temperature between $+50^{\circ}C$ and $-15^{\circ}C$ over a period of about one week.

Since the final stages of the launch vehicle and the satellite are spin stabilised during orbital insertion it is necessary to dynamically balance the satellite to very fine limits. This work will be carried out in Adelaide.

DESCRIPTION OF LAUNCH VEHICLE

The standard SPARTA launch vehicle, incorporating certain structural modifications to accommodate the new payload and cater for the different trajectory, will be used. The vehicle first stage is a refurbished Redstone missile modified to accept two solid propellant upper stages. The complete vehicle is about 70 feet high, 6 feet in diameter and weight of approximately 57 000 lb at launch. The Redstone motor provides a thrust of about 75 000 lb and burns for 122 seconds.

Certain modifications have been made to the upper stages of the launching vehicle in order to cater for the different trajectory requirements and aerodynamic heating effects arising in the case of the WRESAT launch. Close liaison has been maintained between W. R. E. and TRW Systems in specifying and carrying out these modifications to ensure orbital capability of the vehicle.

The checkout and launch of the booster vehicle will be carried out by TRW Systems on behalf of the U. S. Army Missile Command.

TRAJECTORY AND ORBIT DETAILS

The launch will be made from the existing SPARTA launching site at Woomera. The inertial guidance system in the vehicle has been reprogrammed to ensure that the trajectory obtained will allow acceptable first and second stage impact areas to be chosen consistent with a satisfactory orbital geometry and flight safety requirements.

It is intended that, by constraining first stage impact to occur within the existing proclaimed areas of the Simpson Desert and the second stage impact in the Gulf of Carpentaria, a nearly polar elliptical orbit will be obtained. An apogee height of 700 n. m. and a perigee height of 100 n. m. for a satellite weight of about 100 lb (excluding the burnt third stage motor which will not be jettisoned) are expected. Under these circumstances a satellite life time of about 40 days is expected, although battery power limitations may give the satellite a useful transmitting life of only about 10 days.

After burnout of the first stage booster, the second and third stage motors and the satellite, will be separated from the first stage and allowed to coast to a height of about 100 n. m. During this time, the inertial guidance unit, which is attached to the aft end of the configuration, will cause the vehicle to be pitched into an approximately horizontal position. The complete vehicle is then spun by spin rockets up to a maximum roll rate of about $2\frac{1}{2}$ rev/s before ignition of the second stage motor. After burnout, the second stage is discarded and the third stage ignites inserting the satellite into orbit with a tangential velocity of about 26 000 ft/s at a height of about 100 n. m., a latitude of near 27^{o}S and an azimuth angle of about 6^{o} East of North from the launch point.

The satellite, including the burnt third stage motor, will enter orbit therefore with a spin rate about the cone axis of about $2\frac{1}{2}$ rev/s; the attitude of this axis will be about 27^{o} to the earth's rotational axis. In the case of a rigid symmetrical body not acted on by external forces or moments, this attitude would be maintained but due to structural and balance misalignments, lack of infinite rigidity and other factors, the axis of spin will eventually nutate and finally the motion will assume that of a flat spin about the axis of maximum inertia. This axis will be normal to the satellite cone axis, which will be no longer rolling, and will be parallel to the original spin axis on insertion into orbit. The rotational rate will be approximately one half a revolution per second, being the original spin rate factored by the ratio of the axial to the tumble inertia.

As the sensors have a 80^{o} total angle of view and as it is necessary that they see the sun, it is mandatory that sensor orientation and final plane of cone rotation must be positioned so that the sun may be observed at all times when the satellite is in sunlight. In order to achieve this requirement, the satellite will be encouraged to tumble by fitting "wobblers" which are energy dissipation devices released soon after orbit has been established. It is expected that the transfer of the motion from the original to the final rotational mode should occur within the duration of one or two orbits.

Orbital measurements and predictions as well as the telemetered data will be provided by the NASA Global Satellite Tracking and Data Acquisition Network (STADAN). The telemetry data tapes will be sent to W. R. E. for final data reduction.

In addition there are many other centres throughout the world with facilities for receiving satellite data at the frequency of 136.350 MHz; these centres will be invited to receive data from WRESAT and forward it to W. R. E. If, however, they wish to reduce their own data, then calibrations and details of the output will be forwarded to them. The proposed experiment will be advised by COSPAR (Committee for Space Research) to all of its communicating committees.

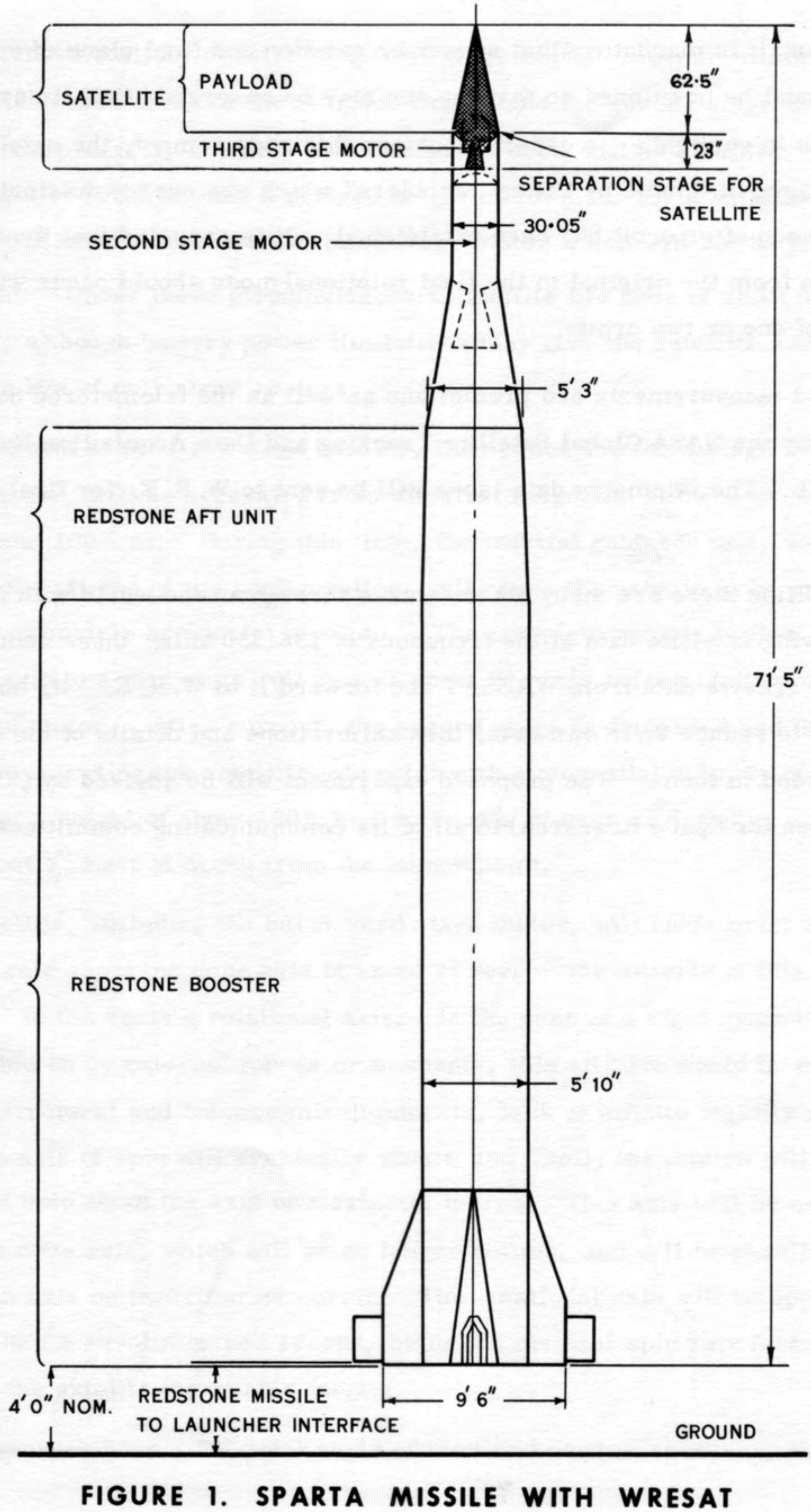


FIGURE 1. SPARTA MISSILE WITH WRESAT

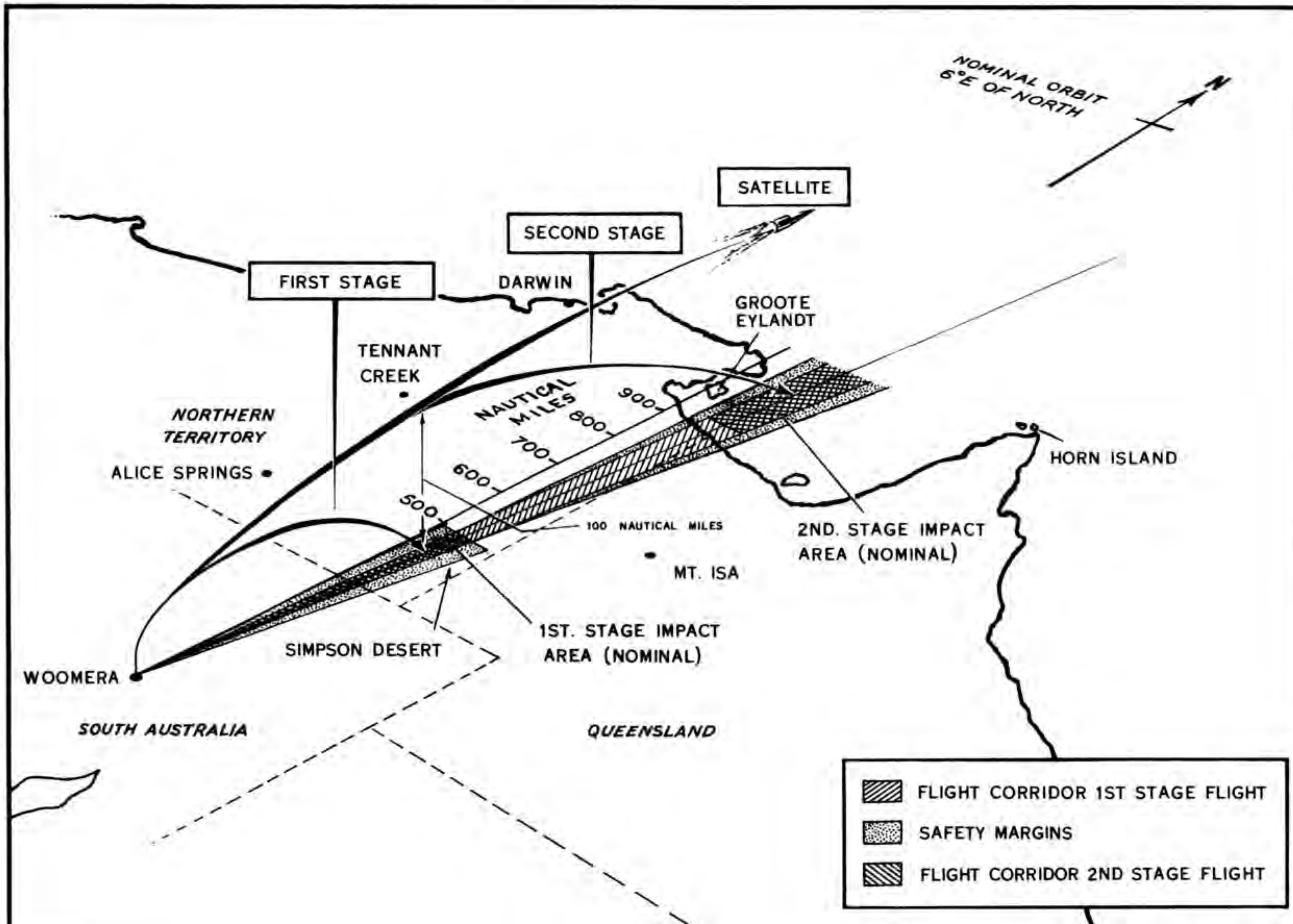
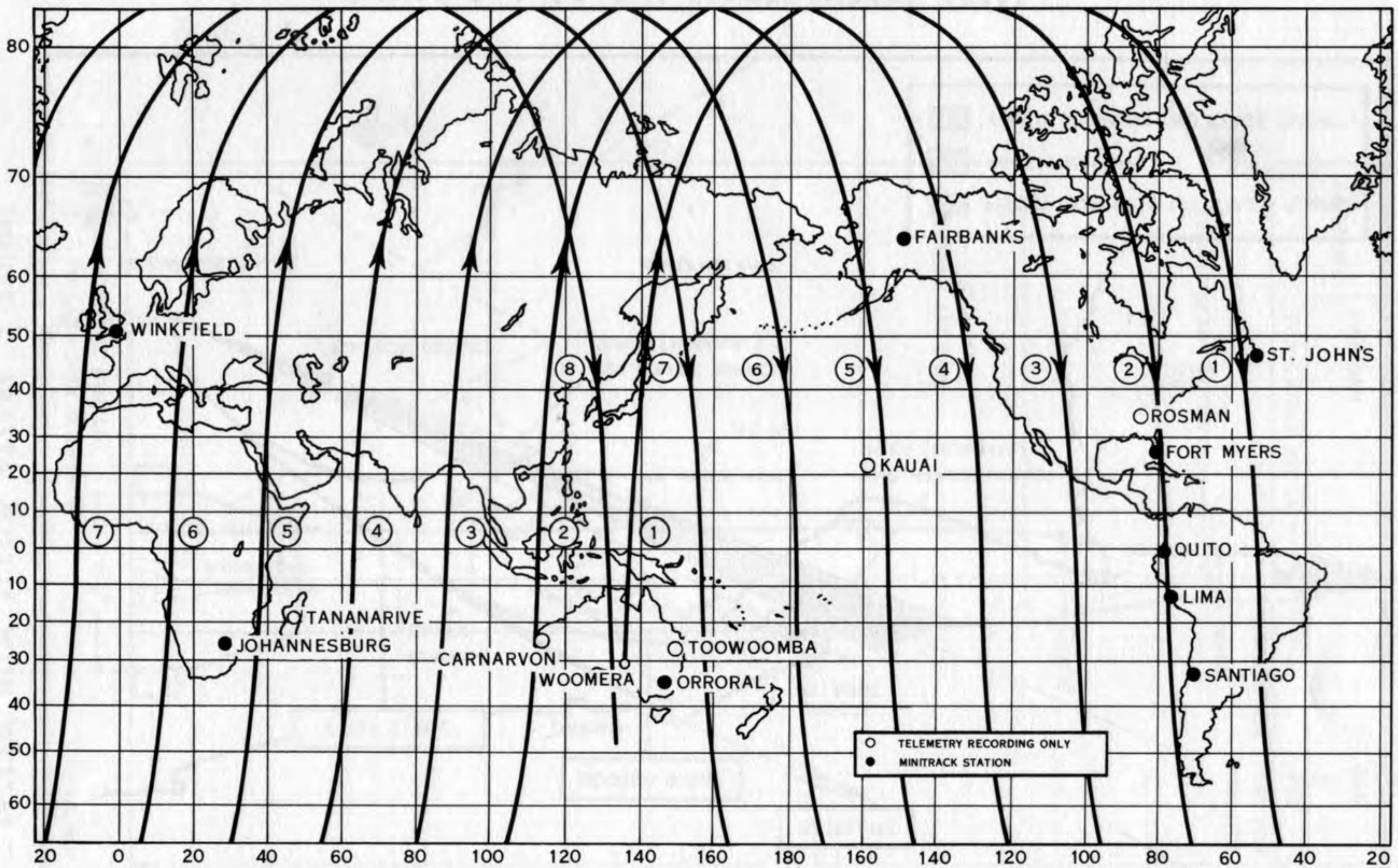


FIGURE 2. 1st. & 2nd. STAGES IMPACT AREAS



PERIGEE - 100 N. MILES
APOGEE - 700 N. MILES
INCLINATION - 83° TO EQUATOR
LIFETIME - 40 DAYS
PERIOD - APPROX. 99 MIN.

FIGURE 3. WRESAT SUB-SATELLITE TRACK

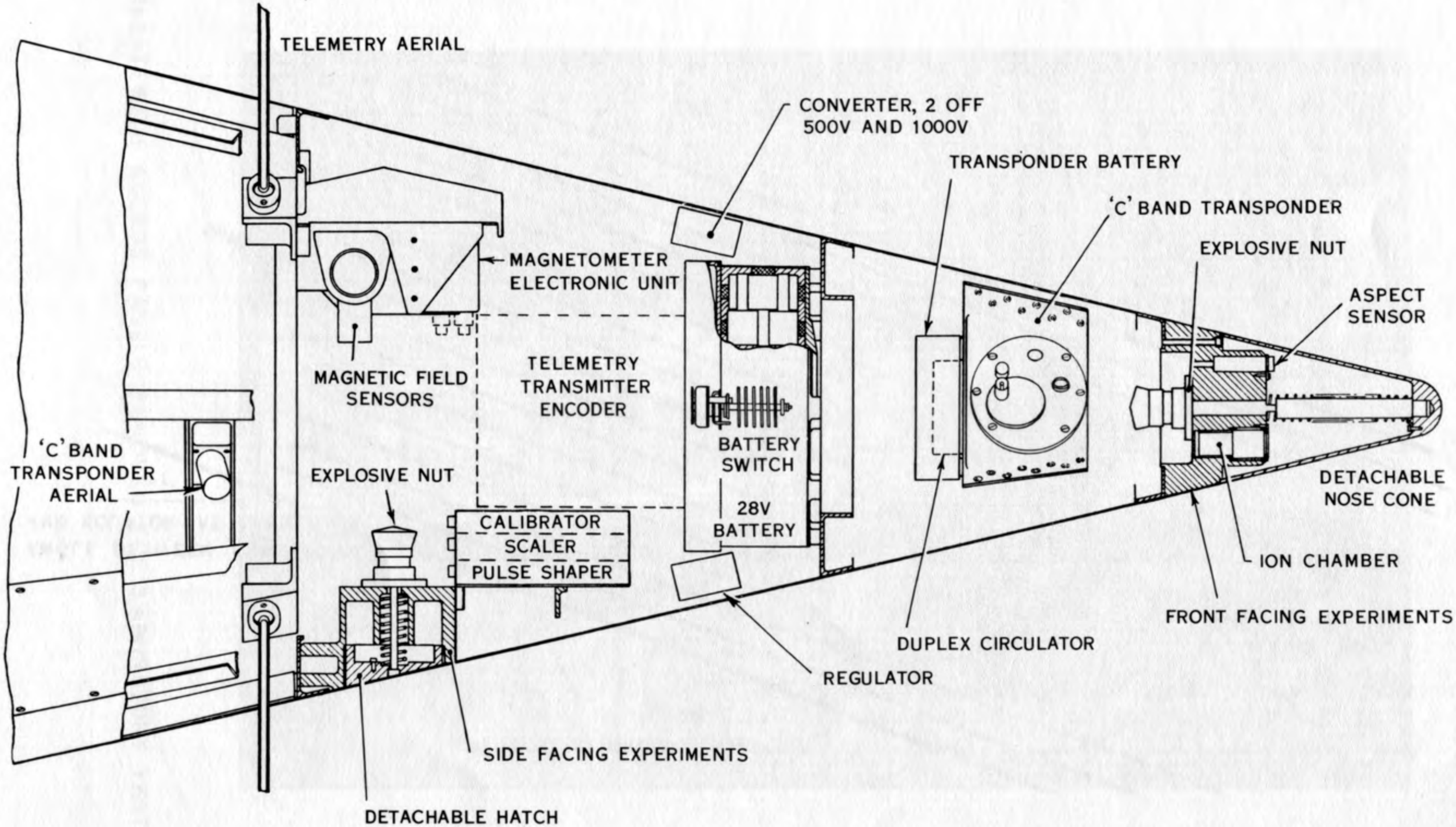


FIGURE 4. WRESAT INSTRUMENTATION LAYOUT

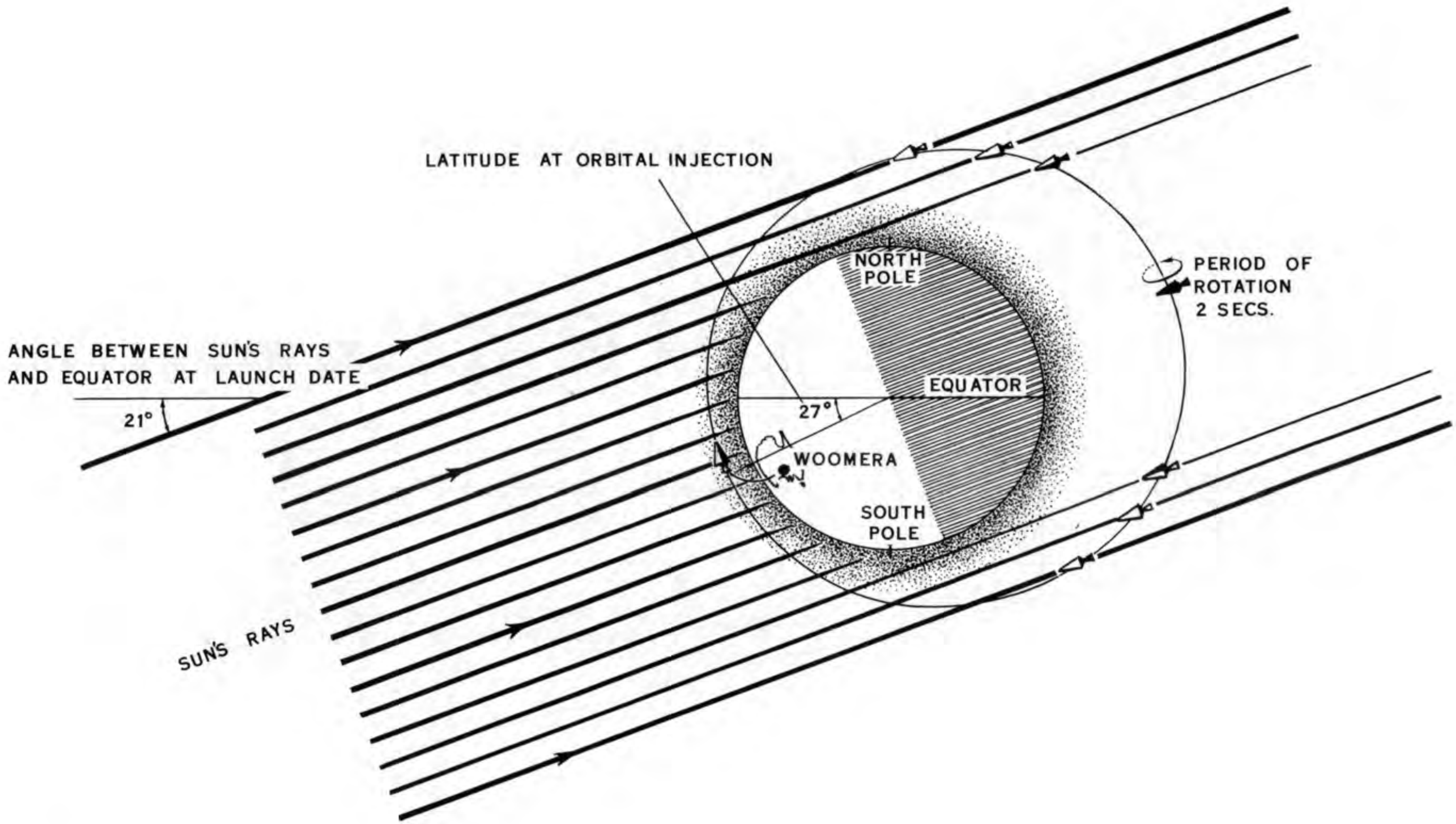
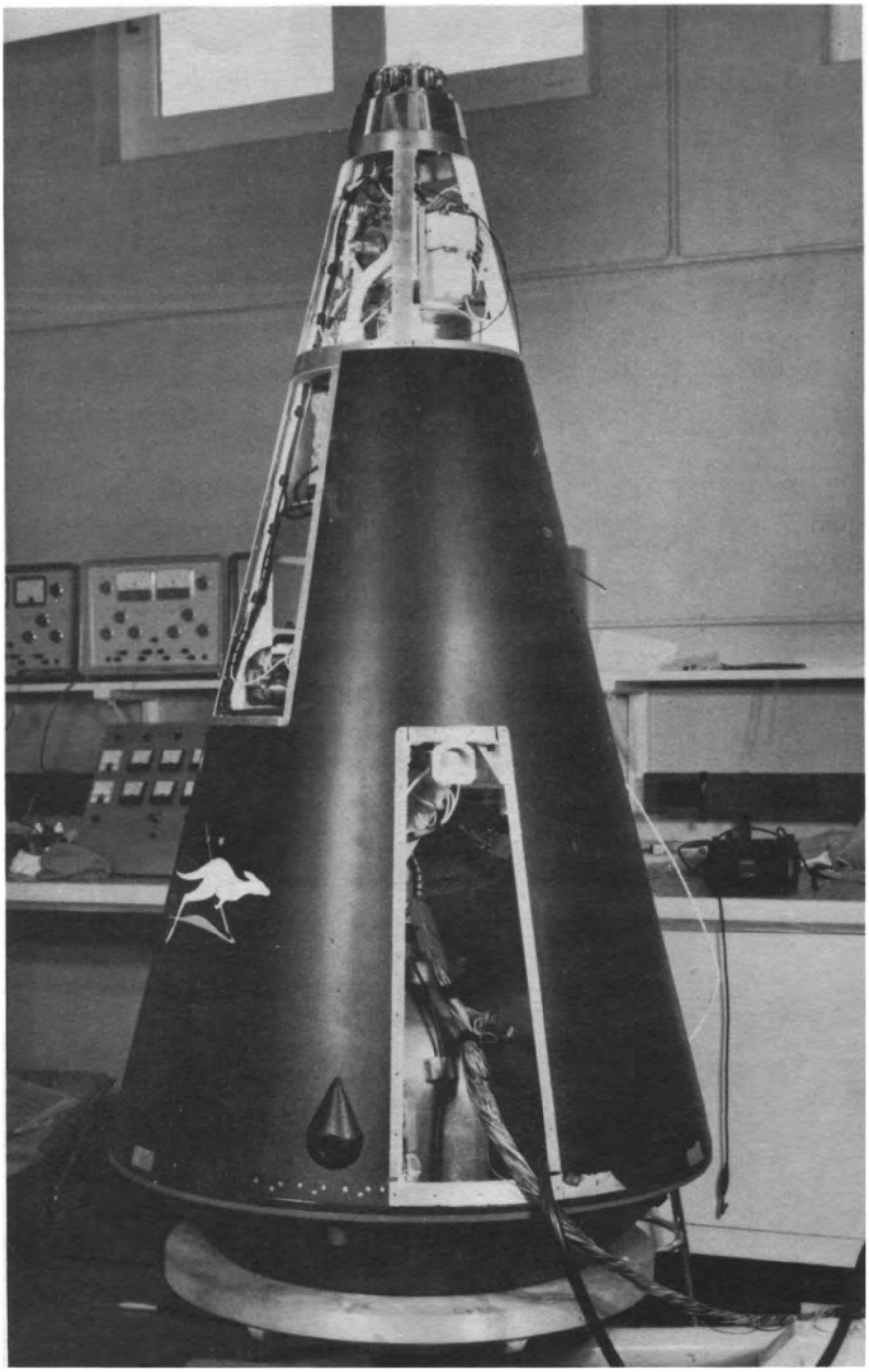
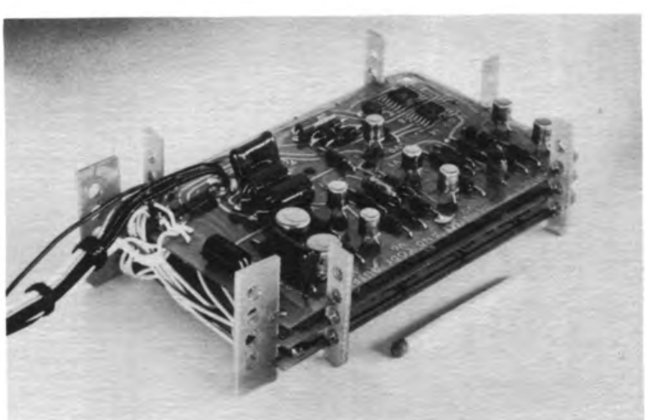


FIGURE 5. SUNRISE-SUNSET EXPERIMENT

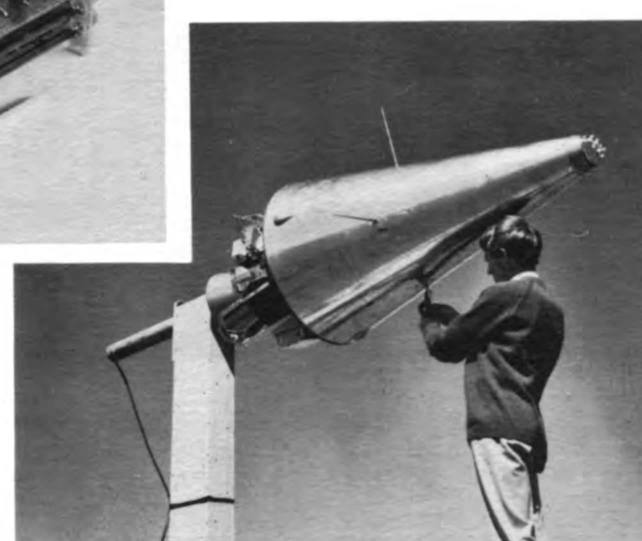


WRESAT WITH ACCESS PANELS REMOVED FOR LABORATORY TESTING

STRUCTURAL MODEL UNDERGOING VIBRATION TESTS



MICRO-MINIATURE CIRCUITRY IN TIMING UNIT



PREPARING WRESAT MODEL FOR DETERMINING POLAR DIAGRAM OF TELEMETRY AERIALS

DESIGNED AND PRINTED BY
TECHNICAL SECRETARIAT GROUP WRE