VOLUME 1

NASA DIRECTORY OF OBSERVATION STATION LOCATIONS

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA DIRECTORY OF

OBSERVATION STATION

LOCATIONS

Volume 1

EDGE INDEX

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ABSTRACT

This directory documents geodetic information for NASA tracking stations and observation stations in the NASA Geodetic Satellites Program.

A Geodetic Data Sheet is provided for each station, giving the position of the station and describing briefly how it was established. Geodetic positions and geocentric coordinates of these stations are tabulated on local or major geodetic datums, and on selected world geodetic systems when available information permits.

The directory consists of two volumes. Volume I covers the principal tracking facilities used by NASA, including the NASA Network Facilities, the Deep Space Network, and several large radio telescopes. Positions of these facilities are tabulated on their local or national datums, the Mercury Datum 1960, the Modified Mercury Datum 1968, and the Apollo Reference System. Volume II contains observation stations in the NASA Geodetic Satellites Program and includes stations participating in the National Geodetic Satellite Program. Station positions of these facilities are given on local or preferred major datums, and on the Modified Mercury Datum 1968.

Background and reference material for the directory is contained in Volume I. This includes discussions of requirements for geodetic surveys; a review of geodetic concepts, survey methods, and accuracies; descriptions of the major geodetic datums and the status of the developing world geodetic systems; and formulas and constants.

NOTE

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PREFACE

This directory summarizes the geodetic data available for NASA tracking facilities and for observing stations participating in NASA programs in satellite geodesy. The information has been furnished by many agencies in the United States and other countries, sometimes in detail, but other times with unsatisfying brevity. The user of satellite information must know the quality of the positional data he uses. Precise tracking operations, datum ties, and determination of a unified world geodetic system require unambiguous definition of each station from which observations are made, the coordinate system in which it is computed, and the spheroid to which it is referred. It is unsatisfactory to provide this information in tabular form, and inconvenient to use if all the data in the extended reports are included. The data sheets in this directory are intended to make the essential information easily available in uniform format, and to show when it is lacking.

The second edition of the directory incorporates the revision sheets issued in June 1971 and adds several new stations. Geodetic heights in Europe and Australia have been adjusted to reflect improved geoid charts of those continents. Stations in South America are now published on the South American Datum of 1969. The organization of Volume I has been modified to reflect the consolidation of the Manned Space Flight and STADAN networks at Goddard Space Flight Center.

Additions and changes to the directory will be issued as observation stations are added and improved survey information is received.

VOLUME I

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NASA DIRECTORY OF OBSERVATION STATION LOCATIONS

INTRODUCTION

The NASA Directory of Observation Station Locations provides geodetic locations and related information for observing stations of primary interest to manned space flight operations and other NASA programs, and for observation stations participating in the National Geodetic Satellite Program (NGSP) and the NASA Geodetic Satellites Program (NGP). The directory contains nearly 400 stations with many different types of electronic and optical systems. Among them are range and range-rate trackers, Doppler trackers, radio and laser ranging systems, and stellar cameras.

This directory is a consolidation of geodetic data contained in earlier NASA directories - the Goddard Directory of Tracking Station Locations, and the Geodetic Satellites Observation Station Directory.

The directory is in two volumes. Volume I covers the NASA Network Facilities, the Cape Kennedy launch pads, the Deep Space Network, and three radio telescopes cooperating in NASA programs. Volume II contains the observation stations participating in the NGSP and the NGP. These include the Minitrack Optical Tracking Network, U.S. Navy Doppler stations, U.S. Air Force PC-1000 cameras, C-Band radars, U.S. Army Secor stations, NOS BC-4 cameras, the Goddard Special Optical Network, international camera stations, and the SAO optical network.

The directory is organized into three parts: Part A, section 1 through 5, contains background and reference material to aid in using the Geodetic Data Sheets and coordinate tables. It includes a summary of basic geodetic concepts, and descriptions of the principal geodetic datums involved in satellite tracking and geodetic programs. Part B contains section 6 and the coordinate tables and Geodetic Data Sheets for the NASA Tracking Facilities. Part C is separated in Volume II; it contains section 7 and the coordinate tables and Geodetic Data Sheets for the observing stations participating in the satellite geodesy programs.

Positions of NASA tracking stations in Volume I are tabulated on their local datums, on Mercury Datum 1960, on Modified Mercury Datum 1968, and on the Apollo Reference System. In Volume II positions are listed on local or preferred datums and on the Modified Mercury Datum 1968. A brief explanation of the coordinate systems follows:

Local datums. On the local (or major) datum tabulation the coordinates are based on the spheroid of the datum on which the geodetic position is furnished. Geodetic latitude, longitude, and height, and geocentric rectangular coordinates are listed.

Mercury Datum 1960. This world geodetic system was derived in 1959 by the U.S. Army Map Service from available astro-geodetic, gravimetric and satellite data. Its principal elements are a semi-major axis of 6 378 166 meters, a flattening of 1/298.3, and a set of transformation constants by which it was related to the major geodetic datums (North American, European, Arc, and Tokyo). The Mercury Datum was adopted by NASA in 1960 for Manned Space Flight Operations. This system is now outdated for worldwide tracking operations, but it is still being used for certain analytic programs within NASA. Coordinate tabulations in this directory for this system include geodetic latitude, longitude, and height, geocentric rectangular coordinates, and geocentric latitude and radius.

Modified Mercury 1968. This world geodetic system is based on a combined analysis of terrestrial and satellite data available in 1967. The system incorporates astro-geodetic and surface gravity data with results from Baker-Nunn camera and Doppler observations. This new system retains the 1/298.3 flattening of Mercury 1960, but has a sixteen meter shorter semi-major axis (6 378 150 m). Transformation constants to relate all the major geodetic datums and many minor datums to the system are provided. Modified Mercury 1968 Datum has not been adopted by NASA but is accepted for use in this directory as a current interim system, pending establishment of a unified world geodetic system from the geodetic satellite programs.

Apollo Reference System. These are the official positions used by NASA for manned space flight operations. This system is an outgrowth of the Mercury 1960 Datum and is referenced to its spheroid (a = 6 378 166, f = 1/298.3). The positions in it are subject to modification from continuing analysis of tracking results. Results from Mercury, Gemini and Apollo missions, as well as deep space probes, have contributed to the solutions. Frequent revisions of this table may be expected as additional geodetic refinements are made based on the data obtained from future missions.

Other coordinate reference systems are used by various tracking networks. The set of station locations current for a particular network may be obtained from the appropriate network management.

The Geodetic Data Sheets are the principal contents of the directory. The text is intended to make them more useful, and the tabulations are based on them. An effort has been made to include the most recent and accurate information available. This is a continuing process, and as new or better data are received, additions and revisions to the sheets will be distributed.

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PART A - BACKGROUND AND REFERENCE MATERIAL

SECTION 1
SOME ELEMENTS OF GEODESY

1.1 INTRODUCTION

To establish a world network for satellite tracking, and to minimize the position error of each tracking facility with respect to others, each station in the system should be accurately located on the earth's surface and precisely referenced to a geodetic datum.

Positioning as it applies to a tracking station may be considered as involving two separate tasks: the precise positioning of each station relative to its local or national datum; and the determination of datum relationships to permit referencing all stations to a common worldwide system. The Geodetic Data Sheets in this directory contain data to define the position and orientation of each facility. In this section certain basic geodetic concepts are briefly described to permit a fuller understanding of the data, their limitations, and the problems of obtaining the accuracy required for satellite tracking operations. More detailed information can be obtained from the references listed.

1.2 REFERENCE SURFACES

Three different reference surfaces are used in determining positions on the earth: the actual topographic surface of the earth, the geoid, and the reference ellipsoid. All are important in the development of geodetic control, although there are limitations imposed on the use of each by practical considerations or requirements for precision.

The first, the earth's topographic surface, is irregular with its variety of land forms, mountains, valleys, and ocean deeps; however it is the only surface on which geodetic measurements can actually be made.

The geodesist reduces his measurements and refers his observations to the geoid. The geoid is an equipotential surface resulting only from the earth's gravitation and rotation. It is everywhere normal to the gravity vector and coincides with the smooth but undulated surface to which mean sea level of the earth would adjust if free of disturbing forces, and which may be imagined to extend through the continents. Due to the complex distribution of earth crustal materials and the irregular masses of varied densities below the surface, the gravitational force varies from place to place, not only in amount but in direction. Unlike the topographic surface, which departs from the ellipsoid by several kilometers at slopes of almost any amount, the geoid scarcely deviates from the ellipsoid by as much as a hundred meters, at slopes rarely exceeding one minute of arc. The geoidal slopes, though relatively small, are quite troublesome, since the gravity vector is always perpendicular to the geoidal surface, and surveying instruments when leveled will be oriented to it and not to the ellipsoid.

The forces that deflect the gravity vector act on sea level as well, causing it to display a warped surface. To avoid the problems of position determination on this non-mathematical figure, computations are normally made on a spheroid deduced as the geometrical figure which best fits the geoid or some portion of it. The ellipsoid (or spheroid) is defined by two numbers, the length of the semi-major axis and the flattening, which assign both size and mathematical shape to the surface. Since the ellipsoid is a regular surface it does not coincide with the geoid, and the areas of separation are known as geoid heights or geoid separations. There is no way to measure the geoid separation directly, though sufficient geodetic data may permit a good estimate of it. This circumstance complicates the establishment of completely accurate survey datums.

Several increasingly precise determinations of the dimensions of the best-fitting spheroid have been made; in fact one of the primary functions of geodesy has been the determination of the size and shape of the earth. The uncertainties in the various dimensions as evidenced by the several spheroids in use around the world illustrate the difficulty in the problem of determining the relative positions of tracking stations. Sea level itself, the best reference surface, is only an approximation since there are many dynamic effects, both long and short term, that modify it. It was not until the Sputnik and Vanguard satellites were launched and observations made of their orbits that it was possible to narrow the estimates of the flattening and the dependent radius.

1.3 GEODETIC SURVEYS

Geodetic surveys are those which take into consideration the curvature of the earth. Within the limits that a given spheroid is used to define the shape of the earth, we can measure distances and directions over the earth's surface and compute latitudes, longitudes and azimuths which will be accurate relative to each other. Thus positions from geodetic surveys are known as geodetic positions and must be used whenever accurate relative distances and directions are desired. It should be made clear that insofar as relative distance within the coverage of the geodetic net is concerned, no errors other than the mechanical errors of measurement are involved. Geodetic positions are the result of measurements made on the surface of the earth, and if a different spheroid were used all the positions and azimuths would be redefined, but the relative distances would remain unchanged.

1.3.1 Horizontal Positioning

Four surveying techniques have been in general use for determining positions on the earth's surface: 1) astronomic positioning, 2) triangulation, 3) trilateration, and 4) traverse. During the past decade new methods have been added utilizing satellite geodesy (see section 4.3.3).

1) Astronomic observations are made with optical instruments containing leveling devices, and when in use the vertical axis of the instrument is made to coincide with the gravity vector. At a point on the topographic surface observations are made on celestial bodies which, with precise knowledge of the time of observation, can be used to derive a position or azimuth referred to the geoid. A high degree of repeatability can be expected, but since the geoid to which the positions are referenced is an irregular, non-mathematical surface, and distances are not measured, positions observed some distance

apart are wholly independent of each other. The calculated distance and azimuth between them cannot be expected to agree with actual horizontal survey results.

2) Triangulation is also carried out with optical instruments in which the vertical axis coincides with the local gravity vector. In this system, the length of one line (the base line) is measured directly; all other distances are derived by measuring the angles of triangles and calculating the sides by trigonometry. Directions are controlled by observations of the stars at selected stations. The ground between stations does not have to be traversed; thus the accuracy with which a distant station may be located is nearly independent of the character of the intervening country.

3) Trilateration is the procedure employed in extending control when only the triangle sides are measured directly. The angles are calculated trigonometrically and geodetic positions determined relative to an origin, as in conventional triangulation. This method may be used in trigonometric figures of any convenient size, but in practice it is most frequently used over long distances with airborne electronic distance measuring equipment.

4) Traverse, the simplest means of extending control, requires measurement of angles and distances between a number of intervisible survey points. Generally the angles are measured optically and the distances by tape or electronic distance measuring equipment. The position of each control point relative to the origin can be computed from the direction and distance data derived.

All methods yield varying degrees of accuracy depending on the instruments used and the methods and techniques of observation and data reduction. The internal consistency of a trigonometric figure as computed is an indication of accuracy, as is the ability of a chain of figures to close upon itself. Since the survey instruments are leveled to the geoid and the computations are made on the ellipsoid, a small correction should be made to the measured horizontal angles. The differences are not serious unless the elevation angles to the distant targets are large. Corrections can be applied when the geoidal slopes are known, but this has seldom been possible until recently. Of greater significance is the fact that for most of the geodetic work in the past the measured baselines or traverse lengths have been reduced to mean sea level, or the geoid, whereas they should be reduced to the reference ellipsoid on which the work is computed. Any future readjustment of the continental networks will correct this deficiency, since the geoidal heights are now better known.

1.3.2 Vertical Positioning

Vertical control is normally extended by one of three techniques: 1) spirit leveling, 2) trigonometric elevations, and 3) barometric readings.

1) Topographic elevations are determined with the greatest accuracy by spirit leveling, a method in which short and balanced horizontal sights are taken with a level instrument of high precision. Elevations thus obtained are related to the geoid, which is appropriate for mapping and engineering projects. The accuracy of this method is such that the error in the middle of the North American continent is probably no more than one or two feet.

2) Trigonometric elevations are obtained by measuring the vertical angle between the horizon (or the zenith) and a distant station. This method is often used in connection with triangulation and topographic mapping. These elevations are subject to much larger errors than spirit leveling. The lines sighted are long, and since the resulting elevation difference over a line depends only on the gravity vectors at each end of the line, the averaging process of spirit leveling is almost completely lacking. The uncertainty of refraction of the line of sight in a vertical plane also contributes substantially to the errors.

Where errors of millimeters and centimeters may be expected in spirit leveling over moderate distances, decimeters and meters occur in uncontrolled trigonometric leveling.

3) Barometric readings are the least precise of leveling methods. This method employs instruments calibrated to measure the difference in barometric pressure between two sites, which can be converted to difference in elevation. Although the accuracy is not high it provides a means of obtaining a large number of elevations in a short time, and is often used in reconnaissance.

1.3.3 Satellite Geodesy

The use of geodetic satellites in recent years has made possible tremendous strides in the extension of geodetic control and in the positioning of widely separated stations. Satellite geodesy can be divided into two categories, geometric and dynamic.

Geometric satellite geodesy has as its ultimate purpose the establishment of all points on the physical surface of the earth in a worldwide three-dimensional Cartesian or polar coordinate system with its origin at the center of mass, and with one axis coincident with the rotation axis of the earth. In this process, geometric geodesy utilizes space intersection (triangulation and trilateration) and the orbital method.

In the space intersection method, the satellite is considered a triangulation or trilateration mark in space which is observed simultaneously from stations of known positions and also stations of unknown positions. Observations from the known stations yield the position of the satellite at the instant of observation, from which positions of the unknown station can be calculated. The method can be used in triangulation to passive satellites or flashing lights carried by a satellite, and in trilateration to an active satellite equipped with an electronic ranging transponder.

In the orbital method, the satellite is observed photographically or electronically from several stations and the observations compared with predictions based on assumed or known orbital parameters and station coordinates. If comparisons are obtained in sufficient numbers, corrections can be made to the orbital elements and the coordinates of the observers, so that both the orbit and positions are determined. In this way, a set of coordinates is obtained for the various observing stations on a common datum.

In using a satellite for dynamic geodesy, its motion is observed from widely separated ground stations at various times, and the forces acting on the satellite are deduced by analysis of its motions. Observations must be sufficiently precise to develop a theory of motion to predict future positions at least as accurately as they can be observed. To do so an extensive mathematical theory of the motion is required as well as precise knowledge of such physical parameters as gravitational constants, air density, etc., and the accurate geodetic position of the observing stations. Actually, the observed position of the satellite will differ from the predicted one, and by analyzing the differences improved values of the physical parameters can be deduced. As the artificial satellite is much closer to the earth than any other planet, it is quite sensitive to variations in the earth's gravitational field, and its path can be used to determine the parameters which define the gravitational field. These in turn can be used to develop information on the shape and mass dis- distribution of the earth. There are, of course, other elements which affect the motion of the satellite, such as radiation pressure, magnetic effects, attraction of other celestial bodies, etc., but when the satellite is at a high altitude and has small weight-to-drag ratio these factors become insignificant compared to gravitational perturbations, so that a detailed definition of the earth's gravity field can be a prime objective of dynamic observational techniques.

A combination of the geometric and dynamical observations is being used under the NASA Geodetic Satellites Program (see Part C) for a complete determination of an earth-centered world geodetic system. The synthesis will include data of several types from many sources: directions from the camera systems, range-rate from the Doppler network, and range from the radars and lasers.

Unlike classical geodetic operations, dependence upon the direction of gravity for leveling instruments is unnecessary in satellite observations. Computations are almost never made on the surface of a reference ellipsoid, but are based on a geocentric coordinate system. In geometric work confined to a single continent the origin may be a selected triangulation station, but in general the origin is at the center of the earth, supposedly the center of mass. These coordinates can readily be converted to conventional latitude, longitude, and height.

1.4 GEODETIC DATUMS

Geodetic field operations of the classical type are for the determination of latitude and longitude (horizontal), or for the determination of elevation (vertical). These two kinds of surveys are conducted almost completely independently of one another, and each is based on a datum of its own.

1.4.1 Horizontal Geodetic Datums

A horizontal geodetic datum has been traditionally defined by five quantities: the lengths of the semi-major and semi-minor axes (or by a ratio, flattening) of its spheroid, the latitude and longitude of the point of origin, and azimuth from the point of origin to another point. Actually, the azimuth is of little importance, since in most cases the orientation of a datum is obtained by many Laplace azimuths (astronomic azimuths corrected to geodetic for the deflection of the vertical) scattered through the triangulation.

A change in any of these established quantities or in the assumptions regarding deflection will result in a change in the computed coordinates of any point based on the datum defined. Thus there will be lack of conformity in position, distance, and azimuth derived from geodetic surveys having points in common but based on different datums.

1.4.2 Vertical Geodetic Datums

The full definition of position includes the third dimension, height. It has long been recognized that the use of geocentric distances would be desirable to avoid the uncertain factor of geoid separation. For several reasons this is not convenient: the origin is inaccessible and instruments cannot be oriented to it; its position must be deduced from multiple observations. Thus in practice elevations are generally referred to mean sea level, or the geoid. As in the interconnection of horizontal datums, ties between vertical datums reveal many discrepancies, since sea level is an approximation affected by tides, winds, and currents that displace the waters. Development of the datum over a survey area is further complicated by continental instability and the fact that the total volume of sea water seems to vary with time. If a continental vertical datum is to be set up by a series of tide stations in which the mean sea level of each is held as zero, the precise leveling network must undergo a little warping when adjusted to these points.

1.5 DATUM ESTABLISHMENT

1.5.1 Establishment of Horizontal Datums

It was the practice in some countries to base the horizontal datum on observations at a single astronomic station. The geodetic and astronomic coordinates of this origin are then identical, the deflection is zero, and the geoidal and spheroidal surfaces are implicitly tangent. If the adopted spheroid is poorly chosen, or the origin is in a geophysically disturbed area, differences between astronomic and geodetic latitudes and longitudes will become excessive and unbalanced numerically at greater distances from the origin.

A definite improvement can be obtained by adjusting the geodetic latitude and longitude of the origin so as to minimize the deflections at a number of well distributed stations over the network. Another influence on the values of the deflection components is in the choice of spheroid. If the deflections increase continuously and systematically with the distance from the origin, the curvature of the adopted ellipsoid is a bad fit for the area of the network. Such a condition was noted in the United States and resulted in a change in 1880 from the Bessel to the Clarke 1866 Spheroid.

Rather than computing geodetic positions on an assumed ellipsoid from the triangulation, it is possible to derive a best fitting ellipsoid from the same triangulation data. Hayford employed this method in the United States in 1909, but while the spheroid he developed (the International) was widely adopted, it has never been used in North America.

Astro-geodetic methods do not refer the geodetic datum directly to the earth's center of mass. The center of mass is a function of mass distribution within the earth and therefore of its gravitational field. Observations independent of the gravitational field are required to refer positions to the center of the mass in a true world geodetic system. Dynamic studies of near-earth satellites are directed toward solution of this problem.

1.5.2 Establishment of Vertical Datums

The geoid, represented by mean sea level as observed in coastal areas, is commonly the datum to which elevations are related in geodetic control. The level of this surface relative to fixed bench marks ashore is usually established by a period of hourly tide observations designed to balance out the influence of the sun, moon, winds, atmospheric pressure, and other anomalies. The length of the period of observations is important in evaluating vertical datum accuracy, particularly where there are large diurnal inequalities, great differences in the height at springs and neaps, or seasonal variations in water surface height. At primary tide stations this period is usually 19 years, which constitutes a full tidal cycle. In practice considerably shorter periods are sometimes used without serious loss of accuracy. Mean sea level usually can be recovered along most of the world's coasts within two meters by one day's observation of the rise and fall of the tide, and within one half meter by a month's observation.

An example of a large precise leveling net is the Sea Level Datum of 1929 in the United States. Originally based on twenty-one tidal stations in the U.S.

and Canada, it now includes about thirty stations, and it is expected that in time ten or twenty more tidal gauges will be added. First-order spirit leveling has extended this datum over most of the continent.

Similar precise datums cover Europe and much of Africa, some based on single observation stations, some on several. Among them are the Newlyn datum in the United Kingdom, the Nivellement General de France, NAP in the Netherlands based on a single gauge in Amsterdam, the related Normal Null of Germany, and the Pierre du Niton of Berne.

In Australia the sea level datums have been regional; at Port Augusta, on which the Woomera area is based, the position of the tide gauge is at the head of a major estuary, Spencer Gulf, which introduces some doubt as to its accuracy. A single adjustment for the entire continent is expected to be published late in 1971, to be known as the Australian Height Datum.

1.6 DATUM CONNECTIONS

On most continents the horizontal geodetic control was started in separate regions using different origins and even different reference ellipsoids. As a result multiple geodetic datums existed simultaneously on the same land masses. These control networks were expanded until they came together and incorporated common stations. In Europe, for example, although connections between datums had long been available, little was done to compute and adjust the continent onto a common datum. Even after a common datum was established, it is usual for countries to continue to use their old datums domestically.

To relate datums on different continents directly was a practical impossibility until the development of new geodetic tools in the past quarter century. Airborne radar was developed into the geodetic measuring operation Shoran, and refined as Hiran. Measurements of 500 kilometers or more became possible, permitting island-hopping across the North Atlantic from Canada to Northern Europe. The real breakthrough in intercontinental datum connections and worldwide geodesy came with the advent of the artificial earth satellite.

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SECTION 2
GEODETIC ACCURACIES

2.1 INTRODUCTION

Geodetic accuracies may be considered in two categories - those relating points within a single geodetic datum, and those referring to a world system and the earth's center of mass. Proportionately the ultimate accuracy of each is roughly the same, one part in 10^6; this may approach one part in 10^7 in the future. But at present the relative errors within single datums are generally much smaller than those between datums in world-wide systems.

The listing of accuracy figures for a wide range of geodetic operations in this section is based in part on theoretical considerations, but is modified by practical considerations and the results of experience. Accuracy is emphasized as a better measure of the validity of results than precision as measured by the repeatability of an operation in attaining the results. Unless otherwise stated, accuracy figures in this document are given as standard error.

2.2 HORIZONTAL SURVEYS

For basic triangulation, traverse, and trilateration, quoted accuracy figures usually apply to a single continental geodetic datum, and refer to the relative position of points as a function of the distance between them measured along the survey scheme. It is assumed that the chosen spheroid fits the area of the datum reasonably well. Positional errors developed by attempting to over-extend a datum, such as the North American Datum to South America, or the European Datum to South Africa, become excessive as the separation of the spheroid from the geoid increases. Reducing the measured base lines to the spheroid where the geoid heights are known reduces the error, but introduces undesirable distortions.

2.2.1 Triangulation

Random error may be expected to propagate with the one-half power of the distance or the number of figures in a triangulation arc. But this applies to a single spur arc, unsupported by loops with other arcs and the adjustment process. It is reasonable to expect that the simultaneous adjustment of many loops will eliminate much of the error propagation through the arcs and leave, perhaps, a small scale error which would be proportional to the first power of the distance. It is then reasonable to expect the power of the distance in the formula to lie somewhere between one-half and unity; e.g., two-thirds. From a study of the loop and section closures developed during the 1927 adjustment of the North American Datum, L. G. Simmons derived the formula: $E = 0.029\ K^{2/3}$, in which E is the standard error in meters in the relative positioning of two points, and K is the distance between them in kilometers. (This is the equivalent of the more familiar form of the expression, one part in 20,000 $M^{1/3}$, for a two-sigma error when M is in miles.)

Analysis of the triangulation nets of other countries indicates that this formula is a reasonable estimate of most primary triangulation which has been adjusted as a continental network. Since the rule was derived from triangulation in the form of many loops rigidly adjusted it should be used with caution or modification when applied in other situations, such as the extension of NAD to Alaska or South America. For future field work and adjustment most national geodetic agencies hope to meet the standard accepted by the International Association of Geodesy of $E = 0.055\ K^{\frac{1}{2}}$, or perhaps more realistically, $E = 0.020\ K^{2/3}$.

2.2.2. Traverse

The accuracy of traverse surveys has varied considerably over the years and in different parts of the world. Specifications for first-order traverse in the United States state that the lengths shall be accurate within 1:35,000, and that the closure in position shall not exceed 1:25,000. Assigning three sigma values to these, the standard error is about 1:100,000 in length measurements, and 1:75,000 in position closure. There is not enough evidence in the way of large networks of inter-connecting loops of basic traverse surveys in the United States on which to base an accuracy estimate analagous to that for triangulation.

Since electronic distance measuring equipment has become available the accuracy of traverse surveys has increased significantly. The Australians, employing micro-wave equipment (Tellurometer), have completed a comprehensive traverse network covering the entire continent. The average loop closure of this work is 2.2 parts per million, and the maximum is 4.3 ppm. This would place the accuracy of the overall network at least on a par with that of the triangulation network in the United States.

Extreme accuracy is being achieved in the transcontinental traverse in the United States. Electro-optical equipment (Geodimeter) is used for distance observations. Complete astronomic observations for latitude, longitude, and azimuth are made at every second station for orientation and the determination of geoid heights. These observations approach the known accuracy of the speed of light, now estimated at one part in 10^6 standard error. Tests of the Geodimeter traverse indicate that 10^{-6} is the maximum error, whether for a single line of ten to twenty kilometers or a loop of several hundred, to a few thousand, kilometers. With improvement in the determination of the speed of light, the only serious limitations to the accuracy of the Geodimeter traverse will be in the determination of air density and possible accumulation of azimuth error.

2.2.3 Trilateration

Use of this method in geodesy is largely confined to the use of airborne electronic ranging systems. Shoran, the first version, was developed by the U.S. Air Force, and used extensively by the Geodetic Survey of Canada. Hiran replaced Shoran in Air Force operations, and recently Shiran was developed as the most accurate of the air-to-ground distance measurement systems. From theory, modified by practical application from adjustment data, the following accuracies have been estimated: Shiran, $E = 0.23\ K^{\frac{1}{2}}$; Hiran, $E = 0.36\ K^{\frac{1}{2}}$; Shoran, $E = 0.56\ K^{\frac{1}{2}}$; where E is the standard error in meters, and K is the distance measured in kilometers. These represent the accumulation of error of relative position between two points as measured along the trilateration scheme. Since trilateration must have outside control for azimuth, the estimated error is actually in distance. Recent evidence indicates these error estimates may be overly optimistic in some cases.

2.3 VERTICAL SURVEYS

2.3.1 Precise Leveling

There have been many specifications and estimates of accuracy for first-order leveling, leveling of high precision, precise leveling, spirit leveling, etc. Some of these are complicated and difficult to interpret. But what is known as first-order leveling in the United States is roughly equivalent to the basic leveling in most other countries. While leveling in Europe is probably of higher accuracy than that in the United States, the difference is not enough to substantially affect error estimates over great distances.

The basic specification for first-order leveling in the United States is that the check between forward and backward runnings over a section between bench marks, or the closure of a loop, shall not exceed, in millimeters, $4 K^{\frac{1}{2}}$, where K is the length of the section or loop in kilometers. Considering this as the maximum error, the standard error of loop closure would be about $1.5 K^{\frac{1}{2}}$. This is reasonable up to about 100 kilometers, where sigma would be 15 mm, but as the distance increases the allowable standard error becomes unreasonably small, until for a continental distance of 5000 kilometers it would be only 106 mm. Because of the presence of other than random errors, the power of K in the error formula should probably be between one-half and unity as in the accumulation of triangulation error. A reasonable standard error in a basic level net after it has been adjusted would then be: $E = 1.5 K^{\frac{2}{3}}$ mm. This results in errors which are perhaps a little high for the shorter distances (less than 50 to 100 km) but should be adequate for evaluating errors between points in a large continental network.

2.3.2 Elevations by Vertical Angle

In areas many miles removed from the basic leveling network, the only elevations available may be those established by vertical angles in connection with triangulation or traverse. Such elevations are subject to much larger errors than those in the basic network. A conventional rule for primary work is that the elevation difference, determined trigonometrically, should not be in error by more than 0.1 meter a mile of line length. Assuming this to be a two-sigma level (95 percent error), the rule reduced to kilometers is: E = 0.03 K, with E in meters. For a series of lines the individual errors are combined by the root-sum-square process. Thus E for three lines, 5, 10, and 15 kilometers long, would be $0.03\sqrt{25 + 100 + 225} = 0.56$ meter. The theoretical basis of this method of estimating the errors of elevations by vertical angles is tenuous, but it is supported by experience.

2.3.3 Geoid Heights

Earlier in this discussion elevations determined by vertical surveys have referred to the geoid, or mean sea level. But to express the true relationship of points on the earth's surface to each other or to the earth's center of mass, the elevation of the geoid above or below the adopted ellipsoid must be known. Determining geoid heights in an absolute sense is very difficult, chiefly because of a lack of world-wide gravity coverage of sufficient density, particularly in the ocean areas.

Astro-geodetic leveling has been employed to develop geoidal profiles with or without the aid of surface gravity for interpolation. Astro-geodetic deflections of the vertical define the slope of the geoid with reference to some arbitrarily chosen ellipsoid and geodetic datum. Such slopes can be determined within 0".2 by first-order methods, and better than one second by second-order astronomic observations.

Most geoidal profiles result from existing triangulation arcs with their astronomic Laplace stations, which may be 125 kilometers apart. In the United States several thousand miles of surveys have been run specifically for geoidal profile determination. The accuracy is quite high as indicated by many loop adjustments. The average correction to an observed geoid height difference (ΔN) is about 1.0 mm/km, and the maximum is 3 mm/km. The average spacing of astro-geodetic deflections is twenty to twenty-five kilometers.

Relative geoid heights are now well determined on some major geodetic datums such as the North American, European, and Australian. These datums are well supplied with astro-geodetic deflections and have fair gravity coverage. The standard error of relative geoid heights in these areas is probably about two or three meters. In large unsurveyed areas and over the oceans, geoid height determinations depend primarily on dynamic satellite observations for the gravitational field, and may have a standard error of ten to fifteen meters or more.

2.4 ASTRONOMIC OBSERVATIONS

The errors in astronomic coordinates as noted on the Geodetic Data Sheets are given by the observing agency and reflect the internal consistency of the observations. They do not include any systematic error that may be present, nor do they reflect differences in the procedures used by different agencies, or by the same agency at different times.

In general a first-order observation of latitude may be expected to have a maximum error not exceeding 0.''3. The accuracy of longitude would be the same were it not for personal equation, which enters even impersonal micrometer observations. While this may be negligible for an observer whose personal equation is frequently checked, this procedure is not universal, and errors of 0.''5 of arc may result from this source even in first-order observations. This may be reduced by averaging the determinations of more than one observer, as practiced by some agencies.

Second-order observations may be expected to have twice the error of first-order observations. In latitude this may be estimated at 0.''5, in longitude from 0.''5 to one second (of arc), depending on the care with which the personal equation of the observer has been measured.

The accuracy of astronomic azimuth is also reflected only partially in the quoted residuals. A first-order observation should have a standard error of less than 0.''45 based on internal evidence. But Australian geodesists, having compared a hundred reciprocal Laplace azimuths, calculated that the real standard error of such an observation is about one second.

Apart from the probable errors in observation is the fact that observational data may be published with or without corrections for sea level, for variation of the pole, or for the occasional adjustments of the nominal longitude of the time source. The reduction of latitude to sea level, known to be approximate, reaches 0".3 at 1700 meters elevation and 45° latitude. Polar motion has a secular component of 0".002 and a periodic component of 0".3 a year. Changes in the longitude of the U.S. Naval Observatory have not exceeded 0.05 seconds of time (0".45 arc) since 1900. Without access to the particular procedures followed in each case an ambiguity of some half second must be presumed in a given astronomic position. The reductions are not precise, and errors of some hundredths of a second are inescapable. Timing biases, errors in star positions, and problems in refraction will contribute to the total error in an absolute sense. The effect of errors is not cumulative, but lack of awareness of the sources of error may give false confidence in the precision of the observations.

2.5 WORLD SYSTEMS

The relative accuracies within an established geodetic datum are quite high and can be significantly increased by the addition of new Laplace azimuths, baselines, and satellite observations. These will be included in the general readjustments contemplated in America and Europe. Of greater interest in connection with world-wide networks of satellite tracking stations is the accuracy of station positions on a global basis. If left uncorrected to a common world system, the station positions of points on different datums could be in relative error by several hundred meters, and on remote islands by as much as one or two kilometers.

Datum shifts and new ellipsoid dimensions have been determined through satellite observations by several organizations, such as the Army Topographic Command, the Smithsonian Astrophysical Observatory, and the Naval Weapons Laboratory. A comparison of the transformation constants for the world geodetic systems (section 6.10) indicates a general agreement in the three components of the datum shifts and the ellipsoidal constants. It is reasonable to expect that a combined solution of the observational data from all the networks will yield determinations for these constants within a standard error of ten meters.

When all the data are in from the geodetic satellites observing programs, and a combined, properly weighted adjustment is made, maximum position errors in relation to the earth's center of mass of five to ten meters may be expected, with errors of no more than ten to fifteen meters between widely separated stations.

SECTION 3
DEVELOPMENT OF THE MAJOR GEODETIC DATUMS

3.1 INTRODUCTION

Much of the inhabited area of the world is covered with geodetic networks consisting mostly of triangulation, although some are in the form of traverse surveys, e.g., those established by Australia in the 1960's, or Shoran trilateration as established by Canada in the 1950's. The most notable voids of great extent are the interior of Brazil, portions of west, central, and northern Africa, much of China, and northern Siberia.

These geodetic operations date back to the last part of the 18th century, and it was common practice from that time to the early part of the 20th century to employ separate origins or datums in each country, and even more than one origin in some countries, e.g., the United States. Even in the early days astronomically determined latitudes were rather easily established as one coordinate of the origin. But longitudes were another matter for two reasons: 1) there is no natural common plane of reference such as the equator for latitude, and 2) even if a common plane, such as that of the Greenwich Meridian, were agreed upon, there was no accurate method of observing longitude before the electric telegraph and the associated lines of transmission, including submarine cables, were developed.

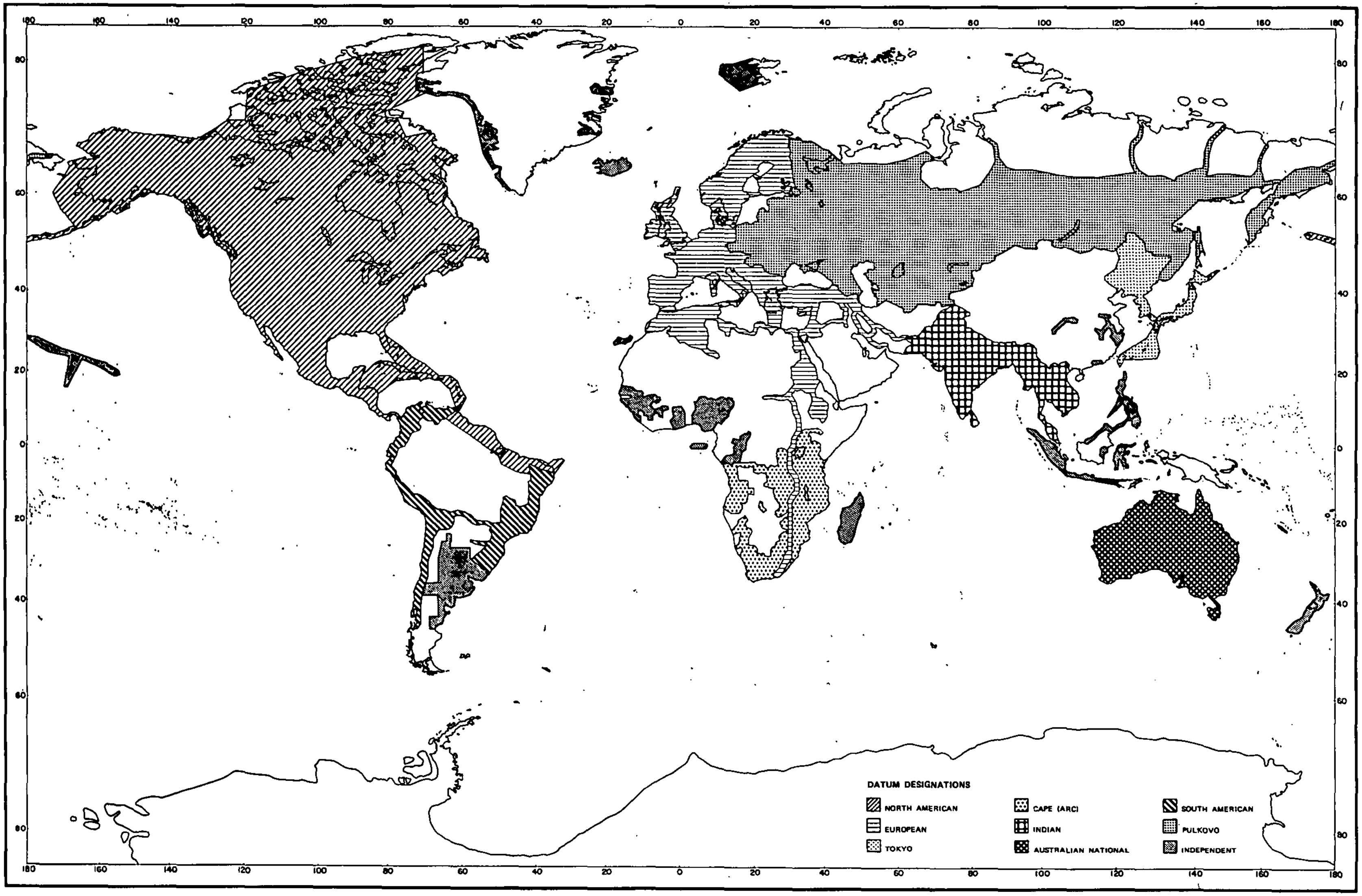
The longitude problem taxed the ingenuity of the astronomers in the first half of the 19th century. Lunar culminations, occultations, and distances were observed along with solar eclipses in an attempt to determine differences of longitude of widely separated points. These methods depended on "fixing" the moon as it moves among the stars, but because of the relatively slow movement of the moon among the stars and the irregularity of the moon's limb, this approach was inherently inaccurate. It gave way to the transportation of chronometers to be used to time observations of the stars. This method, which reached its peak about the middle of the 19th century, was replaced by telegraph and, later, radio time signals. With the recent development of crystal and atomic clocks, transportation of time is again in use.

In the early days longitudes of a geodetic system were often based on the position of an astronomic observatory usually situated in or near the capital city of a country. A reference ellipsoid was chosen for the datum, and the latitudes and longitudes of all other geodetic points were derived by computation through the triangulation. This meant that the many datums, computed on different ellipsoids and based on astronomic observations at separate origins, were not accurately related in a geodetic sense, although the astronomic latitudes were of high caliber.

There was a slow trend toward accepting the Greenwich Meridian as the basis for longitude, and by 1940 practically all important geodetic networks were based on it. But there still remained the separate geodetic datums employing a variety of ellipsoids and methods for determining the coordinates of the origins. The only computations of extensive geodetic work of an international nature, based on a single datum, were those for long arcs done in an effort to improve the knowledge of the size and shape of the earth.

Since World War II much has been accomplished in combining separate datums on the continents and in relating datums between the continents. The advent of artificial satellites has made possible the tremendous task of correlating all datums and, ultimately, of placing all geodetic points on a single worldwide geodetic system.

The first step in this process, taken after World War II, was the selection of several so-called "preferred datums," into which many local geodetic systems were reduced. The more important datums appear on the accompanying map, figure 1.



MAJOR GEODETIC DATUM BLOCKS

FIGURE 1

3.2 THE NORTH AMERICAN DATUM OF 1927

Most extensive of the "preferred datums," the North American Datum of 1927 is the basis of all geodetic surveys on the North American Continent. This datum is based ultimately on the New England Datum, adopted in 1879 for triangulation in the northeastern and eastern areas of the United States. The position of the origin of this datum, station PRINCIPIO in Maryland, was based on 58 astronomic latitude and seven astronomic longitude stations between Maine and Georgia.

At the turn of the century, when the computations for the transcontinental triangulation were complete, it was feasible to adopt a single datum for the entire country. Preliminary investigation indicated that the New England Datum might well serve as a continental datum. Accordingly, in 1901 the New England Datum was officially adopted, and became known as the United States Standard Datum. A subsequent examination of the astrogeodetic deflections available at that time at 204 latitude, 68 longitude, and 126 azimuth stations scattered across the entire country indicated that the adopted datum approached closely the ideal under which the algebraic sum of the deflection components is zero [1].

A later test was applied to the U.S. Standard Datum. Using Hayford's observation equations based on astronomic observations for 381 latitude, 131 longitude, and 253 azimuth stations available in 1909, a solution was made for the shift at MEADES RANCH, the chosen datum point, to best satisfy the observed data. Observed deflections uncorrected for topography were used, and the parameters of the Clarke Spheroid of 1866 were held fixed. The computed corrections to the latitude and longitude were, respectively, only $0''.41$ and $0''.11$.

In 1913, after Canada and Mexico had adopted the U.S. Standard Datum as the basis for their triangulation, the designation was changed to "North American Datum" with no difference in definition.

Beginning in 1927 a readjustment was made of the triangulation in the United States, and the resulting positions were listed on the North American

Datum of 1927 [2]. In this readjustment the position of only MEADES RANCH was held fixed. As a matter of fact this is really all that sets MEADES RANCH apart from all other triangulation stations. Its choice as the datum origin was purely arbitrary and was made because it was near the center of the United States and at the intersection of the Transcontinental and 98th Meridian Arcs of the triangulation. The deflection at MEADES RANCH is not zero as is sometimes assumed; in fact it was not determined until the late 1940's. Its deflection components in the meridian and prime vertical are, respectively, approximately $-1''.3$ and $+1''.9$, in the sense astronomic minus geodetic, with latitude and longitude measured positively north and east.

Loop closures and corrections to sections in the 1927 readjustment of the triangulation in the United States indicate that distances between points separated by at least 2000 kilometers are determined to an accuracy of five parts per million, and transcontinental distances are known to four parts per million. Gravimetric and other studies suggest that the position of the datum origin is within one arc-second in an absolute sense, and recent satellite triangulation points to an accuracy of better then one second in the overall orientation of the 1927 adjustment. These statements do not necessarily apply to the extension of the North American Datum of 1927 into Mexico, Canada, and Alaska.

Although a geodetic azimuth is included in the fundamental data of MEADES RANCH, this is of only minor importance, since the orientation of the triangulation is controlled by many Laplace azimuths scattered throughout the network.

In summary the North American Datum of 1927 is defined by the following position and azimuth at Meades Ranch:

Latitude (N)	$39^\circ\ 13'\ 26''.686$
Longitude (W)	$98^\circ\ 32'\ 30''.506$
Azimuth to Waldo (from South)	$75^\circ\ 28'\ 09''.64$

The latitude is based on 58 astronomical latitude stations, the longitude is based on seven astronomical longitude stations, and the azimuth is based on nearby Laplace azimuth control. The basis for computations is the Clarke Spheroid of 1866. All measured lengths are reduced to the geoid (mean sea level), not to the spheroid.

3.3 EUROPEAN DATUM

Until 1947 each country in Europe had established its own triangulation, computed on its own datum, which usually consisted of a single astronomic latitude and longitude of a selected origin. Moreover at least three different spheroids were used. This situation, coupled with the inevitable accumulation of errors in the networks, led to differences at international boundaries of nearly 500 meters in extreme cases.

Although considerable thought over a period of many years was given to unification of the European triangulation, no results became available until after World War II. For several years before the war extensive surveys were conducted to connect many separate national triangulations; thus the groundwork was laid for a general adjustment of the major European networks.

Under the general supervision of the U.S. Army Map Service and with the assistance of the U.S. Coast and Geodetic Survey, the Land Survey Office at Bamberg, Germany, commenced the adjustment of the Central European Network in June 1945 and completed it two years later. This triangulation network roughly covers the region that lies from 47° to 56° North latitude and between 6° and 27° East longitude, and is generally in the form of area, rather than arc, coverage. The basis for the computation is the International Ellipsoid.

In order to expedite the work in a practical manner, triangles were selected to form a few strong arcs of the parallel and meridian to build a network susceptible of the Bowie junction method of adjustment. A scheme was selected which included 23 junction figures, each of which contained at least one base line and one Laplace azimuth. A total of 52 base lines and 106 Laplace azimuths scaled and oriented the Central European Network.

The datum of this network depends on the study of 173 astronomic latitudes, 126 astronomic longitudes, and 152 azimuths of which 106 are of the Laplace type. No one station can be logically designated as the datum point. The Central European Datum has been referred to as a "condition of the whole," not to any single point. However, as a matter of convenience, Helmert Tower near Potsdam, being rather centrally located, is sometimes referred to as the origin for comparison of the Central European Datum with other datums.

The Central European Network was extended by the addition of two separate adjustments of large networks of triangulation known as the Southwestern Bloc and the Northern Bloc [3]. The Central Network was substantially held fixed and, with the addition of the two blocs, forms the European Triangulation based on what is now designated as the European Datum.

The Southwestern Bloc is comprised of 1230 triangulation stations in Belgium, France, Spain, Portugal, Switzerland, Austria, Italy, and North Africa, whereas the Northern Bloc includes 822 stations in Finland, Estonia, Latvia, Denmark, Norway, and Sweden. As in the Central European Adjustment, arcs were selected and adjusted in loops, not by the Bowie junction method but by a modified simultaneous approach.

Triangle and loop closures indicate, on the average, that the accuracy of the Central Network and the Northern Bloc of triangulation is somewhat greater than that in the United States, possibly three parts per million for determination of distances of several hundred kilometers. On the average the accuracy of the Southwestern Bloc is not as high, probably nearer five or six parts per million. These are average estimates: the accuracies vary considerably within the blocs. There is no evidence that any of the base lines were reduced to a common spheroid, certainly not to the International Ellipsoid.

Although the European Datum is based on a relatively large number of astronomic observations scattered through the Central European Net, later studies of the geoid in Europe indicate that to approach an ideal or absolute datum the geodetic coordinates of Helmert Tower perhaps should be changed by roughly three seconds in latitude and one and one-half seconds in longitude.

Since the completion of the original adjustment of the European triangulation networks, the European Datum has been connected to work in Africa and, upon completion of the 30th Meridian Arc, as far as South Africa, as well as to the Indian Datum through ties made in the Middle East. It is also possible by computation to carry the European Datum to the North American Datum of 1927 by way of the North Atlantic Hiran connection.

3.4 THE INDIAN DATUM

A brief history of the Great Trigonometric Survey of India and of the Indian Datum is of particular interest, if for no other reason than that the geodetic operations were commenced at such an early date and in an area so remote from any similar activity and from the country responsible for conducting them. Operations were begun in about 1802, and the Madras Observatory was first selected as the origin of the trigonometric coordinates as it was the only institution equipped with precision instruments.

It was, however, many years before any real progress was made on what is now known as the primary triangulation. Col. George Everest, who was appointed Surveyor General of India in 1830, decided in 1840 to adopt as the origin the triangulation station at Kalianpur H.S. [4]. This station was selected because it was centrally located at the intersection of two great arcs of triangulation, and because it is on a broad plateau at what was thought to be a safe distance from the Himalayan mass and its adverse effect on the plumb line.

In 1847 a value of $77^\circ\ 41'\ 44\overset{''}{.}75$ E was accepted as the astronomic and geodetic longitude at Kalianpur. It was based on a preliminary value of the position of Madras Observatory. But in 1894-95 a reliable determination of the longitude of Karachi was made possible by telegraphic observations, and it was learned that the Indian longitudes should be corrected by $-2'\ 27\overset{''}{.}18$. Thus the corrected longitude at the origin is $77^\circ\ 39'\ 17\overset{''}{.}57$ E. But since this was considered as the astronomic longitude, and a deflection of $+2\overset{''}{.}89$ in the prime vertical had been adopted, a further correction to the geodetic longitude was needed to maintain this deflection. These modern longitudes were introduced in India in 1905; prior to this, the mapping longitudes of India were off by about two and a half miles.

The first comprehensive adjustment of the Indian triangulation was undertaken about 1880. There were no Laplace stations in the strict sense of the word at this time, but expedients were adopted to approximate the Laplace correction from telegraphic longitudes available at certain cities. There appear to have been only about eleven base lines at the time.

After the recommendation of the International Spheroid by the I.U.G.G. in 1927, it was decided to use this spheroid in India for scientific purposes. The Everest Spheroid which was used had long been known to be unsuitable. A least squares solution was accomplished to best fit the geoid in India to the International Spheroid. In this adjustment the deflections at Kalianpur were +2.''42 and +3.''17 in the meridian and prime vertical respectively, and the geoid height was 31 feet.

In 1938 a detailed adjustment of the Indian triangulation was made on the Everest Spheroid, but it lacked the rigor of least squares; it employed detailed diagrams of misclosures in scale, azimuth and circuit closures, and personal judgment in the distribution of these errors of closure.

The Indian work comprises about 9400 miles of primary arcs of triangulation and nearly as many more miles of secondary arcs. In the primary work, the mean square error of an observed angle ranges among the various sections from 0.''15 to 1.''00, and averages about 0.''5. Thus the angle observations are of very high caliber, but the number of base lines and Laplace azimuths is deficient. There are now about 127 Laplace stations available in India, which will greatly strengthen any future readjustment of the work. Before this is done, however, the plan is to raise the accuracy of the secondary work to primary standards by reobservation, and to provide additional work in many of the existing gaps.

To summarize the datum information for the 1938 adjustment the following table is given. As has been the custom for India, the deflections rather than the position coordinates are given at the origin; a plus sign indicates the plumb line is south or west of the spheroid normal.

Spheroid, Everest: a = 6 377 276 meters, f = 1/300.8017
Origin, Kalianpur.
Deflection in meridian -0."29, in prime vertical +2."89
Geoid height at origin is zero by definition

3.5 TOKYO DATUM

The origin of the Tokyo Datum is the astronomic position of the meridian circle of the old Tokyo Observatory. The adopted coordinates were:

Latitude	35° 19' 17."5148	North
Longitude	139° 44' 40."9000	East

Reference surface, Bessel Spheroid, 1841

The latitude was determined from observations by the Tokyo Observatory, and the longitude by the Hydrographic Department of the Imperial Navy by telegraphic submarine cable between Tokyo and the United States longitude station at Guam. This datum is known to be in considerable error as related to an ideal world datum because of large deflections of the plumb line in the region of Tokyo.

The primary triangulation of Japan proper consists of 426 stations and 15 baselines established between 1883 and 1916 [5]. The mean error of an observed angle is 0."66, which is roughly equivalent to a probable error of 0."3 as applied to an observed direction. This puts the accuracy of the work about on a par with that of the United States in this respect.

After completion of the primary work in Japan proper, the Tokyo Datum was extended in the mid-1920's into the Karahuto portion of Sakhalin. The Manchurian triangulation, established by the Japanese Army after 1935, has been connected through Korea to the Tokyo Datum. The quality of the primary triangulation in Korea and Manchuria is believed to be about, though not quite, equal to that of Japan proper.

3.6 AUSTRALIAN GEODETIC DATUM

Until 1961 the spheroid generally used in Australia was the Clarke of 1858. Since the triangulation in Australia was initiated in several separate areas there was no single national datum but several distinct origins. The most important were Sydney Observatory, Perth Observatory - 1899, and Darwin Origin Pillar.

During the early 1960's an ambitious geodetic survey was started to establish complete coverage of the continent and connect all important existing geodetic surveys. For a short period in 1962 computations were performed on the so-called "NASA" Spheroid (a = 6 378 148 m; f = 1/298.3) with the origin at Maurice, but these have been completely superseded.

The first comprehensive computation of the new geodetic survey was made on the "165" Spheroid (a = 6 378 165; f = 1/298.3). This was based on the "Central Origin," in use since 1963, and depended on 155 astro-geodetic stations distributed over most of Australia except Cape York and Tasmania.

It appeared at this time that there might be international agreement on one spheroid, which Australia might adopt officially. Many modern determinations had been made for which the ranges in a and f were so narrow as to have no practical significance. On the strength of the acceptance of a spheroid by the International Astronomical Union, the Australian National Spheroid was adopted in April 1965, with the only difference that the flattening of the spheroid used for astronomy was rounded to 1/298.25 (exactly). The semi-major radius is 6 378 160 meters.

Holding the Central origin, which was defined by the coordinates of station GRUNDY, a complete readjustment of the geodetic network was made in 1966, using the Australian National Spheroid [6]. The mean deflection, uncorrected for topography, at 275 well-distributed stations was: +0."12 in meridian and -0."33 in prime vertical.

The Central origin has in effect been retained. Instead of being defined, as originally, in terms of station GRUNDY, it is now defined by equivalent coordinates for Johnston Memorial Cairn. These are: latitude 25° 56' 54."5515 S, longitude 133° 12' 30."0771 E, and height 571.2 meters. The geoid height at this point is zero by definition.

A study of the observations of satellite orbits indicates there is a rather uniform and relatively heavy tilt of the geoidal surface over Australia, which would introduce a bias to the astro-geodetic deflections determined on the Australian Geodetic Datum of 4."7 and 4."4 in the meridian and prime vertical respectively. This tilt is in such a direction that the astronomic zenith is pulled approximately 6."5, on the average, southwest of where an ideal or absolute geodetic zenith would be.

The survey net of Australia consists of 161 sections which connect 101 junction points and form 58 loops. Virtually all the surveys are of the traverse type in which distances were determined by electronic measuring equipment, specifically the Tellurometer. There are 2506 stations, of which 533 are Laplace points, and the total length of the traverses is 33,100 miles.

Measured lengths were reduced to the geoid, not the spheroid, because of lack of knowledge of the separation of these surfaces at the time of the general adjustment. The method of adjustment may briefly be described as follows: each section was given a free adjustment by which the length and azimuth between the end points were determined; these lengths and azimuths were then put into a single adjustment to determine the final coordinates of the junction points connected by the sections; each section was then adjusted to the final coordinates of the pertinent junctions. The average loop length is about 900 miles; the average closure is 2.2 parts per million, with a maximum closure of 4.3 ppm. The closures appear to place the accuracy of the Australian geodetic network on about a par with the Northern and Central European networks, and perhaps a little above that of the United States triangulation. This is a remarkable accuracy for traverse type surveys.

Tasmania has been connected by two new sections across Bass Strait via King and Flinders Islands. A connection to New Guinea and the Bismarck

Archipelago has been effected by a Tellurometer traverse up Cape York and the USAF Hiran network of 1965, placing an additional 135 points on the Australian Geodetic Datum.

3.7 SOUTH AMERICAN DATUM

By 1953 the Inter-American Geodetic Survey of the U.S. Corps of Engineers had completed the triangulation from Mexico, through Central America and down the west coast of South America to southern Chile. This was done in cooperation with the various countries through which the work extended, and marked the completion of the longest north-south arc of triangulation ever accomplished. It had an amplitude of over one hundred arc degrees through North and South America.

In 1956 the Provisional South American Datum was adopted as an interim reference datum for the adjustment of the triangulation in Venezuela, Columbia, and the meridional arc along the West Coast [7]. Instead of depending on one astronomic station as the origin and assuming its deflection components to be zero, or attempting to average out the deflections at many astronomic stations by the astrogeodetic method, one astronomic station was chosen as the datum origin, but its deflection components were determined gravimetrically. The gravity survey covered an area about 75 kilometers in radius centered on the origin, station LA CANOA in Venezuela. The reference figure was the International Ellipsoid, and the geoid height at LA CANOA was zero by definition.

A major portion of the South American work was adjusted on the Provisional South American Datum, including the extensive Hiran trilateration along the northeast coast of the continent. The principal exceptions were the networks in Argentina, Uruguay, and Paraguay.

Considering the geographic location of LA CANOA, with all of the continent on one side and the Puerto Rican ocean trench on the other, the gravity coverage was insufficient to produce a deflection for a continentally well-fitting datum. From the astro-geodetic deflections based on this datum it can be inferred that the geoid drops about 280 meters below the spheroid in Chile at about latitude 41° south. This drop is more or less uniform in a southerly direction for a distance of roughly 5500 km. In 5500 km, 280 meters is very nearly ten seconds of arc; such a correction to the meridian deflection component at LA CANOA would produce a better fit of the International Ellipsoid to the area of the South American adjustment. But the LA CANOA Datum has not been corrected for this large and increasing geoidal separation, and thus contains large distortions. For example, cross-continental distances may be several tens of meters too short. In addition the Hiran net has also been shown to be tens of meters too short.

An investigation of the astro-geodetic data from the long meridional arc in the Americas and the 30th Meridian Arc from Finland to South Africa led to the conclusion that the equatorial radius of the International Ellipsoid should be reduced by at least 100 meters (a subsequent change in the flattening inferred from satellite observations suggested another 100 meter reduction), and that the North American and European Datums were not at all well suited for the continents to the south. Thus it became apparent that consideration must be given to the selection of another datum for South America.

A Working Group for the Study of the South American Datum was asked in 1965 by the Committee for Geodesy of the Cartographic Commission of the Pan American Institute of Geography and History to select a suitable geodetic datum for South America, and to establish a coherent geodetic system for the entire continent. This was achieved, and the "South American Datum 1969" was accepted by the Cartographic Commission in June 1969 at the IX General Assembly of PAIGH in Washington, D.C. [8]. This new datum is computed on the Reference Ellipsoid 1967, accepted by the International Union of Geodesy and Geophysics in Lucerne in 1967, with the minor difference that the flattening is rounded (a = 6 378 160 meters, f = 1/298.25). Both CHUA and CAMPO INCHAUSPE, the National datum points of Brazil and Argentina, respectively, were assigned minimal geoid heights (zero and two meters respectively). CHUA is taken to be the nominal origin. A vast amount of recent triangulation, Hiran, astronomic, and satellite data were incorporated in the solution, and SAD 1969 is expected to provide the basis for a homogeneous geodetic control system for the continent.

3.8 ARC DATUM

The origin of the old South African, or Cape, Datum is at Buffelsfontein. The latitude at this origin was adopted after a preliminary comparison of the astronomic and geodetic results, rejecting those stations at which the astronomic observations were quite likely affected by abnormal deflections of the plumb line. The longitude of this origin depends upon the telegraphic determination of longitude of the Cape Transit Circle, to which was added the difference of geodetic longitude computed through the triangulation. Computations were based on the modified Clarke Spheroid of 1880. The geodetic coordinates of Buffelsfontein are:

Latitude (S)	33° 59' 32".000
Longitude (E)	25° 30' 44".622

Over the years this datum has been extended over much of South, East, and Central Africa. Through the 30th Meridian Arc, completed in the 1950s, it has been connected to the European Datum. Because the 30th Meridian Arc is the backbone of this work, which also includes triangulation in the Congo and Portuguese Africa, the published geodetic coordinates are now referred to the Arc Datum [9]. The whole comprises a uniform system from the Cape to the Equator.

The accuracy of the South African work and of the 30th Meridian Arc compares favorably with that of the other major systems of the world, but some of the related triangulation requires additional length control and Laplace azimuths.

3.9 PULKOVO DATUM 1942

The development of the triangulation network in the USSR parallels to some extent the development of the network in the United States. The Russian work began in 1816 in the Baltic states, and was gradually extended by the Corps of Military Topographers (KTV) as well as by provincial organizations [10]. An important early accomplishment was the establishment of the Struve-Tenner arc of the meridian from Finland to the mouth of the Danube, the results of which were used for figure-of-the earth studies.

These early surveys were established independently, and were based on different ellipsoids and datum points. By the turn of the century over twenty independent sets of coordinates were in use. About this time the first effort was made to unify the many systems and place them on the Bessel Ellipsoid, with the Tartu Observatory as the initial point. Not much was done until a new plan was formulated by the KTV in which arcs of triangulation were to be observed along parallels and meridians, spaced from 200 to 300 miles, with Laplace azimuths and base lines at their intersections. The Bessel Ellipsoid was chosen again, but the initial point was changed to the Pulkovo Observatory. The coordinates assigned to Pulkovo are now referred to as the Old Pulkovo Datum.

This plan was implemented in 1910 and, after interruption by World War I and the Revolution, was pursued vigorously until 1944, at which time 47,000 miles of arc and associated astronomic observations and base lines were completed. In 1928 Prof. Krassovski was commissioned to augment the original plan. He called for closer spacing of arcs, Laplace stations, and base lines, and a breakdown between primary arcs by lower order work. The standards of accuracy were comparable to those in North America.

During this period triangulation had begun in the Far East, and by 1932 two basic datums were in use, both on the Bessel Ellipsoid but with different initial points -- Pulkovo, and an astronomic position in the Amur Valley of Siberia. The coordinates of Pulkovo were changed slightly (less than one second) from those of the Old Pulkovo Datum.

When the two systems were finally joined, a discrepancy of about 900 meters in coordinates of the common points naturally developed. This was due principally to the use of the Bessel Ellipsoid, now known to be seriously in error.

In 1946 a new unified datum was established, designated the "1942 Pulkovo System of Survey Coordinates." This datum employs the ellipsoid determined by Krassovski and Izotov, and new values for the coordinates of Pulkovo. The ellipsoid is defined by an equatorial radius of 6 378 245 meters, and a flattening of 1/298.3. The coordinates of Pulkovo are latitude 59° 46' 18."55

North, longitude 30° 19' 42".09 East of Greenwich. Deflections at the origin are +0".16 and -1".78 in the meridian and prime vertical respectively.

3.10 BRITISH DATUM

The original primary network of Great Britain was the result of a selection of observations from a large amount of accumulated triangulation done in a piecemeal fashion. The selected network covered the whole of the British Isles, was scaled by two base lines, and was positioned and oriented by observation at the Royal Observatory, Greenwich. The adjustment was accomplished in 21 blocks, computed on the Airy Spheroid.

In the Retriangulation of 1936 only the original work in England, Scotland, and Wales was included. Original stations were used when practicable, and many stations were added, including secondary and tertiary points. The adjustment was carried out in seven main blocks. The scale, orientation and position were an average derived from comparison with 11 stations in Block 2 (central England), common to the two triangulations. Other blocks were adjusted sequentially, holding fixed previously adjusted blocks. The result, known as OSGB 1936 Datum, has not proved to be entirely satisfactory. No new base lines were included, and subsequent checks with Geodimeter and Tellurometer indicated that the scale of the Retriangulation was not only too large, but varied alarmingly.

To correct this situation a new adjustment has been made, described as the Ordnance Survey of Great Britain Scientific Network 1970 (OSGB 1970 (SN)). This is a variable quantity and consists, at any moment, of the best selection of observations available. It consists now of 292 primary stations connected by 1900 observed directions, 180 measured distances, and 15 Laplace azimuths. Published positions of all orders on the OSGB 1936 Datum (given as rectangular coordinates on the National Grid) are not altered, nor is the grid on Ordnance Survey maps to be changed, under present policy [11].

At present (July 1971) only the values of the first-order stations are available on OSGB 1970 (SN). More accurate conversions to the European Datum will become available when Block 6 of the European readjustment is completed, sometime after March 1972.

The Airy spheroid was used for all three British datums. The origin is the Royal Observatory at Herstmonceux.

3.11 WORLD GEODETIC SYSTEMS

A World Geodetic System may be defined as that in which all points of the system are located with respect to the earth's center of mass. A practical addendum to this definition is usually the inclusion of the parameters of an earth ellipsoid which best fits the geoid as a whole. In such a system the locations of all datum origins with respect to the center of mass are expressed by their rectangular space coordinates, X, Y, and Z. This implies three more designations to specify the directions of the axes unambiguously. Conventionally, in reference to the earth-centered ellipsoid, X and Y are in the equatorial plane, X positive toward zero longitude, Y toward 90° East, and Z is positive toward North. The relationship between the X, Y, and Z coordinates and the conventional ellipsoid coordinates of latitude, longitude, and height is expressed by relatively simply transformations.

As indicated, there are a number of preferred datums which provide satisfactory solutions to large areas, even continental in extent. The points within each datum are interrelated with a high order of accuracy. There are some connections between these datums, made by terrestrial surveys, but these are usually tenuous at best. Part of the trouble in extending datum connections is that the chosen spheroid is usually not suitable for areas remote from the datum proper, which results in excessive deflections and geoid heights. These in turn can seriously distort the triangulation if the geoid heights are not taken into account in base line reduction. Even when the heights are taken into account the result is not satisfactory.

Realizing that the development of a world geodetic system is desirable for scientific purposes, some of which are of a practical nature, the geodesists began attacking the problem of developing such a system. For example, the program of observing satellite orbits from points around the world required better approximations of the coordinates of the observation stations on a world basis. Worldwide oceanographic programs demand accurate positioning at sea, and such approaches as Loran C and Doppler satellite navigation need a coherent worldwide geodetic framework.

A brief assessment of the uncertainties in positioning geodetic datums by classical methods may be made by considering the North American Datum of 1927, the European Datum, and the Tokyo Datum. The figures expressing uncertainties are given in the two sigma sense, or twice the standard error. Such a figure approaches the outside error and might be considered a practical limit of uncertainty. The relative positions of the datum points of North America and Europe, as presently defined, are probably known within 300 meters, whereas the figure for North America and Tokyo is considerably larger, possibly 600 or 700 meters. On the other hand, the positions of islands determined astronomically at a single point may be in error, in an absolute geodetic sense, by as much as one or two kilometers.

In recent years the satellite development of world geodetic reference systems, which include translation shifts of the major datums, has reduced the uncertainties of the relative positioning of the major datums by a factor of about ten. The goal of the National Geodetic Satellite Program is positioning accuracy of primary geodetic points of ten meters (standard deviation) in an absolute sense.

3.11.1 Mercury Datum (1960)

Prior to the advent of specifically geodetic satellites, geodesists from the Army Map Service developed an astro-geodetic world system, using all available data, including an early determination of earth's ellipticity (1/298.3) from observations on Sputnik I and Vanguard. This system was selected by NASA to position the original Project Mercury tracking stations, and came to be known as the Mercury Datum [12].

AMS made three solutions in fitting the major geodetic datums into a single world geodetic system, using various combinations of data [13]. The differences in the solutions were small, and one was adopted as the basis of the Mercury Datum. The adopted solution was based on the proposition that minimizing the differences between astrogeodetically and gravimetrically derived geoidal heights on the major datums would place the datums in proper relative position. The size and shape of the adopted ellipsoid are expressed by an equatorial radius of 6 378 166 meters and ellipticity of 1/298.3. The solution also provided the X, Y, and Z components of the translation vectors to shift the centers of the reference ellipsoids of the major datums to the center of the Mercury Datum, which supposedly is at the earth's center of mass. Conversion formulas are also available to transform positions of certain minor datums - i.e., South American, Cape, and Indian - to the major datums, and through them to the Mercury Datum.

3.11.2 Modified Mercury Datum, 1968

In 1968 a modification of the Mercury Datum was proposed by I. Fischer of the Army Map Service to reflect the accumulation of new data, particularly dynamic satellite results, in the form of geoid charts and observing-station coordinates, which provide improved connections between isolated astro-geodetic datum blocks [14]. Moreover, the dynamic observations provide a superior method for determining relationships to the earth's center of mass. The adopted constants of the earth ellipsoid for the modification are: $a = 6\ 378\ 150$ and $1/f = 298.3$. New sets of translation components for shifts of eighteen datums to the Modified Mercury Datum 1968 were published.

3.11.3 Standard Earth, SAO

The Smithsonian Astrophysical Observatory has long been engaged in satellite observations. The basic instrument has been the Baker-Nunn satellite tracking camera, but other observations are included in their analysis, especially laser. There were twelve basic SAO stations rather well distributed among the major geodetic networks of the world. From this base some extensions were made in determining the coordinates of additional stations.

A combination was used of simultaneous geometric observations between paired stations, and of single observations for orbital dynamics. An iterative process was used to obtain successive improvements of the orbital elements of the satellites, the harmonic coefficients of the gravitational field, and, finally, the station coordinates. Since the observations produced only directions, a scale must be introduced. SAO considers the value of GM (gravitational constant times earth mass) to be known within one part in 10^6 from geodetically determined distances between widely separated points on the earth's surface. Because of this and the fact that GM is an important constant in orbital analysis, it was judged best not to introduce a scale inconsistent with the adopted value of GM.

Earlier solutions for a standard earth by the Smithsonian Astrophysical Observatory, C5, C6, and C7 [15, 16], have been superseded by what is designated as 1969 Smithsonian Standard Earth (II), [17]. Four different types of data were used in a combination solution; i.e., routine and simultaneous observations on satellites, observations of deep space probes, and observations for terrestrial gravity. Determined in the final solution were spherical harmonic coefficients of the gravity field to degree and order 16, plus a few higher degree terms, and the geocentric coordinates of some 40 observation stations.

Scale was primarily determined dynamically, but also included laser ranging, and spin axis distances derived by JPL. Apparently ground surveys were not included as input, which is just as well because of the uncertainties of the connections of some stations to their geodetic datum.

Accuracy claimed for the geocentric coordinates ranges from 5 to 17 meters, on a one sigma basis, and for most stations it was 10 meters or less.

The values adopted as the basis for scale and the reference ellipsoid are:

$$GM = 3.986013 \times 10^{20} \ \text{cm}^3/\text{sec}^2$$
$$c = 2.997925 \times 10^{10} \ \text{cm/sec}$$
$$a = 6,378,155 \ \text{meters}$$
$$f = 1/298.257$$

3.11.4 NWL-8 Geodetic Parameters

The U.S. Naval Weapons Laboratory had been carrying out Doppler observations on artificial satellites for geodetic purposes for some time. Essentially three solutions have been published, NWL-8B, NWL-8C, and NWL-8D. The last solution employed the most data, including satellites with seven orbital inclinations. Determined were the best-fitting earth-centered ellipsoid, the coordinates for about fifty tracking stations based on the new system, the components of the shifts of certain geodetic datums to the new system, an extensive set of coefficients for the gravity field, and geoid heights [18]. Datum shifts, ellipsoid dimensions, and geoid heights were determined with an estimated accuracy of fifteen meters at 90% confidence (about 1.65 sigma).

Some of the geodetic parameters of the NWL-8D solution are:

Equatorial Radius	a = 6 378 145 m
Flattening	f = 1/298.25
GM	= 398601 Km^3/sec^2

3.11.5 Summary of World Datum Relationships

A table of the geometric parameters of the variously determined world geodetic systems is given to show the present status (table 1). Disregarding the early Mercury 1960 solution, a comparison of the various earth ellipsoids and the shifts required to bring the major datums into a world system indicates a definite convergence toward values whose standard errors should not exceed 10 to 20 meters. The agreement in general is indeed remarkable in view of quite different techniques employed. As suggested in section 5, when all observational data are available, including all possible methods of providing scale, and these are combined into a well-planned, properly-weighted, simultaneous adjustment, the relative positions of points in the world network and the earth's center of mass should be known within one part in a million (standard error), or roughly between five and ten meters.

TABLE 1
TRANSFORMATION CONSTANTS FOR WORLD GEODETIC SYSTEMS

Datum \ System		Mercury 1960	Modified Mercury 1968	NWL-8D	*SAO-C7	**SAO-1969
	a	6 378 166	6 378 150	6 378 145	6 378 142	6 378 155
	1/f	298.3	298.3	298.25	298.255	298.25
NAD 1927	ΔX	3	- 18	- 23	- 26	- 26
	ΔY	111	145	159	155	163
	ΔZ	225	183	185	185	167
European	ΔX	- 71	- 81	- 81	- 93	- 27
	ΔY	- 15	-104	- 99	-132	-121
	ΔZ	-122	-121	-118	-143	- 83
Tokyo	ΔX	-158	-162	-147	-140	
	ΔY	648	482	530	510	
	ΔZ	613	671	676	689	
Indian (Everest)	ΔX		194		293	
	ΔY		734		697	
	ΔZ		259		228	
Australian National	ΔX		-105	-114	- 88	
	ΔY		- 44	- 12	- 36	
	ΔZ		94	140	86	
Old Hawaiian	ΔX		68	52	59	
	ΔY		-278	-262	-263	
	ΔZ		-193	-183	-203	
Cape (Arc)	ΔX	-125	-166		-130	
	ΔY	- 48	- 38		-147	
	ΔZ	-315	-283		-347	

* The shifts for SAO-C5 (a = 6 378 165, 1/f = 298.25) and C6 (a = 6 378 155, 1/f = 298.25) differ from the C7 solution an average of about 5 meters and no more than 11 meters.

** Shifts derived by Lambeck [19] from Standard Earth '69.

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SECTION 4
GEODETIC FORMULAS AND CONSTANTS

4.1 FORMULAS

4.1.1 Computation on Rectangular and Polar Geocentric System

The following equations are used to compute rectangular and polar geocentric coordinates:

$$X = (\nu + h) \cos\phi \cos\lambda = R \cos\psi \cos\lambda$$
$$Y = (\nu + h) \cos\phi \sin\lambda = R \cos\psi \sin\lambda$$
$$Z = (\nu \bar{e}^2 + h) \sin\phi = R \sin\psi$$

$$R = (X^2 + Y^2 + Z^2)^{\frac{1}{2}}$$
$$\psi = \tan^{-1} \left[Z / (\nu + h) \cos\phi \right]$$

X, Y, Z are a righthanded coordinate system fixed in the spheroid. X and Y are in plane parallel to the equator, X positive toward the Prime Meridian, Y toward 90° East longitude. Z is positive toward North.

R, the geocentric radius, is the distance from the center of the spheroid to the station.

ψ, the geocentric latitude, is the angle between the plane of the equator of the spheroid and the radius vector to the station.

ϕ, is geodetic north latitude.

λ, is geodetic (and geocentric) East longitude.

h is geodetic height (the sum of the elevation above mean sea level and the geoid height at the station).

ν is the radius of curvature in the prime vertical.

e is the eccentricity of the spheroid.

4.1.2 Coordinate Transformations

The following equations are used to transform geodetic coordinates from one coordinate system to another. Derivation of these equations can be found in Hotine [17]; some of the equations can be found in Molodenskiy [18] and Veis [19].

$$\Delta\phi = \frac{1}{(\rho + h)} [- \sin\phi \cos\lambda \, \Delta X - \sin\phi \sin\lambda \, \Delta Y + \cos\phi \, \Delta Z$$

$$+ (\nu e^2 \sin\phi \cos\phi / a) \, \Delta a + (\nu \bar{e} + \rho / \bar{e}) \sin\phi \cos\phi \, \Delta f]$$

$$\Delta\lambda = \frac{\cos\lambda \, \Delta Y - \sin\lambda \, \Delta X}{(\nu + h) \cos\phi}$$

$$\Delta h = \cos\phi \cos\lambda \, \Delta X + \cos\phi \sin\lambda \, \Delta Y + \sin\phi \, \Delta Z$$

$$- (a/\nu) \, \Delta a + (\nu \bar{e} \sin^2 \phi) \, \Delta f$$

ΔX, ΔY, ΔZ are the shifts applied to the rectangular coordinates of the station on one system to give its coordinates on another.

$\Delta\phi$, $\Delta\lambda$ are changes in the latitude and longitude of the stations.

Δh is the change in the geodetic height, and hence in the geoid height.

a is the length of the semi-major axis of the spheroid (old).

b is the length of the semi-minor axis of the spheroid (old).

f is the flattening of the spheroid (old).

Δa is the difference in equatorial radius of the two spheroids.

Δf is the difference in flattening of the two spheroids.

ρ is the radius of curvature in the meridian (old).

(All Δs are in the sense new minus old.)

$$\nu = \frac{a}{(1 - e^2 \sin^2 \phi)^{\frac{1}{2}}} \qquad e^2 = \frac{a^2 - b^2}{a^2} = 2f - f^2$$

$$\rho = \frac{a\,(1 - e^2)}{(1 - e^2 \sin^2 \phi)^{3/2}} \qquad f = \frac{a - b}{a} \qquad \overline{e}^2 = 1 - e^2$$

As a result of the above changes in geodetic coordinates, geodetic azimuths (α) and geodetic elevation angles (E) to reference marks will change as follows:

$$\Delta\alpha = \sin\phi\ \Delta\lambda + \tan E\ (\sin\alpha\ \Delta\phi - \cos\alpha \cos\phi\ \Delta\lambda)$$

$$\Delta E = \cos\phi\ \sin\alpha\ \Delta\lambda + \cos\alpha\ \Delta\phi$$

α is the geodetic azimuth measured clockwise from the North.

$\Delta\alpha$ is the difference in geodetic azimuth.

E is the elevation angle measured from the horizontal plane passing through the station. The elevation angle is positive in the direction of the local zenith and negative toward the local nadir. In the geodetic system the horizontal plane is by definition parallel to the tangent plane to the spheroid at the intersection of the foot of the normal to the spheroid passing through the station. In the astronomical system, the horizontal plane is perpendicular to the local gravity vector. The tilt angle of the astronomical and geodetic horizontal planes is given by the deflection of the vertical.

ΔE is the difference in elevation angle.

4.1.3 Datum Shifts in Different Coordinate Systems

Datum shifts in this directory are given in the form ΔX, ΔY, and ΔZ. Elsewhere they may be given as $\Delta\phi$, $\Delta\lambda \cos\phi$, and ΔH, that is, north, east, and up. Since the shifts are seldom as much as a few hundred meters, and the spheroids in common use do not vary greatly from each other or from a sphere, comparison between the two forms of shifts can be made with simplified formulas; the errors of the approximation will be much smaller than the uncertainties of the given shifts.

From polar to rectangular coordinates:

$$\Delta X = -\sin\phi\cos\lambda\Delta\phi - \sin\lambda\Delta\lambda\cos\phi + \cos\phi\cos\lambda\Delta H$$

$$\Delta Y = -\sin\phi\sin\lambda\Delta\phi + \cos\lambda\Delta\lambda\cos\phi + \cos\phi\sin\lambda\Delta H$$

$$\Delta Z = \cos\phi\Delta\phi + \sin\phi\Delta H$$

From rectangular to polar coordinates:

$$\Delta\phi = -\sin\phi\cos\lambda\Delta X - \sin\phi\sin\lambda\Delta Y + \cos\phi\Delta Z$$

$$\Delta\lambda\cos\phi = -\sin\lambda\Delta X + \cos\lambda\Delta Y$$

$$\Delta H = \cos\phi\cos\lambda\Delta X + \cos\phi\sin\lambda\Delta Y + \sin\phi\Delta Z$$

For accuracy better than one percent, three place function tables may be used, latitude and longitude may be rounded to a minute, and 30.9 m may be used for a second of arc in the meridian or prime vertical (not in longitude).

4.2 CONSTANTS OF VARIOUS DATUMS

Table 2 lists the spheroidal constants, semi-major axis and flattening, of the spheroids now in common use. Table 3 lists the datums referred to in this directory. For each datum the table shows the spheroid on which it is computed and the name and position of its origin point.

TABLE 2
SPHEROIDAL CONSTANTS

Spheroid	Semi-major axis (meters)	Reciprocal of flattening (1/f)
Airy	6 377 563.4	299.3250
Bessel	6 377 397.2	299.1528
Clarke 1866	6 378 206.4	294.9787
Clarke 1880	6 378 249.145	293.465
Everest	6 377 276.3	300.8017
International	6 378 388	297.0
Krassovski	6 378 245	298.3
Mercury 1960	6 378 166	298.3
Modified Mercury 1968	6 378 150	298.3
Australian National*	6 378 160	298.25
South American 1969*	6 378 160	298.25

*For the Reference Ellipsoid 1967, a = 6 378 160, 1/f = 298.24716 74273.

TABLE 3
REFERENCE DATUMS

DATUM	SPHEROID	ORIGIN	LATITUDE	LONGITUDE (E)
Adindan (Ethiopia)	Clarke 1880	STATION Z5 ADINDAN	22°10'07".110	31°29'21".608
American Samoa 1962	Clarke 1866	BETTY 13 ECC	-14 20 08.341	189 17 07.750
Arc-Cape (South Africa)	Clarke 1880	Buffelsfontein	-33 59 32.000	25 30 44.622
Argentine	International	Campo Inchauspe	-35 58 17	297 49 48
Ascension Island 1958	International	Mean of three stations	-07 57	345 37
Australian Geodetic	Australian National	Johnston Memorial Cairn	-25 56 54.55	133 12 30.08
Bermuda 1957	Clarke 1866	FT. GEORGE B 1937	32 22 44.360	295 19 01.890
Berne 1898	Bessel	Berne Observatory	46 57 08.660	07 26 22.335
Betio Island, 1966	International	1966 SECOR ASTRO	01 21 42.03	172 55 47.90
Camp Area Astro 1961-62 USGS	International	CAMP AREA ASTRO	-77 50 52.521	166 40 13.753
Canton Astro 1966	International	1966 CANTON SECOR ASTRO	-02 46 28.99	188 16 43.47
Christmas Island Astro 1967	International	SAT.TRI.STA. 059 RM3	02 00 35.91	202 35 21.82
Chua Astro (Brazil-Geodetic)	International	CHUA	-19 45 41.16	311 53 52.44
Corrego Alegre (Brazil-Mapping)	International	CORREGO ALEGRE	-19 50 15.140	311 02 17.250
Easter Island 1967 Astro	International	SATRIG RM No. 1	-27 10 39.95	250 34 16.81
European	International	Helmert Tower	52 22 51.45	13 03 58.74
Graciosa Island (Azores)	International	SW BASE	39 03 54.934	331 57 36.118
Gizo, Provisional DOS	International	GUX 1	-09 27 05.272	159 58 31.752
Guam	Clarke 1866	TOGCHA LEE NO. 7	13 22 38.49	144 45 51.56
Heard Astro 1969	International	INTSATRIG 0044 ASTRO	-53 01 11.68	73 23 22.64
Iben Astro, Navy 1947 (Truk)	Clarke 1866	IBEN ASTRO	07 29 13.05	151 49 44.42
Indian	Everest	Kalianpur	24 07 11.26	77 39 17.57
Isla Socorro Astro	Clarke 1866	Station 038	18 43 44.93	249 02 39.28
Johnston Island 1961	International	JOHNSTON ISLAND 1961	16 44 49.729	190 29 04.781
Kusaie, Astro 1962,1965	International	ALLEN SODANO LIGHT	05 21 48.80	162 58 03.28
Luzon 1911 (Philippines)	Clarke 1866	BALANCAN	13 33 41.000	121 52 03.000
Midway Astro 1961	International	MIDWAY ASTRO 1961	28 11 34.50	182 36 24.28
New Zealand 1949	International	PAPATAHI	-41 19 08.900	175 02 51.000
North American 1927	Clarke 1866	MEADES RANCH	39 13 26.686	261 27 29.494
*NAD 1927 (Cape Canaveral)	Clarke 1866	CENTRAL	28 29 32.364	279 25 21.230
*NAD 1927 (White Sands)	Clarke 1866	KENT 1909	32 30 27.079	253 31 01.306
Old Bavarian	Bessel	Munich	48 08 20.000	11 34 26.483
Old Hawaiian	Clarke 1866	OAHU WEST BASE	21 18 13.89	202 09 04.20
Ordnance Survey G.B. 1936	Airy	Herstmonceux	50 51 55.271	00 20 45.882
Pico de las Nieves (Canaries)	International	PICO DE LAS NIEVES	27 57 41.273	344 25 49.476
Pitcairn Island Astro	International	PITCAIRN ASTRO 1967	-25 04 06.97	229 53 12.17
Potsdam	Bessel	Helmert Tower	52 22 53.954	13 04 01.153
Provisional S. American 1956	International	LA CANOA	08 34 17.17	296 08 25.12
Provisional S. Chile 1963	International	HITO XVIII	-53 57 07.76	291 23 28.76
Pulkovo 1942	Krassovski	Pulkovo Observatory	59 46 18.55	30 19 42.09
South American 1969	South American 1969	CHUA	-19 45 41.653	311 53 55.936
Southeast Island (Mahe)	Clarke 1880		-04 40 39.460	55 32 00.166
South Georgia Astro	International	ISTS 061 ASTRO POINT 1968	-54 16 38.93	323 30 43.97
Swallow Islands (Solomons)	International	1966 SECOR ASTRO	-10 18 21.42	166 17 56.79
Tananarive	International	Tananarive Observatory	-18 55 02.10	47 33 06.75
Tokyo	Bessel	Tokyo observatory (old)	35 39 17.51	139 44 40.50
Tristan Astro 1968	International	INTSATRIG 069 RM No.2	-37 03 26.79	347 40 53.21
Viti Levu 1916 (Fiji)	Clarke 1880	MŌNAVATU (latitude only) SUVA (longitude only)	-17 53 28.285	178 25 35.835
Wake Island, Astronomic 1952	International	ASTRO 1952	19 17 19.991	166 38 46.294
Yof Astro 1967 (Dakar)	Clarke 1880	YOF ASTRO 1967	14 44 41.62	342 30 52.98

* Local datums of special purpose, based on NAD 1927 values for the origin stations.

4.3 TRANSFORMATION CONSTANTS FOR MERCURY DATUM 1960

The following transformation constants were used to convert positions of the NASA tracking stations to Mercury Datum 1960. The constants represent shifts of the rectangular coordinates X, Y, and Z of the station to transform from one geodetic datum to another.

Datum Shifts to Mercury 1960

From	dX	dY	dZ
NAD 1927[1]	+ 3	+111	+225m
European[1]	- 71	- 15	-122
Cape (Arc)[1]	-125	- 48	-315
Tokyo[1]	-158	+648	+613
Old Hawaiian[2]	+ 61	-256	-153
	$\Delta\phi$		$\Delta\lambda(E)$
Pico de las Nieves[3] (Canary Islands)	$-1\overset{''}{.}28$		$+4\overset{''}{.}18$

[1] AMS Technical Report No. 28

[2] Geodetic Coordinates Manual, AF Western Test Range, July 1969

[3] Geonautics report, Project Mercury; Application of Geodesy to a World-Wide Satellite Tracking System, April 1961.

4.4 TRANSFORMATION CONSTANTS FOR MODIFIED MERCURY DATUM 1968

Coordinate conversion constants for Modified Mercury Datum 1968 are given in the following table. Only those constants which were used in preparing the coordinate tables in Parts B and C of the directory are listed.

Datum Shifts to Modified Mercury 1968 *

From	ΔX	ΔY	ΔZ
NAD 1927	- 18	+145	+183
European	- 81	-104	-121
Australian	-105	- 44	+ 94
Tokyo	-162	+482	+671
Arc	-166	- 38	-283
Old Hawaiian	+ 68	-278	-193
Adindan	-151	- 28	+220
Canton I.	+235	+244	-467
Johnston I.	+181	- 45	-198
SAD 1969**	- 74	- 9	- 39

* A Modification of the Mercury Datum, Fischer 1968, Army Map Service Technical Report No. 67, June 1968.

** Letter from Chief, Department of Geodesy and Geophysics, USATOPOCOM, to GSFC 19 October 1971.

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SECTION 5
CRITERIA FOR STATION POSITIONING

5.1 INTRODUCTION

If satellite tracking facilities and geodetic satellite observing systems are to provide useful scientific data, it is essential that the stations be positioned accurately on their local or national datums. This requires that just as much care be given to site surveys and documentation of survey information as is exercised in obtaining and reducing satellite observations.

Accuracy requirements for tracking station locations have increased proportionately with the needs for improved trajectory analysis and orbit determination. It is planned that eventually all tracking facilities and geodetic satellite observing stations will be positioned within the same degree of accuracy, that is, within an absolute accuracy of ten meters with respect to a reference system based on the earth's center of mass. To achieve this accuracy on a worldwide basis, each station should be geodetically connected to its local datum within about one meter. In terms of geodetic survey specifications this should be interpreted as the maximum permissible error in the horizontal and vertical connection of the observation station to the primary geodetic and leveling networks. This one-meter requirement should not be difficult to meet in most instances if the availability of existing control and access to it are considered when the sites for observation stations are selected.

Unless survey data are properly documented, the reliability of station coordinates on their local datums will remain in question. Suggested procedures for determining station coordinates and documenting survey data are outlined in this section. These are presented primarily to assist organizations participating in observation programs which may not have personnel experienced in conducting site surveys, or which may not be familiar with the survey documentation which should be made available to users of satellite observational data. The suggestions are intended only as guidelines for planning surveys and to help identify problem areas. It should be emphasized that experienced geodetic engineers should be engaged for these surveys, and that each survey is unique and requires its own method of solution.

5.2 SURVEY PROCEDURES

Basic survey data required for all observation stations are the horizontal position on the local geodetic datum and an elevation related to the local sea level datum. In both horizontal position and elevation determination the minimum requirement is establishment of the coordinates of the station to an accuracy of one meter relative to the control points.

With the establishment of the requirements, a competent geodetic engineer is in a position to plan the necessary surveys to connect the observation station to the nearest existing points on the local geodetic datum. The procedures adopted must meet the accuracy required and should be suited to the local terrain, weather conditions, or any factor peculiar to the situation. The following suggestions are offered:

a. Existing control stations should be clearly identified, and means of recovering their positions from nearby references within one decimeter should be given.

b. The observation station should be given permanent marking so that it can be recovered without doubt in the future.

c. At least two existing control stations should be used in positioning a new station.

d. The least complicated method for making the connection is advisable - a single closed triangle consisting of two existing stations and the new station, for example, or a simple traverse survey between existing and new stations.

e. Taping is adequate for short traverse distance measurements of 200 or 300 meters.

f. Triangulation or electronic traversing is recommended for extended connections; the latter is now often more economical.

g. Azimuth control should be based on existing stations when they are available; astronomic observations of azimuth should be made in other cases.

h. The care necessary in azimuth and length control depends on the extent of the survey; however, modern distance measuring instruments and theodolites yield greater accuracies than are usually required.

i Vertical control is best established by spirit leveling over short distances and fairly level terrain; otherwise reciprocal vertical angles may be used in connection with traverse or triangulation. One-meter accuracy at the observation station is seldom a problem, except when vertical angles must be carried over extensive surveys. Barometric elevations are seldom adequate.

j. An accurate geodetic azimuth is sometimes needed at an observation station. This may require both high-order astronomic azimuth and longitude observations. There may be a nearby deflection station from which a Laplace correction may be estimated. It is well in these cases to ascertain positively the accuracy requirements and whether an astronomic or geodetic azimuth is needed. A geodetic azimuth is applicable only to the datum in which it is used, and may not be what is really needed for the orientation of satellite observing equipment.

k. If satellite observations at a station are to depend in any way on reference to the local gravity vector, then astronomic latitude, longitude, and azimuth should be provided. The suggested standard error in each case is one second of arc, or less.

l. Astronomic latitude and longitude observations will also be needed to estimate the geoidal separation from the primary control if it is more than a few miles distant from the station.

m. A new station monument should have permanent marks set nearby as references, but must be clearly distinguishable from them. Two references about 90° apart are recommended.

n. The relation in distance and azimuth between the new survey monument and a fixed point on the antenna, camera, etc., should be made in such a way that a mathematical check can expose blunders. For instance, an angle right and its explement left can be measured separately; a distance can be measured in both feet and meters.

o. All measurements should be made with sufficient redundancy of observations to provide a check.

p. Notes and sketches should be provided to preclude all doubt as to the application of the measurements.

Monumentation at the site should be permanent; it should be sufficient to permit recovery and use in future surveys. This will eliminate the need for another survey from distant control when instruments are collocated at different times, and will ensure a precise determination of relative position between the collocated instruments, both horizontally and vertically.

Caution should be used in assigning names to monuments. Terms such as "Instrument Center" or "BST" should be reserved for the actual instrument center or the actual boresight tower; if these terms must be used for the monumentation they should be clarified by the use of such qualifying terms as "Eccentric" or "Vertical Ecc." or Horiz. Ecc."

5.3 DOCUMENTATION OF SURVEYS

It is important that geodetic surveys be completely documented. Only then can the user have confidence in the reliability of data and make an accuracy evaluation in relation to other observation stations. The following is a list of items that should be included in the documentation of satellite tracking or observing sites:

a. Geodetic latitude and longitude of the observing equipment on its national datum or a preferred major datum, specifying the horizontal datum used.

b. Elevation above mean sea level, specifying the vertical datum used.

c. Geodetic azimuths to adjacent geodetic control stations.

d. Definition of the precise points on the equipment to which the geodetic position, azimuth, and elevation apply. This should be the exact point of reference for the observations, if possible. If this point moves, the maximum displacement should be noted, e.g., "the instantaneous center of the camera is within four centimeters of the point referred to."

e. Astronomic latitude, longitude, and azimuth, or other information useful in determining deflection of the vertical.

f. Geoid heights, based on astro-geodetic data if available, listing source from which obtained.

g. A brief description of survey procedures used in connecting the position of the observing equipment to existing horizontal and vertical control networks, including instruments used and observation methods, with survey sketches showing geodetic control stations established at the site and the geodetic control stations to which the local survey was connected.

h. Discussion of the results of these surveys, together with estimates of the accuracy obtained.

i. Name of organization which made the surveys, with date of surveys and location of the survey records.

Agencies responsible for positioning NASA tracking facilities and the geodetic satellite observing stations have been requested to furnish the above information for inclusion and dissemination in this directory. On the basis of the data provided, a Geodetic Data Sheet has been compiled for each observing station. An explanation of the format and contents of the data sheet is provided for easy reference just before the data sheets in Parts B and C of this directory.

GLOSSARY OF GEODETIC TERMS

The terms defined here are selected as having special importance to this directory and are defined with the contents of the report in mind. More extended discussion and definitions of geodetic terms may be found in the References. Figure 2 at the end of this section is intended to aid in the definition of some of the terms.

Astronomic Azimuth - The angle measured in the plane of the horizon from the vertical plane through the celestial pole to the vertical plane through the station observed.

Astronomic Latitude - The angle between the celestial equator and the vertical.

Astronomic Meridian - The plane which contains the celestial poles and the vertical. Also a line on the earth's surface having the same astronomic longitude at every point.

Deflection of the Vertical - The angle between the normal to the spheroid and the vertical. It is sometimes called "station error." Since this angle has both a magnitude and a direction it is usually resolved into two components, one in the meridian and the other perpendicular to it in the prime vertical. These components are referred to by the symbols ξ and η. The deflection for any point is arbitrary to the extent that the geodetic datum is arbitrary, depending on the spheroid chosen and the method of datum positioning.

Earth Fixed Rectangular Coordinates - A system of space rectangular coordinates with axes X, Y, and Z having their origin at the center of a spheroid. Subject to limitations outlined below the system can be defined as follows: the center of the spheroid coincides with the center of mass of the earth; the Z axis is parallel to the mean axis of rotation of the earth and is positive to the north; the X axis is parallel to both the mean equatorial and prime meridian planes of the earth and is positive toward the meridian of Greenwich; the Y axis is parallel to the mean equatorial plane, perpendicular to the plane of the prime meridian, and is positive toward India.

The uncertainty of the relationship between the center of the reference spheroid and the center of mass of the earth may amount to as much as a hundred meters standard error. But the parallelism between the Z axis and the mean axis of rotation can generally be insured within a fraction of a second of arc by astronomical observations (Laplace azimuths) incorporated into a geodetic network or, as is usually the case, simply by definition. Transformation equations used in this directory assume that the axis of the spheroid is parallel to the mean axis of rotation of the earth; if the center of mass were better known, the term "parallel" would be replaced by "coincident."

Elevation - The distance of the point above the geoid measured along the vertical through the point.

Ellipsoid - (See Spheroid)

Geocentric Latitude - The angle at the center of the spheroid between the equator and the geocentric radius of a point in space. Geocentric longitude is the same as geodetic longitude. With geocentric radius these terms become the polar coordinate equivalents of earth fixed rectangular coordinates.

Geocentric Radius - The distance from the geometric center of the spheroid to any point. It is also known as the radius vector.

Geodetic Azimuth - The angle between two planes intersecting along the normal to the spheroid at the point of observation: one plane is the geodetic meridian and the other passes through the point sighted on. In this directory azimuths are measured clockwise from North.

Geodetic azimuths are generally carried through the triangulation, but are initially established and subsequently controlled by a pattern of Laplace azimuths. Where Laplace observations are made independently of the geodetic network, the azimuth carried through the triangulation is subject to correction to the Laplace azimuth.

Geodetic Datum - A mathematical model which is designed to best fit part or all of the geoid. It is defined by a spheroid and the relationship between the spheroid and a point on the topographic surface established as the origin of datum. This relationship can be defined by six quantities, generally (but not necessarily) the geodetic latitude, longitude, and the geodetic height of the origin, the two components of the deflection of the vertical at the origin, and the geodetic azimuth of a line from the origin to some other point.

Geodetic Height (Height Above Spheroid) - The algebraic sum of the geoid height and the elevation above the geoid.

Geodetic Latitude - The angle between the plane of the equator and the normal to the spheroid. North latitude is positive.

Geodetic Meridian - The plane which contains the normal to the spheroid and is parallel to the axis of rotation of the earth.

Geoid - The particular equipotential surface which coincides with mean sea level and which may be imagined to extend through the continents. This surface is everywhere perpendicular to the force of gravity.

Geoid Height - The distance from the surface of the reference spheroid to the geoid measured outward along the normal to the spheroid.

Laplace Azimuth - A geodetic azimuth derived from observations of the astronomic longitude and azimuth. The formula for the determination of this azimuth is

$$\alpha_G = \alpha_A - (\lambda_A - \lambda_G) \sin\phi_G$$

where α_A and α_G are the astronomic and geodetic azimuths, λ_A and λ_G

are the astronomic and geodetic east longitudes, and ϕ_G is the geodetic latitude.

Longitude - The angle measured in the plane of the equator between the meridian of some arbitrary origin (usually Greenwich) and the meridian of a point. In this directory longitude is measured east from Greenwich.

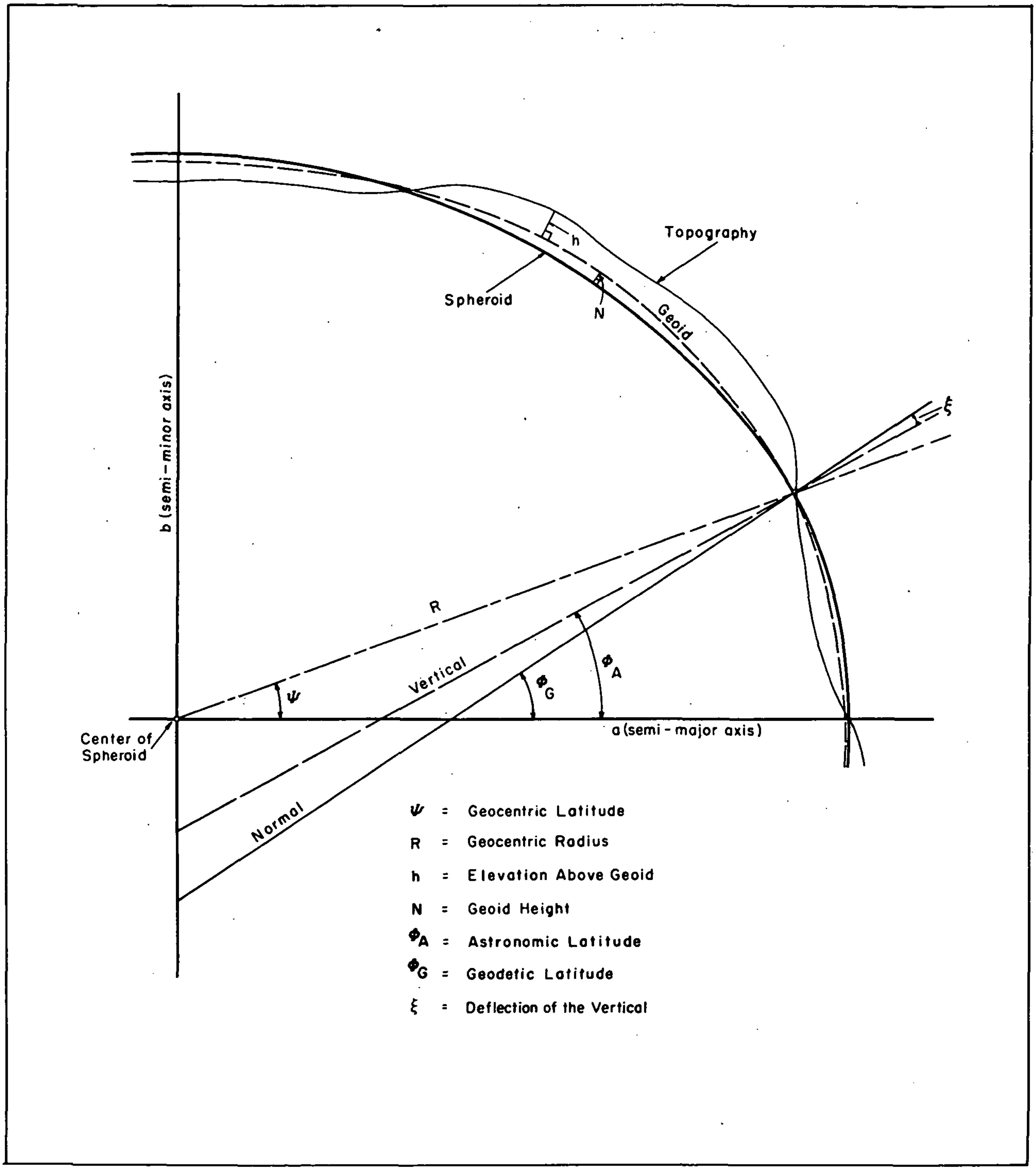
Molodenskiy Correction - A computational correction applied to reduce measurements from the geoid to the spheroid.

Normal - The line perpendicular to the spheroid at any point. The normal seldom coincides with the vertical at the point.

Spheroid - In geodesy, unless otherwise specified, a mathematical figure formed by revolving an ellipse about its minor axis. It is often used interchangeably with ellipsoid. Two quantities define a spheroid; these are usually given as the length of the semi-major axis, a, and the flattening, $f = \frac{a - b}{a}$ where b is the length of the semi-minor axis. Prolate and triaxial ellipsoids are invariably described as such.

Vertical - The line perpendicular to the geoid at any point. It is the direction of the force of gravity at that point.

Vertical Datum - An arbitrarily assumed value for a particular bench mark, or a measured value of sea level at a tide station, or a fixed adjustment of many such measurements in a common adjustment, such as the "Sea Level Datum of 1929," to which most elevations in the U.S. are referred.



RELATIONSHIPS OF GEODETIC SURFACES

FIGURE 2

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PART B - NASA SATELLITE TRACKING STATIONS

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SECTION 6

DESCRIPTION OF NASA TRACKING FACILITIES

6.1 INTRODUCTION

The antennas directly employed for spacecraft tracking by the National Aeronautics and Space Administration are treated in Volume 1 of this directory. Brief descriptions of the equipment at these stations are given in this section, with emphasis on the physical characteristics and orientation of the antennas.

The separation of NASA facilities in the previous issue of this directory into Manned Space Flight and STADAN networks is now historical. To reflect the present unified organization of these networks, the MSFN and STADAN designations have been dropped, and some former code numbers have been modified.

Physical characteristics of the tracking facilities have been summarized in Table 5 at the end of the section. Locations of the various facilities are shown in Figures 3A, 3B, and 4.

6.2 UNIFIED S-BAND ANTENNAS

The Apollo Unified S-Band System provides a Doppler, range, and angle tracking capability with concurrent transmission and reception of voice, command, and telemetry data. The system operates in the 2100-2300 MHz band and is designed as a coherent Doppler and pseudo-random range system. Two types of Cassegrain-feed antennas are used: three 85-foot antennas are located to provide continuous coverage of lunar missions; and twelve 30-foot antennas cover the earth-orbit portion of lunar missions, and back up the 85-foot antennas. Electronic equipment is similar for both types.

6.2.1 USB 85-Foot Antenna

The Apollo 85-foot Cassegrain antenna (figure 5) consists of the main reflector, with 36-foot focal length, a tetrapod which supports the subreflector and acquisition antenna, a feed cone assembly, and the X-Y pedestal. The main reflector is a solid aluminum surface consisting of double-curved

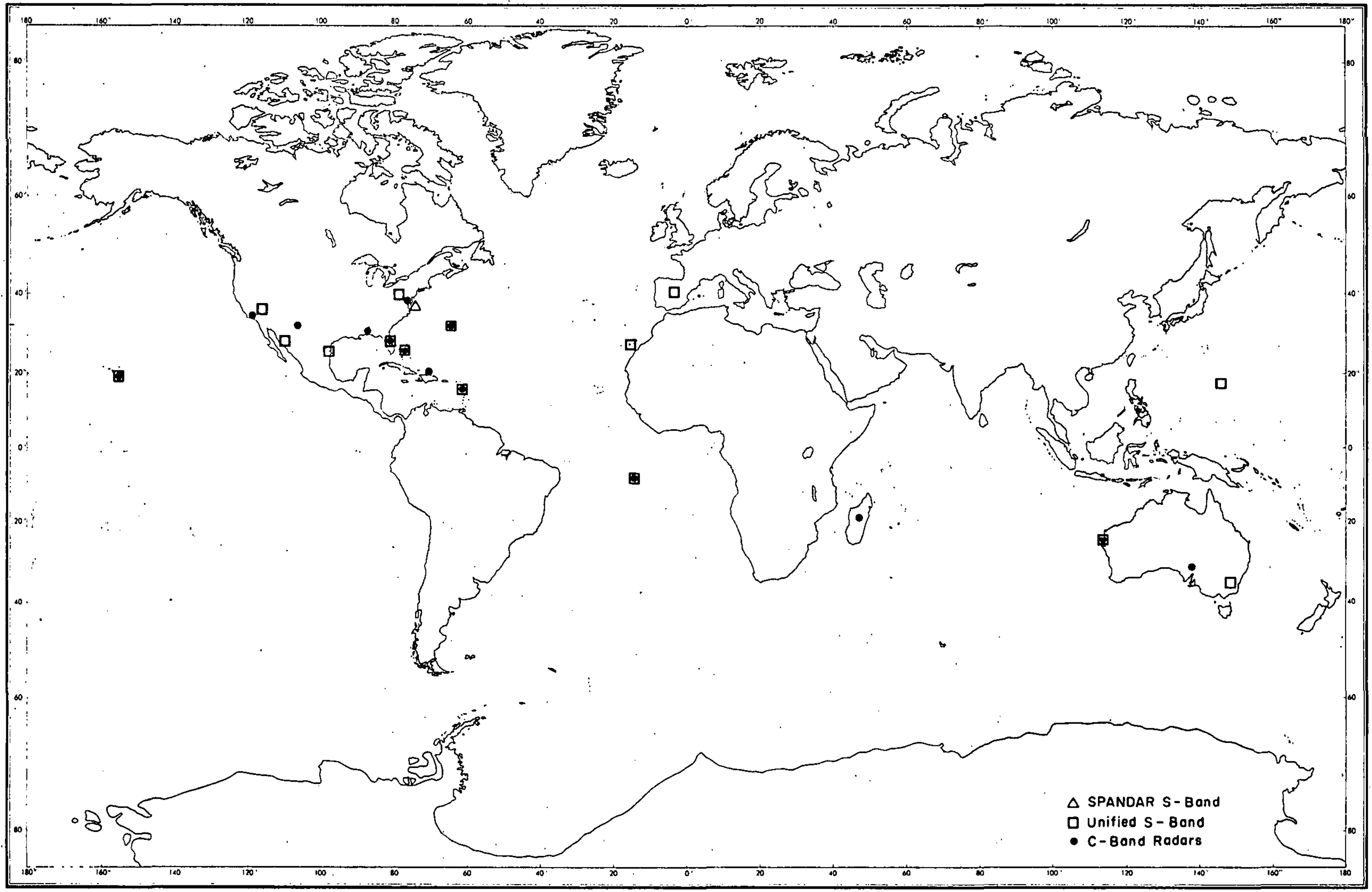

FIGURE 3A

NASA SATELLITE TRACKING SITES

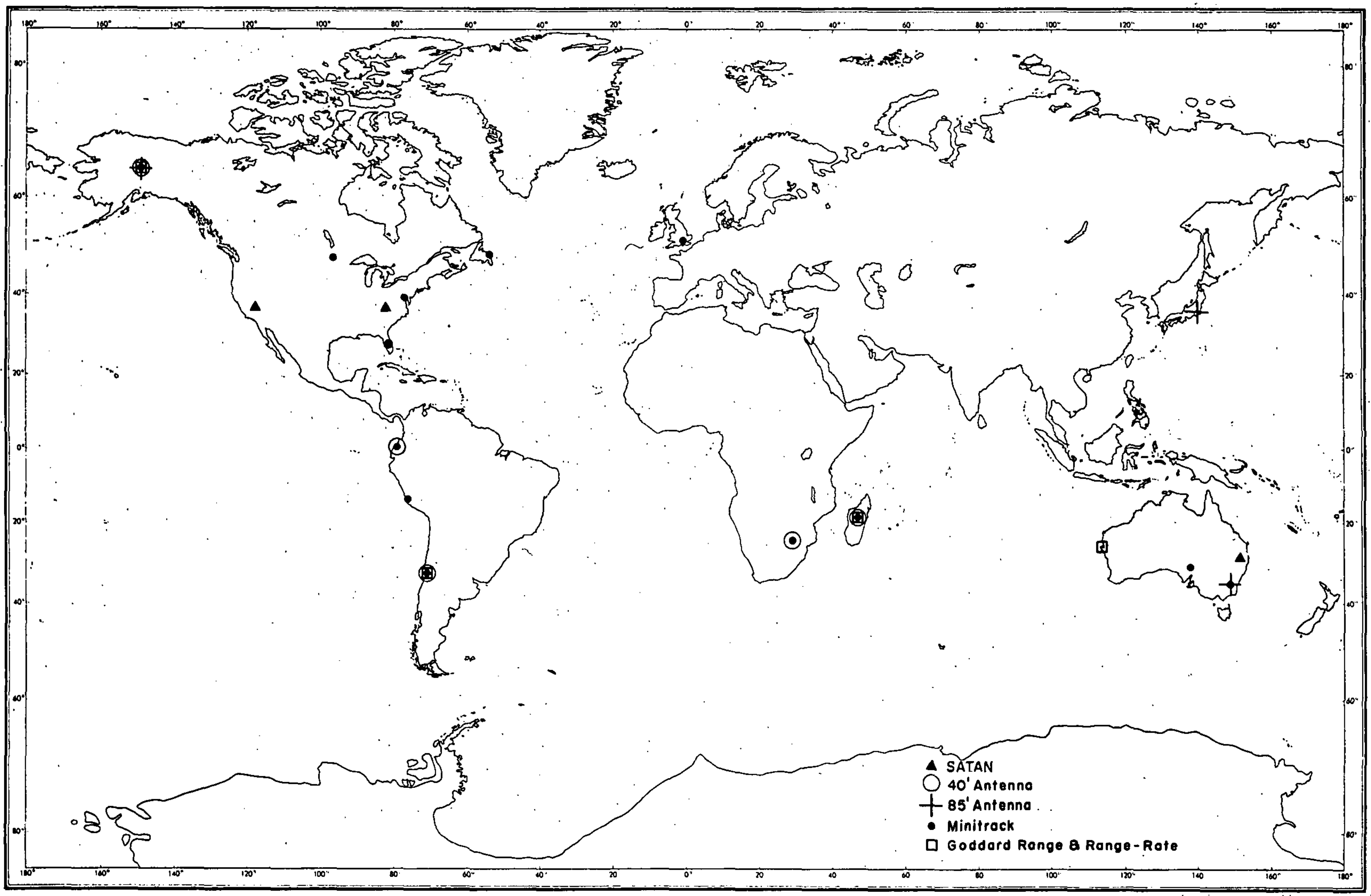

FIGURE 3B

NASA SATELLITE TRACKING SITES

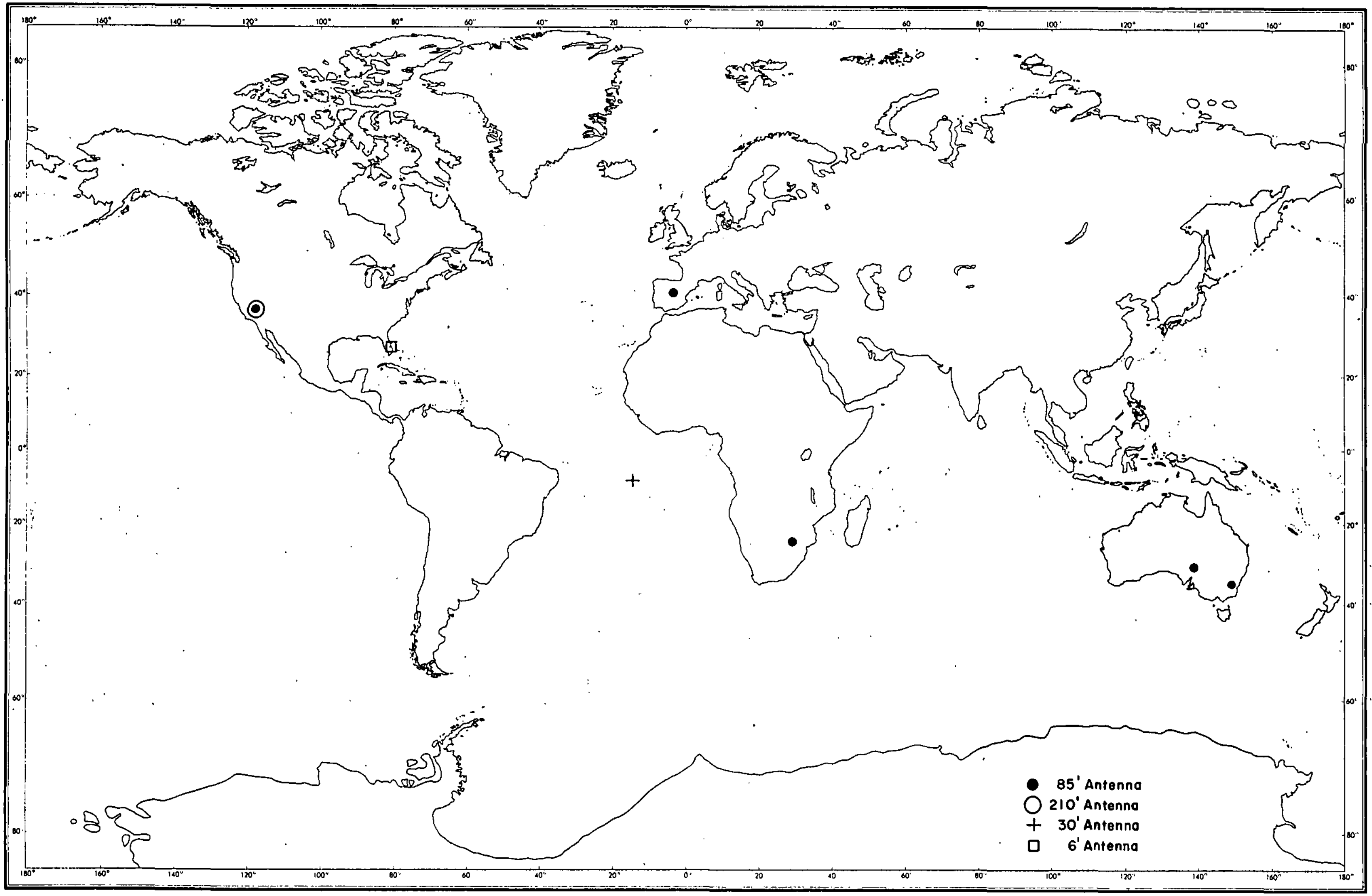

FIGURE 4

DEEP SPACE NETWORK

individual panels which are adjustable to form a best-fit paraboloid. The hyperbolic subreflector is at the focal plane of the main reflector, and 20 feet from the top of the feed cone.

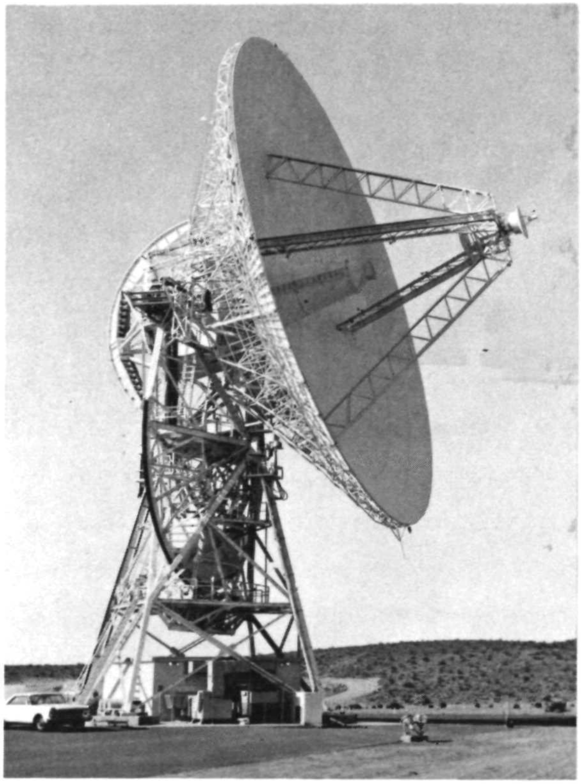

Figure 5. Unified S-Band 85-Foot Antenna

The axes of the X-Y mount are non-coplanar, with the upper Y axis separated 22 feet from the X axis. The X axis is horizontal and oriented in the prime vertical (east-west direction). The X angle is measured in the meridian plane, positive from the zenith toward the south, negative toward the north. The Y axis lies in the meridian plane, perpendicular to the X axis, and is horizontal when the X angle is zero. Y angles measured toward the east are positive; those toward the west are negative. The antenna is able to cover all parts of the sky higher than 2° above the horizon except for semi-conical keyholes of 10° radius at the horizon in the east and west.

6.2.2 USB 30-Foot Antenna

The 30-foot antenna structure (figure 6) consists of the main reflector, a Cassegrain feed subsystem, an X-Y pedestal mount, and supporting equipment. The main reflector is a solid-surface aluminum paraboloid with a 30-foot circular aperture and a 12-foot focal length. The surface is made of 26 double-curved individually adjustable panels. The Cassegrain feed subsystem consists of the monopulse feed assembly and a hyperbolic subreflector on a tetrapod.

The pedestal is a non-coplanar, two-axis mount with the lower X axis horizontal and oriented in the meridian (north-south direction). The X angle is measured in the prime vertical plane, positive from the zenith toward the east, negative toward the west. The Y axis lies in the prime vertical plane, eight feet from the X axis and perpendicular to it. It is horizontal and above the X axis when the X angle is zero. Y angles measured toward the north are positive; those toward the south are negative. The X axis is capable of rotating ± 95° (dead limit) from the zenith; the Y axis is limited to 82° (dead limit) from the zenith. The pedestal with pre-limits allows the antenna to cover all parts of the sky 2° above the horizon except for semi-conical keyholes north and south. The keyholes have 20° maximum width and 10° height above the horizon.

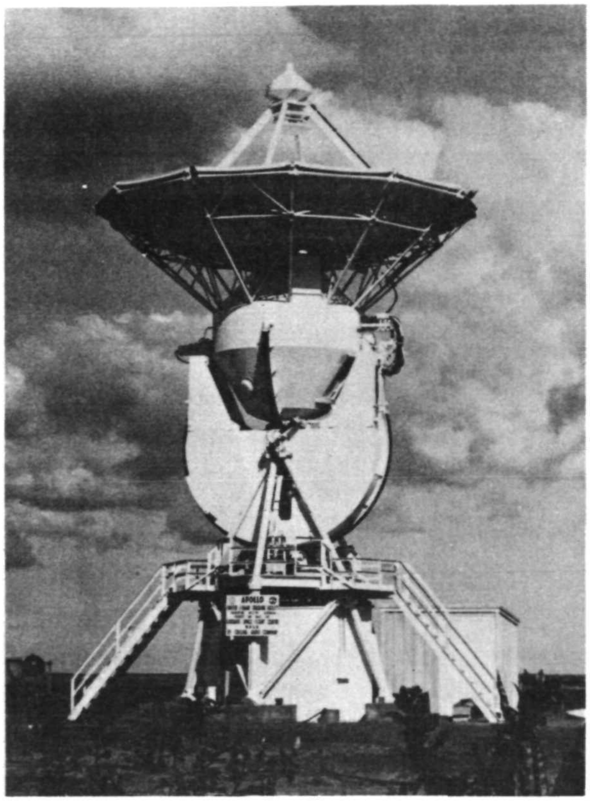

Figure 6. Unified S-Band 30-Foot Antenna

6.3 C-BAND RADARS

The C-Band radars are precision monopulse tracking antennas operating in the 5400-5900 MHz band. These radars were designed specifically for missile test range instrumentation and trajectory analysis, and are in use at all major spacecraft ranges. During the early 1960s they were the main tracking system for Project Mercury and Project Gemini missions.

The radars are of two basic types: the FPS-16 radar, and the FPQ-6 radar (and its mobile version, the TPQ-18). They provide tracking data in the form of range measurements, and azimuth and elevation angles.

6.3.1 FPS-16 Radar

The FPS-16 utilizes a 12-foot diameter paraboloid reflector on an azimuth-elevation pedestal (figure 7). The reflector surface consists of wire mesh panels support by radial trusses. The pedestal is mounted on a reinforced concrete tower which is surrounded by a building containing the electronic equipment. The antenna uses a four-horn monopulse feed located at the focal point of the reflector. A tetrapod supports the monopulse feed.

6.3.2 FPQ-6 and TPQ-18 Radars

The FPQ-6 is a second generation system to the FPS-16 and offers several major improvements: tracking capability to greater distances; greater angle tracking precision; rapid target detection and lock-on; and capability of real-time corrections.

The FPQ-6 is a 29-foot diameter Cassegrain antenna with a five horn monopulse feed. The main reflector is a solid-surface aluminum paraboloid. The feed assembly and hyperbolic subreflector are supported by a tripod.

The TPQ-18 radar is identical to the FPQ-6 except that the electronic system is housed in ten 8 x 16-foot modular shelters.

6.3.3 S-Band Radar (SPANDAR)

This facility, located at the NASA Wallops Island Station, is a high-power conical scan tracking radar. The 60-foot paraboloid reflector is supported by an azimuth-elevation mounting on top of a 95-foot tower.

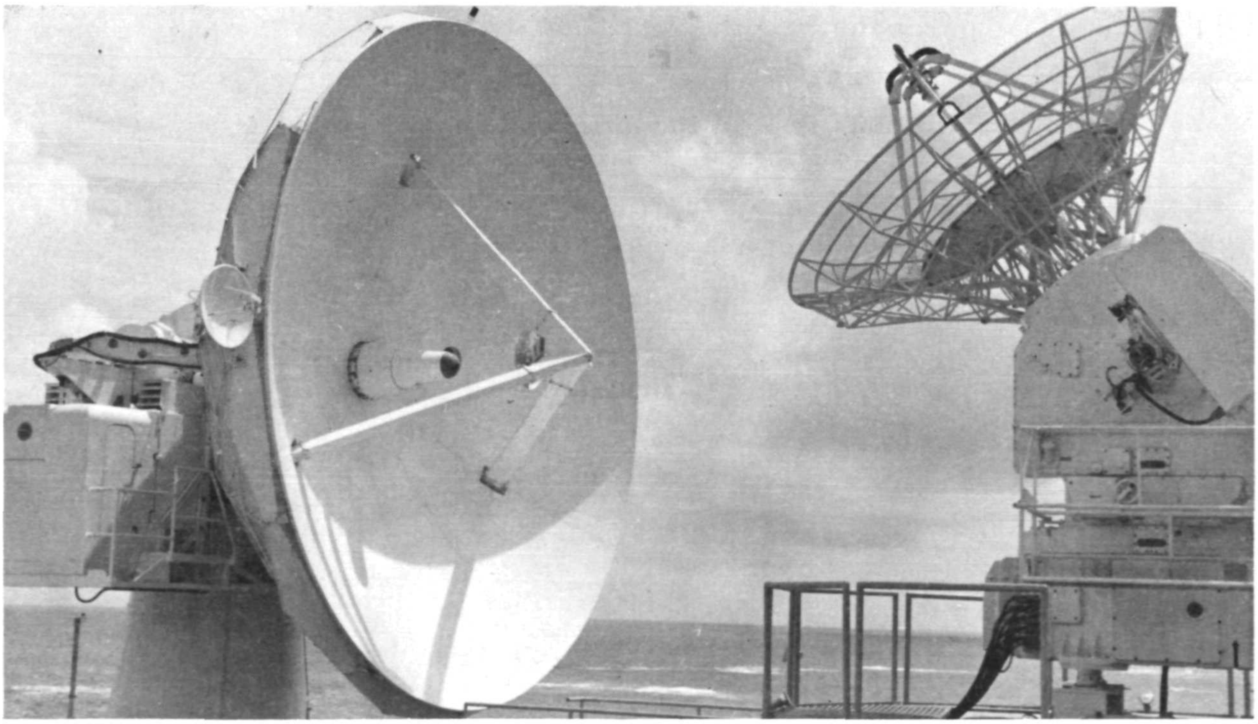

Figure 7. FPQ-6 and FPS-16 C-Band Radars

6.4 GODDARD RANGE AND RANGE-RATE ANTENNAS

The Goddard Range and Range-Rate system is used for determining range and radial velocity of spacecraft at near-earth or lunar distances. Two antennas, 250 to 400 feet apart, one operating at S-band frequency and the other at VHF, are used at each station. Each antenna is X-Y mounted, hydraulically positioned, and can be used for simultaneous transmission and reception. The VHF antenna is normally used as an acquisition aid for the narrow beamwidth S-band antenna, but it can also be used independently for ranging and Doppler measurements. The S-band receiver system operates at 2200-2300 MHz, and the VHF receiver system at 136-138 MHz. The S-band transmits at 1750-1850 MHz and the VHF transmits at 148-150 MHz.

Two types of tracking facilities are in use; the original Goddard Range and Range-Rate system (GRR-1) at Rosman, Carnarvon, and Tananarive, and the second-generation system (GRR-2) at Fairbanks and Santiago.

6.4.1 GRR-1 Facilities

The S-band system (figure 8) consists of two identical Cassegrain-feed 14-foot diameter paraboloids with focal length of 6.6 feet. The parabolas are spaced 15 feet apart on the Y axis, with 12-inch clearance between reflector edges. The X and Y mountings of the VHF and S-band antennas are identical,

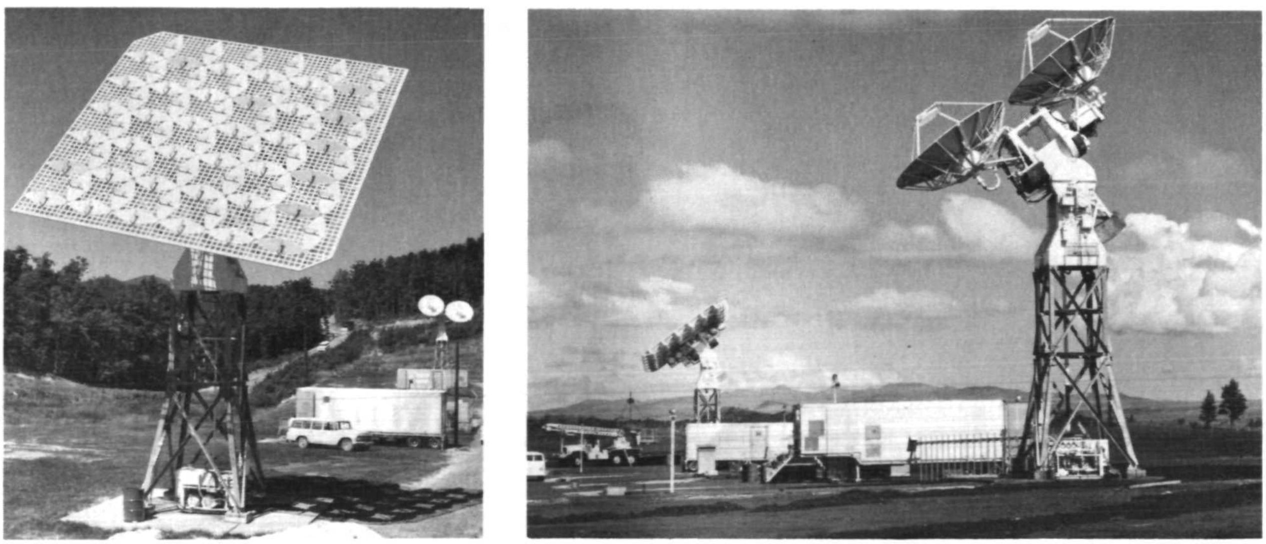

Figure 8. Goddard Range and Range Rate Facility (GRR-1)

with the X axis lower than the Y axis and aligned north-south. The X axis is 10.08 meters above the base of the tower leg, and the Y axis is one meter above it. The original VHF antennas at these stations, 28- by 28-foot monopulse-tracking phased arrays of 72 cavity-backed slots. are being replaced by dipole arrays with backfire elements.

6.4.2 GRR-2 Facilities

The S-band system consists of a single 30-foot Cassegrain antenna with a circular aperture solid surface parabolic reflector, a 45-inch solid hyperbolic subreflector, and a monopulse feed mounted on an X-Y pedestal (figure 9). The main reflector has a 12-foot focal length, and the sub-reflector has a 7-foot focal length. The VHF antenna has a 28- by 28-foot planar array of 32 crossed dipoles arranged in a 6 x 6 pattern with the corner elements missing. The X-Y mounts of both antennas are like those of the 30-foot Unified S-band (par. 6.2.2) in alignment and sky visibility. Both Fairbanks antennas are additionally restricted by keyholes up to 6° above the horizon at the east and west points.

6.5 85-FOOT DATA ACQUISITION ANTENNAS

The 85-foot antennas provide tracking, data acquisition, and communications support for various satellite programs. They are instrumented for

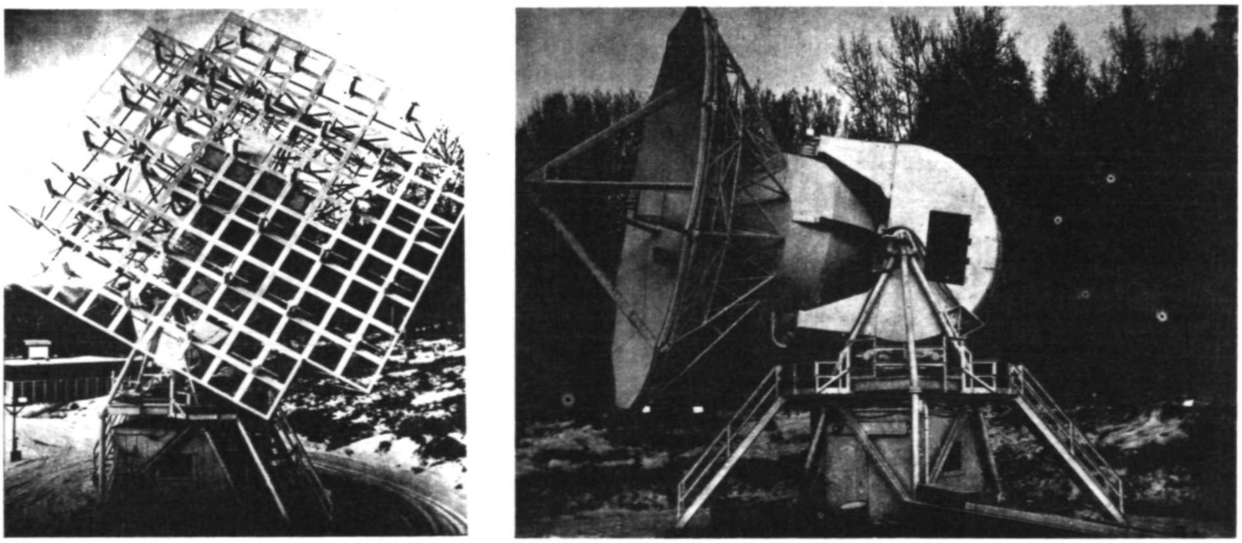

Figure 9. Goddard Range and Range Rate Facility (GRR-2)

monopulse tracking in the 136, 400, and 1700 bands. These antennas (figure 10) have solid-surface aluminum paraboloid reflectors with circular apertures 85 feet in diameter. The focal length is 36 feet. Each section of the reflector surface is individually adjustable, with a surface tolerance of 0.04 inches. All these antennas have a focal-point feed system except the Rosman II antenna, which is also equipped with a removable 11-foot dichroic Cassegrain sub-reflector.

The X-Y antenna mount has the X-axis (the lower axis) aligned in the north-south direction, 13.1 meters above the foundation. The Y axis is perpendicular to the X axis and 7.01 meters from it. Sky coverage is from two degrees above the horizon to zenith except when pointing due north or south, where gimbal lock limits viewing below twelve degrees above the horizon for ten degrees east and west of the 0° and 180° azimuth points. (Rosman II has somewhat greater, although similar, mechanical constraints on its field of view.) The entire antenna weighs about 300 tons and is about 120 feet high in the stow position.

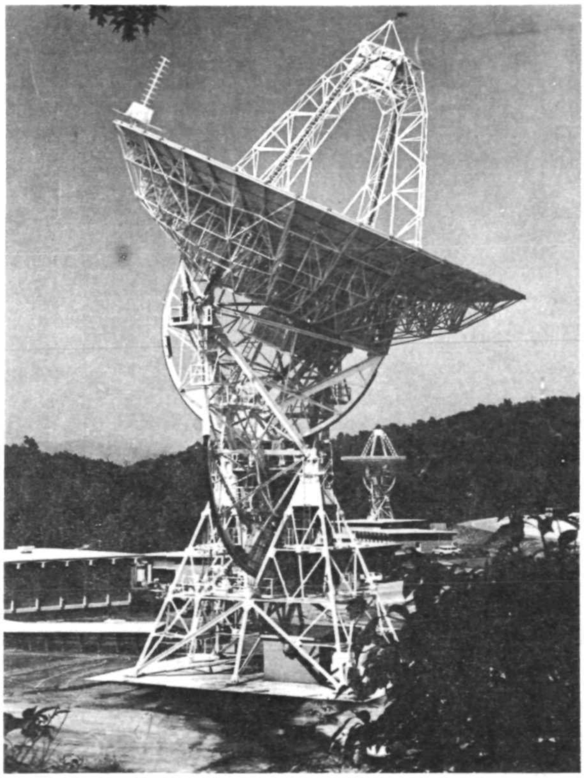

Figure 10. 85-Foot Data Acquisition Antenna

The Japanese-owned 85-foot antenna at Kashima is used primarily for communication experiments for the Applications Technology Satellites (ATS) program. This antenna is a 26-meter solid-surface paraboloid supported on an aximuth-elevation mount. The system uses a Cassegrain feed, and operates in the 3700-4200 MHz and 5925-6425 MHz bands. The azimuth-elevation mount can rotate $\pm 365^\circ$ in azimuth and from -1° to 95° in elevation, with a tracking accuracy of about 0.01°. The intersection of the axes is 21.70 meters above the ground level.

6.6 40-FOOT DATA ACQUISITION ANTENNAS

The function and operation of these antennas are very similar to those of the 85-foot antennas. The 40-foot parabolic reflector is mounted on a coplanar X-Y pedestal (figure 11). The reflector consists of adjustable double-curved solid-surface aluminum panels. The monopulse feed package is supported by a tetrapod at the focus of the reflector (focal length 16 feet). The system receives and transmits in the 136 and 400 MHz bands; the Alaska antenna has also a 1700 MHz capability.

The X-Y mount is oriented with the X axis horizontally aligned in a north-south line, 7 meters above the foundation. The mount design permits pointing of the antenna in all directions above the horizon except for four 4° keyholes centered 12° each side of north and south. The antenna is 57 feet high in the stow position, and its overall weight is 54 tons.

The 40-foot antenna at Goldstone was modified from a prime focus feed to a Cassegrain configuration. Transmitting in the 6000 MHz band and receiving in the 4000 MHz band, its major function is in support of the ATS program.

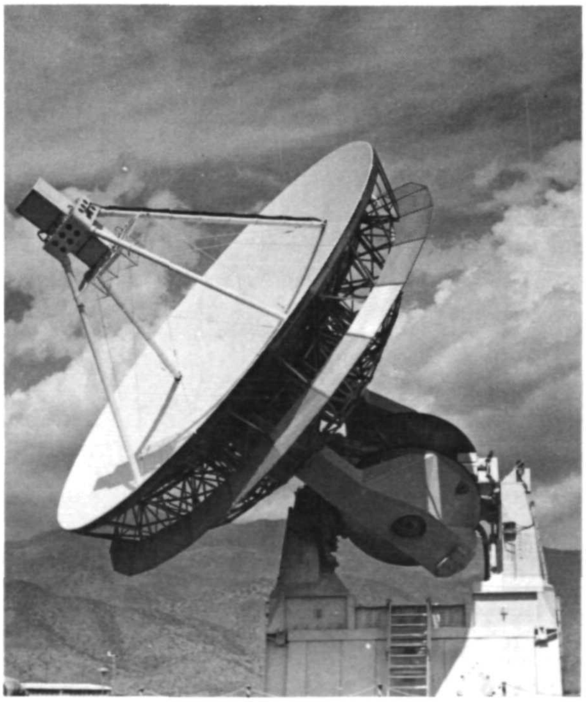

Figure 11. 40-Foot Data Acquisition Antenna

6.7 MINITRACK NETWORK

Minitrack is an interferometer system for measuring the angular position of a transmitting satellite. Measurements are obtained by phase comparisons between multiple pairs of antennas at fixed distances apart. The system consists of thirteen antennas which are precisely leveled and oriented to two crossed baselines approximately 125 meters long, one north-south, the other east-west. Eight of the antennas are on the baselines, 57 wavelengths apart on the N-S baseline and 46 wavelengths apart in the E-W direction, and are used for fine measurements; five are clustered near the center to resolve ambiguities in the fine measurements. Each antenna is a large fixed multi-element slot array with lattice ground screens mounted several feet above the ground on pedestals (figure 12). The system operates in the 136-138 MHz band.

An equatorially mounted astrographic camera (MOTS 40) at the center of the array is used for periodic calibration of the interferometer system. This camera is also used independently for optical tracking of satellites, and is described under camera systems in Section 7.

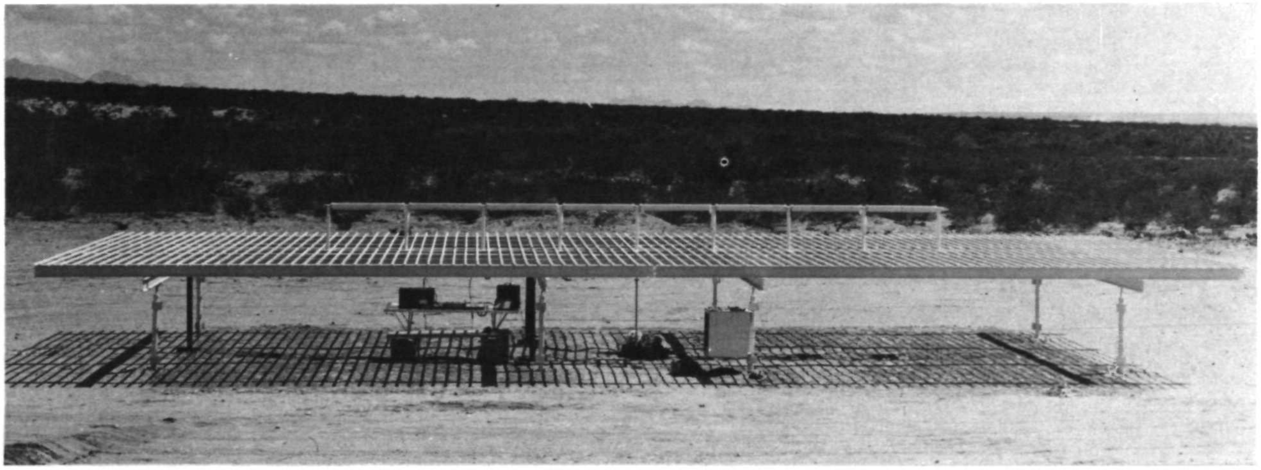

Figure 12. Minitrack Antenna

6.8 DEEP SPACE NETWORK

This network is maintained by NASA with management and technical direction by the Jet Propulsion Laboratory of the California Institute of Technology. It is used for lunar and deep space exploration programs, and in support of Apollo missions. Its facilities include eight 85-foot tracking antennas, and the 210-foot steerable reflector at Goldstone. Two smaller antennas are listed with this group in the Directory, and two additional 210-foot antennas are under construction. A 30-foot Az-El mounted antenna at Goldstone is used for design testing, and is not included among the tracking antennas. The location of these stations are shown in Figure 4.

6.8.1 85-Foot HA-Dec

The standard antenna in use at the Deep Space stations is an 85-foot diameter paraboloid with polar mount (figure 13). Seven facilities are of this type, and essentially identical. Operating in the S-band range, they transmit at 2110-2120 MHz and receive at 2290-2300 MHz. They are equipped for telemetry, one-and two-way doppler, and ranging, as well as for angular measurement.

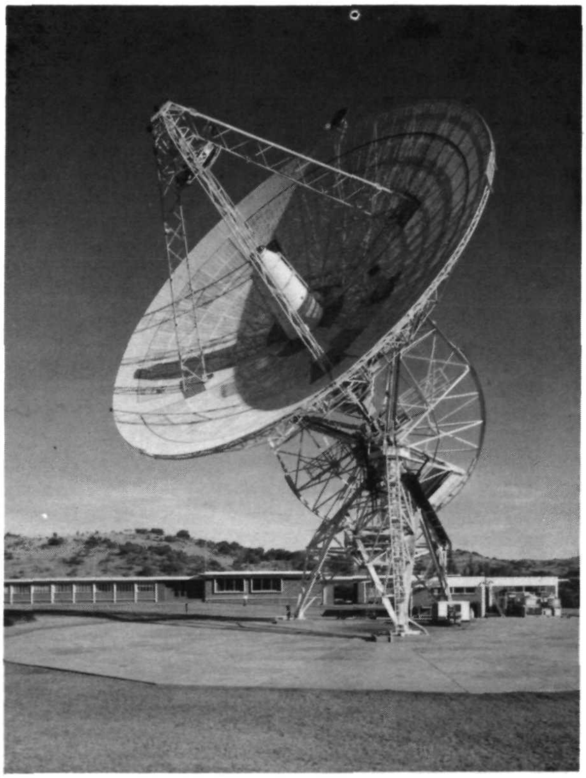

Figure 13. DSN 85-Foot HA-Dec Antenna

Surface panels of the primary reflectors of these Cassegrain antennas are 0.08-inch thick perforated aluminum sheets, with 25% porosity for the inner three-quarters of the dish area, and 50% porosity for the remainder. Mechanical restrictions limit HA-Dec antennas, both in hour angle and in declination. The usual $\pm 90^{\circ}$ hour angle limit has been extended to $\pm 96^{\circ}$ on most of these antennas. The earlier antennas of this type (DSN-1, -2, and -5) have three-legged towers; those built later have four legs.

6.8.2 85-Foot Az-El

Only the Venus facility at Goldstone is of this type. It is used primarily for research, and development and testing of new equipment and methods. Except for its azimuth-elevation mount, it is very similar to the 85-foot HA-Dec antennas. The center of the elevation axis is offset from the center of azimuth rotation by 2.90 meters.

6.8.3 210-Foot Antenna

The 210-foot Advanced Antenna System (figure 14) was placed in operation at the Goldstone Mars station in 1966. Two antennas almost identical to it

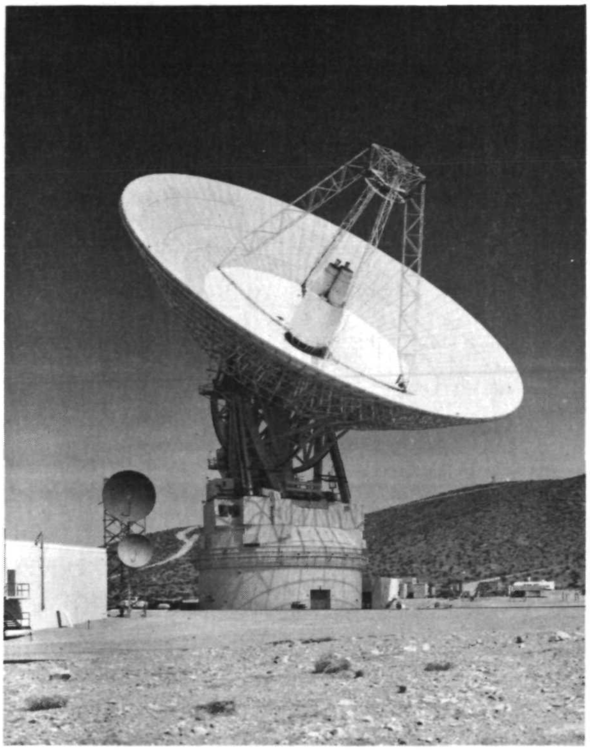

Figure 14. DSN 210-Foot Antenna

are under construction at the Tidbinbilla, Australia, and Madrid sites, to complete (in 1973) the network for continuous communications with deep-space vehicles between 28.5 declination North and South. The fully steerable 210-foot diameter paraboloid has a focal length of 88.941 feet. The reflector is constructed of 1200 aluminum sheeted panels 0.08 inches thick. The surface is solid out to half the radius; the surface for the outer half of the radius is perforated with 1/4-inch holes for 50% porosity. The Cassegrain feed cone, at the vertex of the primary reflector, is divided into four 10-foot modules. The 20-foot solid subreflector is supported by a tetrapod above the focal point of the primary reflector. The system operates at the S-band frequencies of 2100-2300 MHz. It has nearly seven times the transmitting and receiving capacity, or 2.5 times the range, of the 85-foot antenna.

The azimuth-elevation mount is designed to track at 0.5° a second with a dead-load RMS error of 0.23 inch. It can rotate 570° in azimuth and 85 in elevation. Tracking is automatic, or may be programmed for very faint signals. The antenna is about 240 feet high in the zenith-pointing position, and weighs about 8000 tons, 2500 of these being in the moving parts.

6.8.4 30-Foot Az-El

The single antenna of this type was at Ascension Island, where its high angular velocity (6° a second in azimuth and 3° a second in elevation) and acceleration were useful in early acquisition of close-in satellites after launch. This facility was transferred from JPL to GSFC in 1968 and is now dismantled.

It was a 30-foot diameter solid-surface paraboloid on an azimuth-elevation mount. It was equipped with standard DSN S-band equipment, transmitting at 2110-2120 MHz and receiving at 2290-2300 MHz. Two separate feed systems permitted it to operate in either a wide-beam acquisition mode or a narrow-beam Cassegrain mode. Two-way Doppler, precise ranging, and telemetry could be conducted concurrently. The Az-El mount permitted rotation from 0° to 90° in elevation and 360° in azimuth. The antenna with supporting structure and electronic and operating equipment weighed 75,000 pounds, and was mounted on a reinforced concrete foundation.

6.8.5 6-Foot Az-El

One 6-foot diameter paraboloid antenna with an aximuth-elevation mount is located at Cape Kennedy. It is used for final flight spacecraft compatibility validation testing prior to launch, and monitors the spacecraft during the launch phase. Tracking with this antenna is manual, not automatic.

6.9 RADIO TELESCOPES

The following facilities are primarily devoted to studies in radio astronomy, but are listed for their past or potential cooperation with NASA satellite programs.

6.9.1 Jodrell Bank 250-Foot Telescope

The large telescope at Jodrell Bank, England is renowned for its use in tracking the early Russian and American satellites. The 250-foot telescope is a fully steerable paraboloid (alt-azimuth mounted) with a focal length of 62.5 feet. The reflector surface originally consisted of 7,100 3- by 3-foot sections of sheet steel which were welded together. The surface lining has recently (1971) been modified with adjustable solid panels which allow the surface to be maintained as a paraboloid to within 0.1 inch. The central support for the paraboloid was also modified for the added weight of the new panels. These improvements permit full operating efficiency in the 21 cm wavelength region of the radio spectrum. Since modification the telescope is designated the Mark IA.

6.9.2 Parkes 210-Foot Telescope

This telescope has been in operation since 1961 at the Australian National Radio Astronomy Observatory, Parkes, N.S.W. It was designed for research work ar S-band frequencies.

The 210-foot diameter paraboloid has a focal length of 86.1 feet. The supporting structure for the reflector surface consists of a series of radial ribs, cantilevered from a central hub and joined together by a ring girder system. The reflector surface is solid at the center portion over a 30 foot diameter; the remainder of the surface consists of wire mesh panels supported on a series of radial purlins. The mesh surface was selected for optimum power efficiency at a wavelength of 10 cm, and was designed to be accurate in shape to within ± 9 mm for any orientation of the paraboloid. (In 1964 a special photographic system was designed and installed to monitor the surface configuration automatically. This is capable of measuring surface deformations to within a tolerance of ± 1 mm at zenith angles up to 60°.)

The paraboloid is supported by an azimuth-elevation turret structure on top of a reinforced concrete tower. The elevation drive system permits the telescope to rotate from zenith down to 30 above the horizon. In azimuth, the operating range is ± 225°. The supporting tower structure is 39 feet in diameter and about 40 feet high. It houses the control system and rf equipment.

6.9.3 Bonn 100-Meter Telescope

This telescope is located at the Max Planck Institute for Radio Astronomy at Effelsberg, near Bonn, West Germany. The telescope is a fully steerable paraboloid, alt-azimuth mounted, with an aperture of 200 meters for wavelengths as short as 4 cm and of 80 meters for work down to 1.5 cm. The reflector has a focal length of 30 meters (f/0.3). A tetrapod supports a feed assembly at the vertex of the reflector for prime-focus observing, or a secondary reflector (Gregorian mirror) when working in the wavelength range 11 to 3 cm. The reflector surface has solid aluminum panels over an 80-meter diameter. The outer zone of the disk, from 85 to 100 meters diameter is covered with wire netting of 6 mm mesh. Between these zones is a 5-meter wide belt with 38 percent perforation. For the netting the shortest usable wavelength is 4 cm, and this is the limit when the full 100-meter aperture is employed. It is expected that the surface configuration over an area up to 80-meter diameter will provide acceptable efficiency for use down to 1.5 cm wavelength. Astronomical observations with this telescope began in 1971.

REFERENCES

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Anonymous, "Space Tracking and Data Acquisition Network Manual." Report No. X-530-70-454, NASA Goddard Space Flight Center. Dec. 1970.

McKune, W. J., "AMR Instrumentation Handbook Volume I - Operational Systems." Tech. Report MTC-TDR-63-1, Pan American World Airways Guided Missile Range Division, Patrick Air Force Base. February 1963.

Anonymous, "Unified S-Band 30-Foot Antenna System." Technical Manual MH-1058, Collins Radio Company. 1966.

Anonymous, "Present Status of Kashima Earth Station." Radio Research Laboratories Ministry of Posts and Telecommunications, Japan. 1968.

Anonymous, "DSN Capabilities and Plans." Report No. 801-2, Jet Propulsion Laboratory. January 1970.

TABLE 4
ANTENNA CHARACTERISTICS

Directory Group		Equipment	Antenna Type	Main Reflector Diameter ft.	Main Reflector Focal Length ft.	Approx. Overall Height ft.	Axes Orientation	Reference Axis Height ft.	Axes Separation ft.	Angle Readings	Sky Coverage[3]
Unified S-Band		USB 30'	Cassegrain	30	12	50	X: N-S Y: E-W	19.8[1]	8	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to 2° above horizon except N-S keyhole of 20° width and 10° height
Unified S-Band		USB 85'	Cassegrain	85	36	120	X: E-W Y: N-S	45[1]	23	X: +90°(S) to -90°(N) Y: +90°(E) to -90°(W)	Zenith to 2° above horizon except E-W keyhole of 20° width and 10° height
C-Band Radars		FPQ-6 & TPQ-18	Cassegrain	29	8.7	40	Az-El	19[2]	0	Az: 0° at North El: 0° at horizon	Zenith to 2° below horizon except zenith keyhole of 5° radius
C-Band Radars		FPS-16	Prime Focus	12	4.2	20	Az-El	8[2]	0	Az: 0° at North El: 0° at horizon	Zenith to 10° below horizon except zenith keyhole of 5° radius
Goddard Range And Range Rate	1	VHF-Slotted	Planar Array	28x28[4]	-	50	X: N-S Y: E-W	35[1]	3.3	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to 3½° above horizon except N-S keyhole of 10° width and 5° height
Goddard Range And Range Rate	1	S-band Paired 14'	Cassegrain	14	6.6	50	X: N-S Y: E-W	35[1]	3.3	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to 3½° above horizon except N-S keyhole of 10° width and 5° height
Goddard Range And Range Rate	2	VHF-Dipole	Planar Array	28x28	-	50	X: N-S Y: E-W	20[1]	8	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to horizon except N-S keyhole of 10° width and 5° height
Goddard Range And Range Rate	2	S-band 30'	Cassegrain	30	12	50	X: N-S Y: E-W	20[1]	8	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to horizon except N-S keyhole of 10° width and 5° height
Data Acquisition		85' X-Y	Prime Focus[5]	85	36	120	X: N-S Y: E-W	43[1]	23	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to horizon except N-S keyhole of 20° width, 12° height
Data Acquisition		85' Az-El	Cassegrain	85	36	118	Az-El	71[2]	0	Az: 0° at North El: 0° at horizon	5° beyond zenith to 1° below horizon
Data Acquisition		40' X-Y	Prime Focus[6]	40	16	57	X: N-S Y: E-W	23[1]	0	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to horizon except N-S keyhole of 45° width and 5° height
Deep Space		85' HA-Dec	Cassegrain	85			HA-Dec	40-50			
Deep Space		85' Az-El	Cassegrain	85		90	Az-El	36	9.5		
Deep Space		210' Az-El	Cassegrain	210	89	235	Az-El	111	0		
Deep Space		6' Az-El		6			Az-El				
Deep Space		30' Az-El	PF or Cass.	30			Az-El	26	0		

NOTES:
Dimensions shown may vary somewhat with individual antennas, because of local conditions and/or hardware modifications.
1- Height of X-axis above foundation. X-axis is lower, fixed axis.
2- Height of elevation axis above foundation
3- Limitation of keyhole (gimbal lock) shown as maximum width and height of a usually elliptical zone; additional limitations of horizon profile not shown.
4- These antennas will eventually be converted to dipole-backfire.
5- Except for Rosman II, which is equipped for either prime focus or Cassegrain feed.
6- Except for Goldstone, which is Cassegrain.

Station Index

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STATION INDEX
NASA SATELLITE TRACKING STATIONS

Station No.	Location	Equipment
Unified S-Band Antennas		
USB 1	Merritt Island, Florida	30' Antenna
USB 2	Grand Bahama Island	30' Antenna
USB 3	Bermuda	30' Antenna
USB 4	Antigua	30' Antenna
USB 5	Canary Islands	30' Antenna
USB 6	Ascension Island	30' Antenna
USB 7	Madrid, Spain	85' Antenna
USB 8	Carnarvon, Australia	30' Antenna
USB 9	Guam	30' Antenna
USB 10	Canberra, Australia	85' Antenna
USB 11	Kauai, Hawaii	30' Antenna
USB 12	Goldstone, California	85' Antenna
USB 13	Guaymas, Mexico	30' Antenna
USB 14	Corpus Christi, Texas	30' Antenna
USB 15	Greenbelt, Maryland	30' Antenna
USB 16	Greenbelt, Maryland	30' Antenna
USB 17	Goldstone, California	30' Antenna
USB 18	Merritt Island, Florida	30' Antenna
Radars		
RAD 1	Merritt Island, Florida	TPQ-18
RAD 2	Patrick AFB, Florida	FPQ-6
RAD 3	Cape Kennedy, Florida	FPS-16
RAD 4	Grand Bahama Island	TPQ-18
RAD 5	Wallops Island, Virginia	FPQ-6
RAD 6	Wallops Island, Virginia	FPS-16
RAD 7	Grand Turk Island	TPQ-18
RAD 8	Bermuda	FPS-16
RAD 9	Bermuda	FPQ-6
RAD 10	Antigua	FPQ-6
RAD 11	Ascension Island	TPQ-18
RAD 12	Ascension Island	FPS-16
RAD 13	Tananarive, Madagascar	FPS-16
RAD 14	Carnarvon, Australia	FPQ-6
RAD 15	Woomera, Australia	FPS-16
RAD 16	Kauai, Hawaii	FPS-16
RAD 17	Vandenberg AFB, California	TPQ-18
RAD 18	Point Arguello, California	FPS-16
RAD 19	White Sands, New Mexico	FPS-16
RAD 20	Eglin AFB, Florida	FPS-16
RAD 21	Wallops Island, Virginia	SPANDAR

Station No.	Location	Equipment
Launch Sites		
LPD 1	Cape Kennedy Stand 12	
LPD 2	Cape Kennedy Stand 13	
LPD 3	Cape Kennedy Stand 14	
LPD 4	Cape Kennedy Stand 19	
LPD 5	Cape Kennedy Stand 34	
LPD 6	Cape Kennedy Stand 37A	
LPD 7	Cape Kennedy Stand 37B	
LPD 8	Cape Kennedy Stand 39A	
Goddard Range and Range-Rate Stations		
GRR 1S	Fairbanks, Alaska	S-Band 30-Foot Antenna
GRR 1V	Fairbanks, Alaska	VHF Antenna
GRR 2S	Rosman, No. Carolina	S-Band Paired 14-Foot Antenna
GRR 2V	Rosman, No. Carolina	VHF Antenna
GRR 3S	Santiago, Chile	S-Band 30-Foot Antenna
GRR 3V	Santiago, Chile	VHF Antenna
GRR 4S	Tananarive, Madagascar	S-Band Paired 14-Foot Antenna
GRR 4V	Tananarive, Madagascar	VHF Antenna
GRR 5S	Carnarvon, Australia	S-Band Paired 14-Foot Antenna
GRR 5V	Carnarvon, Australia	VHF Antenna
85-foot Antennas		
S85 1	Rosman, No. Carolina	
S85 2	Rosman, No. Carolina	
S85 3	Fairbanks, Alaska	
S85 4	Orroral, Australia	
S85 6	Kashima, Japan	
40-foot Antennas		
S40 1	Gilmore Creek, Alaska	
S40 2	Johannesburg, So. Africa	
S40 3	Quito, Ecuador	
S40 4	Santiago, Chile	
S40 5	Goldstone, California	
S40 6	Tananarive, Madagascar	
S40 7	Greenbelt, Maryland	

STATION INDEX (cont'd)

Station No.	Location	Equipment
Minitrack Stations		
MIN 1	Fairbanks, Alaska	
MIN 2	Fairbanks, Alaska	
MIN 3	Goldstone, California	
MIN 4	East Grand Forks, Minnesota	
MIN 5	Fort Myers, Florida	
MIN 6	Quito, Ecuador	
MIN 7	Lima, Peru	
MIN 8	Blossom Point, Maryland	
MIN 9	Greenbelt, Maryland	
MIN 10	Santiago, Chile	
MIN 11	St. John's, Newfoundland	
MIN 12	Winkfield, England	
MIN 13	Johannesburg, So. Africa	
MIN 14	Tananarive, Madagascar	
MIN 15	Woomera, Australia	
MIN 16	Orroral, Australia	
SATAN Antennas		
SAT 1	Rosman, North Carolina	
SAT 2	Goldstone, California	
SAT 3	Cooby Creek, Australia	
Deep Space Network		
DSN 1	Goldstone, California	85' HA-Dec Antenna
DSN 2	Goldstone, California	85' HA-Dec Antenna
DSN 3	Goldstone, California	85' Az-El Antenna
DSN 4	Goldstone, California	210' Az-El Antenna
DSN 5	Woomera, Australia	85' HA-Dec Antenna
DSN 6	Tidbinbilla, Australia	85' HA-Dec Antenna
DSN 7	Johannesburg, So. Africa	85' HA-Dec Antenna
DSN 8	Madrid, Spain	85' HA-Dec Antenna
DSN 9	Madrid, Spain	85' HA-Dec Antenna
DSN 10	Merritt Island, Florida	6' Az-El Antenna
DSN 11	Ascension Island	30' Az-El Antenna
Radio Telescopes		
RTE 1	Jodrell Bank, England	
RTE 2	Parkes, Australia	
RTE 3	Bonn, West Germany	

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Notes to Coordinate Tabulations

Source data for the tabulations are the Geodetic Data Sheets for each station and section 4, Formulas and Constants. Tabulated positions are not always adequately documented, and the data sheets should be referred to in assessing their reliability.

If no estimate of the geoid separation is given on the data sheet it has been assumed to be zero in the listing of geodetic heights.

Since positions on a common spheroid are required for some purposes, coordinates for all stations in volume 1 have been tabulated on the Mercury 1960 and Modified Mercury 1968 Datums although shifts were not available for all datums. In such cases it was assumed that the local surveys were made on the Mercury spheroids, and that the shifts and changes in geoid heights were zero. The exceptions are Ascension Island, where the local datum is based in part on gravity studies, and Grand Canary, where a topographic-isostatic study had been used to relate the local datum to Mercury 1960.

Stations for which the coordinates are based on these assumptions are marked with asterisks.

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Positions on Local or Major Datums

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POSITIONS ON LOCAL OR MAJOR DATUMS

STATION			GEODETIC COORDINATES			GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)
UNIFIED S-BAND ANTENNAS								
USB 1	MERRITT ISLAND	NAD27	28° 30' 28".22	279° 18' 22".93	19	907 084	-5 535 373	3 025 922
USB 2	GRAND BAHAMA	NAD27	26 37 56.45	281 45 43.47	19	1 163 032	-5 585 587	2 841 709
USB 3	BERMUDA	NAD27	32 21 3.76	295 20 28.53	14	2 308 447	-4 874 469	3 393 207
USB 4	ANTIGUA	NAD27	17 0 57.13	298 14 48.51	40	2 887 329	-5 374 298	1 854 412
USB 5	GRAND CANARY	LOCAL	27 45 46.18	344 22 4.52	160	5 439 469	-1 522 010	2 953 389
USB 6	ASCENSION	LOCAL	-7 57 19.04	345 40 20.72	544	6 121 441	-1 563 474	-876 968
USB 7	MADRID	EUROP	40 27 23.85	355 49 58.23	763	4 847 912	-353 215	4 117 261
USB 8	CARNARVON	AUSTR	-24 54 27.43	113 43 27.17	51	-2 328 874	5 299 236	-2 669 827
USB 9	GUAM	LOCAL	13 18 33.28	144 44 3.89	92	-5 068 819	3 584 355	1 458 650
USB10	CANBERRA	AUSTR	-35 35 5.05	148 58 35.68	1140	-4 450 940	2 676 872	-3 691 494
USB11	KAUAI	OLDHW	22 7 45.93	200 19 55.38	1151	-5 543 898	-2 054 276	2 387 988
USB12	GOLDSTONE	NAD27	35 20 29.63	243 7 38.04	951	-2 354 748	-4 646 936	3 669 205
USB13	GUAYMAS	NAD27	27 57 45.96	249 16 46.28	15	-1 994 697	-5 273 112	2 972 703
USB14	CORPUS CHRISTI	NAD27	27 39 11.78	262 37 17.92	17	-726 064	-5 606 963	2 942 369
USB15	GREENBELT	NAD27	38 59 54.30	283 9 24.85	55	1 129 809	-4 833 315	3 992 019
USB16	GREENBELT	NAD27	38 59 53.58	283 9 27.83	61	1 129 883	-4 833 317	3 992 005
USB17	GOLDSTONE	NAD27	35 20 29.63	243 7 40.46	946	-2 354 692	-4 646 959	3 669 201
USB18	MERRITT ISLAND	NAD27	28 30 26.34	279 18 22.93	19	907 088	-5 535 401	3 025 871
RADARS								
RAD 1	MERRITT ISLAND	NAD27	28 25 27.93	279 20 7.38	21	910 602	-5 539 263	3 017 796
RAD 2	PATRICK AFB	NAD27	28 13 33.99	279 24 1.77	25	918 600	-5 548 515	2 998 452
RAD 3	CAPE KENNEDY	NAD27	28 28 52.79	279 25 23.77	24	918 606	-5 534 898	3 023 342
RAD 4	GRAND BAHAMA	NAD27	26 38 9.02	281 43 55.31	20	1 160 068	-5 586 027	2 842 055
RAD 5	WALLOPS ISLAND	NAD27	37 51 36.51	284 29 25.24	13	1 261 620	-4 881 717	3 893 013
RAD 6	WALLOPS ISLAND	NAD27	37 50 28.39	284 30 52.38	10	1 264 005	-4 882 429	3 891 353
RAD 7	GRAND TURK	NAD27	21 27 43.49	288 52 3.05	42	1 920 453	-5 619 580	2 318 963
RAD 8	BERMUDA	NAD27	32 20 52.30	295 20 44.30	11	2 308 899	-4 874 461	3 392 907
RAD 9	BERMUDA	NAD27	32 20 51.80	295 20 44.51	13	2 308 908	-4 874 467	3 392 895
RAD10	ANTIGUA	NAD27	17 8 34.78	298 12 24.47	48	2 881 626	-5 372 679	1 867 862
RAD11	ASCENSION	LOCAL	-7 58 22.78	345 35 53.90	125	6 118 749	-1 571 221	-878 849
RAD12	ASCENSION	LOCAL	-7 57 6.29	345 35 14.63	92	6 118 733	-1 572 459	-876 518
RAD13	TANANARIVE	LOCAL	-19 0 .99	47 18 54.19	1338	4 091 047	4 435 762	-2 063 839
RAD14	CARNARVON	AUSTR	-24 53 50.76	113 42 57.76	55	-2 328 311	5 300 007	-2 668 805
RAD15	WOOMERA	AUSTR	-30 49 11.00	136 50 13.12	126	-3 998 909	3 750 372	-3 248 821

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POSITIONS ON LOCAL OR MAJOR DATUMS

STATION			GEODETIC COORDINATES			GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)
RADARS								
RAD16	KAUAI	OLDHW	22° 7' 35.83"	200° 19' 53.96"	1155	-5 544 025	-2 054 280	2 387 702
RAD17	VANDENBERG AFB	NAD27	34 39 57.13	239 25 10.43	89	-2 671 836	-4 521 351	3 607 305
RAD18	PT. ARGUELLO	NAD27	34 34 57.95	239 26 21.97	627	-2 673 157	-4 527 170	3 600 024
RAD19	WHITE SANDS	NAD27	32 21 28.62	253 37 50.66	1233	-1 520 195	-5 175 429	3 394 506
RAD20	EGLIN AFB	NAD27	30 25 17.06	273 12 6.44	37	307 463	-5 496 301	3 210 588
RAD21	WALLOPS ISLAND	NAD27	37 51 16.74	284 29 11.61	29	1 261 394	-4 882 175	3 892 542
LAUNCH SITES								
LPD 1	PAD 12	NAD27	28 28 49.13	279 27 28.05	25	921 950	-5 534 397	3 023 243
LPD 2	PAD 13	NAD27	28 29 8.13	279 27 19.22	25	921 667	-5 534 162	3 023 758
LPD 3	PAD 14	NAD27	28 29 27.14	279 27 10.39	25	921 384	-5 533 926	3 024 272
LPD 4	PAD 19	NAD27	28 30 24.15	279 26 43.70	20	920 530	-5 533 214	3 025 812
LPD 5	PAD 34	NAD27	28 31 17.51	279 26 19.11	25	919 743	-5 532 555	3 027 258
LPD 6	PAD 37A	NAD27	28 31 59.42	279 25 53.98	28	918 968	-5 532 061	3 028 393
LPD 7	PAD 37B	NAD27	28 31 53.13	279 26 5.39	28	919 289	-5 532 102	3 028 222
LPD 8	PAD 39A	NAD27	28 36 28.78	279 23 44.34	39	914 845	-5 528 735	3 035 680
GODDARD R/RR STATIONS								
GRR1S	FAIRBANKS	NAD27	64 58 20.89	212 29 22.41	349	-2 282 482	-1 453 517	5 756 536
GRR1V	FAIRBANKS	NAD27	64 58 19.19	212 29 28.12	349	-2 282 482	-1 453 606	5 756 514
GRR2S	ROSMAN	NAD27	35 11 45.05	277 7 26.23	880	647 213	-5 178 486	3 655 963
GRR2V	ROSMAN	NAD27	35 11 41.10	277 7 26.23	880	647 222	-5 178 556	3 655 863
GRR3S	SANTIAGO	SAD69	-33 9 2.73	289 20 3.25	732	1 769 939	-5 044 486	-3 468 381
GRR3V	SANTIAGO	SAD69	-33 9 5.21	289 20 3.25	732	1 769 925	-5 044 447	-3 468 445
GRR4S	TANANARIVE	LOCAL	-19 1 9.33	47 18 12.56	1399	4 091 516	4 434 476	-2 065 846
GRR4V	TANANARIVE	LOCAL	-19 1 11.80	47 18 12.56	1399	4 091 500	4 434 457	-2 065 918
GRR5S	CARNARVON	AUSTR	-24 54 14.96	113 42 54.94	44	-2 328 108	5 299 742	-2 669 476
GRR5V	CARNARVON	AUSTR	-24 54 18.92	113 42 54.94	44	-2 328 087	5 299 695	-2 669 587
85-FOOT ANTENNAS								
S85 1	ROSMAN	NAD27	35 12 .05	277 7 40.57	898	647 542	-5 178 191	3 656 351
S85 2	ROSMAN	NAD27	35 11 55.68	277 7 27.45	894	647 222	-5 178 306	3 656 238
S85 3	FAIRBANKS	NAD27	64 58 37.71	212 29 5.58	309	-2 282 189	-1 453 068	5 756 721
S85 4	ORRORAL	AUSTR	-35 37 52.85	148 57 20.91	947	-4 447 255	2 676 851	-3 695 587
S85 6	KASHIMA	TOKYO	35 57 3.20	140 39 57.83	48	-3 997 747	3 276 074	3 723 440

* INSUFFICIENT DATA

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POSITIONS ON LOCAL OR MAJOR DATUMS

STATION			GEODETIC COORDINATES			GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)
40-FOOT ANTENNAS								
S40 1	GILMORE CREEK	NAD27	64° 58' 36".93	212° 28' 54".00	299	-2 282 285	-1 452 949	5 756 702
S40 2	JOHANNESBURG	ARC	-25 53 9.16	27 42 27.93	1537	5 084 805	2 670 461	-2 768 137
S40 3	QUITO	SAD69	-0 37 22.11	281 25 11.28	3594	1 263 488	-6 255 046	-68 905
S40 4	SANTIAGO	SAD69	-33 9 4.07	289 19 56.40	728	1 769 763	-5 044 521	-3 468 414
S40 5	GOLDSTONE	NAD27	35 19 53.97	243 6 47.76	918	-2 356 156	-4 646 904	3 668 289
S40 6	TANANARIVE	LOCAL	-19 0 34.40	47 18 5.66	1385	4 091 893	4 434 586	-2 064 826
S40 7	GREENBELT	NAD27	38 59 59.64	283 9 29.96	56	1 129 905	-4 833 187	3 992 147
MINITRACK STATIONS								
MIN 1	FAIRBANKS	NAD27	64 52 19.72	212 9 47.17	165	-2 299 238	-1 445 840	5 751 629
MIN 2	FAIRBANKS	NAD27	64 58 38.60	212 28 40.90	292	-2 282 335	-1 452 778	5 756 717
MIN 3	MOJAVE	NAD27	35 19 48.09	243 6 2.73	907	-2 357 214	-4 646 476	3 668 135
MIN 4	EAST GRAND FORKS	NAD27	48 1 21.40	262 59 21.56	256	-521 679	-4 242 198	4 718 544
MIN 5	FORT MYERS	NAD27	26 32 51.89	278 8 3.93	21	807 883	-5 652 137	2 833 328
MIN 6	QUITO	SAD69	-0 37 20.62	281 25 17.94	3593	1 263 690	-6 255 005	-68 859
MIN 7	LIMA	SAD69	-11 46 34.98	282 51 1.63	59	1 388 896	-6 088 430	-1 293 213
MIN 8	BLOSSOM POINT	NAD27	38 25 49.63	282 54 48.22	7	1 118 061	-4 876 472	3 942 793
MIN 9	GREENBELT	NAD27	38 59 56.73	283 9 37.31	52	1 130 090	-4 833 198	3 992 075
MIN10	SANTIAGO	SAD69	-33 8 57.24	289 19 56.40	720	1 769 798	-5 044 623	-3 468 233
MIN11	ST. JOHN'S	NAD27	47 44 29.74	307 16 43.37	106	2 602 802	-3 419 301	4 697 477
MIN12	WINKFIELD	EUROP	51 26 49.11	359 18 14.10	61	3 983 199	-48 394	4 964 833
MIN13	JOHANNESBURG	ARC	-25 52 58.86	27 42 27.93	1522	5 084 916	2 670 519	-2 767 846
MIN14	TANANARIVE	LOCAL	-19 0 27.10	47 18 .46	1378	4 092 050	4 434 532	-2 064 612
MIN15	WOOMERA	AUSTR	-31 23 30.07	136 52 11.02	132	-3 977 146	3 725 691	-3 303 121
MIN16	ORRORAL	AUSTR	-35 37 37.50	148 57 10.71	941	-4 447 355	2 677 211	-3 695 199
SATAN ANTENNAS								
SAT 1	ROSMAN	NAD27	35 12 6.12	277 7 26.36	940	647 176	-5 178 163	3 656 528
SAT 2	GOLDSTONE	NAD27	35 19 53.97	243 6 42.39	915	-2 356 276	-4 646 841	3 668 287
SAT 3	COOBY CREEK	AUSTR	-27 23 50.69	151 56 17.15	551	-5 001 023	2 666 026	-2 917 646
DEEP SPACE NETWORK								
DSN 1	GOLDSTONE	NAD27	35 23 22.35	243 9 5.26	1014	-2 351 415	-4 645 228	3 673 582
DSN 2	GOLDSTONE	NAD27	35 17 59.85	243 11 43.41	967	-2 350 428	-4 652 127	3 665 447
DSN 3	GOLDSTONE	NAD27	35 14 51.79	243 12 21.57	1071	-2 351 115	-4 655 626	3 660 775
DSN 4	GOLDSTONE	NAD27	35 25 33.34	243 6 40.85	1010	-2 353 607	-4 641 491	3 676 871

* INSUFFICIENT DATA

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POSITIONS ON LOCAL OR MAJOR DATUMS

STATION			GEODETIC COORDINATES			GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)
DEEP SPACE NETWORK								
DSN 5	WOOMERA	AUSTR	-31° 22' 59".43	136° 53' 10".12	151	-3 978 584	3 724 898	-3 302 325
DSN 6	TIDBINBILLA	AUSTR	-35 24 8.04	148 58 48.21	664	-4 460 848	2 682 461	-3 674 729
DSN 7	JOHANNESBURG	ARC	-25 53 21.15	27 41 8.53	1391	5 085 574	2 668 367	-2 768 405
DSN 8	MADRID	EUROP	40 25 47.72	355 45 8.28	766	4 849 332	-360 172	4 115 006
DSN 9	MADRID	EUROP	40 27 15.27	355 38 .57	716	4 846 790	-370 090	4 117 029
DSN10	MERRITT ISLAND	NAD27	28 28 45.04	279 26 .77	23	919 617	-5 534 844	3 023 132
DSN11	ASCENSION	LOCAL	-7 57 17.06	345 40 20.72	542	6 121 447	-1 563 476	-876 907
RADIO TELESCOPES								
RTE 1	JODRELL BANK	EUROP	52 14 14.66	357 41 34.39	125	3 911 203	-157 577	5 019 221
RTE 2	PARKES	AUSTR	-33 0 .04	148 15 44.15	396	-4 554 091	2 816 809	-3 454 187
RTE 3	BONN	*						

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Positions on Modified Mercury Datum 1968

POSITIONS ON MODIFIED MERCURY DATUM 1968

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
UNIFIED S-BAND ANTENNAS									
USB 1	MERRITT ISLAND	28°30'29".15	279°18'23".14	-20	907 066	-5 535 228	3 026 105	6 373 290	28°20'49".22
USB 2	GRAND BAHAMA	26 37 57.62	281 45 43.90	-21	1 163 014	-5 585 442	2 841 892	6 373 861	26 28 43.66
USB 3	BERMUDA	32 21 4.13	295 20 30.28	-18	2 308 429	-4 874 324	3 393 390	6 372 046	32 10 38.82
USB 4	ANTIGUA	17 0 59.75	298 14 50.29	-1	2 887 311	-5 374 153	1 854 595	6 376 332	16 54 33.17
USB 5*	GRAND CANARY	27 45 46.18	344 22 4.52	160	5 439 248	-1 521 949	2 953 357	6 373 701	27 36 16.29
USB 6*	ASCENSION	-7 57 18.20	345 40 20.72	544	6 121 215	-1 563 416	-876 935	6 378 288	-7 54 8.96
USB 7	MADRID	40 27 19.38	355 49 53.58	827	4 847 831	-353 319	4 117 140	6 370 019	40 15 55.90
USB 8	CARNARVON	-24 54 24.54	113 43 31.23	22	-2 328 979	5 299 192	-2 669 733	6 374 406	-24 45 36.56
USB 9*	GUAM	13 18 33.28	144 44 3.89	92	-5 068 764	3 584 316	1 458 745	6 377 118	13 13 23.88
USB10	CANBERRA	-35 35 1.19	148 58 39.32	1149	-4 451 045	2 676 828	-3 691 400	6 372 099	-35 24 6.46
USB11	KAUAI	22 7 34.26	200 20 5.30	1131	-5 543 830	-2 054 554	2 387 795	6 376 269	21 59 32.18
USB12	GOLDSTONE	35 20 29.38	243 7 34.81	934	-2 354 766	-4 646 791	3 669 387	6 371 969	35 9 36.56
USB13	GUAYMAS	27 57 46.71	249 16 43.78	-10	-1 994 715	-5 272 967	2 972 886	6 373 470	27 48 14.07
USB14	CORPUS CHRISTI	27 39 12.76	262 37 16.59	-18	-726 082	-5 606 818	2 942 552	6 373 556	27 29 44.35
USB15	GREENBELT	38 59 54.24	283 9 25.49	18	1 129 791	-4 833 170	3 992 202	6 369 743	38 48 37.23
USB16	GREENBELT	38 59 53.52	283 9 28.47	25	1 129 865	-4 833 172	3 992 188	6 369 750	38 48 36.51
USB17	GOLDSTONE	35 20 29.38	243 7 37.23	929	-2 354 710	-4 646 814	3 669 384	6 371 964	35 9 36.56
USB18	MERRITT ISLAND	28 30 27.28	279 18 23.14	-20	907 070	-5 535 256	3 026 054	6 373 290	28 20 47.35
RADARS									
RAD 1	MERRITT ISLAND	28 25 28.87	279 20 7.59	-18	910 584	-5 539 118	3 017 979	6 373 318	28 15 50.04
RAD 2	PATRICK AFB	28 13 34.96	279 24 1.99	-15	918 582	-5 548 371	2 998 635	6 373 383	28 3 58.77
RAD 3	CAPE KENNEDY	28 28 53.73	279 25 23.99	-16	918 588	-5 534 753	3 023 525	6 373 303	28 19 14.15
RAD 4	GRAND BAHAMA	26 38 10.20	281 43 55.74	-20	1 160 050	-5 585 881	2 842 238	6 373 861	26 28 56.17
RAD 5	WALLOPS ISLAND	37 51 36.51	284 29 26.01	-23	1 261 602	-4 881 572	3 893 196	6 370 115	37 40 25.83
RAD 6	WALLOPS ISLAND	37 50 28.40	284 30 53.15	-26	1 263 987	-4 882 284	3 891 536	6 370 119	37 39 17.84
RAD 7	GRAND TURK	21 27 45.40	288 52 4.09	0	1 920 435	-5 619 435	2 319 146	6 375 308	21 19 54.85
RAD 8	BERMUDA	32 20 52.66	295 20 46.05	-20	2 308 881	-4 874 316	3 393 090	6 372 045	32 10 27.38
RAD 9	BERMUDA	32 20 52.16	295 20 46.26	-19	2 308 890	-4 874 322	3 393 078	6 372 046	32 10 26.88
RAD10	ANTIGUA	17 8 37.37	298 12 26.25	8	2 881 608	-5 372 534	1 868 045	6 376 313	17 2 8.26
RAD11*	ASCENSION	-7 58 21.94	345 35 53.90	126	6 118 523	-1 571 163	-878 817	6 377 867	-7 55 12.27
RAD12*	ASCENSION	-7 57 5.45	345 35 14.63	92	6 118 507	-1 572 400	-876 485	6 377 836	-7 53 56.28
RAD13*	TANANARIVE	-19 0 .99	47 18 54.19	1338	4 090 888	4 435 590	-2 063 820	6 377 239	-18 52 55.77
RAD14	CARNARVON	-24 53 47.87	113 43 1.82	27	-2 328 416	5 299 963	-2 668 711	6 374 413	-24 45 .04
RAD15	WOOMERA	-30 49 7.50	136 50 17.03	127	-3 999 014	3 750 328	-3 248 727	6 372 700	-30 38 59.00

* DATUM SHIFTS NOT AVAILABLE

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POSITIONS ON MODIFIED MERCURY DATUM 1968

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
RADARS									
RAD16	KAUAI	22° 7'24".16	200°20' 3".88	1135	-5 543 957	-2 054 558	2 387 509	6 376 274	21°59'22".13
RAD17	VANDENBERG AFB	34 39 56.84	239 25 6.93	77	-2 671 854	-4 521 206	3 607 488	6 371 348	34 29 9.57
RAD18	PT. ARGUELLO	34 34 57.67	239 26 18.47	615	-2 673 175	-4 527 025	3 600 207	6 371 916	34 24 11.17
RAD19	WHITE SANDS	32 21 28.91	253 37 48.44	1205	-1 520 213	-5 175 284	3 394 689	6 373 267	32 11 3.65
RAD20	EGLIN AFB	30 25 17.76	273 12 6.07	-1	307 445	-5 496 156	3 210 771	6 372 700	30 15 13.88
RAD21	WALLOPS ISLAND	37 51 16.74	284 29 12.38	-7	1 261 376	-4 882 030	3 892 725	6 370 133	37 40 6.10
LAUNCH SITES									
LPD 1	PAD 12	28 28 50.06	279 27 28.27	-14	921 932	-5 534 252	3 023 426	6 373 305	28 19 10.49
LPD 2	PAD 13	28 29 9.07	279 27 19.44	-14	921 649	-5 534 017	3 023 941	6 373 303	28 19 29.43
LPD 3	PAD 14	28 29 28.08	279 27 10.61	-14	921 366	-5 533 781	3 024 455	6 373 301	28 19 48.37
LPD 4	PAD 19	28 30 25.08	279 26 43.92	-20	920 512	-5 533 069	3 025 995	6 373 291	28 20 45.17
LPD 5	PAD 34	28 31 18.44	279 26 19.33	-14	919 725	-5 532 410	3 027 441	6 373 292	28 21 38.32
LPD 6	PAD 37A	28 32 .35	279 25 54.20	-12	918 950	-5 531 916	3 028 576	6 373 291	28 22 20.08
LPD 7	PAD 37B	28 31 54.06	279 26 5.61	-12	919 271	-5 531 957	3 028 405	6 373 291	28 22 13.81
LPD 8	PAD 39A	28 36 29.70	279 23 44.56	0	914 827	-5 528 590	3 035 863	6 373 279	28 26 48.45
GODDARD R/RR STATIONS									
GRR1S	FAIRBANKS	64 58 19.25	212 29 12.35	347	-2 282 500	-1 453 372	5 756 719	6 360 968	64 49 27.11
GRR1V	FAIRBANKS	64 58 17.55	212 29 18.06	347	-2 282 500	-1 453 461	5 756 697	6 360 968	64 49 25.40
GRR2S	ROSMAN	35 11 45.28	277 7 26.23	843	647 195	-5 178 341	3 656 146	6 371 929	35 0 53.64
GRR2V	ROSMAN	35 11 41.32	277 7 26.23	843	647 204	-5 178 411	3 656 046	6 371 929	35 0 49.69
GRR3S	SANTIAGO	-33 9 3.97	289 20 .45	749	1 769 865	-5 044 495	-3 468 420	6 372 542	-32 58 30.67
GRR3V	SANTIAGO	-33 9 6.44	289 20 .45	749	1 769 851	-5 044 456	-3 468 484	6 372 542	-32 58 33.14
GRR4S*	TANANARIVE	-19 1 9.33	47 18 12.56	1399	4 091 357	4 434 303	-2 065 827	6 377 295	-18 54 3.76
GRR4V*	TANANARIVE	-19 1 11.80	47 18 12.56	1399	4 091 341	4 434 285	-2 065 899	6 377 295	-18 54 6.21
GRR5S	CARNARVON	-24 54 12.08	113 42 58.99	16	-2 328 213	5 299 698	-2 669 382	6 374 400	-24 45 24.14
GRR5V	CARNARVON	-24 54 16.03	113 42 58.99	16	-2 328 192	5 299 651	-2 669 493	6 374 400	-24 45 28.08
85-FOOT ANTENNAS									
S85 1	ROSMAN	35 12 .27	277 7 40.58	861	647 524	-5 178 046	3 656 534	6 371 946	35 1 8.60
S85 2	ROSMAN	35 11 55.90	277 7 27.46	857	647 204	-5 178 161	3 656 421	6 371 942	35 1 4.24
S85 3	FAIRBANKS	64 58 36.07	212 28 55.52	307	-2 282 207	-1 452 923	5 756 904	6 360 927	64 49 44.00
S85 4	ORRORAL	-35 37 48.99	148 57 24.56	956	-4 447 360	2 676 807	-3 695 493	6 371 890	-35 26 53.88
S85 6	KASHIMA	35 57 14.57	140 39 47.05	60	-3 997 909	3 276 556	3 724 111	6 370 879	35 46 16.88

* DATUM SHIFTS NOT AVAILABLE

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POSITIONS ON MODIFIED MERCURY DATUM 1968

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
40-FOOT ANTENNAS									
S40 1	GILMORE CREEK	64°58'35."29	212°28'43."93	297	-2 282 303	-1 452 805	5 756 885	6 360 917	64°49'43."21
S40 2	JOHANNESBURG	-25 53 10.79	27 42 29.49	1544	5 084 640	2 670 423	-2 768 420	6 375 646	-25 44 7.95
S40 3	QUITO	-0 37 23.38	281 25 8.87	3599	1 263 414	-6 255 055	-68 944	6 381 746	-0 37 8.37
S40 4	SANTIAGO	-33 9 5.30	289 19 53.59	745	1 769 689	-5 044 530	-3 468 453	6 372 539	-32 58 32.00
S40 5	GOLDSTONE	35 19 53.72	243 6 44.53	901	-2 356 174	-4 646 760	3 668 472	6 371 940	35 9 .98
S40 6*	TANANARIVE	-19 0 34.40	47 18 5.66	1385	4 091 734	4 434 414	-2 064 807	6 377 283	-18 53 29.01
S40 7	GREENBELT	38 59 59.58	283 9 30.60	19	1 129 887	-4 833 042	3 992 330	6 369 744	38 48 42.57
MINITRACK STATIONS									
MIN 1	FAIRBANKS	64 52 18.05	212 9 37.12	163	-2 299 256	-1 445 695	5 751 812	6 360 814	64 43 24.34
MIN 2	FAIRBANKS	64 58 36.96	212 28 30.83	290	-2 282 353	-1 452 633	5 756 900	6 360 910	64 49 44.89
MIN 3	MOJAVE	35 19 47.84	243 5 59.50	890	-2 357 232	-4 646 331	3 668 318	6 371 929	35 8 55.11
MIN 4	EAST GRAND FORKS	48 1 21.02	262 59 19.85	220	-521 697	-4 242 053	4 718 727	6 366 598	47 49 52.02
MIN 5	FORT MYERS	26 32 53.09	278 8 4.02	-20	807 865	-5 651 992	2 833 511	6 373 887	26 23 40.35
MIN 6	QUITO	-0 37 21.89	281 25 15.54	3597	1 263 616	-6 255 014	-68 898	6 381 745	-0 37 6.89
MIN 7	LIMA	-11 46 36.23	282 50 59.18	69	1 388 822	-6 088 439	-1 293 252	6 377 336	-11 42 .30
MIN 8	BLOSSOM POINT	38 25 49.60	282 54 48.84	-30	1 118 043	-4 876 327	3 942 976	6 369 902	38 14 35.61
MIN 9	GREENBELT	38 59 56.67	283 9 37.95	15	1 130 072	-4 833 053	3 992 258	6 369 740	38 48 39.65
MIN10	SANTIAGO	-33 8 58.47	289 19 53.59	736	1 769 724	-5 044 632	-3 468 272	6 372 530	-32 58 25.19
MIN11	ST. JOHN'S	47 44 28.99	307 16 46.89	81	2 602 784	-3 419 156	4 697 660	6 366 563	47 32 59.31
MIN12	WINKFIELD	51 26 45.71	359 18 8.66	97	3 983 118	-48 498	4 964 712	6 365 214	51 15 30.05
MIN13	JOHANNESBURG	-25 53 .49	27 42 29.49	1530	5 084 750	2 670 481	-2 768 129	6 375 632	-25 43 57.69
MIN14*	TANANARIVE	-19 0 27.10	47 18 .46	1378	4 091 891	4 434 360	-2 064 592	6 377 277	-18 53 21.75
MIN15	WOOMERA	-31 23 26.57	136 52 14.96	131	-3 977 251	3 725 647	-3 303 027	6 372 516	-31 13 11.59
MIN16	ORRORAL	-35 37 33.64	148 57 14.36	950	-4 447 459	2 677 167	-3 695 105	6 371 885	-35 26 38.56
SATAN ANTENNAS									
SAT 1	ROSMAN	35 12 6.35	277 7 26.37	903	647 158	-5 178 018	3 656 711	6 371 987	35 1 14.66
SAT 2	GOLDSTONE	35 19 53.72	243 6 39.16	898	-2 356 294	-4 646 696	3 668 470	6 371 936	35 9 .98
SAT 3	COOBY CREEK	-27 23 46.81	151 56 20.36	581	-5 001 128	2 665 982	-2 917 552	6 374 233	-27 14 22.03
DEEP SPACE NETWORK									
DSN 1	GOLDSTONE	35 23 22.09	243 9 2.03	997	-2 351 433	-4 645 083	3 673 765	6 372 016	35 12 28.89
DSN 2	GOLDSTONE	35 17 59.61	243 11 40.19	950	-2 350 446	-4 651 982	3 665 630	6 372 000	35 7 7.13
DSN 3	GOLDSTONE	35 14 51.55	243 12 18.35	1054	-2 351 133	-4 655 481	3 660 958	6 372 123	35 3 59.50
DSN 4	GOLDSTONE	35 25 33.08	243 6 37.61	993	-2 353 625	-4 641 346	3 677 054	6 371 998	35 14 39.59

* DATUM SHIFTS NOT AVAILABLE

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POSITIONS ON MODIFIED MERCURY DATUM 1968

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
DEEP SPACE NETWORK									
DSN 5	WOOMERA	-31°22′55″93	136°53′14″06	150	-3 978 689	3 724 854	-3 302 231	6 372 537	-31°12′41″05
DSN 6	TIDBINBILLA	-35 24 4.17	148 58 51.84	674	-4 460 953	2 682 417	-3 674 635	6 371 688	-35 13 10.85
DSN 7	JOHANNESBURG	-25 53 22.78	27 41 10.09	1398	5 085 408	2 668 329	-2 768 688	6 375 499	-25 44 19.87
DSN 8	MADRID	40 25 43.25	355 45 3.63	831	4 849 251	-360 276	4 114 885	6 370 032	40 14 19.87
DSN 9	MADRID	40 27 10.80	355 37 55.91	781	4 846 709	-370 194	4 116 908	6 369 973	40 15 47.32
DSN10	MERRITT ISLAND	28 28 45.98	279 26 .99	-17	919 599	-5 534 699	3 023 315	6 373 303	28 19 6.42
DSN11*	ASCENSION	-7 57 16.22	345 40 20.72	542	6 121 221	-1 563 418	-876 875	6 378 285	-7 54 6.99
RADIO TELESCOPES									
RTE 1	JODRELL BANK	52 14 11.27	357 41 28.74	161	3 911 122	-157 681	5 019 100	6 364 990	52 3 .07
RTE 2	PARKES	-32 59 56.20	148 15 47.72	409	-4 554 196	2 816 765	-3 454 093	6 372 254	-32 49 24.36
RTE 3	BONN	**							

* DATUM SHIFTS NOT AVAILABLE
**INSUFFICIENT DATA

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Positions on Mercury Datum 1960

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POSITIONS ON MERCURY DATUM 1960

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
DEEP SPACE NETWORK									
DSN 5*	WOOMERA	-31°22'59".33	136°53'10".12	144	-3 978 584	3 724 898	-3 302 325	6 372 546	-31°12'44".44
DSN 6*	TIDBINBILLA	-35 24 7.93	148 58 48.21	657	-4 460 848	2 682 461	-3 674 729	6 371 687	-35 13 14.59
DSN 7	JOHANNESBURG	-25 53 23.26	27 41 9.09	1425	5 085 449	2 668 319	-2 768 720	6 375 542	-25 44 20.36
DSN 8	MADRID	40 25 43.15	355 45 7.42	820	4 849 263	-360 187	4 114 886	6 370 037	40 14 19.77
DSN 9	MADRID	40 27 10.71	355 37 59.71	770	4 846 721	-370 105	4 116 909	6 369 978	40 15 47.23
DSN10	MERRITT ISLAND	28 28 46.60	279 26 1.55	20	919 620	-5 534 733	3 023 357	6 373 355	28 19 7.05
DSN11*	ASCENSION	-7 57 16.22	345 40 20.72	542	6 121 236	-1 563 422	-876 877	6 378 301	-7 54 6.99
RADIO TELESCOPES									
RTE 1	JODRELL BANK	52 14 11.08	357 41 33.45	148	3 911 132	-157 592	5 019 099	6 364 993	52 2 59.89
RTE 2*	PARKES	-32 59 59.93	148 15 44.15	389	-4 554 091	2 816 809	-3 454 187	6 372 249	-32 49 28.08
RTE 3	BONN	**							

* DATUM SHIFTS NOT AVAILABLE
**INSUFFICIENT DATA

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POSITIONS ON MERCURY DATUM 1960

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
UNIFIED S-BAND ANTENNAS									
USB 1	MERRITT ISLAND	28°30'29".78	279°18'23".70	16	907 087	-5 535 262	3 026 147	6 373 343	28°20'49".85
USB 2	GRAND BAHAMA	26 37 58.30	281 45 44.40	16	1 163 035	-5 585 476	2 841 934	6 373 914	26 28 44.32
USB 3	BERMUDA	32 21 4.59	295 20 30.45	22	2 308 450	-4 874 358	3 393 432	6 372 102	32 10 39.28
USB 4	ANTIGUA	17 1 .67	298 14 50.37	34	2 887 332	-5 374 187	1 854 637	6 376 382	16 54 34.10
USB 5**	GRAND CANARY	27 45 44.90	344 22 8.70	160	5 439 311	-1 521 847	2 953 329	6 373 717	27 36 15.01
USB 6**	ASCENSION	-7 57 18.20	345 40 20.72	544	6 121 230	-1 563 420	-876 938	6 378 304	-7 54 8.90
USB 7	MADRID	40 27 19.29	355 49 57.38	813	4 847 841	-353 230	4 117 139	6 370 021	40 15 55.80
USB 8*	CARNARVON	-24 54 27.34	113 43 27.17	44	-2 328 874	5 299 236	-2 669 827	6 374 443	-24 45 39.35
USB 9*	GUAM	13 18 33.28	144 44 3.89	92	-5 068 777	3 584 325	1 458 749	6 377 134	13 13 23.88
USB10*	CANBERRA	-35 35 4.94	148 58 35.68	1133	-4 450 940	2 676 872	-3 691 494	6 372 099	-35 24 10.21
USB11	KAUAI	22 7 35.48	200 20 4.49	1129	-5 543 837	-2 054 532	2 387 835	6 376 283	21 59 33.39
USB12	GOLDSTONE	35 20 30.10	243 7 36.16	959	-2 354 745	-4 646 825	3 669 430	6 372 011	35 9 37.29
USB13	GUAYMAS	27 57 47.54	249 16 44.94	15	-1 994 694	-5 273 001	2 972 928	6 373 511	27 48 14.91
USB14	CORPUS CHRISTI	27 39 13.50	262 37 17.51	13	-726 061	-5 606 852	2 942 594	6 373 603	27 29 45.10
USB15	GREENBELT	38 59 54.53	283 9 26.02	58	1 129 812	-4 833 204	3 992 244	6 369 799	38 48 37.52
USB16	GREENBELT	38 59 53.80	283 9 29.00	65	1 129 886	-4 833 206	3 992 230	6 369 806	38 48 36.80
USB17	GOLDSTONE	35 20 30.10	243 7 38.58	954	-2 354 689	-4 646 848	3 669 426	6 372 005	35 9 37.28
USB18	MERRITT ISLAND	28 30 27.90	279 18 23.70	16	907 091	-5 535 290	3 026 096	6 373 343	28 20 47.98
RADARS									
RAD 1	MERRITT ISLAND	28 25 29.50	279 20 8.15	18	910 605	-5 539 152	3 018 021	6 373 371	28 15 50.67
RAD 2	PATRICK AFB	28 13 35.59	279 24 2.54	22	918 603	-5 548 405	2 998 677	6 373 436	28 3 59.41
RAD 3	CAPE KENNEDY	28 28 54.36	279 25 24.54	21	918 609	-5 534 787	3 023 567	6 373 356	28 19 14.78
RAD 4	GRAND BAHAMA	26 38 10.87	281 43 56.23	16	1 160 071	-5 585 916	2 842 280	6 373 913	26 28 56.85
RAD 5	WALLOPS ISLAND	37 51 36.83	284 29 26.49	17	1 261 623	-4 881 606	3 893 238	6 370 171	37 40 26.16
RAD 6	WALLOPS ISLAND	37 50 28.71	284 30 53.63	14	1 264 008	-4 882 318	3 891 578	6 370 175	37 39 18.16
RAD 7	GRAND TURK	21 27 46.21	288 52 4.39	36	1 920 456	-5 619 469	2 319 188	6 375 360	21 19 55.66
RAD 8	BERMUDA	32 20 53.13	295 20 46.21	20	2 308 902	-4 874 350	3 393 132	6 372 101	32 10 27.85
RAD 9	BERMUDA	32 20 52.63	295 20 46.43	21	2 308 911	-4 874 356	3 393 120	6 372 102	32 10 27.35
RAD10	ANTIGUA	17 8 38.29	298 12 26.33	42	2 881 629	-5 372 568	1 868 087	6 376 364	17 2 9.18
RAD11*	ASCENSION	-7 58 21.94	345 35 53.90	126	6 118 538	-1 571 167	-878 819	6 377 883	-7 55 12.27
RAD12*	ASCENSION	-7 57 5.45	345 35 14.63	93	6 118 523	-1 572 404	-876 487	6 377 852	-7 53 56.28
RAD13*	TANANARIVE	-19 0 .99	47 18 54.19	1338	4 090 898	4 435 601	-2 063 825	6 377 255	-18 52 55.77
RAD14*	CARNARVON	-24 53 50.67	113 42 57.76	49	-2 328 311	5 300 007	-2 668 805	6 374 451	-24 45 2.83
RAD15*	WOOMERA	-30 49 10.90	136 50 13.12	119	-3 998 909	3 750 372	-3 248 821	6 372 707	-30 39 2.38

* DATUM SHIFTS NOT AVAILABLE
** See Pages 58 & 101

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POSITIONS ON MERCURY DATUM 1960

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
RADARS									
RAD16	KAUAI	22° 7'25".38	200°20' 3".07	1133	-5 543 964	-2 054 536	2 387 549	6 376 288	21°59'23".34
RAD17	VANDENBERG AFB	34 39 57.62	239 25 8.32	100	-2 671 833	-4 521 240	3 607 530	6 371 387	34 29 10.35
RAD18	PT. ARGUELLO	34 34 58.45	239 26 19.86	638	-2 673 154	-4 527 059	3 600 249	6 371 955	34 24 11.95
RAD19	WHITE SANDS	32 21 29.60	253 37 49.57	1234	-1 520 192	-5 175 318	3 394 731	6 373 312	32 11 4.34
RAD20	EGLIN AFB	30 25 18.37	273 12 6.79	34	307 466	-5 496 190	3 210 813	6 372 752	30 15 14.48
RAD21	WALLOPS ISLAND	37 51 17.06	284 29 12.86	33	1 261 397	-4 882 064	3 892 767	6 370 188	37 40 6.42
LAUNCH SITES									
LPD 1	PAD 12	28 28 50.69	279 27 28.83	22	921 953	-5 534 286	3 023 468	6 373 357	28 19 11.12
LPD 2	PAD 13	28 29 9.70	279 27 20.00	22	921 670	-5 534 051	3 023 983	6 373 356	28 19 30.05
LPD 3	PAD 14	28 29 28.71	279 27 11.17	22	921 387	-5 533 815	3 024 497	6 373 354	28 19 49.00
LPD 4	PAD 19	28 30 25.71	279 26 44.48	17	920 533	-5 533 103	3 026 037	6 373 344	28 20 45.80
LPD 5	PAD 34	28 31 19.07	279 26 19.89	22	919 746	-5 532 444	3 027 483	6 373 344	28 21 38.95
LPD 6	PAD 37A	28 32 .98	279 25 54.76	25	918 971	-5 531 950	3 028 618	6 373 343	28 22 20.71
LPD 7	PAD 37B	28 31 54.68	279 26 6.17	25	919 292	-5 531 991	3 028 447	6 373 344	28 22 14.44
LPD 8	PAD 39A	28 36 30.32	279 23 45.12	36	914 848	-5 528 624	3 035 905	6 373 331	28 26 49.07
GODDARD R/RR STATIONS									
GRR1S	FAIRBANKS	64 58 19.80	212 29 15.40	369	-2 282 479	-1 453 406	5 756 761	6 361 006	64 49 27.67
GRR1V	FAIRBANKS	64 58 18.11	212 29 21.11	369	-2 282 479	-1 453 495	5 756 739	6 361 006	64 49 25.97
GRR2S	ROSMAN	35 11 45.71	277 7 26.89	881	647 216	-5 178 375	3 656 188	6 371 983	35 0 54.07
GRR2V	ROSMAN	35 11 41.76	277 7 26.89	880	647 225	-5 178 445	3 656 088	6 371 983	35 0 50.13
GRR3S	SANTIAGO	-33 9 1.73	289 19 59.73	734	1 769 860	-5 044 538	-3 468 363	6 372 544	-32 58 28.43
GRR3V	SANTIAGO	-33 9 4.20	289 19 59.73	734	1 769 846	-5 044 499	-3 468 427	6 372 544	-32 58 30.90
GRR4S*	TANANARIVE	-19 1 9.33	47 18 12.56	1399	4 091 368	4 434 314	-2 065 832	6 377 311	-18 54 3.76
GRR4V*	TANANARIVE	-19 1 11.80	47 18 12.56	1399	4 091 351	4 434 296	-2 065 904	6 377 311	-18 54 6.21
GRR5S*	CARNARVON	-24 54 14.87	113 42 54.94	37	-2 328 108	5 299 742	-2 669 476	6 374 438	-24 45 26.93
GRR5V*	CARNARVON	-24 54 18.83	113 42 54.94	37	-2 328 087	5 299 695	-2 669 587	6 374 437	-24 45 30.87
85-FOOT ANTENNAS									
S85 1	ROSMAN	35 12 .71	277 7 41.23	899	647 545	-5 178 080	3 656 576	6 371 999	35 1 9.04
S85 2	ROSMAN	35 11 56.34	277 7 28.11	895	647 225	-5 178 195	3 656 463	6 371 996	35 1 4.68
S85 3	FAIRBANKS	64 58 36.63	212 28 58.56	329	-2 282 186	-1 452 957	5 756 946	6 360 965	64 49 44.56
S85 4*	ORRORAL	-35 37 52.74	148 57 20.91	940	-4 447 255	2 676 851	-3 695 587	6 371 889	-35 26 57.62
S85 6	KASHIMA	35 57 11.10	140 39 41.83	92	-3 997 905	3 276 722	3 724 053	6 370 928	35 46 13.42

* DATUM SHIFTS NOT AVAILABLE

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POSITIONS ON MERCURY DATUM 1960

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
40-FOOT ANTENNAS									
S40 1	GILMORE CREEK	64°58'35".84	212°28'46".98	319	-2 282 282	-1 452 838	5 756 927	6 360 955	64°49'43".77
S40 2	JOHANNESBURG	-25 53 11.28	27 42 28.49	1571	5 084 680	2 670 413	-2 768 452	6 375 689	-25 44 8.44
S40 3	QUITO	-0 37 22.98	281 25 9.55	3600	1 263 438	-6 255 068	-68 932	6 381 763	-0 37 7.98
S40 4	SANTIAGO	-33 9 3.06	289 19 52.87	731	1 769 684	-5 044 573	-3 468 396	6 372 540	-32 58 29.76
S40 5	GOLDSTONE	35 19 54.44	243 6 45.88	926	-2 356 153	-4 646 794	3 668 514	6 371 981	35 9 1.70
S40 6*	TANANARIVE	-19 0 34.40	47 18 5.66	1385	4 091 745	4 434 425	-2 064 812	6 377 299	-18 53 29.01
S40 7	GREENBELT	38 59 59.87	283 9 31.13	59	1 129 908	-4 833 076	3 992 372	6 369 800	38 48 42.86
MINITRACK STATIONS									
MIN 1	FAIRBANKS	64 52 18.62	212 9 40.15	185	-2 299 235	-1 445 729	5 751 854	6 360 852	64 43 24.91
MIN 2	FAIRBANKS	64 58 37.52	212 28 33.88	312	-2 282 332	-1 452 667	5 756 942	6 360 948	64 49 45.46
MIN 3	MOJAVE	35 19 48.56	243 6 .85	915	-2 357 211	-4 646 365	3 668 360	6 371 971	35 8 55.83
MIN 4	EAST GRAND FORKS	48 1 21.18	262 59 21.05	256	-521 676	-4 242 087	4 718 769	6 366 650	47 49 52.19
MIN 5	FORT MYERS	26 32 53.78	278 8 4.60	16	807 886	-5 652 026	2 833 553	6 373 939	26 23 41.03
MIN 6	QUITO	-0 37 20.55	281 25 15.62	3598	1 263 622	-6 255 030	-68 857	6 381 762	-0 37 5.56
MIN 7	LIMA	-11 46 34.86	282 50 59.14	73	1 388 827	-6 088 466	-1 293 215	6 377 355	-11 41 58.94
MIN 8	BLOSSOM POINT	38 25 49.91	282 54 49.37	10	1 118 064	-4 876 361	3 943 018	6 369 957	38 14 35.93
MIN 9	GREENBELT	38 59 56.95	283 9 38.48	55	1 130 093	-4 833 087	3 992 300	6 369 796	38 48 39.94
MIN10	SANTIAGO	-33 8 56.23	289 19 52.87	722	1 769 720	-5 044 675	-3 468 215	6 372 532	-32 58 22.95
MIN11	ST. JOHN'S	47 44 28.95	307 16 46.71	123	2 602 805	-3 419 190	4 697 702	6 366 621	47 32 59.28
MIN12	WINKFIELD	51 26 45.46	359 18 13.28	86	3 983 128	-48 409	4 964 711	6 365 218	51 15 29.80
MIN13	JOHANNESBURG	-25 53 .98	27 42 28.49	1556	5 084 791	2 670 471	-2 768 161	6 375 675	-25 43 58.18
MIN14*	TANANARIVE	-19 0 27.10	47 18 .46	1378	4 091 901	4 434 371	-2 064 597	6 377 293	-18 53 21.75
MIN15*	WOOMERA	-31 23 29.96	136 52 11.02	125	-3 977 146	3 725 691	-3 303 121	6 372 525	-31 13 14.97
MIN16*	ORRORAL	-35 37 37.39	148 57 10.71	934	-4 447 355	2 677 211	-3 695 199	6 371 884	-35 26 42.30
SATAN ANTENNAS									
SAT 1	ROSMAN	35 12 6.79	277 7 27.02	941	647 179	-5 178 052	3 656 753	6 372 041	35 1 15.11
SAT 2	GOLDSTONE	35 19 54.44	243 6 40.51	923	-2 356 273	-4 646 730	3 668 512	6 371 978	35 9 1.71
SAT 3*	COOBY CREEK	-27 23 50.60	151 56 17.15	544	-5 001 023	2 666 026	-2 917 646	6 374 212	-27 14 25.80
DEEP SPACE NETWORK									
DSN 1	GOLDSTONE	35 23 22.81	243 9 3.38	1023	-2 351 412	-4 645 117	3 673 807	6 372 057	35 12 29.62
DSN 2	GOLDSTONE	35 18 .33	243 11 41.54	975	-2 350 425	-4 652 016	3 665 672	6 372 041	35 7 7.85
DSN 3	GOLDSTONE	35 14 52.27	243 12 19.70	1080	-2 351 112	-4 655 515	3 661 000	6 372 164	35 4 .23
DSN 4	GOLDSTONE	35 25 33.80	243 6 38.97	1018	-2 353 604	-4 641 380	3 677 096	6 372 040	35 14 40.31

* DATUM SHIFTS NOT AVAILABLE

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Positions on Apollo Reference System

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POSITIONS ON APOLLO REFERENCE SYSTEM*

Sta. No.	Acronym	Station	Radar	Geodetic Coordinates: Latitude	Geodetic Coordinates: Longitude	Geodetic Coordinates: Height Above Ellipsoid (m)	Geocentric Rectangular Coordinates(1): Latitude	Radius (m)	X (meters)	Y (meters)	Z (meters)
RAD 3	CKYF	Cape Kennedy(G)	FPS-16	28°28'54.36"±1.0"	279°25'24.82" ±1.2"	-38±40	28°19'14.77"	6 373 297	918 608±32	-5 534 735±38	3 023 539±34
RAD 1	MLAT	Merritt Island (G)	TPQ-18	28°25'29.49"±1.0"	279°20'08.42" ±1.2"	-40 ±40	28°15'50.66"	6 373 313	910 604±32	-5 539 100±38	3 017 993±34
USB 1	MIL3		USB 30' MSFN (Dual)	28°30'29.78"±1.0"	279°18'23.97" ±1.2"	-42 ±40	28°20'49.84"	6 373 285	907 086±32	-5 535 211±38	3 026 119±34
RAD 2	PATQ	Patrick Air Force(G) Base	FPQ-6	28°13'35.55"±1.0"	279°24'02.81" ±1.2"	-36 ±40	28°03'59.36"	6 373 378	918 602±32	-5 548 354±38	2 998 648±35
RAD 4	GBIT	Grand Bahama Island	TPQ-18	26°38'11.86"±1.0"	281°43'54.82" ±1.2"	19 ±41	26°28'57.84"	6 373 916	1 160 030±32	-5 585 913±39	2 842 308±34
USB 15	ETC 3	NT&TF Greenbelt, Md.	USBS 30'	38°59'54.53"(2)	283°09'24.60" (2)	55 (2)	38°48'37.53"	6 369 796	1 129 778(2)	-4 833 209(2)	3 992 242(2)
RAD 5	WLPQ	Wallops Island	FPQ-6	37°51'36.74" (2)	284°29'24.99" (2)	.13 (2)	37°40'26.07"	6 370 167	1 261 587(2)	-4 881 614(2)	3 893 234(2)
RAD 7	GTKT	Grand Turk Island	TPQ-18	21°27'46.40"±1.0"	288°52'03.87" ±1.2"	28 ±42	21°19'55.85"	6 375 352	1 920 439±33	-5 619 465±40	2 319 190±34
RAD 8	BDAF	Bermuda (G)	FPS-16	32°20'53.04"±1.2"	295°20.47.50" ±1.4"	-37 ±43	32°10'27.76"	6 372 044	2 308 913±39	-4 874 294±41	3 393 100±39
RAD 9	BDAQ		FPQ-6	32°20'52.54" ±1.2"	295°20'47.71" ±1.4"	-36 ±43	32°10'27.26"	6 372 045	2 308 922±39	-4 874 300±41	3 393 087±39
USB 3	BDA3		USBS 30' MSFN	32°21'04.50"±1.2"	295°20'31.73" ±1.4"	-34 ±43	32°10'39.19"	6 372 046	2 308 460±34	-4 874 302±41	3 393 400±39
RAD 10	ANTQ	Antigua Island	FPQ-6	17°08'38.36" ±1.1"	298°12'24.39" ±1.2"	42 ±42	17°02'09.25"	6 376 364	2 881 578±35	-5 372 595±40	1 868 089±34
USB 5	CYI 3	Grand Canary Island (G)	USBS 30'	27°45'52.33" ±4.6"	344°21'58.14" ±1.3"	173 ±51	27°36'22.42"	6 373 730	5 439 141±40	-1 522 100±40	2 953 538±40
RAD 11	ASCT	Ascension Island (G)	TPQ-18	-7°58'21.00" ±3.4"	345°35'54.85" ±2.3"	103 ±73	-7°55'11.34"	6 377 861	6 118 528±43	-1 571 134±103	-878 787±105
USB 6	ACN 3		USBS 30' MSFN (Dual)	-7°57'17.26" ±3.4"	345°40'21.67" ±2.3"	522 ±73	-7°54'08.02"	6 378 282	6 121 220±43	-1 563 388±103	-876 906±105
RAD 13	TANF	Tananarive	FPS-16	-19°00'06.49" (2)	47°18'53.03" (2)	1320 (2)	-18°53'01.25"	6 377 236	4 090 874(2)	4 435 525(2)	-2 063 979(2)
RAD 14	CROQ	Carnarvon Australia (G)	FPQ-6	-24°53'47.01" ±2.3"	113°43'03.46" ±1.0"	-11 ±83	-24°44'59.19"	6 374 392	-2 328 454±70	5 299 937±70	-2 668 678±70
USB 8	CRO 3		USBS 30' MSFN (Dual)	-24°54'23.68" ±2.3"	113°43'32.87" ±1.0"	-15 ±83	-24°45'35.70"	6 374 385	-2 329 018±70	5 299 166±70	-2 669 700±70
USB 9	GWM 3	Guam (G)	USBS 30' MSFN (Dual)	13°18'38.07" (2)	144°44'10.82" (2)	143 ±55	13°13'28.65"	6 377 185	-5 068 910(2)	3 584 164(2)	1 458 904(2)
RAD 16	HAWF	Hawaii (G)	FPS-16	22°07'24.61"±2.3"	200°20'03.87" ±1.2"	1139 ±43	21°59'22.57"	6 376 294	-5 543 970±76	-2 054 562±70	2 387 529±70
USB 11	HAW 3		USBS 30' MSFN (Dual)	22°07'34.71"±2.3"	200°20'05.29" ±1.2"	1135 ±43	21°59'32.63"	6 376 290	-5 543 843±70	-2 054 559±70	2 387 815±70
RAD 17	CALT	Vandenberg AFB Calif.	TPQ-18	34°39'57.24" (2)	239°25'07.44" (2)	45 (2)	34°29'09.97"	6 371 333	-2 671 833(2)	-4 521 196(2)	3 607 489(2)
USB 14	TEX 3	Corpus Christi, Tex.	USBS 30' MSFN (Dual)	27°39'13.50"±1.0"	262°37'16.08" ±1.1"	-20 ±40	27°29'45.10"	6 373 570	-726 096±30	-5 606 819±38	2 942 579±32
USB 10	HSK 8	Canberra, Australia (J)	USBS 85' MSFN (Dual)	-35°35'00.58" (2)	148°58'40.18" (2)	1145 (2)	-35°24'05.86"	6 372 111	-4 451 074(2)	2 676 820(2)	-3 691 392(2)
DSN 6	HSKW	Tidbinbilla, Australia (J)	USBS 85' DSN (Dual)	-35°24'03.56" (2)	148°58'52.69" (2)	670 (2)	-35°13'10.24	6 371 701	-4 460 982(2)	2 682 410(2)	674 627(2)
USB 7	MAD 8	Madrid, Spain (J)	USBS 85' MSFN	40°27'17.97" (2)	355°49'53.58" (2)	778 (2)	40°15'54.49"	6 369 986	4 847 834(2)	-353 319(2)	4 117 085(2)
DSN 8	MADW	(Robledo) (J)	USBS 85' DSN (Dual)	40°25'41.85" (2)	355°45'03.64" (2)	770 (2)	40°14'18.47"	6 369 988	4 849 245(2)	-360 275(2)	4 114 823(2)
USB 12	GDS8	Goldstone, Calif. (J) (Mojave)	USB 85' MSFN (Dual)	35°20'29.74" (2)	243°07'35.05" (2)	907 (2)	35°09'36.93"	6 371 959	-2 354 754(2)	-4 646 780(2)	3 669 390
DSN 1	GDSW	(Pioneer) (J)	USBS 85' DSN (Dual)	35°23'22.45" (2)	243°09'02.28" (2)	971 (2)	35°12'29.26"	6 372 006	-2 351 421	-4 645 073	3 673 768

(1) The geocentric rectangular coordinate system consists of a X axis at the intersection of the earth's equatorial plane with the Greenwich meridian, a Z axis along the earth's rotational axis, and a Y axis such to complete a right-handed coordinate system.

(2) Uncertainties not available.

*These station locations are the basic locations used for Apollo 15.

(G) GSFC derived coordinates.

(J) JPL derived coordinates.

(Dual) Indicates a common antenna, two receivers and two transmitters. Geodetic coordinates referenced to the Fischer Ellipsoid of 1960.

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GEODETIC DATA SHEET

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EXPLANATORY NOTES FOR THE GEODETIC DATA SHEET

The Geodetic Data Sheets provide a summary description of geodetic surveys performed and survey data gathered in positioning and orienting equipment at each observation site. This information is for site personnel in checking geodetic references, for operations and planning personnel in preparing, changing, or adding observation instruments at established stations, and for analysis personnel in assessing positional accuracies and future geodetic needs. More comprehensive records are maintained by the organizations responsible for the survey operations.

The Geodetic Data Sheet describes the procedures and results of the local tie of the equipment to the geodetic datum. The sheet is intended to answer questions of date and reliability, and to provide direction for further inquiry, and to simplify efforts to improve the position. It should provide documentation for assessment of the accuracy of the connection to the datum. It may enable a facility to be moved with minimum re-survey research and expense by identifying fixed survey monuments at or near the site. It should aid in establishing the latest or most accurate information, thereby reducing the common problem of having contradictory positions without date or source.

Explanatory notes for items on the Geodetic Data Sheets follow:

Station Number and Name - The identification adopted by GSFC or NASA - Multi-Satellite Control Center for the station. "Station" in this directory refers to the fixed point of reference for a particular piece of equipment. If equipment is moved to a new position, even though at the same site, a new code name and number must be assigned. Different types of equipment occupying the same point have different numbers and names. These are based where possible on existing code designations.

Other Codes - COSPAR, DoD, or other code designations to identify the same station in other descriptive systems.

Location - Geographic name of station. When different names are used for a site they are given under General Notes.

Equipment - Type of equipment used at this station.

Agency - Participating organization responsible for the operation of the station.

Point Referred to - Description of the exact point of reference for the geodetic data. Usually this is a fixed point as near the optical or electronic center of the equipment as convenient. For rotating systems this may be the center of rotation, intersection of axes, center of lower axis (offset X-Y mounts), center of gimbal ring (Baker-Nunn camera), etc.

Geodetic Coordinates - The position is usually given on the datum of survey. If the position has been computed on a preferred datum these coordinates will usually be given. South latitudes are designated by a minus sign. All longitudes in the directory are positive east of Greenwich, unless west is specified.

Astronomic Coordinates - Generally given only when the astronomic observation was made within a few hundred meters of the station. When an estimate of the deflection of the vertical is made from more distant astronomic observations, it is defined by the components in the meridian and the prime vertical, ξ and η. The line, "Based on" indicates the source of astro-data, designating the agency, date, and quality of the observation, and its approximate distance from the tracking station.

Elevation Above Mean Sea Level - Height of reference point above geoid.

Geoid Height - Height of geoid above ellipsoid, preferably derived from astronomic-geodetic studies. The source for this information is given in the General Notes; a list of sources appears at the end of these explanatory notes.

Height Above Ellipsoid - The algebraic sum of the two preceding numbers.

Azimuth Data - This provides space for listing astronomic and geodetic azimuths. Distance is the geodetic distance between points unless the slant range is specified. Azimuth here is the clockwise angle measured from North.

Description of Surveys and General Notes - These notes include a brief description of the survey by which the position was established, including by whom and when. The relationship to the national geodetic net is described. A sketch showing the tie is usually included. The method by which the elevation was determined is indicated. In most cases more detailed survey information will be retained at the agency which performed the survey.

Accuracy Assessment - The accuracy assessments to local control attempt only to indicate whether a one-meter criterion has been met. The precision of the surveys usually ranges from a few millimeters to nearly a meter, as reflected in the survey descriptions. The accuracy to datum origin is estimated by Simmons' Rule (section 2) as an approximation of the standard error that may be expected within a well-constructed datum. The assessment of the error to the vertical datum is the maximum error that should be expected between the elevation given and the geoid at that station, again with a one meter minimum standard. Inspection of the survey description will often show the error to be much smaller.

References - Principal sources for the information on the sheet.

Date - Date of compilation or last review of the data sheet.

The agency responsible for the operation of each station was requested to furnish the information for the Geodetic Data Sheets. Appropriate information was also obtained from other sources for many of the stations as noted on the data sheets. Sources have included United States and foreign government agencies, international organizations, national surveying and space-communication groups, engineering contractors, surveying firms, and private individuals. In the United States the principal sources for information for the directory are:

National Ocean Survey, NOAA
(formerly U.S. Coast and Geodetic Survey, ESSA)

DoD GEOSAT Records Center, USATOPOCOM

Physical Plant Engineering Branch, GSFC-NASA
(formerly Field Facilities Branch, GSFC-NASA)

Eastern Test Range, Patrick AF Base

Western Test Range, Vandenberg AF Base

U.S. Naval Oceanographic Office

First Geodetic Survey Squadron (MAC), USAF

Inter-American Geodetic Survey

Jet Propulsion Laboratory

Foreign Sources have included:

Australia:	Department of National Development, Division of National Mapping
Canada:	Dominion Geodesist, Ottawa
France:	National Center of Space Studies
Germany:	German Geodetic Research Institute
	German Research Institute for Air and Space Travel
Great Britain:	Directorate of Overseas Surveys
	Royal Radar Establishment
	Ordnance Survey of Great Britain
Greece:	National Technical University
Japan:	Radio Research Laboratories
Madagascar:	National Geographic Institute
Netherlands:	Geodetic Institute of the Technological University
Norway:	Geographic Survey
So. Africa:	National Institute for Telecommunications Research
Sweden:	Institute of Geodesy
Switzerland:	Astronomical Institute of the University of Berne

Observatories of Bochum (Germany), Meudon (France), Edinburgh (Great Britain), Strasbourg (France), Nice (France), Tokyo (Japan), and Naini Tal (India) have been additional sources for geodetic information.

Geoid heights given on the data sheets and used in the tabulations are taken from the following sources:

Geoid Charts of North and Central America, Irene Fischer et al, Army Map Service Technical Report No. 62, October 1967.

A Study of the Earth's Gravitational Field in the Australian Region, R. S. Mather et al, XV General Assembly IUGG, Moscow, August 1971.

Geoid Chart of Area Conventionally Referred to Tokyo Datum, I. Fischer, Army Map Service Technical Report No. 67, p. 21, June 1968.

The Astro-Geodetic Geoid in Europe and Connected Areas, G. Bomford, XV General Assembly IUGG, Moscow, August 1971.

Geoid heights for stations on the South American Datum 1969 are furnished by USATOPOCOM (1971) on their Geodetic Summary for each station. Heights are referred to a zero geoid separation at station CHUA.

Abbreviations and symbols used on geodetic data sheets are:

Organizations, etc.

AFB	Air Force Base
AFETR	U.S. Air Force Eastern Test Range
AFWTR	U.S. Air Force Western Test Range
AGU	American Geophysical Union (National Committee of the U.S. for the IUGG)
AMS	U.S. Army Map Service (now USATOPOCOM)
ATS	Applications Technology Satellite
C&GS	U.S. Coast and Geodetic Survey (now National Ocean Survey)
CE	U.S. Corps of Engineers
CNES	Centre National d'Etudes Spatiales (France)
COSPAR	Committee for Space Research (International Council of Scientific Unions)
CSIRO	Commonwealth Scientific and Industrial Organization (Australia)
DOS	Directorate of Overseas Surveys (Great Britain)
DSIF	Deep Space Instrumentation Facility, JPL (now DSN)
DSN	Deep Space Network (JPL)
ERTS	Earth Resources Technology Satellite
ESLD	Engineering Survey Liaison Detachment (1381st)
FFB	Field Facilities Branch (now Physical Plant Engineering Branch), GSFC
GSFC	Goddard Space Flight Center (Greenbelt, Maryland)
IAGS	Inter-American Geodetic Survey
IGM	Instituto Geografica Militar
IGN	Institut Geographique National (France)
IUGG	International Union of Geodesy and Geophysics

JPL	Jet Propulsion Laboratory (California Institute of Technology)
NAVOCEANO	U.S. Naval Oceanographic Office
NGP	NASA Geodetic Satellites Program
NGSP	National Geodetic Satellite Program
NOS	National Ocean Survey (formerly C&GS)
NTTF	Network Training and Test Facility (GSFC)
OSGB	Ordnance Survey of Great Britain
PMR	U.S. Navy Pacific Missile Range
RASC	Royal Australian Survey Corps
RE	Royal Engineers
SAO	Smithsonian Astrophysical Observatory
USAF	U.S. Air Force
USATOPOCOM	U.S. Army Topographic Command (formerly AMS)
USED	U.S. Engineer Department (Corps of Engineers)
USGS	U.S. Geological Survey
USNOO	U.S. Naval Oceanographic Office
WEST	West European Satellite Triangulation Program
WSMR	U.S. Army White Sands Missile Range (New Mexico)

Equipment

B-N	Baker-Nunn camera
MOTS	Minitrack Optical Tracking System
R/RR	Range and Range-Rate
SECOR	Sequential Collation of Range (TOPOCOM)
STADAN	Satellite Tracking and Data Acquisition Network (now in NASA Network Facilities - GSFC)
VHF	Very High Frequency

Sea Level Datums

SLD 1929	Sea Level Datum of 1929 (USA)
NAP	Nederlands Algemeen Peil (Amsterdam)
NN	Normal Null (Germany)
P. du N.	Pierre du Niton (Switzerland)
N.g.d.F.	Nivellement general de France
N.g.d.M.	Nivellement general de Madagascar
Newlyn	British Ordnance vertical survey datum

Geodetic Terms

A-G	astronomic minus geodetic
Az Mk	azimuth mark
BM	bench mark (an elevation station)
IGY	International Geophysical Year
MSL	mean sea level
obs	observation, observatory
PE	probable error
PV	prime vertical
RM	reference mark
S/R	slant range
TBM	temporary bench mark

Symbols

ϕ, ϕ_G	geodetic latitude
ϕ_A	astronomic latitude
λ, λ_G	geodetic longitude (east)
λ_A	*astronomic longitude (east)*
Δ	triangulation station
ξ	deflection in the meridian, plus if astronomic position is north of geodetic
η	deflection in the prime vertical, plus if astronomic position is east of geodetic

Unified S-Band Antennas

Station No. USB 1

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 193301; APOLLO MIL 3

Location: Merritt Island, Florida

Equipment: Unified S-Band (30-foot)

Agency: NASA-Goddard Space Flight Center

USB 1

Point referred to: center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 30' 28".219	Latitude	ξ = + 0.8" ± 1".0
Longitude (E)	279 18 22.933	Longitude (E)	η = + 1.2 ± 1.0
Datum	NAD 1927 (CC)*	Based on	interpolation by C&GS, 1966

Elevation above mean sea level 9.17 meters | Geoid height + 10 meters | Height above ellipsoid 19 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ S-BAND ANTENNA	Δ S-BAND BST	1168	346° 14' 03"
Geodetic	Δ S-BAND ANTENNA	Δ S2 1965	121.888	179 58 58

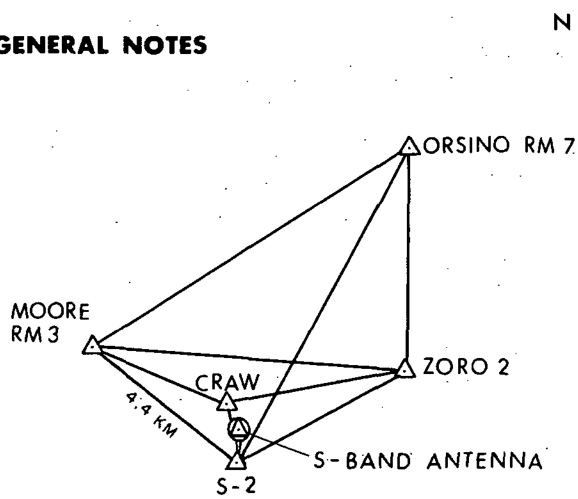
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by USC&GS in 1965 before construction of the antenna. First-order triangulation and traverse were used.

Station S-BAND ANTENNA 1965 was set (elev. 2.618 m) 6.55 m directly below the proposed center of the X-axis. Nine alignment markers were set on NS and EW lines (most at 15 to 122 m from the center) to control construction.

*Cape Canaveral Datum is within a few centimeters of NAD 1927 in this area.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.05 meters	6 meters
Vertical	0.1 meters	0.2 meters

REFERENCES

USC&GS Report; AFETR Geodetic Coordinates Manual, August 1969.

Station No. USB 2

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes APOLLO GBM 3

Location Grand Bahama Island, British West Indies
Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 2

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	26° 37' 56.449	Latitude	ξ = - 8"
Longitude (E)	281 45 43.472	Longitude (E)	η = + 7
Datum	NAD 1927 (CCD)*	Based on	C&GS obs. 1964 at Δ ROUGH (1st order) and 1952 at Δ ASKANIA, 2 km distant

Elevation above mean sea level 11.4 meters   Geoid height + 8 meters   Height above ellipsoid 19 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ APOLLO ANT CTR	Δ COL TWR	1158.142	293° 00' 29".51
Geodetic	Δ APOLLO ANT CTR	Δ NORTH 2	304.80	359 59 57

DESCRIPTION OF SURVEYS AND GENERAL NOTES

This antenna has been removed.

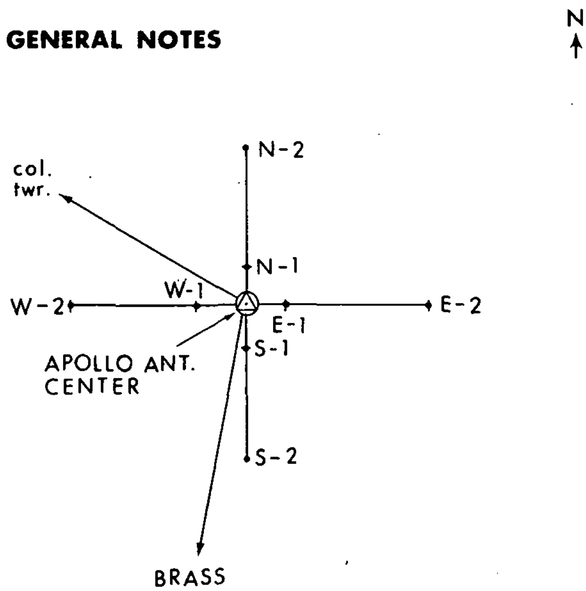
Surveyed by Facility Construction Branch, GSFC, in October 1966. Station APOLLO ANTENNA CENTER is marked by a tablet at the center of the concrete foundation of the antenna (elev. 4.83 m).

The position was fixed by a Geodimeter and Wild T-3 traverse between USC&GS first-order stations HIGH ROCK and PELICAN. Three intermediate stations were established: NAIL, BRASS, and ROD. The traverse closure was 1:337 000.

Elevation was by third-order levels from C&GS first-order BM M-1 1959.

*1969 adjustment to Cape Canaveral Datum from AFETR Geodetic Coordinates Manual August 1969.

Geoid height from TOPOCOM geoid charts 1967.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.1 meters	1 meters

REFERENCES

Report of Facilities Construction Branch, GSFC, November 1966.

Station No. USB 3

Code Name -

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes APOLLO BDA 3

Location Bermuda

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 3

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	32° 20' 59".496	Latitude	ξ = - 10".5
Longitude (E)	295 20 30.552	Longitude (E)	η = + 19.2
Datum	Bermuda 1957 (USC&GS)	Based on	C&GS first-order obs. at Δ SOLD, 660 m distant

Elevation above mean sea level 22.594 meters

Geoid height ______ meters

Height above ellipsoid ______ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANTENNA CENTER	Δ PAYNTERS HILL	4432.43	250° 04' 19".1
Geodetic	Δ ANTENNA CENTER	Δ COL. TOWER	732.10	316 20 07.8

DESCRIPTION OF SURVEYS AND GENERAL NOTES

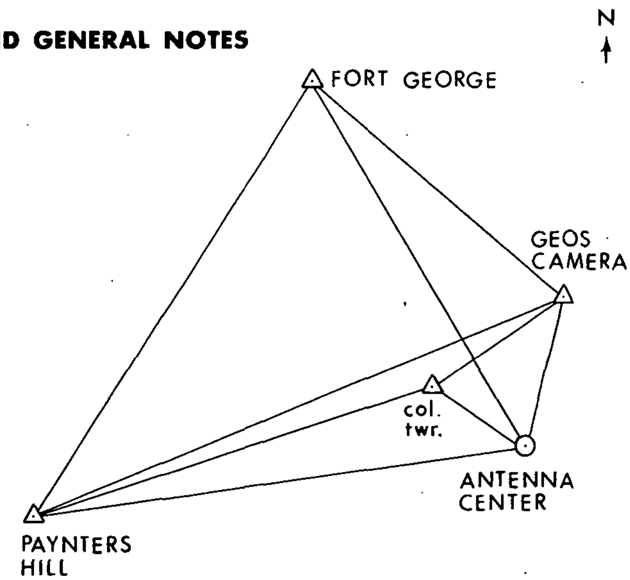
Surveyed by Field Facilities Branch, GSFC, Sept. 1965. Horizontal control was based on USC&GS first-order stations FORT GEORGE and PAYNTERS HILL. A first-order quadrilateral was formed with GEOS CAMERA and ANTENNA CENTER as shown. Eight alignment marks were set N,E,W, and (offset) S from center. Elevation was determined by third-order methods from a USC&GS bench mark. X-axis is 6.525 meters above station mark in base of antenna. Sea level datum is based on local sea-level datum at Customhouse. GSFC survey was prior to construction; Geonautics' survey in May 1966 verified results of the GSFC survey.

The station position on NAD 1927 by the USAF 1969 tie is:

ϕ 32° 21' 03".761

λ 295 20 28.527

Geoid height -9 m.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.05 meters	0.5 meters
Vertical	0.05 meters	1 meters

REFERENCES

Geodetic Survey Report of USB Antenna and GEOS Camera at Coopers Is., Bermuda, Facilities Construction Branch, GSFC, 14 March 1966.

Station No. USB 4

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO ANG 3

Location Antigua, West Indies Associated States

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 4

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	17° 00' 57".13	Latitude	
Longitude (E)	298 14 48.51	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 34.4 meters | Geoid height + 6 meters | Height above ellipsoid 40 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ DOW	Δ COL. TOWER	814.8	220° 26' 10"
Geodetic	Δ DOW	Δ A-3 (RE)	1576.4	187 08 09

DESCRIPTION OF SURVEYS AND GENERAL NOTES

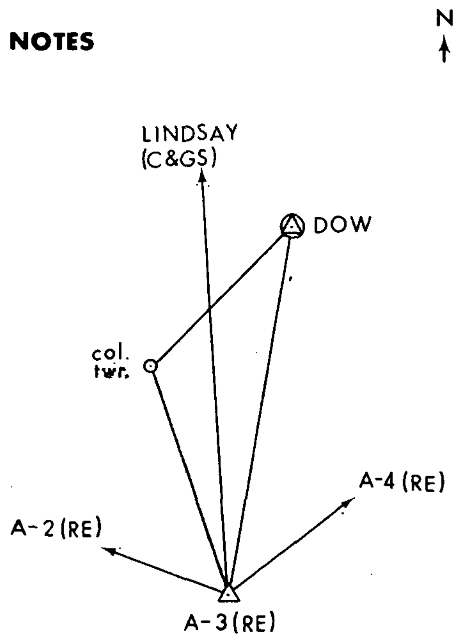
This antenna has been moved to Greenbelt, Md.

Surveys performed by Facilities Construction Branch, GSFC, January 1967.

The mark is a NASA GSFC tablet stamped "DOW", in the center of the antenna foundation. The station was fixed by closed traverse with Wild T-3 theodolite and 4D Geodimeter from station A-3 (Royal Engrs. 1945). Δ A-3 and the azimuth stations were tied to the C&GS first-order survey of 1963. The position above is based on the 1969 USAF satellite tie to Cape Canaveral Datum. (The position of Δ DOW on the 1953 IV Hiran tie to NAD is: ϕ 17° 00' 56".504, λ = 298° 14' 48".524.)

Elevation of Δ DOW (27.81 m) was by third-order levels from the Canadian Hydrographic Survey's tidal BM-4-1966, Nelson's Harbour. The X-axis of this type of antenna is 6.55 m above the foundation.

Geoid height from TOPOCOM geoid charts 1967. (The geoid height from the USAF 1969 satellite tie is + 13.4 m.)



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	10 meters
Vertical	1 meters	1 meters

REFERENCES

FCB-GSFC Survey Report on USB Antenna at Antigua, January 1967.

Station No. USB 5

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes APOLLO CYI 3

Code Name

Location Gran Canaria, Canary Islands

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 5

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	27° 45' 46".180	Latitude	
Longitude (E)	344 22 04.516	Longitude (E)	
Datum	Pico de las Nieves	Based on	

Elevation above mean sea level 160.36 meters   Geoid height ______ meters   Height above ellipsoid ______ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ USB ANTENNA	Δ WEST 2	1099.00	269° 59' 54".8
Geodetic	Δ USB ANTENNA	USB col.tower	934.602*	303 59 35.9

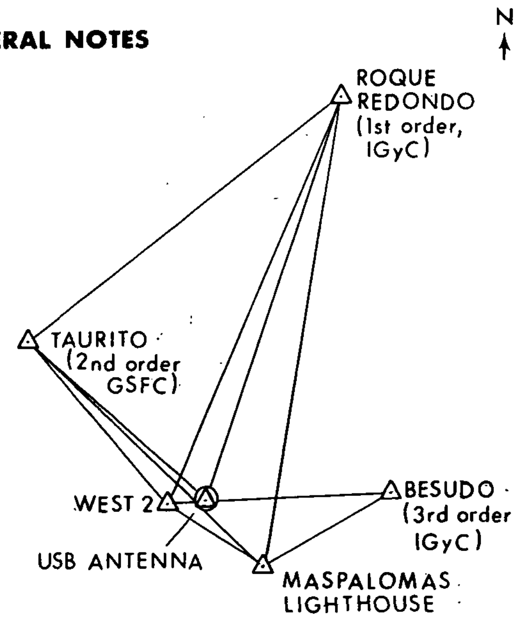
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Facilities Construction Branch, GSFC in 1967. Antenna position (Δ USB ANTENNA) fixed by second-order triangulation based on three Instituto Geografico y Catastral stations.

Nearest astro obs. is at Δ PLAYA 3 miles distant; deflection gradient is too great for transfer.

Spirit levels were run from Δ PLAYA to site. Center of X-axis is 6.55 m above Δ USB ANTENNA (153.81 m) in foundation. Elevation datum based on 60-day tide series by Geonautics, Inc. at Maspalomas Lighthouse in 1960.

*The slope distance from the centerline of the Y-axis of the USB antenna (when pointed to the col. tower) to the vertex of the subreflectors on the col. tower is 931.806 m.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.05 meters	0.5 meters
Vertical	0.05 meters	0.5 meters

REFERENCES

Geodetic Survey Report of USB Antenna at Grand Canary Island, Facilities Construction Branch, GSFC, May 1967.

Station No. USB 6

Code Name ______

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: APOLLO ACN 3

Location: Ascension Island

Equipment: Unified S-Band (30-foot)

Agency: NASA-Goddard Space Flight Center

USB 6

Point referred to: center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	-07° 57' 19".043	Latitude	ξ = - 0".1 ± 3"
Longitude (E)	345 40 20.716	Longitude (E)	η + 14.5 ± 3
Datum	Ascension Island 1958	Based on	C&GS grav./topo analysis 1966

Elevation above mean sea level: 544.2 meters   Geoid height ______ meters   Height above ellipsoid ______ meters

AZIMUTH DATA

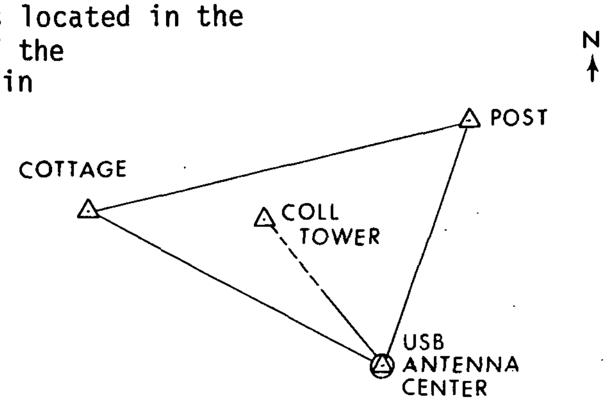
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ USB ANT CTR	Δ COLL. TOWER	1274.708	317° 38' 55".4
Geodetic	Δ USB ANT CTR	Δ POST	1355.4	358 47 49

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Facilities Construction Branch, GSFC, in 1965, prior to antenna construction. The survey included work for JPL 30-foot az-el antenna. Point of reference is 6.55 m above location of original concrete mark probably destroyed at time of antenna construction (elevation 537.67 m).

Horizontal control consisted of first-order triangle based on two USC&GS stations. Terrain permitted only five alignment marks to be established at the antenna site: E1, E2, S1, S2, and W1. Station COLL. TOWER is located in the apron of the Mech. Eqpt. Bldg. about 5 m SSE of the center of the tower which is an unmarked point in a concrete block 2 feet square.

The elevation given above was obtained from USN Y&D Drawing 1025712 (Corrected to AS-BUILT-Aug. 16, 1966). Island MSL datum is based on an 11-month tide series at Georgetown.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	0.3 meters
Vertical	1 meters	1 meters

REFERENCES

Geodetic Survey Report for USB Antenna and JPL DSN Antenna at Ascension Island, Facil. Constr. Br., GSFC; and C&GS Ltr. dated 16 Sept. 1966 to GSFC.

Station No. USB 7

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO MAD 8

Location Madrid, Spain

Equipment Unified S-Band (85-foot)

Agency NASA-Goddard Space Flight Center

USB 7

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	40° 27' 23".85	Latitude	
Longitude (E)	355 49 58.23	Longitude (E)	
Datum	European	Based on	

Elevation above mean sea level 785.1 meters   Geoid height -22 meters   Height above ellipsoid 763 meters

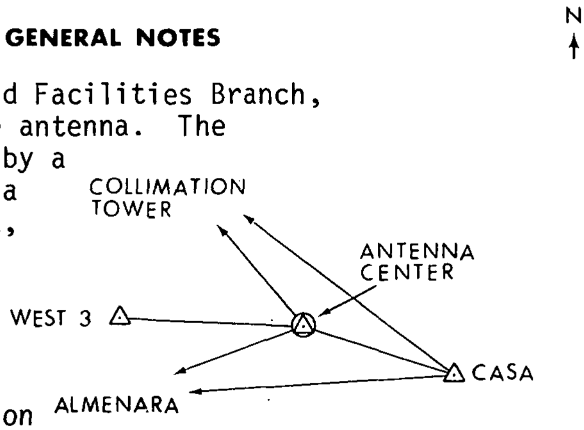
AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANTENNA CTR	Δ WEST THREE	817.719	269° 59' 59"
Geodetic	Δ ANTENNA CTR	Δ COL. TOWER	6421.295	316 36 28.01

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The geodetic survey was performed by the Field Facilities Branch, GSFC, NASA, in 1964 prior to construction of the antenna. The location of the center of the antenna is marked by a disk, stamped ANTENNA CENTER, set in the top of a concrete post. Stations COLLIMATION TOWER, CASA, and nine alignment marks were also set.

The survey consisted of first-order triangulation and traverse based on two Instituto Geografico y Cadastral stations, ALMENARA and VALDIHUELO. Astro-azimuth of the line ANTENNA CENTER to CASA was observed as a check. Elevation (based on MSL at Alicante) was determined by leveling from third-order IGyC bench marks about 3 km distant. The elevation of Δ ANTENNA CENTER is 774.07 m.



Geoid height from G. Bomford's geoid chart of Europe, N. Africa and S.W. Asia, February, 1971.

DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	5 meters
Vertical	0.2 meters	0.5 meters

REFERENCES

"Geodetic Survey Report of Apollo Antenna Site of Madrid, Spain," GSFC, January 1965.

Station No. USB 8

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO CRO 3

Location Carnarvon, Australia

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 8

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	-24° 54' 27".4334	Latitude	ξ = + 1".4
Longitude (E)	113 43 27.1728	Longitude (E)	η = + 0.7
Datum	Australian Geodetic	Based on	first-order obs at Δ GC 18A, 1.1 km from site

Elevation above mean sea level 44.5 meters

Geoid height + 6.2 meters

Height above ellipsoid 51 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Survey Section, Department of Interior, Perth, 1962-1966. Astro-observations were made by the Dept. of Lands and Surveys, WA, in April 1964.

The connection between the antenna and the Australian Geodetic Survey at Brown Range GC 18A was by a closed Tellurometer traverse.

Elevation based on mean sea level at Carnarvon.

Geoid height from Mather et al, IUGG Moscow 1971.

DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.05 meters	6 meters
Vertical	0.1 meters	1 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia - Carnarvon, Division of National Mapping, Canberra, June 1969.

Station No. USB 9

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO GWM 3

Location GUAM

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 9

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	13° 18' 33".2775	Latitude	
Longitude (E)	144 44 03.8891	Longitude (E)	
Datum	Guam 1963	Based on	

Elevation above mean sea level 92.07 meters

Geoid height ______ meters

Height above ellipsoid ______ meters

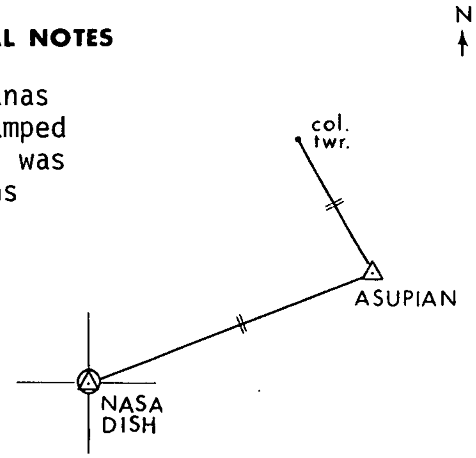
AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ NASA DISH	Δ ASUPIAN	1192.224	85° 12' 55"
Geodetic	Δ NASA DISH	col. tower mk	1155.2	81 39 16
	Δ NASA DISH	subreflectors	1152.399 slant range	

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Bureau of Yards & Docks Contracts, Marianas (C. W. O'Mallan) in August 1965. The station mark, stamped NASA DISH, set in the center of the antenna foundation, was located by first-order taping and direction observations from Δ ASUPIAN (C&GS first-order, 1963). Eleven alignment monuments were set on grid N-S and E-W lines through the central station. Mark at base of collimation tower was established by a similar method.

Precise levels were run from Δ ASALONSA GG and bench mark N1, which were included in C&GS first-order leveling of 1963. The elevation of Δ NASA DISH is 85.525 m.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	< 1 meters
Vertical	< 1 meters	< 1 meters

REFERENCES

Ltr. Bur. Y&D Contracts, Marianas, to Facilities Construction Branch, GSFC, 21 August 1965; Report FCB-GSFC 26 September 1966.

Station No. USB 10

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO HSK 8

Location Canberra, Australia

Equipment Unified S-Band (85-foot)

Agency NASA-Goddard Space Flight Center

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	-35° 35' 05".0512	Latitude	-35° 34' 58".42 ± 0".13
Longitude (E)	148 58 35.6780	Longitude (E)	148 58 45.14 ± 0.37
Datum	Australian Geodetic	Based on	second-order obs. 1965 Div. Nat. Mapping, at Δ HONEYSUCKLE LAPLACE

Elevation above mean sea level 1130.8 meters

Geoid height + 9.3 meters

Height above ellipsoid 1140 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ HON. APOLLO	col. tower	3224.09	226° 24' 05".72
Geodetic	Δ HON. APOLLO	Δ HON. LAPLACE	164.340	246 30 56
Astronomic	Δ HON. LAPLACE	Apollo R.O.	1256.537	246 30 54.07

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Geodetic survey by Survey Branch, Dep. of Interior, Canberra, February 1966.

The station mark, HONEYSUCKLE APOLLO, is located at the center of the four concrete piers which support the antenna. It was connected to the National Geodetic Survey at Mount Stromlo by a closed Tellurometer traverse. Two alignment marks were set in each cardinal direction.

The X-axis is about 13 meters above ground level. Elevation is referred to Canberra City Datum.

Laplace and geodetic azimuths corresponding to the astronomic azimuth above are:

Laplace azimuth	246° 30' 59".57
Geodetic azimuth (after adjustment)	246° 30' 59".21

Geoid height from Mather et al, IUGG Moscow 1971.

DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.5 meters	5 meters
Vertical	1 meters	1 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, August 1969.

Station No. USB 11

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes APOLLO HAW 3

Location Kauai, Hawaii

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 11

Point referred to center of X-axis

GEODETIC COORDINATES

Latitude 22° 07' 45".928

Longitude (E) 200 19 55.379

Datum Old Hawaiian

Elevation above mean sea level 1150.9 meters

Geoid height ______ meters

ASTRONOMIC COORDINATES

Latitude $\xi = +7''$

Longitude (E) $\eta = -11$

Based on second-order obs C&GS 1961 at Δ MANU, 300 m distant

Height above ellipsoid ______ meters

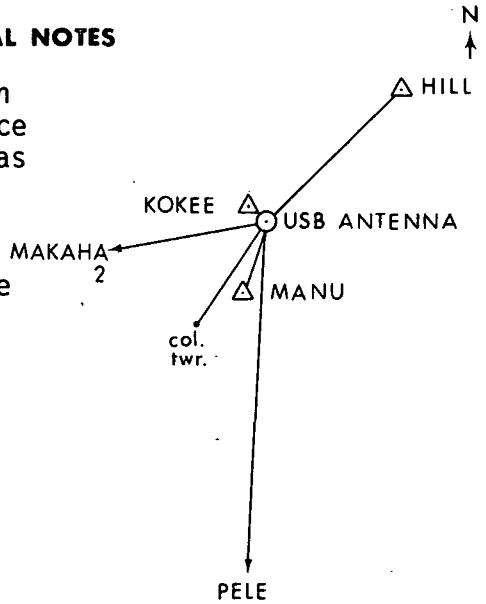
AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	antenna center	Δ KOKEE	18.798	344° 30' 17"
Geodetic	antenna center	col. tower	778.76	196 05 53.2
	center X-axis	subreflectors	777.068 slant range	

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Facilities Construction Branch, GSFC, in 1965 after construction. Since the antenna was in place the antenna center could not be occupied and no mark was set. The position was determined by a closed traverse from USC&GS Δ MANU (second-order) through Δ HILL (FCB) using the theodolite mounts on the X-axis as eccentric stations. The position was checked by another traverse from Δ MANU via the eccentric stations and Δ HILL to Δ PELE (USC&GS), as well as by distance and azimuth from Δ KOKEE (USC&GS). Stations MANU, MAKAHA 2, and HILL were used for azimuth alignment of the antenna.

Elevation was determined by levels for Δ KOKEE. It is based on MSL at Port Allen (1950).



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	1 meters
Vertical	0.1 meters	1 meters

REFERENCES

"Geodetic Survey Report for USB Antenna at Kokee, Kauai, Hawaii," April 1966, rev. 1 June 1966, FCB, GSFC.

Station No. USB 12

Code Name ______

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO GDS 8

Location Goldstone, California

Equipment Unified S-Band (85-foot)

Agency NASA-Goddard Space Flight Center

USB 12

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 20' 29".630	Latitude	ξ = - 2" ± 2"
Longitude (E)	243 07 38.043	Longitude (E)	η = - 4 ± 3
Datum	NAD 1927	Based on	mean of deflections at Pioneer and Echo antennas

Elevation above mean sea level 973 meters

Geoid height - 22 meters

Height above ellipsoid 951 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ FFB APOLLO	Δ APPLE	2632.58	305° 38' 22".44
Geodetic	Δ FFB APOLLO	Δ COL. TOWER	2756.90	136 59 19.11

DESCRIPTION OF SURVEYS AND GENERAL NOTES

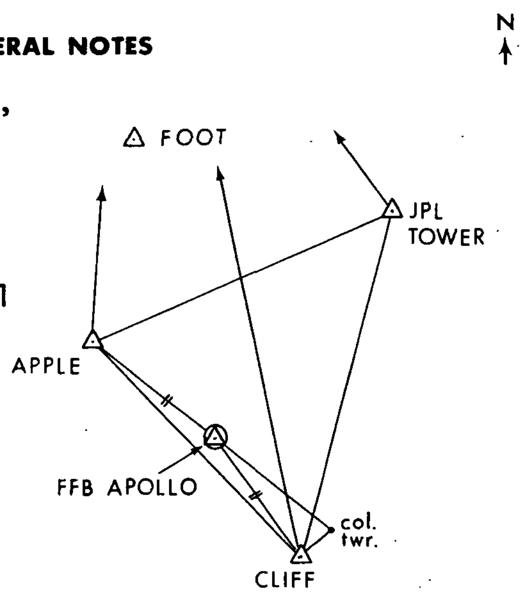
Surveyed by Field Facilities Branch, GSFC in 1965, before antenna construction. The station, probably destroyed later, was marked by a bronze disk at ground level stamped FFB-APOLLO.

The survey consisted of a quadrilateral with two C&GS first-order stations, FOOT and JPL TOWER, and two new stations, APPLE and CLIFF, with an additional azimuth check to Δ MARS (C&GS). Position of the antenna was determined by a geodimeter traverse from Δ CLIFF to Δ APPLE.

Eight alignment marks were set, two each on the N, E, S, and W radials from the antenna center.

Elevation was by fourth-order methods.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	4 meters
Vertical	0.5 meters	1 meters

REFERENCES

Trip Report, Mojave Test Facility, Barstow, Calif., FFB-GSFC, 23 April 1965, by Charles R. Myers.

Station No. USB 13

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO GYM 3

Location Guaymas, Mexico

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 13

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	27° 57' 45".9581	Latitude	ξ = - 0".1
Longitude (E)	249 16 46.2771	Longitude (E)	η = - 11.1
Datum	NAD 1927	Based on	second-order obs Geonautics 1960 at Verlort antenna, 0.5 km south of USB

Elevation above mean sea level 23.92 meters

Geoid height - 9 meters

Height above ellipsoid 15 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANTENNA CENTER	Δ SOUTH TWO	304.5	180° 00' 00".85
Geodetic	Δ ANTENNA CENTER	Δ COL. TOWER	1153.23	195 54 40
	center X-axis	subreflector	1151.259 slant range	

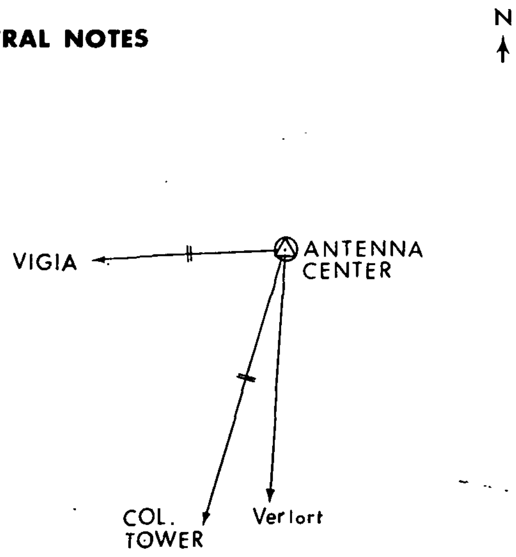
DESCRIPTION OF SURVEYS AND GENERAL NOTES

This antenna has been moved to Goldstone, Calif.

Surveyed by the Facilities Construction Branch, GSFC, in December 1965 before antenna construction. The station is marked by an unstamped NASA-GSFC survey disk set in the center of the concrete antenna foundation.

The positions of the antenna center and collimation tower sites were determined by geodimeter traverse from VIGIA and BABI, two IAGS first-order triangulation stations. Eight antenna alignment marks were set: two each on the east, west, and south radials and on a north offset line. Third-order leveling was carried into the site from first-order DCM-IAGS bench marks. The X-axis is 6.55 m above the disk in the foundation.

Geoid height extrapolated from TOPOCOM geoid charts 1967.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	4 meters
Vertical	1 meters	2 meters

REFERENCES

"Geodetic Survey Report of USB Antenna at Guaymas, Sonora, Mexico," FCB-GSFC March 10, 1966.

Station No. USB 14

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes APOLLO TEX 3

Location Corpus Christi, Texas

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB 14

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	27° 39' 11".7826	Latitude	ξ = + 5" ± 2"
Longitude (E)	262 37 17.9213	Longitude (E)	η = 0 ± 2"
Datum	NAD 1927	Based on	estimated from observations made 1905-31 from 6 to 25 miles distant

Elevation above mean sea level 12.34 meters

Geoid height + 5 meters

Height above ellipsoid 17 meters

AZIMUTH DATA

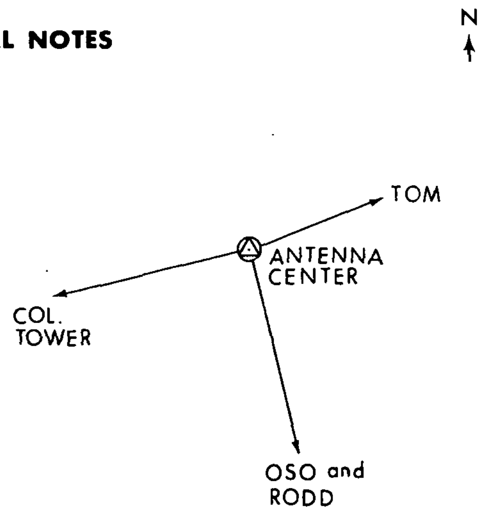
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANTENNA CENTER	Δ OSO	1559.467	170° 06' 14".6
Geodetic	Δ ANTENNA CENTER	Δ COL. TOWER	731.479	252 32 32
	center Y-axis	subreflectors	728.010 slant range	

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by Facilities Construction Branch, GSFC, in January 1966 prior to construction of the antenna. The center is marked by an unstamped disk in the foundation. Its position was determined by traverse with Wild T-3 and 4D Geodimeter between two C&GS second-order stations, TOM and RODD, via the antenna mark and a new station, OSO. Two alignment marks were established on each of four radials, N, E, W, and S offset (SE).

The elevation was determined by third-order leveling from a C&GS second-order bench mark in the area. The foundation mark is 6.55 meters below the X-axis (elev. 5.794 m).

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	4 meters
Vertical	1 meters	2 meters

REFERENCES

Geodetic Survey Report of USB Antenna at Corpus Christi, Texas, FCB-GSFC, March 1966.

Station No. USB 15

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes APOLLO ETC 3

Code Name

Location Greenbelt, Maryland

Equipment Unified S-Band (30-foot)

Agency NASA-Goddard Space Flight Center

USB-15

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	38° 59' 54".30	Latitude	ξ = - 1".5
Longitude (E)	283 09 24.85	Longitude (E)	η = + 6.2
Datum	NAD 1927	Based on	first-order obs C&GS 1962 at Δ GODDARD 3 km N of antenna

Elevation above mean sea level 53.7 meters — Geoid height + 1 meters — Height above ellipsoid 55 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ M-1	Δ HAR	243.20	85° 44' 30".6
Geodetic	Δ M-1	Δ COLT	723.39*	337 55 05.4

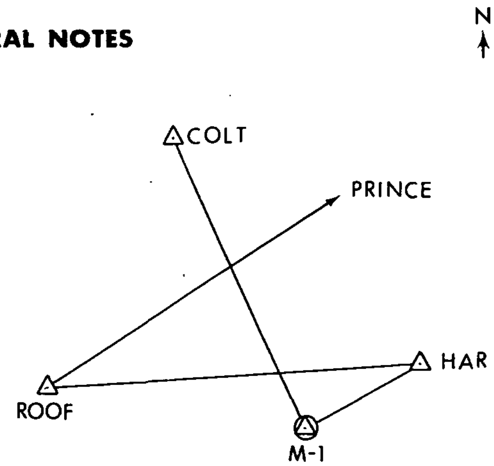
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by USNAVOCEANO in November 1966 prior to construction. Supplementary surveys were made by Field Facilities Branch, GSFC, in 1968 and by Geonautics, Inc. in 1968 and 1969. An unstamped disk (Δ M-1) in the foundation marks the center of the antenna. The survey consisted of third-order triangulation and traverse from Δ PRINCE (USC&GS) and Δ ROOF (USNOO), both second-order stations. The center of the foundation of the collimation tower is marked by Δ COLT.

The X-axis is 6.54 meters above Δ M-1 (elev. 47.13 m).

*Slant range from centerline of Y-axis to transmitting reflector with antenna boresighted to collimation tower = 720.96 m.

Geoid height from TOPOCOM geoid charts 1967.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.5 meters	5 meters
Vertical	1 meters	1 meters

REFERENCES USNAVOCEANO GP Sheet 18 Nov 1966 (Archive No. 306295), "Survey Report of USB Antenna-Col. Tower Relationship, NTTF, GSFC," FFB, GSFC, Feb 1968; NTTF Surveys Geonautics, 1968-1969.

Station No. USB 16

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes

Location: Greenbelt, Maryland

Equipment: Unified S-Band 30-foot

Agency: NASA-Goddard Space Flight Center

Point referred to: center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	38° 59' 53".58	Latitude	
Longitude (E)	283 09 27.83	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 60.2 meters — Geoid height + 1 meters — Height above ellipsoid 61 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

This ERTS antenna at NTTF-GSFC was formerly at Antigua.

The position is preliminary. It is based on station MICRO (see Station MIN 9).

The X-axis is 6.53 m above the foundation (elev. 53.668 m). The Washington Suburban Sanitary Datum is within a few centimeters of SLD 1929.

Geoid height from TOPOCOM geoid charts 1967.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	< 1 meters	1 meters

REFERENCES

Preliminary report of Physical Plant Engineering Branch, GSFC, 16 September 1971.

Station No. USB 17

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Goldstone, California

Equipment Unified S-Band 30-foot

Agency NASA-Goddard Space Flight Center

USB 17

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 20' 29".63	Latitude	
Longitude (E)	243 07 40.46	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 967.6 meters

Geoid height - 22 meters

Height above ellipsoid 946 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The preliminary position for this ERTS antenna (formerly at Guaymas) is based on pre-construction drawings.

The X-axis is 6.53 m above the (design) elevation of the foundation (961.09 m).

Geoid height from TOPOCOM geoid charts 1967.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	4 meters
Vertical	1 meters	1 meters

REFERENCES

Preliminary report of Physical Plant Engineering Branch, GSFC, 16 September 1971.

Station No. USB 18

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Merritt Island, Florida

Equipment: Unified S-Band (30-foot)

Agency: NASA-Goddard Space Flight Center

Point referred to: center of X-axis

GEODETIC COORDINATES

Latitude: 28° 30' 26".34

Longitude (E): 279 18 22.93

Datum: NAD 1927

ASTRONOMIC COORDINATES

Latitude:

Longitude (E):

Based on:

Elevation above mean sea level: 9.1 meters

Geoid height: + 10 meters

Height above ellipsoid: 19 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

This is a preliminary position for the ERTS antenna, which is not yet installed.

The X-axis is 6.53 m above the foundation (elev. 2.6 m).

Geoid height from TOPOCOM geoid charts 1967.

DATE: September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	meters	6 meters
Vertical	meters	meters

REFERENCES

Preliminary report of Physical Plant Engineering Branch, GSFC, 16 September 1971.

USB 18

Radars

Station No. RAD 1

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: AFETR 191801; APOLLO MLAT; NGSP 4082

Location: Merritt Island, Florida

Equipment: TPQ-18 radar

Agency: USAF-Eastern Test Range

RAD 1

Point referred to: intersection of axes of rotation

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 25' 27".9276	Latitude	ξ = + 0.76 ± 0".12
Longitude (E)	279 20 07.3758	Longitude (E)	η = + 1.53 ± 0.08
Datum	NAD 1927 (CC)[1]	Based on	first-order obs C&GS 1964 at Δ REED RM2, 15 m from antenna

Elevation above mean sea level: 11.250 meters — Geoid height: + 10 meters — Height above ellipsoid: 21 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	boresight horn	609.170[2]	166° 33' 50"
Geodetic	intersection axes	Luneberg lens	7126.432 S/R	38 04 16
Geodetic	intersection axes	Δ REED	26.604	110 49 46

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys by USC&GS 1964, 1381st AF GSS Jan '68.

Position by triangulation and traverse from C&GS first-order station REED 1964.

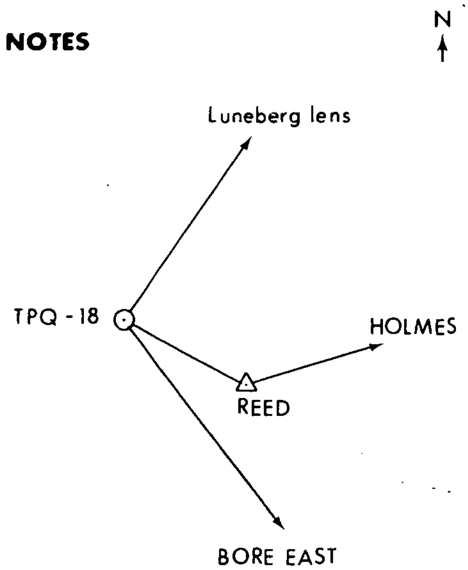
Elevation by USC&GS first-order levels Mar 1964.

Boresight tower is not stable: accuracy azimuth and elevation angles ± 5".

Geoid height from TOPOCOM geoid charts 1967.

[1] Cape Canaveral and NAD 1927 Datums are interchangeable in the Cape area.

[2] Slant range 610.209 meters.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	6 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Data from USAF 1381st Geodetic Survey Squadron, ETR, to Geonautics May 1968.

Station No. RAD 2

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 001801; APOLLO PATQ; NGSP 4060

Location: Patrick Air Force Base, Florida

Equipment: FPQ-6 radar

Agency: USAF-Eastern Test Range

RAD 2

Point referred to: intersection of horizontal and vertical rotation axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 13' 33".9867	Latitude	ξ = + 1.73
Longitude (E)	279 24 01.7723	Longitude (E)	η = + 1.38
Datum	NAD 1927 (CC)	Based on	C&GS first-order obs 1963 at Δ TECH, 60 yds from antenna

Elevation above mean sea level 14.91 meters Geoid height + 10 meters Height above ellipsoid 25 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	boresight	608.829*	268° 21' 05".20
Geodetic	intersection axes	Luneberg lens	20200.967**	165 45 24.54

DESCRIPTION OF SURVEYS AND GENERAL NOTES

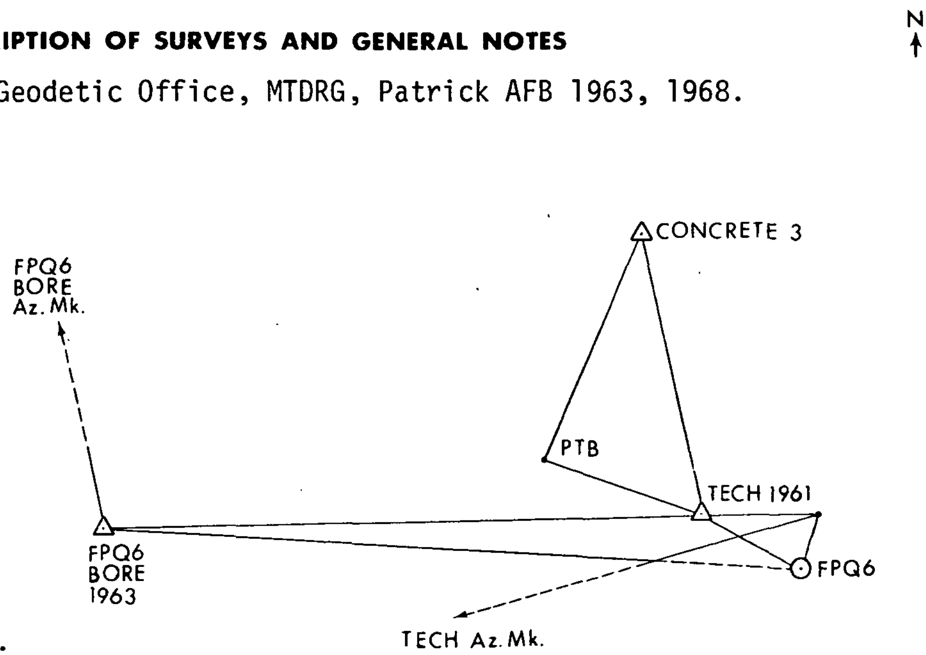
Surveys by USC&GS Range Geodetic Office, MTDRG, Patrick AFB 1963, 1968.

Position was fixed by first-order class I horizontal surveys (adjusted).

Elevation was determined by first-order levels (adjusted).

The position above has been adjusted to Cape Canaveral Datum by C&GS.

Geoid height from TOPOCOM geoid charts 1967.



*Slant range = 609.690 m.
**Slant range = 20201.035 m.

DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	6 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Data from USAF 1381st Geodetic Survey Squadron, ETR, to Geonautics May 1968.

Station No. RAD 3

Code Name CKYF

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes AFETR 011601
APOLLO CKYF
NGSP 4041

RAD 3

Location Cape Kennedy, Florida

Equipment FPS-16 radar

Agency USAF-Eastern Test Range

Point referred to intersection of horizontal and vertical rotation axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 28' 52."7925	Latitude	ξ = + 1."0
Longitude (E)	279 25 23.7692	Longitude (E)	η = + 1.4
Datum	NAD 1927 (CC)	Based on	first-order obs C&GS 1960 at Δ LAB 500 m from antenna

Elevation above mean sea level 13.646 meters — Geoid height + 10 meters — Height above ellipsoid 24 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	boresight calibration horn	457.550*	306° 33' 47"
Geodetic	intersection axes	Luneberg lens	4268.05**	260 36 49
Geodetic	intersection axes	SKID 1963	11.2804	246 10 24

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Range Geodetic Office, MTDRG, Patrick Air Force Base 1963; re-surveys to April 1968.

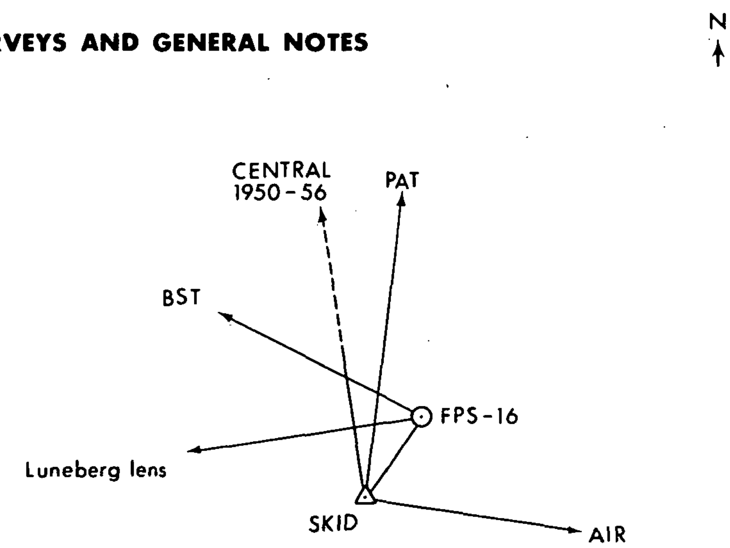
Position was fixed by first-order class I horizontal surveys (not adjusted).

Elevation was determined by first-order levels (not adjusted). All work was by USC&GS personnel.

The position of this station is the same on both Cape Canaveral Datum and NAD 1927 (C&GS).

Geoid height from TOPOCOM geoid charts 1967.

*Slant range = 458.024 meters.
**Slant range = 4268.06 meters.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	.03 meters	6 meters
Vertical	.03 meters	< 1 meters

REFERENCES

Data from USAF 1381st Geodetic Survey Squadron, ETR, to Geonautics May 1968.

Station No. RAD 4

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 031801; APOLLO GBIT

Location: Grand Bahama Island

Equipment: TPQ-18 radar

Agency: USAF-Eastern Test Range

Point referred to: intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	26° 38' 09".022	Latitude	26° 38' 02".56
Longitude (E)	281 43 55.314	Longitude (E)	281 44 03.61
Datum	NAD 1927	Based on	first-order obs C&GS 1964 at Δ ROUGH, 20 m from antenna

Elevation above mean sea level 11.905 meters — Geoid height 8 meters — Height above ellipsoid 20 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	BST feeder horn	624.80	179° 22' 28"
Geodetic	Δ ROUGH 1964	Δ BORE W		177 52 38.7

DESCRIPTION OF SURVEYS AND GENERAL NOTES

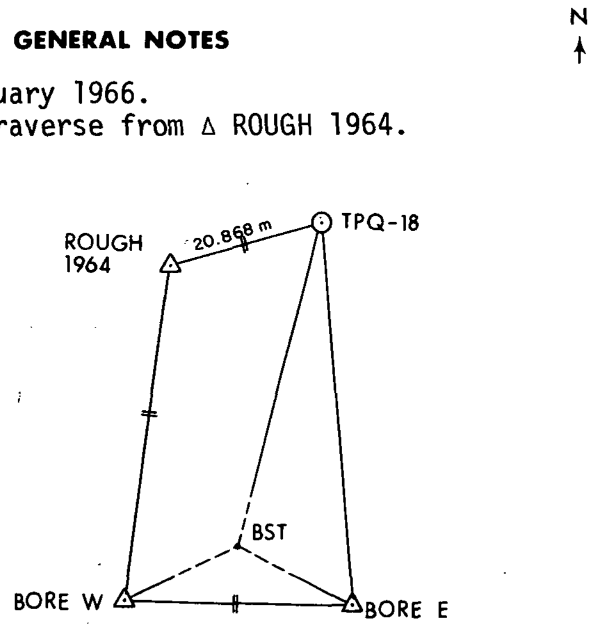
Surveyed by USC&GS June 1964; resurveyed February 1966.
The position was fixed by triangulation and traverse from Δ ROUGH 1964.

Elevation was by C&GS first-order levels to a first-order line (320 m).

The tie to NAD is by the AFETR solution of 1969.

The Luneberg lens is at a slant range of 3005.374 m from the intersection of axes. Slant range from the axes' intersections to the feeder horn is 625.794 m. The boresight tower was not stable at the time of the survey (± 5 sec).

Geoid height from TOPOCOM geoid charts 1967. (The geoid height by the AFETR satellite solution is the same, + 8 m).



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	1 meters

REFERENCES

USC&GS Geod. Pos. Sheet 2 February 1966; AFETR Geodetic Coordinates Manual August 1969.

Station No. RAD 5

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: NASA WI#5; APOLLO WLPQ; NGSP 4860

Location: Wallops Island, Virginia

Equipment: FPQ-6 radar

Agency: NASA-Wallops Island Station

Point referred to: center of rotation of antenna axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	37° 51' 36".509	Latitude	
Longitude (E)	284 29 25.236	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 14.953 meters — Geoid height - 2 meters — Height above ellipsoid 13 meters

AZIMUTH DATA

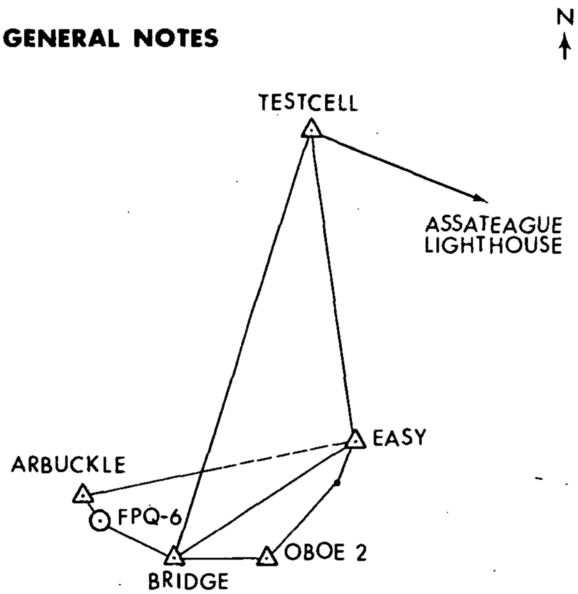
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center of rotation	Δ BRIDGE	1908.898	117° 59' 02".43
Geodetic	center of rotation	Δ ARBUCKLE	696.22	339 56 42.39

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Field Facilities Branch, GSFC, March 1968, with first-order accuracy, using a Wild T-3 theodolite and an AGA Model 6 Geodimeter. Control was extended from USC&GS stations EASY and TESTCELL, with Δ ASSATEAGUE LIGHTHOUSE as an azimuth check.

Elevation is third-order in reference to USC&GS first-order benchmarks G 421 1963, A 299 1949, and K 421 1963.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	5 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Geodetic survey report, Field Facilities Branch, GSFC April 1968.

Station No. RAD 6

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes		
	NASA	WI#3
	APOLLO	WLPF
	NGSP	4840

Location Wallops Island, Virginia

Equipment FPS-16 radar

Agency NASA-Wallops Island Station

RAD 6

Point referred to center of rotation of antenna axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	37° 50' 28".393	Latitude	
Longitude (E)	284 30 52.378	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 12.393 meters

Geoid height - 2 meters

Height above ellipsoid 10 meters

AZIMUTH DATA

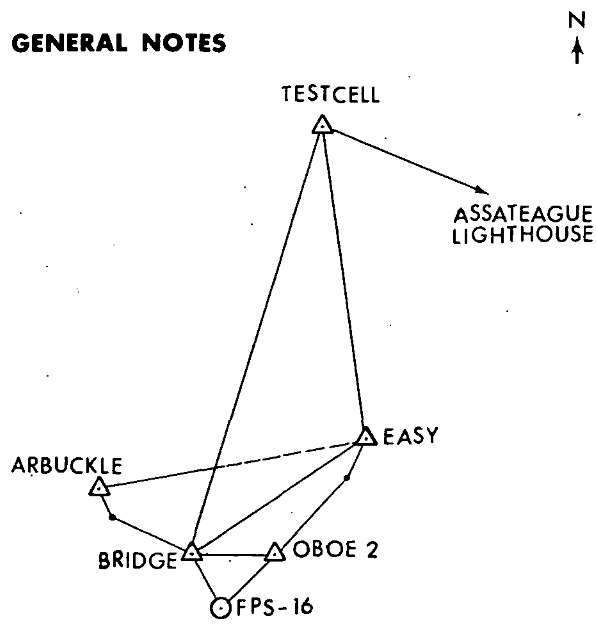
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center of rotation	Δ BRIDGE	1283.715	339° 43' 55".75
Geodetic	center of rotation	Δ OBOE 2	1849.616	50 37 49.15

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Field Facilities Branch GSFC, March 1968, with first-order accuracy, using a Wild T-3 theodolite and an AGA Model 6 Geodimeter. Control was extended from USC&GS stations EASY and TESTCELL, with Δ ASSATEAGUE LIGHTHOUSE as an azimuth check. USC&GS Δ ARBUCKLE was used as a check station.

Elevation is third-order in reference to USC&GS first-order benchmarks G 421 1963, A 299 1949 and K 421 1963.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	5 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Geodetic survey report, Field Facilities Branch, GSFC April 1968.

Station No. RAD 7

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: AFETR 071801; APOLLO GTKT; NGSP 4081

Location: Grand Turk, Bahama Islands

Equipment: TPQ-18 radar

Agency: USAF-Eastern Test Range

RAD 7

Point referred to: intersection of horizontal and vertical axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	21° 27' 43".487	Latitude	21° 27' 57".02
Longitude (E)	288 52 03.051	Longitude (E)	288 52 12.18
Datum	NAD 1927	Based on	first-order obs C&GS 1963 at SKI AZIMUTH (USNHO), 20 m from antenna

Elevation above mean sea level: 36.00 meters | Geoid height: + 6 meters | Height above ellipsoid: 42 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	boresight horn	621.284*	169° 43' 24"
Geodetic	intersection axes	Luneberg lens	4140.704**	358 58 26
Geodetic	intersection axes	Δ SALT	29.746	227 05 49

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by USC&GS 1963, and USAF ETR 1968.

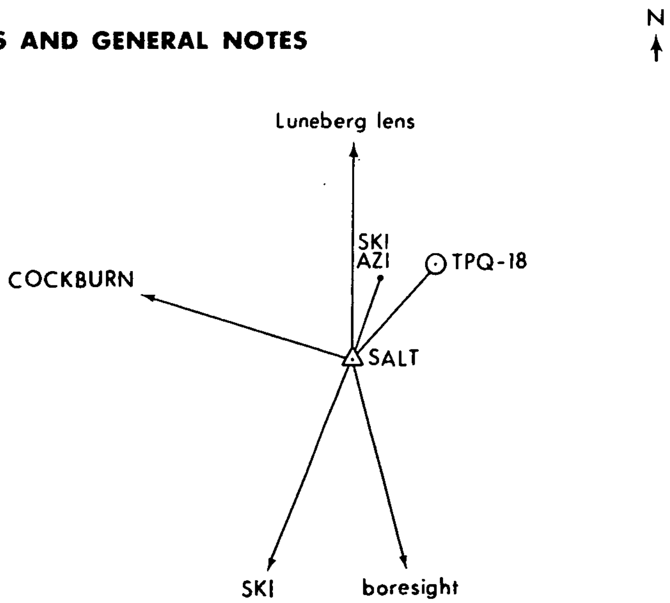
Position was fixed by first-order class I horizontal surveys (adjusted). Two Laplace azimuths, 3 taped bases and 5 Geodimeter measurements furnished azimuth and length control for the adjustment. Δ SALT is a Laplace azimuth station (1963). The tie to NAD is by the USAF 1969 satellite solution.

Elevation was determined by first-order levels.

Geoid height from TOPOCOM geoid charts 1967. (Geoid height from the USAF 1969 satellite solution is 1.5 m.)

*Slant range = 622.039 meters.

**Slant range = 4140.737 meters.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	7 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Data from USAF 1381st Geodetic Survey Squadron, ETR, to Geonautics May 1968; AFETR Geodetic Coordinates Manual August 1969.

Station No. RAD 8

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 671601 / APOLLO BDAF / NGSP 4740

Location Bermuda

Equipment FPS-16 radar

Agency NASA-Goddard Space Flight Center

RAD 8

Point referred to rotational center of antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	32° 20' 48".033	Latitude	ξ = - 10".5
Longitude (E)	295 20 46.321	Longitude (E)	η = + 19.2
Datum	Bermuda 1957 (USC&GS)	Based on	first-order obs C&GS 1962 at Δ SOLD, 130 m from antenna

Elevation above mean sea level 19.857 meters   Geoid height ____ meters   Height above ellipsoid ____ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	rotational center	BST feedhorn	534*	282° 45' 45"
Geodetic	rotational center	boresight ant. over PAYNTERS BORE	4720.63*	255 42 14

*slant range

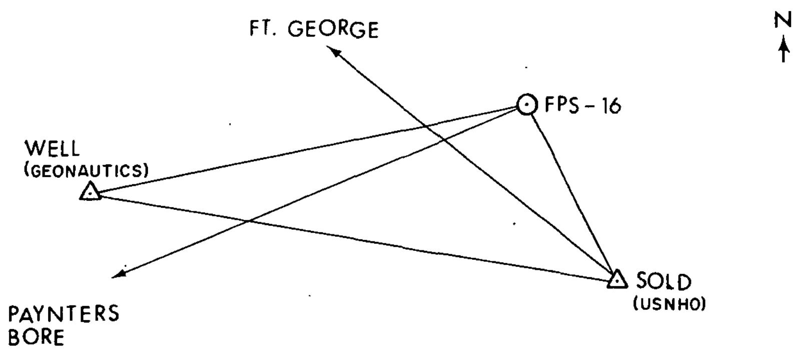
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by USC&GS Survey 1963; Geonautics, Inc. 1965, 1966.

The FPS-16 was positioned by angle and taped distance (base line procedures) from Δ SOLD (USNHO 1959), a station in a survey which held fixed the position of FT. GEORGE (B-1937) on the Bermuda 1957 Datum (φ 32° 22' 44".3600, λ (W) 64° 40' 58".1100). Three Laplace azimuths and eight Geodimeter lengths were used for azimuth and distance control of this survey.

To change this position to NAD 1927 by the 1969 AFETR satellite survey add 4".265 to φ, subtract 2".025 from λ (E). Geoid height = - 8.6 m on NAD.

The geodetic azimuth from the optical axis (direct) to the boresight antenna over Δ PAYNTERS BORE is 255° 43' 30".



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	< 1 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Report on Results of Survey Bermuda Is.-1963, USC&GS; AFETR Geodetic Coordinates Manual, August 1969.

Station No. RAD 9

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: APOLLO BDAQ; NGSP 4760

Location: Bermuda

Equipment: FPQ-6 radar

Agency: NASA-Goddard Space Flight Center

RAD 9

Point referred to: intersection of axes of rotation

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	32° 20' 47".530	Latitude	ξ = - 10".5
Longitude (E)	295 20 46.532	Longitude (E)	η = + 19.2
Datum	Bermuda 1957 (C&GS)	Based on	first-order obs C&GS 1962 at Δ SOLD, 111 meters from antenna

Elevation above mean sea level 21.1 meters   Geoid height ____ meters   Height above ellipsoid ____ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	center of face of feedhorn	1287.16*	314° 12' 39"
Geodetic	intersection axes	Paynters Hill transponders	4722	255 54 10

DESCRIPTION OF SURVEYS AND GENERAL NOTES

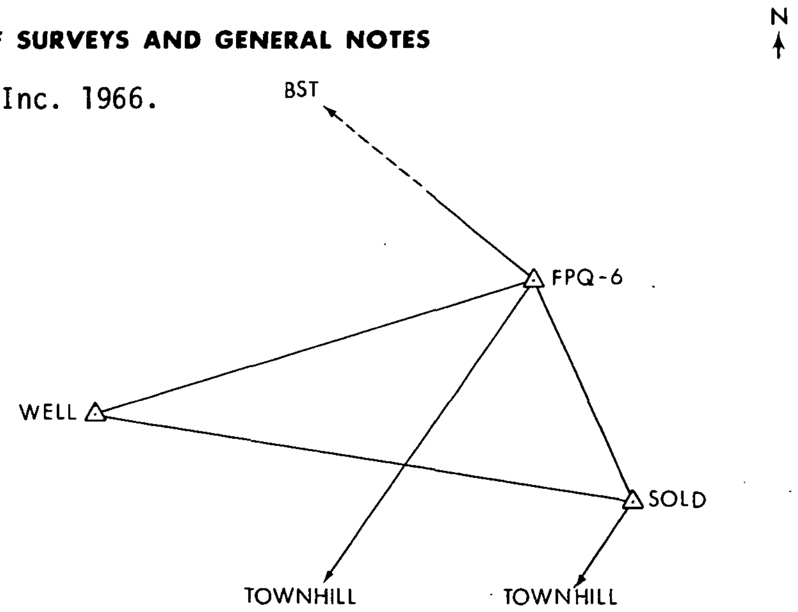
Surveys performed by Geonautics, Inc. 1966.

Position of FPQ-6 antenna was established by triangulation using the triangle TOWNHILL, SOLD and FPQ-6 as the primary figure. The triangle, WELL, SOLD and the FPQ-6, was used as a check.

Elevation was determined by third-order leveling.

The geodetic azimuth from the optical axis, direct, with the telescope on left of radar facing target, to the lighthouse at Gibbs Hill is 238° 20' 02", distance 20,070 meters.

*Slant range = 1287.47 meters.
See MCB 8 for shift to NAD.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	< 1 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Bermuda Station Survey Report, Geonautics Sept 1966.

Station No. RAD 10

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: AFETR 911801; APOLLO ANTQ; NGSP 4061

Location: Antigua, West Indies Associated States

Equipment: FPQ-6 radar

Agency: USAF-Eastern Test Range

RAD 10

Point referred to: intersection of axes of rotation

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	17° 08' 34"777	Latitude	17° 08' 40"1
Longitude (E)	298 12 24.472	Longitude (E)	298 12 37.2
Datum	NAD 1927 (CC)	Based on	first-order obs C&GS 1963 at Δ HARRIS, 50 m from antenna

Elevation above mean sea level: 42.296 meters; Geoid height: + 6 meters; Height above ellipsoid: 48 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	boresight	607.982[1]	71° 47' 51"
Geodetic	intersection axes	Luneberg lens	2062.591[2]	115 08 00
Geodetic	intersection axes	Δ HARRIS	50.045	185 33 38

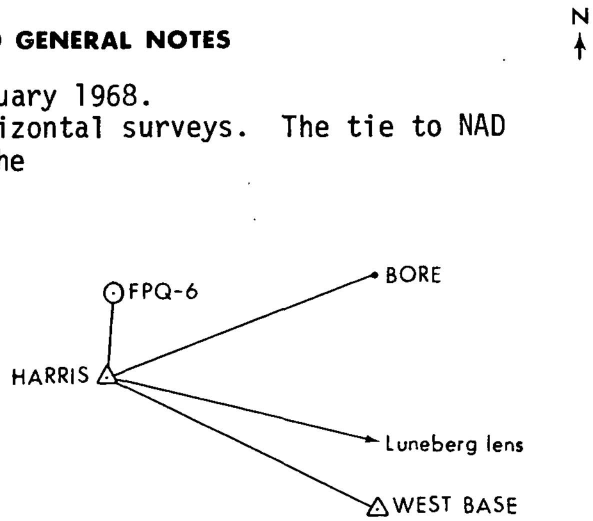
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys by USC&GS 1963, and 1381st AF GSS January 1968.

Position was fixed by first-order class I horizontal surveys. The tie to NAD 1927 is the USAF satellite solution of 1969. (The position on the 1953 IV Hiran tie to NAD is ϕ 17° 08' 34"15, λ 298° 12' 24"48.)

Elevation is by first-order levels C&GS (adjusted).

Geoid height from TOPOCOM geoid charts 1967. (The geoid height from the USAF 1969 tie is + 13.4 m.)



[1]Slant range = 608.059 meters.
[2]Slant range = 2062.649 meters.

DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	10 meters
Vertical	0.3 meters	1 meters

REFERENCES

Data from USAF 1381st Geodetic Survey Squadron, ETR, to Geonautics May 1968; AFETR Geodetic Coordinates Manual August 1969.

Station No. RAD 11

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Code Name ______

Other Codes: AFETR 121801; APOLLO ASCT; NGSP 4080

Location: Ascension Island

Equipment: TPQ-18 radar

Agency: USAF-Eastern Test Range

RAD 11

Point referred to: intersection of axes of rotation

GEODETIC COORDINATES

Latitude: - 07° 58' 22".7786

Longitude (E): 345 35 53.8981

Datum: Ascension Island 1958

Elevation above mean sea level: 125.378 meters

Geoid height ______ meters

ASTRONOMIC COORDINATES

Latitude: $\xi = -2''.3 \pm 0''.2$

Longitude (E): $\eta = -4.2 \pm 0.2$

Based on: C&GS gravimetric/topographic determination at Δ CON, 121 m from antenna

Height above ellipsoid ______ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	boresight feedhorn	990.483*	109° 14' 50"
Geodetic	intersection axes	Luneberg lens	2288.001**	358 37 15
Geodetic	Δ CON 1958	Δ COS 1958	84.854	178 19 12

DESCRIPTION OF SURVEYS AND GENERAL NOTES

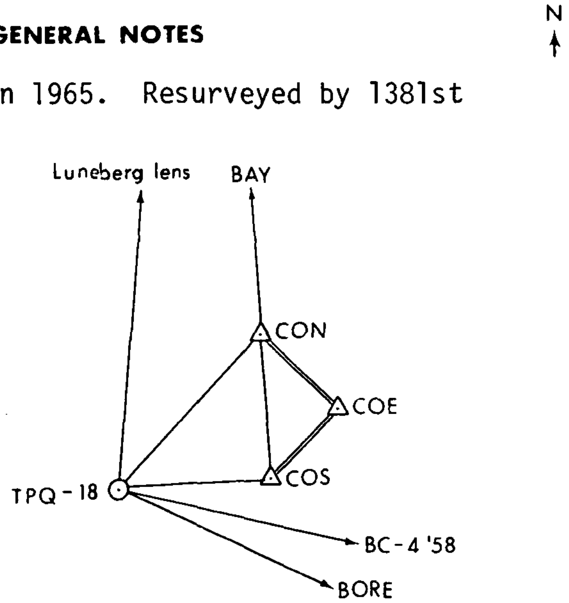
This station is no longer in operation.

Surveys performed by USC&GS 1963; resurveyed Jan 1965. Resurveyed by 1381st AF Geodetic Survey Squadron Nov 1967.

The position was fixed by first-order class II horizontal surveys, adjusted March 1965.

Elevation was determined by first-order levels (not adjusted). Sea-level datum was established by 11-month observations (to May 1959) at Georgetown.

The probable error of the deflection components is based on the consistency of the gravimetric deflection residuals at the three primary astro stations (first-order) on which the 1958 Datum is based. The absolute error is estimated to be ± 3 seconds.



*Slant range = 990.857 meters.
**Slant range = 2290.42 meters.

DATE: September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	< 1 meters
Vertical	< 1 meters	< 1 meters

REFERENCES

Ltr. Patrick AFB to NASA-GSFC, 3 April 1964.

Station No. RAD 12

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 121601; APOLLO ASCF; NGSP 4042

Location: Ascension Island

Equipment: FPS-16 radar

Agency: USAF-Eastern Test Range

RAD 12

Point referred to: center of rotating base

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 07° 57' 06".2898	Latitude	ξ = + 3".19 ± 0".2
Longitude (E)	345 35 14.6257	Longitude (E)	η = - 6.64 ± 0.2
Datum	Ascension Island 1958	Based on	topo/gravity/astro study C&GS 1966

Elevation above mean sea level: 92.344 meters

Geoid height: meters

Height above ellipsoid: meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center of rotating base	Δ CAT 1958	80.568	36° 17' 36".51
Geodetic	center of rotating base	calibration horn	1226.232	95 18 04.66
Geodetic	Δ CAT	Δ BAY RM A	1180.914	99 08 38.44

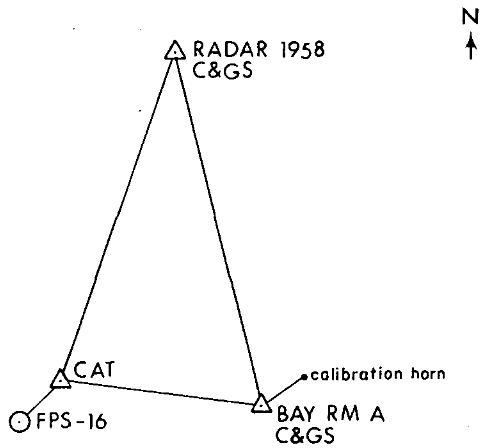
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by USC&GS 1959, 1964 (1965 adjusted); 1381st GSS Nov 1967.

The position was fixed by angle and distance from station CAT 1958 (USC&GS). The antenna is a revolving dish 12 feet in diameter, mounted on a rotating base 10 feet in diameter. It is on the roof of a two-story building. Entire structure is about 51 feet high.

The deflection values are derived from topographic/gravimetric studies by USC&GS based on (1957) astro-positions of three stations.

Elevation was determined by first-order levels from a sea level datum based on 11-month observation (to May 1959) at Georgetown.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	1 meters
Vertical	0.1 meters	1 meters

REFERENCES

Report on Field Surveys, Ascension Island, USC&GS, 7 December 1959.

Station No. RAD 13

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: APOLLO TANF; NGSP 4741

RAD 13

Location: Tananarive, Madagascar

Equipment: FPS-16 (Capri) radar

Agency: NASA-Goddard Space Flight Center

Point referred to: intersection of horizontal and vertical axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 19° 00' 00".991	Latitude	
Longitude (E)	47 18 54.191	Longitude (E)	
Datum	Tananarive	Based on	

Elevation above mean sea level 1338.3 meters — Geoid height ______ meters — Height above ellipsoid ______ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Survey performed by H. Monge, Tananarive Annexe, Institut Geographique National, Paris.

No description of the survey is available.

The local datum is based on a single astronomic observation at the Tananarive Observatory.

DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	1 meters
Vertical	< 1 meters	1 meters

REFERENCES

Memo Facility Construction Branch to Data Operation Branch, GSFC, 6/7/67.

Station No. RAD 14

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: APOLLO CROQ; NGSP 4761

Location: Carnarvon, Australia

Equipment: FPQ-6 radar

Agency: NASA-Goddard Space Flight Center

RAD 14

Point referred to: center of horizontal axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 24° 53' 50".7550	Latitude	- 24° 53' 49".4
Longitude (E)	113 42 57.7645	Longitude (E)	113 42 58.6
Datum	Australian Geodetic	Based on	obs by Dep. Lands and Surveys WA 1964 at GC 18A, 400 m from antenna

Elevation above mean sea level: 49.0 meters; Geoid height: + 6.2 meters; Height above ellipsoid: 55 meters

AZIMUTH DATA

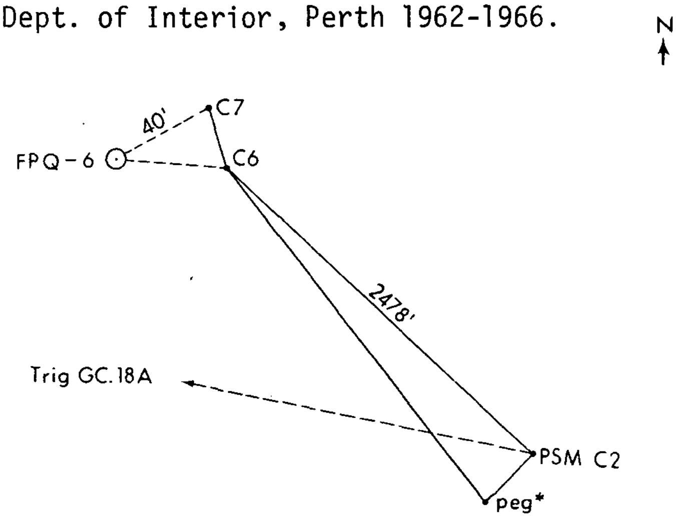
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center hor. axis	center BST horn	767.77	138° 28' 50".1
Laplace	Δ GC 18A	Δ GC 17		176 39 28.32
Astro	Δ GC 18A	Δ GC 17		176 39 27.99

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Survey Branch of Dept. of Interior, Perth 1962-1966.

Station was tied to first-order station GC 18A by a closed Tellurometer traverse.

Geoid height from Mather et al, IUGG Moscow 1971.



* Peg is 45.0 m below center of boresight horn. (see sketch)

DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	6 meters
Vertical	< 1 meters	1 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, June 1969.

Station No. RAD 15

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: APOLLO WOMF; NGSP 4946

Location: Woomera, Australia

Equipment: FPS-16 radar

Agency: Australian National Weapons Research Establishment

RAD 15

Point referred to: intersection of horizontal and vertical axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 30° 49' 11".0025	Latitude	- 30° 49' 09".58
Longitude (E)	136 50 13.1203	Longitude (E)	136 50 12.16
Datum	Australian Geodetic	Based on	first-order obs 1960 by Div. of Nat. Mapping at Δ RED LAKE TRIG, 30 m from radar

Elevation above mean sea level 128.0 meters — Geoid height - 1.6 meters — Height above ellipsoid 126 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Astronomic	Δ RED LAKE TRIG	Δ SANDY POINT		129° 34' 57".79
Laplace	Δ RED LAKE TRIG	Δ SANDY POINT		129 34 57.30
Geodetic	Δ RED LAKE TRIG	Δ SANDY POINT		129 34 56.16

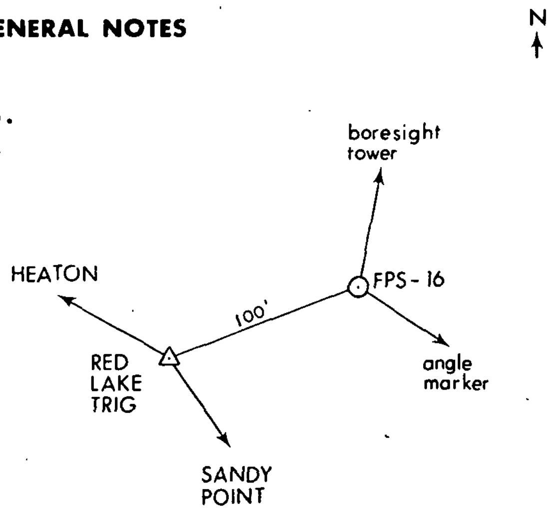
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site is known as "Red Lake."

The intersection of axes is a point called R38. It was positioned by the Survey Section, Department of Interior, Woomera, June 1960. The tie to the national geodetic net at Δ SANDY POINT was by a closed Tellurometer traverse.

Elevation was established by spirit leveling to the Pimba Railway Datum. This is based on mean sea level at Port Augusta, at the head of a major estuary, Spencer Gulf.

Geoid height from Mather et al, IUGG Moscow 1971.



DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	2 meters
Vertical	0.3 meters	1 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of National Mapping, July 1969.

Station No. RAD 16

Code Name ______

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFWTR 333001; APOLLO HAWF; NGSP 4742

Location: Kauai, Hawaii

Equipment: FPS-16 radar

Agency: NASA-Goddard Space Flight Center

RAD 16

Point referred to: intersection of axes of motion

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	22° 07' 35".828	Latitude	ξ = + 7"
Longitude (E)	200 19 53.962	Longitude (E)	η = - 11
Datum	Old Hawaiian	Based on	second-order obs C&GS 1961 at Δ MANU, 300 m from antenna

Elevation above mean sea level 1155 meters; Geoid height ______ meters; Height above ellipsoid ______ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
	radar antenna	radar reflector	8260.865 (slant-range)	

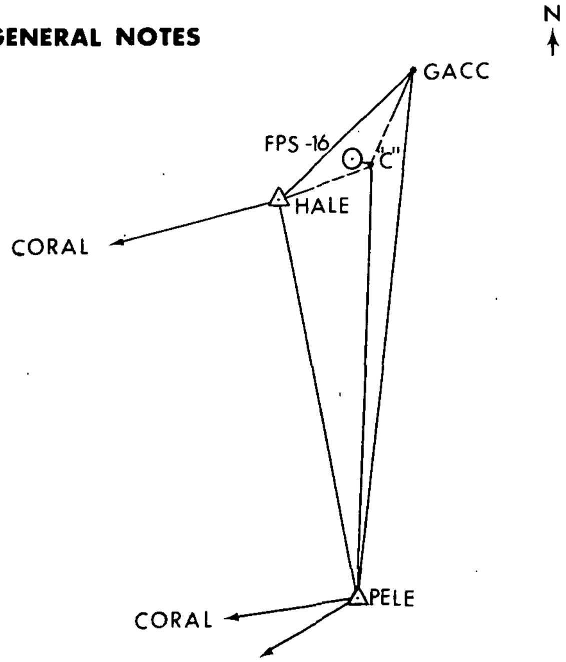
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Geonautics, Inc., 1960. Leveling by R. S. Yokoyoma, Reg. Prof. Surveyor, Lihue, Kauai.

Positioned by triangulation, intersection and traverse from USC&GS 3rd-order stations. Δ HALE had been destroyed and repositioned, so position was checked by observations at stations HALE, CORAL, and PELE, as shown in sketch. All angles in triangle GACC - PELE - HALE were observed and position of GACC computed. "C" was observed from GACC, PELE, and HALE, and position computed. Position of antenna was computed from taped distance and measured direction from "C". All angles measured with Wild T-3, using 3rd-order methods.

Elevation of horizontal axis was determined by precision spirit level from USGS 3rd-order bench mark "3545."

The station is also called Kokee Park.



DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	2 meters	2 meters
Vertical	1 meters	1 meters

REFERENCES

Project Mercury survey files, Geonautics, Inc.

Station No. RAD 17

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFWTR 023003; APOLLO CALT; NGSP 4280

Location: Vandenberg Air Force Base, California

Equipment: TPQ-18 radar

Agency: USAF-Western Test Range

RAD 17

Point referred to: intersection of axes of motion

GEODETIC COORDINATES

Latitude: 34° 39' 57".1310

Longitude (E): 239 25 10.4313

Datum: NAD 1927

ASTRONOMIC COORDINATES

Latitude: ξ = + 1".0 ± 1".5

Longitude (E): η = - 8.0 ± 2.0

Based on: several A-G obs and free air gravity in area (C&GS) 1966

Elevation above mean sea level: 123.0 meters

Geoid height: - 34 meters

Height above ellipsoid: 89 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Boresight TV lens	Boresight feed horn	627.5*	267° 43' 05"
Geodetic	Boresight TV lens	Range target lens	4516.2*	353 22 58

*slant range

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by U.S. Naval Oceanographic Office 1966.

Position by first-order triangulation and traverse from station ARGUELLO II, 1959.

Geoid height from TOPOCOM geoid charts 1967.

DATE: July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	5 meters
Vertical	0.3 meters	< 1 meters

REFERENCES

Geodetic Coordinates Manual, Parts I and II, USAF-Western Test Range, June 1968.

Station No. RAD 18

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFWTR 023001; APOLLO CALF

Location: Point Arguello, California

Equipment: FPS-16 radar (No. 1)

Agency: USAF-Western Test Range

RAD 18

Point referred to: (horizontal) electrical center; (vertical) intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	34° 34' 57".950	Latitude	34° 34' 53".92
Longitude (E)	239 26 21.970	Longitude (E)	239 26 09.90
Datum	NAD 1927	Based on	first-order obs by USAF in 1960, 12 meters away

Elevation above mean sea level 661.5 meters — Geoid height - 34 meters — Height above ellipsoid 628 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	FPS-16	boresight tower	954.66	287° 36' 56".34

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by USC&GS.

The local surveys are second-order or better.

Elevations by first- and second-order leveling from C&GS bench marks by C&GS personnel.

Astronomic observations by USAF 1381st Geodetic Squadron.

Geoid height from TOPOCOM geoid charts 1967.

DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.2 meters	5 meters
Vertical	0.1 meters	< 1 meters

REFERENCES

FPS-16 Instrumentation Radar Constants, rev. 29 July 1960; AFWTR Geodetic Coordinates Manual, July 1969.

Station No. RAD 19

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: WSMR R-113; APOLLO WHSF; NGSP 4143

RAD 19

Location: White Sands, New Mexico

Equipment: FPS-16 radar

Agency: U.S. Army - White Sands Missile Range

Point referred to: intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	32° 21' 28".623	Latitude	ξ = + 0".86
Longitude (E)	253 37 50.659	Longitude (E)	η = - 2.26
Datum	NAD 1927	Based on	zenith camera obs at station C, 800 m from antenna

Elevation above mean sea level: 1234 meters Geoid height: - 1 meters Height above ellipsoid: 1233 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	intersection axes	boresight horn	457.4	185° 30' 52"

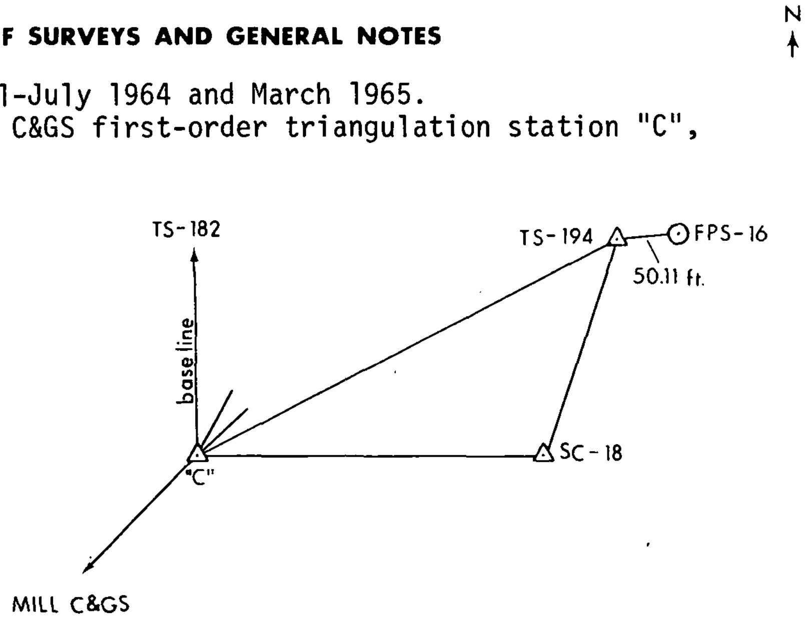
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by USC&GS April-July 1964 and March 1965.

Distance and direction were from C&GS first-order triangulation station "C", about 2500 ft away.

Elevation was determined by second-order levels of WSMR from C&GS elevation at station C (New Mexico line 101).

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	4 meters
Vertical	< 1 meters	< 1 meters

REFERENCES

Ltr. Director Nat'l Range Operations, WSMR to Geonautics, 3/29/67.

Station No. RAD 20

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: APOLLO EGLF; Eglin AFB Radar 20; AFETR 321.16

RAD 20

Location: Eglin Air Force Base, Florida — Equipment: FPS-16

Agency: USAF-Air Proving Ground Center

Point referred to: intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	30° 25' 17".064	Latitude	30° 25' 18".70 ± 0".09
Longitude (E)	273 12 06.442	Longitude (E)	273 12 05.97 ± 0.15
Datum	NAD 1927	Based on	first-order obs by Vitro Corp. in 1961, 250 feet from antenna

Elevation above mean sea level: 27.85 meters — Geoid height: + 9 meters — Height above ellipsoid: 37 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	SLANT DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	axes intersection	C-Band feed horn top	445.43	355° 31' 52".0
Geodetic	axes intersection	C-Band feed horn bottom	445.47	355 31 37.5
Geodetic	axes intersection	range calib target	7074.41	115 53 05.84

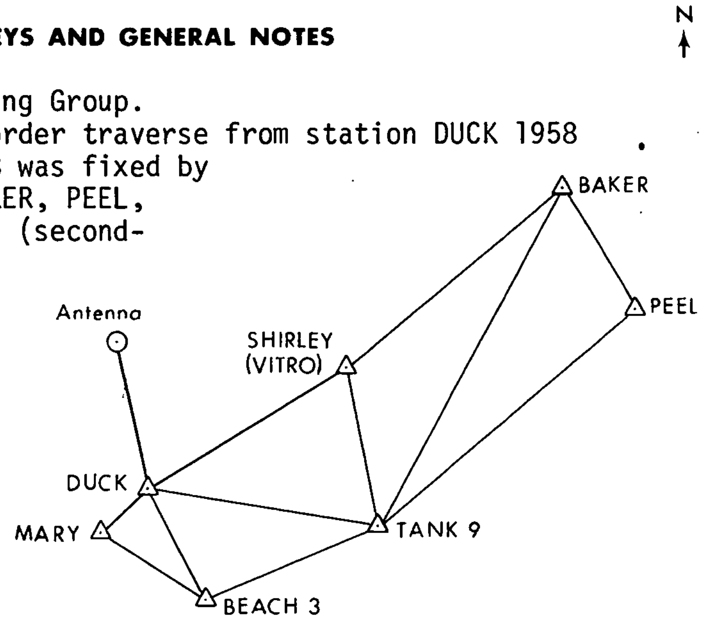
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Vitro Corp. Range Engineering Group.

Position of antenna is based on third-order traverse from station DUCK 1958 (Vitro), about 300 m distant. Δ DUCK 1958 was fixed by triangulation from five C&GS stations, BAKER, PEEL, TANK 9, MARY (all first-order) and BEACH 3 (second-order). Eight positions were observed at night from Bilby towers with a Wild T-3. Laplace-azimuth checks the geodetic azimuth carried through triangulation within 1 second of arc. The astro-azimuth is based on 59 positions of Polaris on three nights (p.e. ± 0".23).

Elevation was by precision leveling from C&GS line No. 46. Elev. of DUCK 1958 is 9.937 m.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.2 meters	4 meters
Vertical	0.1 meters	< 1 meters

REFERENCES

Letter, Eglin AFB to Geonautics, 30 January 1964.

Station No. RAD 21

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Wallops Island, Virginia

Equipment: 60-foot antenna (SPANDAR)

Agency: NASA - Goddard Space Flight Center

RAD 21

Point referred to: intersection of horizontal and vertical axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	37° 51' 16".742	Latitude	
Longitude (E)	284 29 11.606	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 30.8 meters   Geoid height - 2 meters   Height above ellipsoid 29 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Survey by Thomas Savage, Sr., Wallops Station, October 1966.

The position of this SPANDAR antenna is based on C&GS first-order stations CHINCO SW BASE and CHINCO NE BASE.

Geoid height from TOPOCOM geoid charts 1967.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	< 1 meters	1 meters

REFERENCES

Geodetic Data Sheet, T.J. Savage, Wallops Station, Wallops Island, Virginia, 25 October 1966.

Launch Sites

Station No. LPD 1

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes AFETR 015012

Location Cape Kennedy, Florida

Equipment Stand 12 (Atlas-Agena)

Agency NASA-John F. Kennedy Space Center

LPD 1

Point referred to center of E-W launch arm pins (not marked)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 28' 49".1255	Latitude	ξ = + 0".91
Longitude (E)	279 27 28.0486	Longitude (E)	η = + 2.16
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1956 at Δ 12 NW, 216 m distant

Elevation above mean sea level 14.973 meters Geoid height + 10 meters Height above ellipsoid 25 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ STAND 12	WEST PIN	1.4850	285° 01' 40"
Geodetic	Δ TWELVE 2	Δ CENTRAL SE BASE		170 47 59.78

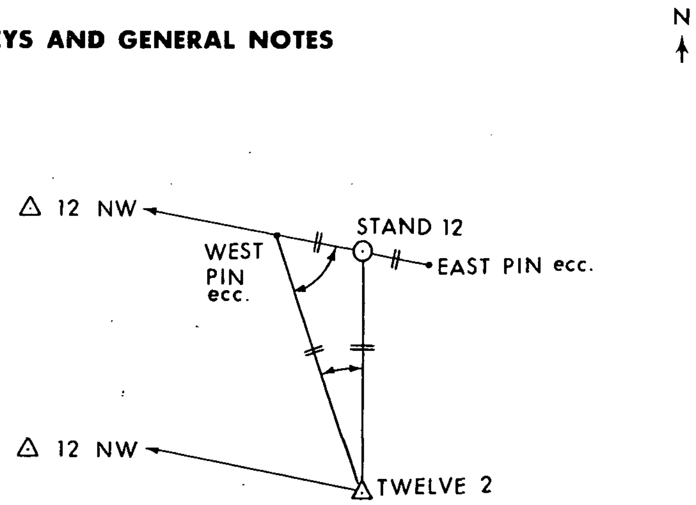
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The position is based on a resurvey by USC&GS, 1963. The survey consisted of precise triangulation and traverse from C&GS stations TWELVE 2 (1960) and 12 NW (1956).

The elevation was determined by first-order leveling by C&GS from nearby first-order bench marks.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, August 1969.

Station No. LPD 2

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 015013

Location Cape Kennedy, Florida

Equipment Stand 13 (Atlas-Agena)

Agency NASA-John F. Kennedy Space Center

LPD 2

Point referred to center of E-W launch arm pins (not marked)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 29' 08".1333	Latitude	ξ = + 0".9
Longitude (E)	279 27 19.2204	Longitude (E)	η = + 2.2
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1956 at Δ NW 12, 530 m distant

Elevation above mean sea level 15.004 meters

Geoid height + 10 meters

Height above ellipsoid 25 meters

AZIMUTH DATA

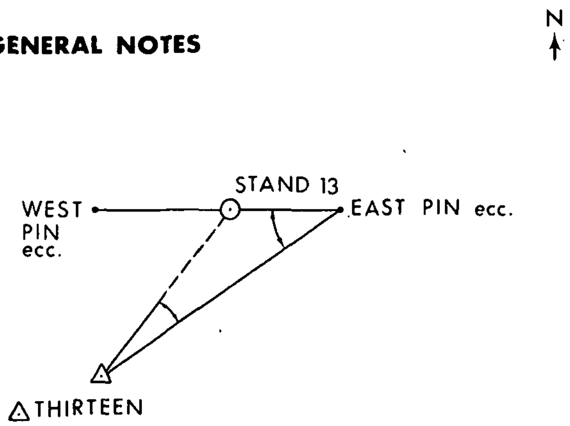
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ THIRTEEN	Δ AIR		233° 51' 24".60

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by USC&GS in 1963. Triangulation and traverse were extended from Δ THIRTEEN (1957). The elevation was determined by first-order leveling from nearby first-order bench marks.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)



DATE JULY 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, August 1969.

Station No. LPD 3

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes AFETR 015014

Location Cape Kennedy, Florida

Equipment Stand 14 (Atlas-Agena)

Agency NASA-John F. Kennedy Space Center

LPD 3

Point referred to center of E-W launch arm pins (not marked)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 29' 27".1428	Latitude	ξ = + 1
Longitude (E)	279 27 10.3893	Longitude (E)	η = + 2
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1956 at Δ 12 NW, 1.2 km distant

Elevation above mean sea level 14.962 meters — Geoid height + 10 meters — Height above ellipsoid 25 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ FOURTEEN	Δ AIR		213° 20' 31".14

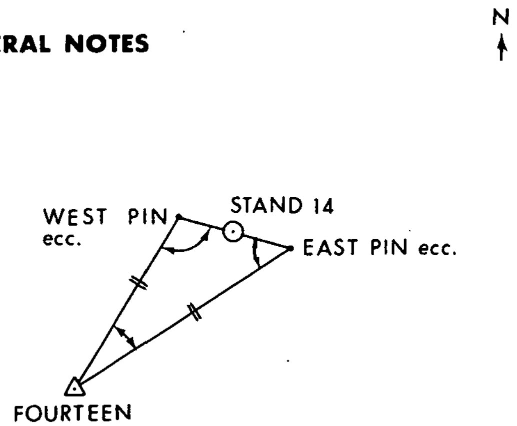
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by USC&GS in 1963. Precise triangulation and traverse were extended from Δ FOURTEEN (1956). The elevation was determined by first-order leveling from nearby first-order bench marks.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)

This stand has been deactivated.



DATE SEPTEMBER 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, August 1969.

Station No. LPD 4

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 015019

Code Name

Location: Cape Kennedy, Florida

Equipment: Stand 19 (Gemini-Titan)

Agency: NASA-John F. Kennedy Space Center

LPD 4

Point referred to: center of flame bucket (not marked)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 30' 24".1497	Latitude	28° 30' 25".1
Longitude (E)	279 26 43.6993	Longitude (E)	279 26 45.3
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1958 at NINETEEN RM 1 at site

Elevation above mean sea level: 9.72 meters (top edge thrust ring)

Geoid height: + 10 meters

Height above ellipsoid: + 20 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	△ STAND 19	NINETEEN RM 2	30.624	166° 11' 10"
Geodetic	NINETEEN RM 2	△ NINETEEN		358 34 06.6

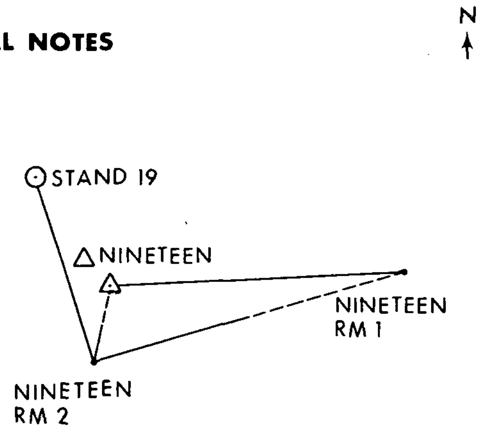
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The position is based on a resurvey by USC&GS in 1964. The survey consisted of precise triangulation and traverse from station NINETEEN RM 2 (1959). The elevation was determined by first-order levels from nearby first-order bench marks.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)

This stand has been deactivated.



DATE SEPTEMBER 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, August 1969.

Station No. LPD 5

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 015034

Location: Cape Kennedy, Florida

Equipment: Stand 34

Agency: NASA-John F. Kennedy Space Center

LPD 5

Point referred to: center of launch arm pins

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 31' 17".5063	Latitude	ξ = + 1".3
Longitude (E)	279 26 19.1131	Longitude (E)	η = + 2.2
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1956 at Δ KIMBALL ECC 300 m distant

Elevation above mean sea level: 15.00 meters | Geoid height: 10 meters | Height above ellipsoid: 25 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ STAND 34	Δ THIRTY FOUR	113.606	100° 00' 59"

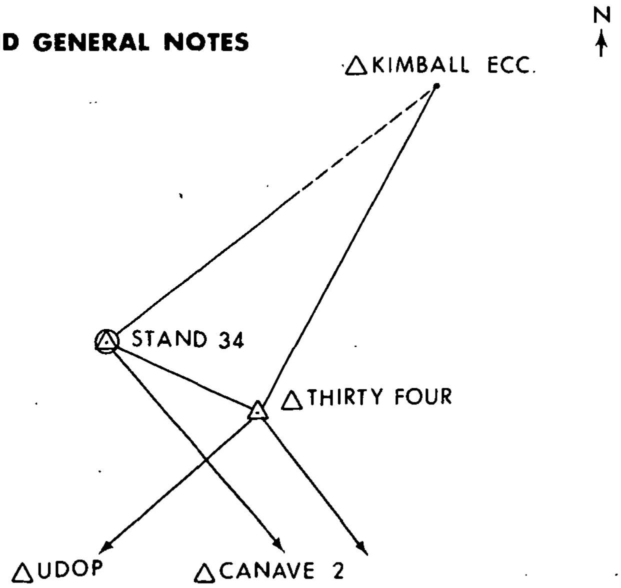
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by USC&GS in November 1961. The survey consisted of precise triangulation and traverse from stations THIRTY FOUR (1961), KIMBALL ECC (1934), and CANAVE 2 (1934). Δ THIRTY FOUR is an astro-azimuth station.

The elevation of Δ STAND 34, the brass bolt at pad level beneath the launch arms, is 13.095 m. It was determined by first-order leveling by C&GS in 1965.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)



DATE: July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, March 1970.

Station No. LPD 6

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 015037

Code Name

LPD 6

Location Cape Kennedy, Florida

Equipment Stand 37A

Agency NASA-John F. Kennedy Space Center

Point referred to center of launch arms

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 31' 59".4227	Latitude	ξ = + 1"
Longitude (E)	279 25 53.9824	Longitude (E)	η = + 2"
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1956 at Δ KIMBALL ECC, about 1 km distant

Elevation above mean sea level 17.57 meters

Geoid height + 10 meters

Height above ellipsoid 28 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ STAND 37A	RM 3	50.940	222° 27' 30"
Geodetic	STAND 37A RM 3	RM 2	100.014	121 58 48

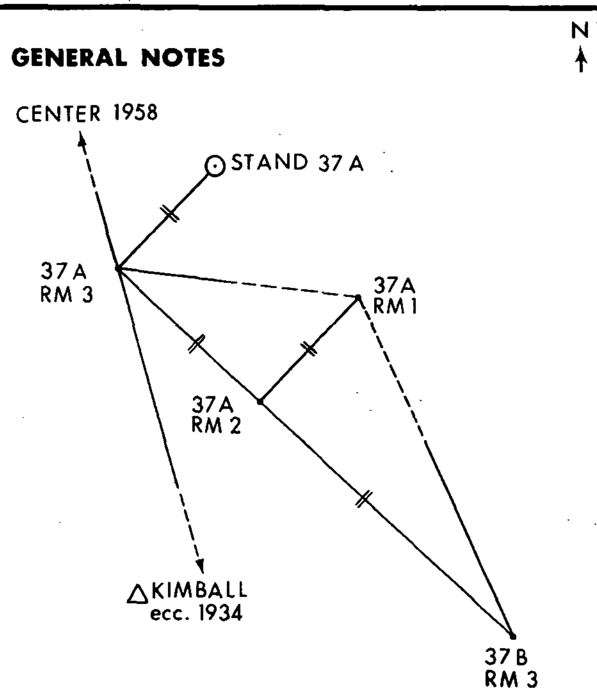
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by USC&GS in 1965. The position was determined by precise traverse from Δ THIRTY SEVEN B and STAND 37A, stations included in a dense first-order net.

The elevation of Δ STAND 37A, the mark under the center of the launch arms, was determined by first-order leveling to be 15.557 m. The center of the launch arms is 2.01 meters above the mark.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, August 1969.

Station No. LPD 7

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 015037

Location: Cape Kennedy, Florida

Equipment: Stand 37B

Agency: NASA-John F. Kennedy Space Center

LPD 7

Point referred to: center of launch arms

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 31' 53".1263	Latitude	ξ = + 1
Longitude (E)	279 26 05.3919	Longitude (E)	η = + 2
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1956 at Δ KIMBALL ECC 1.6 km distant

Elevation above mean sea level: 17.55 meters; Geoid height: 10 meters; Height above ellipsoid: 28 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ STAND 37B	Δ THIRTY SEVEN B	17.827	325° 21' 26".0
Geodetic	Δ THIRTY SEVEN B	Δ KIMBALL ECC		145 42 00.88

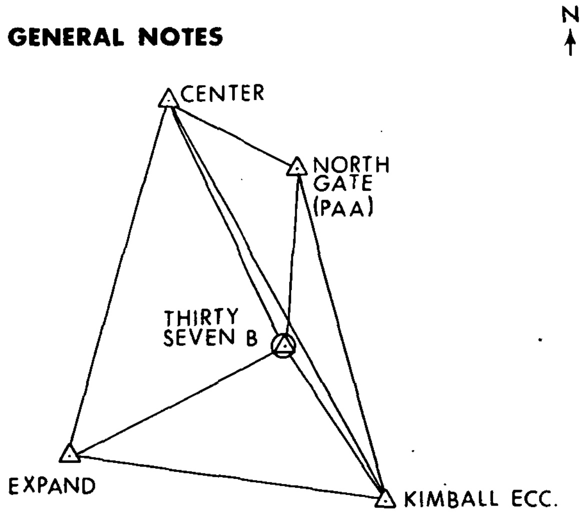
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by USC&GS in 1963. The position was determined by precise triangulation and traverse from Δ THIRTY SEVEN B (1963). This station was a point in a dense first-order network.

The elevations were determined by first-order leveling by C&GS in 1964. The launch arms are 2.01 m above bench mark P 192.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, August 1969.

Station No. LPD 8

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 335039

Location Cape Kennedy, Florida

Equipment Pad 39A

Agency NASA-John F. Kennedy Space Center

LPD 8

Point referred to center of launch arms

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 36' 28".7749	Latitude	ξ = + 2".1
Longitude (E)	279 23 44.3439	Longitude (E)	η = + 2.5
Datum	NAD 1927 (CC)*	Based on	first-order obs C&GS 1964 at Δ CHESTER 2, 0.6 km distant

Elevation above mean sea level 28.905 meters

Geoid height + 10 meters

Height above ellipsoid 39 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

There is no mark under the launch arms.

The site was surveyed by USC&GS in 1966. The survey consisted of first-order (Class I) triangulation and traverse.

The launch arms are 2.62 m above the base.

*Cape Canaveral Datum and NAD 1927 are interchangeable in this area.

Geoid height from TOPOCOM geoid charts 1967. (The value given by AFETR is 8 m.)

DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	6 meters
Vertical	0.01 meters	< 1 meters

REFERENCES

AFETR Geodetic Coordinates Manual, August 1969.

Goddard Range and Range-Rate Stations

Station No. GRR 1S

Code Name ULASKR

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NGSP 1128

Location Fairbanks, Alaska

Equipment Goddard Range and Range Rate S-Band 30-foot antenna

Agency NASA-Goddard Space Flight Center

GRR 1S

Point referred to center of X-axis of S-Band antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	64° 58' 20".886	Latitude	
Longitude (E)	212 29 22.415	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 346.6 meters

Geoid height + 2 meters

Height above ellipsoid 349 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	iron peg	Δ HILLSIDE	687.6	254° 47' 41".23
Geodetic	iron peg	col. tower	739.4	252 19 04.55

DESCRIPTION OF SURVEYS AND GENERAL NOTES

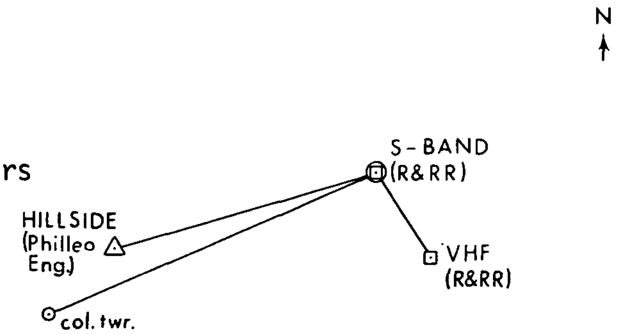
The surveyed point is an iron peg at the proposed center of the S-Band antenna. Field surveys by Field Facilities Branch, GSFC, 1965. This third-order field position is based on a Geodimeter traverse from Δ HILLSIDE (Philleo Engineering Company) using a Model 4D Geodimeter and a Wild T-3 theodolite.

Elevations near antenna:

West monument 337.3 m
North monument 339.4 m
East monument 339.2 m

The X-axis of the antenna will be 6.55 meters above the foundation slab (poured after this survey).

Geoid height from TOPOCOM geoid charts 1967.



DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	11 meters
Vertical	5 meters	5 meters

REFERENCES

Geodetic Survey Report for Alaska STADAN, Field Facilities Branch, GSFC 1966.

Station No. GRR 1V

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Fairbanks, Alaska

Equipment: Goddard Range and Range Rate VHF antenna

Agency: NASA-Goddard Space Flight Center

GRR 1V

Point referred to: center of X-axis of VHF antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	64° 58' 19".191	Latitude	
Longitude (E)	212 29 28.122	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level: 347 meters Geoid height: +2 meters Height above ellipsoid: 349 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	iron peg	Δ VHF (iron peg)	91.4	125° 02' 50".34

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The surveyed point is an iron peg at the proposed center of the VHF antenna.

Field surveys by Field Facilities Branch, GSFC, 1965. This third-order field position is based on a Geodimeter traverse from Δ HILLSIDE (Philleo Engineering Company) using a Model 4D Geodimeter and a Wild T-3 theodolite.

See Station No. GRR 1S.

Geoid height from TOPOCOM geoid charts 1967.

DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	11 meters
Vertical	5 meters	5 meters

REFERENCES

Geodetic Survey Report for Alaska STADAN, Field Facilities Branch, GSFC 1966.

Station No. GRR 2S

Code Name ROSRAN

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NGSP 1126

GRR 2S

Location Rosman, North Carolina

Equipment Goddard Range and Range Rate S-Band paired 14-foot antenna

Agency NASA-Goddard Space Flight Center

Point referred to center of X-axis of S-Band antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 11' 45".051	Latitude	ξ = - 9".30
Longitude (E)	277 07 26.230	Longitude (E)	η = + 9.14
Datum	NAD 1927	Based on	first-order obs AMS 1962 1/2-km away

Elevation above mean sea level 873.9 meters | Geoid height + 6.4 meters | Height above ellipsoid 880 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by AMS 1962; Field Facilities Branch GSFC, 1963.

Antenna monuments were set by Goddard FFB on a N-S line previously established by AMS (CE). Precise taping was used for distances.

The AMS survey was based on USC&GS first-order station BLACK MOUNTAIN, about 8 miles from the site. A Tellurometer traverse connects the site monuments to the C&GS network. Points on AMS Stations (1962) "RANGE & RANGE-RATE NORTH" and "RANGE & RANGE-RATE SOUTH" define the north-south line of the R&RR antennas. The X-axis of antenna is 33 feet (10.1 m) above the tower leg base.

Elevation of concrete pad is 863.8 m.

Geoid height from TOPOCOM geoid charts 1967.

DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	4 meters
Vertical	< 1 meters	1 meters

REFERENCES

Letter Field Facilities Branch, GSFC to Data Operations Branch, GSFC May 12, 1965.

Station No. GRR 2V

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Rosman, North Carolina

Equipment: Goddard Range and Range Rate VHF antenna

Agency: NASA-Goddard Space Flight Center

GRR 2V

Point referred to: center of X-axis of VHF antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 11' 41".097	Latitude	ξ = - 9".30
Longitude (E)	277 07 26.230	Longitude (E)	η = + 9.14
Datum	NAD 1927	Based on	first-order obs AMS 1962 1/2-km away

Elevation above mean sea level 873.9 meters — Geoid height + 6 meters — Height above ellipsoid 880 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by AMS 1962; Field Facilities Branch GSFC, 1963.

Antenna monuments were set by Goddard FFB on a N-S line previously established by AMS (CE). Precise taping was used for distances.

The AMS survey was based on USC&GS first-order station BLACK MOUNTAIN, about 8 miles from the site. A Tellurometer traverse connects the site monuments to the C&GS network. Points on AMS Stations (1962) "RANGE & RANGE-RATE NORTH" and "RANGE & RANGE-RATE SOUTH" define the north-south line of the R&RR antennas. The X-axis of the antenna is 33 feet (10.1 m) above the tower leg base.

Elevation of concrete pad is 863.8 m.

Geoid height from TOPOCOM geoid charts 1967.

See Station No. GRR 2S.

DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	4 meters
Vertical	< 1 meters	1 meters

REFERENCES

Letter Field Facilities Branch, GSFC to Data Operations Branch, GSFC May 12, 1965.

Station No. GRR 3S

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Code Name

Location Santiago, Chile

Equipment Goddard Range and Range Rate S-Band 30-foot antenna

Agency NASA-Goddard Space Flight Center

GRR 3S

Point referred to center of X-axis of S-Band antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 33° 09' 02".734	Latitude	- 33° 09' 13".4
Longitude (E)	289 20 03.255	Longitude (E)	289 19 38.8
Datum	South American 1969	Based on	first-order obs by IAGS 1956 at Δ PELDEHUE 300 m NW of S-Band

Elevation above mean sea level 705.7 meters — Geoid height + 26.2 meters — Height above ellipsoid 732 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	S-band antenna	Δ PELDEHUE	245.3	313° 36' 42"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Position from scaled distances to Minitrack monument PELDEHUE, which was surveyed by IAGS, June 1966. (See No. MIN 10.)

X-axis of the antenna is 6.6 m above foundation (elev. 699.1 m).

A precise survey is expected soon to revise this preliminary position slightly.

Geoid height from CHUA base, TOPOCOM 1971.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	7 meters
Vertical	2 meters	3 meters

REFERENCES

Memo: Field Facilities Branch, GSFC, to Geonautics, 24 June 1966; Geodetic Summary USATOPOCOM August 1971.

Station No. GRR 3V

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

GRR 3V

Location Santiago, Chile

Equipment Goddard Range and Range Rate VHF antenna

Agency NASA-Goddard Space Flight Center

Point referred to center of X-axis of VHF antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 33° 09' 05."208	Latitude	- 33° 09' 15."8
Longitude (E)	289 20 03.255	Longitude (E)	289 19 38.8
Datum	South American 1969	Based on	first-order obs by IAGS 1956 at Δ PELDEHUE 300 m NW of S-Band

Elevation above mean sea level 706 meters

Geoid height + 26.2 meters

Height above ellipsoid 732 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Position from scaled distances to Minitrack monument PELDEHUE, which was surveyed by IAGS, June 1966.

X-axis of the antenna is 6.6 m above foundation (elev. 699.1 m).

A precise survey is expected soon to revise this preliminary position slightly.

Geoid height from CHUA base, TOPOCOM 1971.

See Station No. GRR 3S.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	7 meters
Vertical	2 meters	3 meters

REFERENCES

Memo: Field Facilities Branch, GSFC, to Geonautics, 24 June 1966; Geodetic Summary USATOPOCOM August 1971.

Station No. GRR 4S

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes NGSP 1123

Location Tananarive, Madagascar

Agency NASA-Goddard Space Flight Center

Equipment Goddard Range and Range Rate S-Band paired 14-foot antenna

GRR 4S

Point referred to center of X-axis of S-band antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 19° 01' 09".33	Latitude	
Longitude (E)	47 18 12.56	Longitude (E)	
Datum	Tananarive	Based on	

Elevation above mean sea level 1399 meters   Geoid height ____ meters   Height above ellipsoid ____ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	S-band	VHF	76.2	179° 56' 10"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The local survey was by H. Monge of the Tananarive Annexe of the Institut Geographique National of Paris, in August 1967. The work is not described but was presumably a traverse from the earlier site 130 m away (a third-order position) to a base plate in the antenna foundation.

The elevation is based on the Nivellment general de Madagascar (MSL).

Before May 1968 this equipment was at:
ϕ - 19° 01' 13".32, λ 47° 18' 09".45, elevation 1402.7 m.
When at this location it had NGSP No. 1122.

DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	1 meters
Vertical	2 meters	2 meters

REFERENCES

Note with sketch from H. Monge to GSFC August 1967.

Station No. GRR 4V

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Tananarive, Madagascar

Equipment: Goddard Range and Range Rate VHF antenna

Agency: NASA-Goddard Space Flight Center

GRR 4V

Point referred to: center of X-axis of VHF antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 19° 01' 11".80	Latitude	
Longitude (E)	47 18 12.56	Longitude (E)	
Datum	Tananarive	Based on	

Elevation above mean sea level 1399 meters   Geoid height ____ meters   Height above ellipsoid ____ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	VHF	S-Band	76.2	359° 56' 10"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The local survey was by H. Monge of the Tananarive Annexe of the Institut Geographique National of Paris, in August 1967. The work is not described but was presumably a traverse from the earlier site 130 m away (a third-order position) to a base plate in the antenna foundation.

The elevation is based on the Nivellment general de Madagascar (MSL).

See Station No. GRR 4S.

DATE June 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	1 meters
Vertical	2 meters	2 meters

REFERENCES

Note with sketch from H. Monge to GSFC August 1967.

Station No. GRR 5S

Code Name CARVON

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NGSP 1152

Location Carnarvon, Australia

Equipment Goddard Range and Range Rate S-Band paired 14-foot antenna

Agency NASA-Goddard Space Flight Center

GRR 5S

Point referred to center of X-axis of S-band antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 24° 54' 14".964	Latitude	- 24° 54' 13".60
Longitude (E)	113 42 54.938	Longitude (E)	113 42 55.73
Datum	Australian Geodetic	Based on	first-order obs 1964 by Dep. Lands & Surveys WA, 400 m from station

Elevation above mean sea level 37.9 meters   Geoid height + 6.2 meters   Height above ellipsoid 44 meters

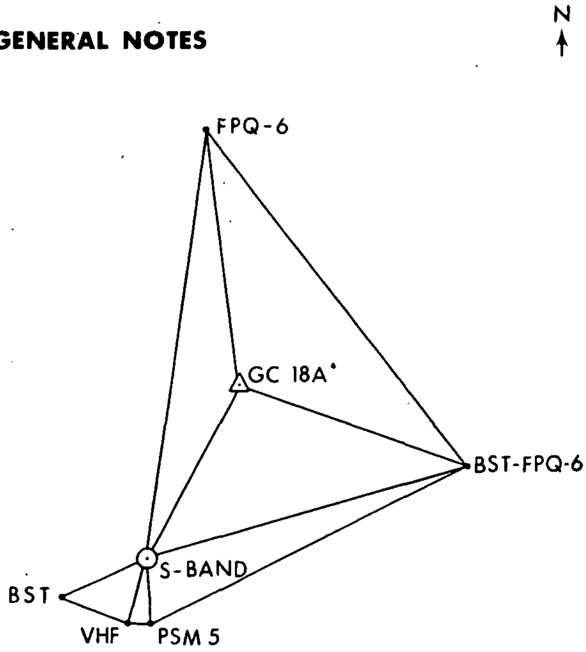
AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Astronomic	Δ GC 18A	Δ GC 17		176° 39' 27".99
Laplace	Δ GC 18A	Δ GC 17		176 39 28.32
Geodetic	Δ GC 18A	Δ GC 17		176 39 28.57

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Survey Section, Dept. of Interior, Perth, 1962-1966. The tie to the Nat. Geodetic Survey at Brown Range GC 18A was by a closed Tellurometer traverse.

Elevation of plane of rims of antenna dishes when elevated 90° is 134.64 feet; of Y-axis, 127.98 feet; top of NE mounting bolt = 94.58 ft. Elevation, range and bearing change with antenna position. The X-axis of the antenna is 10 m above the base of the tower leg.



Geoid height from Mather et al, IUGG Moscow 1971.

DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	6 meters
Vertical	< 1 meters	2 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, June 1969.

Station No. GRR 5V

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Carnarvon, Australia

Equipment Goddard Range and Range Rate VHF antenna

Agency NASA-Goddard Space Flight Center

GRR 5V

Point referred to center of X-axis of VHF antenna

GEODETIC COORDINATES

Latitude -24° 54' 18".923

Longitude (E) 113 42 54.937

Datum Australian Geodetic

ASTRONOMIC COORDINATES

Latitude - 24° 54' 17".56

Longitude (E) 113 42 55.73

Based on first-order obs 1964 by Dep. Lands & Surveys WA, 400 m from Station

Elevation above mean sea level 37.9 meters

Geoid height + 6.2 meters

Height above ellipsoid 44 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Astronomic	Δ GC 18A	Δ GC 17		176° 39' 27".99
Laplace	Δ GC 18A	Δ GC 17		176 39 28.32
Geodetic	Δ GC 18A	Δ GC 17		176 39 28.57

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Survey Section, Dept. of Interior, Perth, 1962-1966. The tie to the Nat. Geodetic Survey at Brown Range GC 18A was by a closed Tellurometer traverse.

Elevation, range and bearing change with antenna position. The X-axis of the antenna is 10 m above the base of the tower leg.

Geoid height from Mather et al, IUGG Moscow 1971.

See Station No. GRR 5S.

DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	6 meters
Vertical	< 1 meters	2 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, June 1969.

85-foot Antennas

Station No. S85 1

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NASA Rosman I

Location Rosman, North Carolina

Equipment 85-foot X-Y antenna (I)

Agency NASA-Goddard Space Flight Center

S85 1

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 12' 00".048	Latitude	35° 11' 50".75 ± 0".09
Longitude (E)	277 07 40.572	Longitude (E)	277 07 51.76 ± 0.06
Datum	NAD 1927	Based on	first-order obs by AMS in 1962 at site

Elevation above mean sea level 892 meters

Geoid height + 6 meters

Height above ellipsoid 898 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANT CENTER	Δ TR A-2 AMS	2013.638	268° 57' 58".88
Astronomic	Δ ANT CENTER	Δ TR A-Z AMS		268 58 05.50 ± 0".23

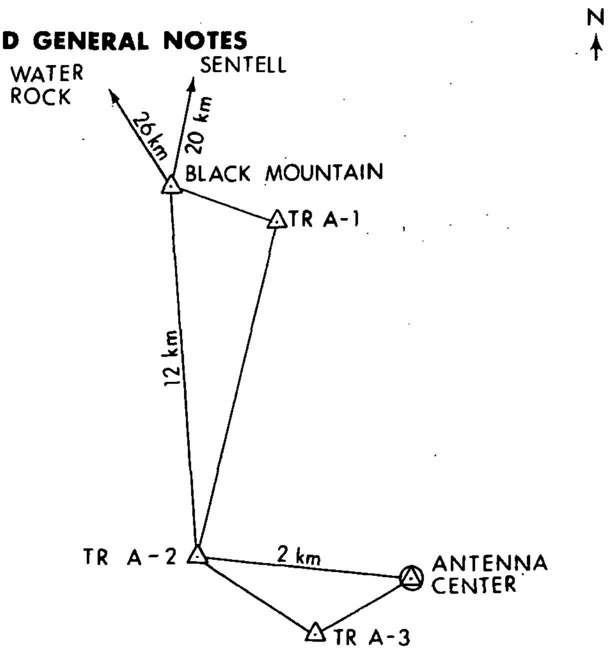
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The station ANTENNA CENTER is a punch mark and etched cross on a survey disk.

The survey by Army Map Service in 1962 was a loop traverse with Wild T-3 and Tellurometer through Δ TR A-2 from BLACK MOUNTAIN, with azimuth from SENTELL and WATER ROCK (three first-order C&GS stations), with another loop traverse from TR A-2 to ANTENNA CENTER to TR A-3 with Geodimeter and T-3. Nine alignment markers were precisely set along cardinal points from ANTENNA CENTER. The mark was destroyed during construction but replaced from the alignment markers by a later Geodimeter survey.

The station mark (elev. 879 m) is 13 m below the X-axis.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.2 meters	4 meters
Vertical	1 meters	1 meters

REFERENCES

AMS report Rosman Survey, 14 January 1963.

Station No. S85 2

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes ROSMAN II

Location Rosman, North Carolina

Equipment 85-foot X-Y antenna (II)

Agency NASA-Goddard Space Flight Center

S85 2

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 11' 55".677	Latitude	ξ = - 9.3
Longitude (E)	277 07 27.451	Longitude (E)	η = + 9.2
Datum	NAD 1927	Based on	first-order AMS obs 1962 at Rosman I

Elevation above mean sea level 888 meters — Geoid height + 6 meters — Height above ellipsoid 894 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANT CTR (RII)	Δ ANT CTR (RI)	358.206	67° 54' 43"
Geodetic	Δ ANT CTR (RII)	col. twr. (RII)	6836.20	319 03 08.40

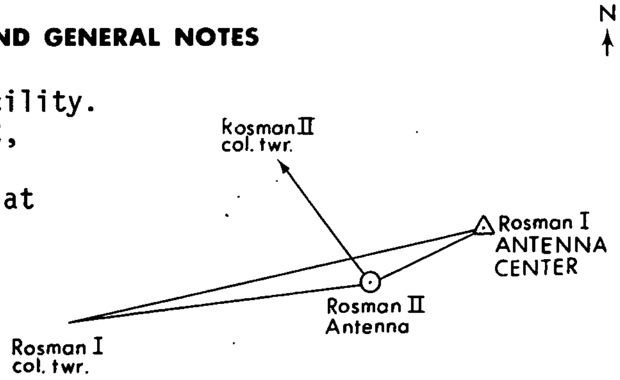
DESCRIPTION OF SURVEYS AND GENERAL NOTES

This is an Applied Technology Satellite facility.

The survey by Field Facilities Branch, GSFC, July 1965, was a first-order Geodimeter and Wild T-3 traverse from station ANTENNA CENTER at Rosman I.

Elevation was by third-order leveling from bench mark LR 728 (USGS) (third-order). Station mark (elev. 874.73 m) is 13 m below the X-axis.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.2 meters	4 meters
Vertical	1 meters	1 meters

REFERENCES

FFB-GSFC description card.

Station No. S85 3

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: NASA ULASKA

S85 3

Location: Fairbanks, Alaska

Equipment: 85-foot X-Y antenna

Agency: NASA-Goddard Space Flight Center

Point referred to: center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	64° 58' 37".711	Latitude	
Longitude (E)	212 29 05.579	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level: 307 meters   Geoid height: + 2 meters   Height above ellipsoid: 309 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ULASKA	Tower No. 1	638.737	39° 59' 28"
Geodetic	Δ ULASKA	Tower No. 2	5688.3	77 21 56
Geodetic	Δ ULASKA	Δ N. NIMBUS	66.566	180 00 00

DESCRIPTION OF SURVEYS AND GENERAL NOTES

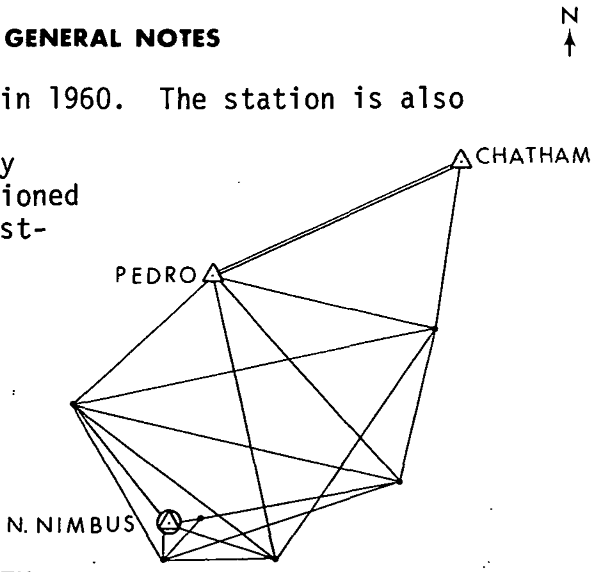
Surveyed by Philleo Engrg. and Arch. Service in 1960. The station is also called Gilmore Center or Ulaska.

The position was fixed by traverse from survey station NORTH NIMBUS (66 meters) which was positioned by triangulation from USC&GS stations PEDRO (first-order) and CHATHAM (second-order), about five miles north of the site. Several figures and six auxiliary control monuments were used to bring control into the valley of the site.

Azimuth checks were within the specified 5 seconds. Solar observations were within two seconds of triangulation azimuth.

Elevation is referred to bench marks of unknown accuracy. The probable error of the elevation given in the report for station PEDRO is high, according to USC&GS. Station NORTH NIMBUS (elev. 294.4 m) is 13 m lower than the X-axis.

Geoid height from TOPOCOM geoid charts 1967.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	11 meters
Vertical	5 meters	5 meters

REFERENCES

Site Survey Report - Δ ULASKA, Philleo E&A, 31 July 1963.

Station No. S85 4

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

S85 4

Location Orroral, Australian Capital Territory

Equipment 85-foot X-Y antenna

Agency NASA-Goddard Space Flight Center

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 35° 37' 52".8542	Latitude	- 35° 37' 47".22
Longitude (E)	148 57 20.9076	Longitude (E)	148 57 31.95
Datum	Australian Geodetic	Based on	second-order obs 1964/5 by Div. of Nat. Mapping at Δ OR.LAP. 76.4 m South of antenna

Elevation above mean sea level 938.0 meters

Geoid height + 9.3 meters

Height above ellipsoid 947 meters

AZIMUTH DATA

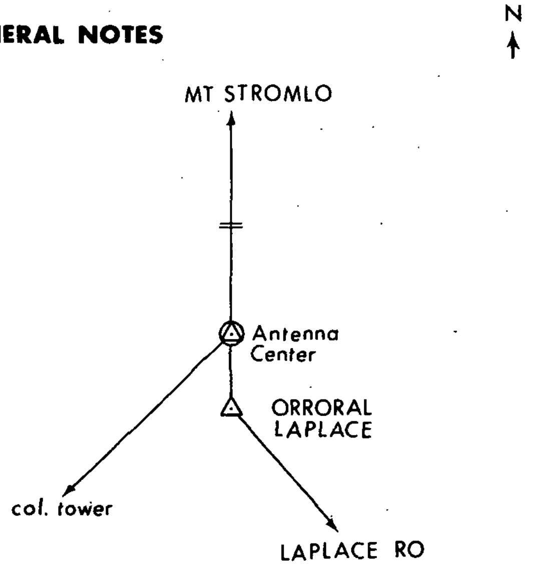
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ Antenna Center	col. tower	1753.0	245° 09' 50".47
Laplace	Δ ORRORAL LAPLACE	Δ LAPLACE RO	2987.07	156 32 46.32
Astronomic	Δ ORRORAL LAPLACE	Δ LAPLACE RO		156 32 40.19

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by the Survey Branch, Department of Interior, Canberra, April-July 1966. The geodetic position of the center of the 6 supporting piers was determined by closed loops of second-order Tellurometer traverse from Δ MT STROMLO of the National Geodetic Survey.

The elevation is based on mean sea level at Sydney from which spirit leveling was extended into the area. The X-axis is about 13 m above the base. The mean elevation of the tops of the six supporting piers is 924.85 m.

Geoid height from Mather et al, IUGG Moscow 1971.



DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	5 meters
Vertical	1 meters	1 meters

REFERENCES Geodetic Information for Space Tracking Stations in Australia, Div. of National Mapping, August 1969.

Station No. S85 6

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Kashima, Japan

Equipment 85-foot Az-El antenna

Agency Radio Research Laboratories, Ministry of Posts and Telecommunications

S85 6

Point referred to intersection of rotation axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 57' 03".202	Latitude	
Longitude (E)	140 39 57.834	Longitude (E)	
Datum	Tokyo	Based on	

Elevation above mean sea level 45.149 meters   Geoid height + 3 meters   Height above ellipsoid 48 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	ref. point 26-m ant	ref. pt. col.twr.	3159.83	128° 25' 25"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

This Applications Technology Satellite antenna is 90 km ENE of Tokyo. (Address: Hirai, Kashima-machi, Ibaraki Prefecture.) Near this 26-m parabaloid antenna are a 30-m parabaloid and a Yagi antenna, not used for precise tracking. The 26-m antenna has an Az-El mount with a common point of rotation of the axes.

The local survey, by Hasshu Surveying Co. Ltd. in June 1968, was by triangulation from stations TAKAMAGAHARA (first-order) and IGIRI (third-order). Elevation was from Δ OHFUNATSU.

Geoid height from TOPOCOM geoid map of Tokyo Datum 1968.

DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.01 meters	1 meters
Vertical	0.01 meters	1 meters

REFERENCES

"Present Status of Kashima Earth Station" 1968, Rad. Res. Lab., Japan; letter Nat'l Space Dev. Agency, 16 March 1970.

40-foot Antennas

Station No. S40 1

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes

Location Gilmore Creek, Alaska

Equipment 40-foot antenna

Agency NASA-Goddard Space Flight Center

S40 1

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	64° 58' 36".926	Latitude	
Longitude (E)	212 28 53.999	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 297 meters Geoid height + 2 meters Height above ellipsoid 299 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ FATS	Δ NECT	794.39	204° 38' 32".0
Geodetic	Δ FATS	North Azimuth		359 59 58.92

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Facilities Construction Branch, GSFC, in 1966. Gilmore and Rose Creek area, near Fairbanks.

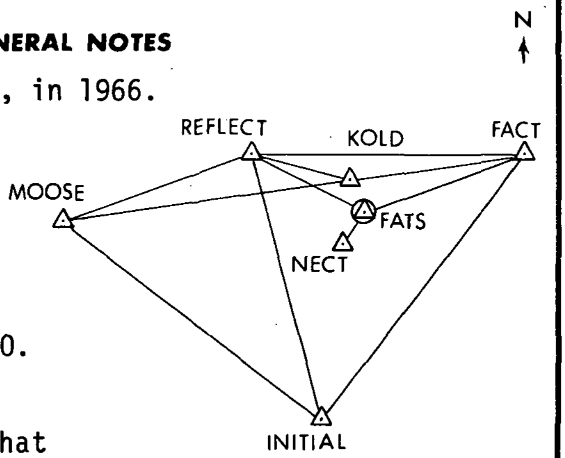
The station is marked by a punch hole at the center of an etched cross on a NASA-GSFC brass tablet stamped "FATS 1966," in the concrete floor at the center of the foundation of the antenna.

The position was established by a high precision closed geodimeter traverse from NASA stations REFLECT and FACT, with closures better than 1:60,000. These were in turn set by triangulation from C&GS first-order stations INITIAL and MOOSE with a maximum closure error of 1".65. The survey is part of that for the Minitrack and related to that for the R&RR in 1965.

Elevations on Δ KOLD and Δ FATS (290.057 m) were by levels from Δ ULASKA, previously tied to C&GS bench marks. The X-axis of this type of antenna is 7 m above the foundation.

Monuments in this area are subject to frost movement.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.5 meters	11 meters
Vertical	1 meters	2 meters

REFERENCES

Geodetic Survey Report for Alaska STADAN, GSFC 1966.

Station No. S40 2

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes

Code Name

Location Johannesburg, Republic of South Africa Equipment 40-foot antenna

Agency NASA-Goddard Space Flight Center

S40 2

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 25° 53' 09".16	Latitude	ξ = - 3.4
Longitude (E)	27 42 27.93	Longitude (E)	η = + 3.7
Datum	Cape (Arc)	Based on	third-order obs at Δ MTS, 340 m west of antenna

Elevation above mean sea level 1537 meters Geoid height meters Height above ellipsoid meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ CENTER MON. (40-ft. ant.)	Δ CENTER MON. (Minitrack)	317.00	0° 00' 00"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by I. B. Watt, L.S., for National Institute of Telecom. Research in 1961.

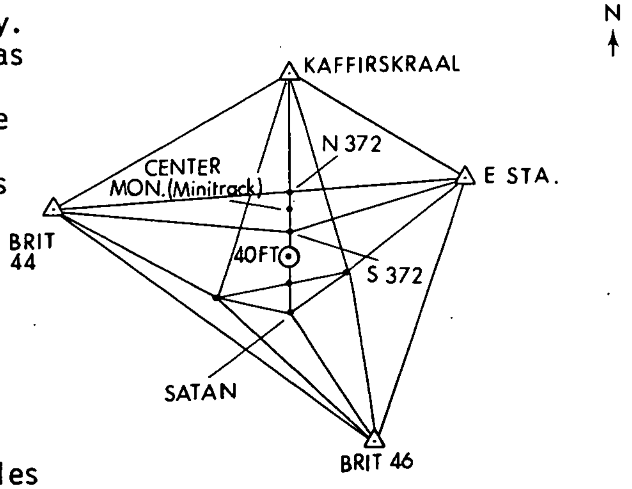
Position is based on preconstruction survey. Position of Δ CENTER MONUMENT (40-ft. ant.) was fixed by precise chaining from Δ CENTER MONUMENT (Minitrack) and Δ S372. Results were checked by triangulation as shown in diagram. This survey is directly connected with surveys for nearby Minitrack and Deep Space stations.

Elevation of the monument is given as 1530 ± 3 m. The height to X-axis from foundation for this type of antenna is 7 m.

Elevations near the antenna are:

S372 ..... 4998.68 ft. (1523.60 m)
N100 ..... 5016.26 ft. (1528.96 m)
BT .... 5050.49 ft. (1539.39 m)

Elevations were determined by vertical angles from trig elevations of the five control stations.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	3 meters
Vertical	3 meters	4 meters

REFERENCES

Ltr. Halberstadt, Dent, & Course, Johannesburg, to National Institute for Telecom. Research, 15 January 1964.

Station No. S40 3

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Code Name ______

Other Codes ______

Location Quito, Ecuador

Equipment 40-foot antenna

Agency NASA-Goddard Space Flight Center

S40 3

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 00° 37' 22".109	Latitude	- 00° 37' 21".90 ± 0".1
Longitude (E)	281 25 11.277	Longitude (E)	281 25 03.40 ± 0.2
Datum	South American 1969	Based on	first-order IAGS obs 1956 200 m from antenna

Elevation above mean sea level 3570 meters

Geoid height + 24.3 meters

Height above ellipsoid 3594 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ 40-FT ANT.	Δ MINITRACK CEN	211	77° 29' 29"
Geodetic	Δ 40-FT ANT.	Δ COL. TOWER	394.8	94 12 33

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Facilities Construction Branch, GSFC.

The tablet in the foundation of the 40-ft tower was located with third-order accuracy in reference to Δ MINITRACK at the center of the Minitrack array. (See Station No. MIN 6.) Elevation was by levels from Δ MINITRACK CENTER. The survey mark (elev. 3563.0 m) is about 7 m below the X-axis.

Geoid height from CHUA base, TOPOCOM 1971.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	8 meters
Vertical	1 meters	2 meters

REFERENCES

GSFC position sheet; Geodetic Summary, USATOPOCOM May 1971.

Station No. S40 4

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes

Code Name

Location Santiago, Chile

Equipment 40-foot antenna

Agency NASA-Goddard Space Flight Center

S40 4

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 33° 09' 04.″070	Latitude	- 33° 09' 14.″7
Longitude (E)	289 19 56.402	Longitude (E)	289 19 32.0
Datum	South American 1969	Based on	first-order obs by IAGS 1956 at Δ PELDEHUE, 211 m S.

Elevation above mean sea level 702.3 meters

Geoid height + 26.2 meters

Height above ellipsoid 729 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by construction contractor and checked by personnel of Facilities Construction Branch, GSFC, March 1963.

The station was located from Δ PELDEHUE (at the center of the Minitrack array) with third-order accuracy. (See Station No. MIN 10.)

Elevation was by plane-table alidade method with fourth-order accuracy, estimated to be ± 0.5 ft. in relation to the trig elevation of Δ PELDEHUE. The survey mark (elev. 695.3 m) is about 7 meters below the intersection of the axes.

Geoid height from CHUA base, TOPOCOM 1971.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	7 meters
Vertical	2 meters	3 meters

REFERENCES

Position Sheet NASA-GSFC; Geodetic Summary USATOPOCOM August 1971.

Station No. S40 5

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Goldstone, California

Equipment 40-foot antenna

Agency NASA-Goddard Space Flight Center

S40 5

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 19' 53"970	Latitude	ξ = - 2" ± 2"
Longitude (E)	243 06 47.762	Longitude (E)	η = - 4 ± 3
Datum	NAD 1927	Based on	mean of deflections at Pioneer and Echo antennas

Elevation above mean sea level 940 meters

Geoid height - 22 meters

Height above ellipsoid 918 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ 40-FT ANTENNA	Δ LAKE	1151.67	260° 56' 55"
Geodetic	Δ 40-FT ANTENNA	Δ COL. TOWER	3536.09	310 17 38

DESCRIPTION OF SURVEYS AND GENERAL NOTES

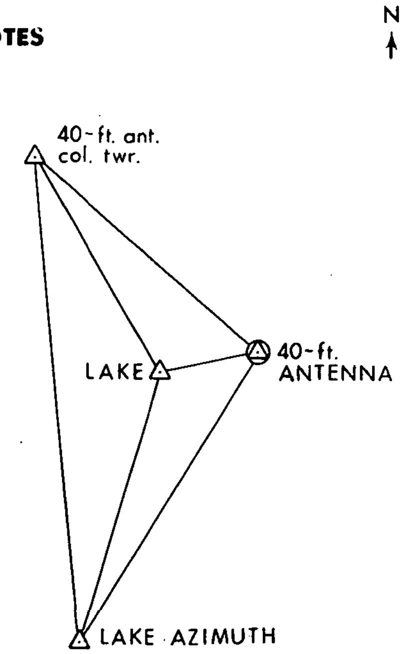
This is an Applied Technology Satellite facility.

Surveyed by Facilities Construction Branch, GSFC, in 1964. The center is marked by an unstamped disk at ground level.

The geographic position was established by third-order triangulation based on two AMS first-order stations established in 1960, LAKE and LAKE AZIMUTH.

Elevation of Δ 40-FT ANTENNA (933.3 m) was determined by spirit leveling from Δ LAKE, whose elevation was determined by vertical angles in the 1960 survey. The X-axis is estimated to be about 7 meters above the mark.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	4 meters
Vertical	2 meters	3 meters

REFERENCES

Facilities Construction Branch, GSFC, Position Sheet, May 1964.

Station No. S40 6

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Code Name

Other Codes

Location Tananarive, Madagascar

Equipment 40-foot antenna

Agency NASA-Goddard Space Flight Center

S40 6

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 19° 00' 34".40	Latitude	
Longitude (E)	47 18 05.66	Longitude (E)	
Datum	Tananarive	Based on	

Elevation above mean sea level 1385.2 meters — Geoid height ___ meters — Height above ellipsoid ___ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Ant. Ref. Pt.	Δ ANTONGONA		344° 52' 57"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

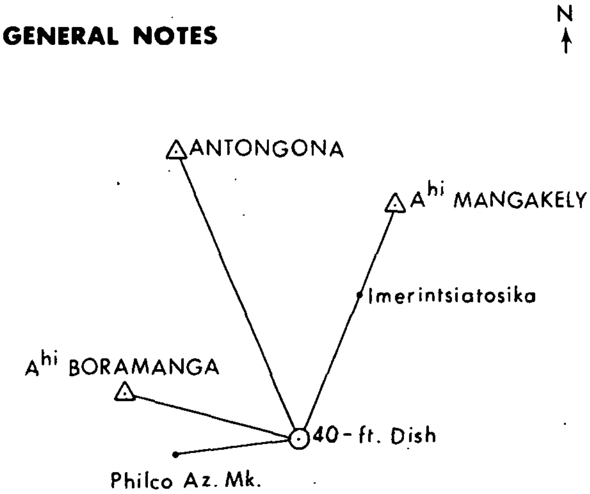
Surveyed by Institut Geographique National, Paris, Annexe de Tananarive (H. Monge), 1966.

Located with third-order accuracy from Δ MINITRACK CENTER, with a check from three triangulation stations used in the Minitrack Survey. (See Station MIN 14.)

Madagascar is not connected geodetically to a major datum. The local datum is based on a single astronomic observation at the observatory at Tananarive.

Elevation is third-order from previously established elevation in Minitrack array.

The brass plug in the foundation floor (elev. 1378.167) is 7 meters below the X-axis.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.5 meters	1 meters
Vertical	< 1 meters	1 meters

REFERENCES

Ltr. Dir. IGN, Paris, A. de Tan., 29 August 1966; Report IGN, Paris, A. de Tan., July 1966.

Station No. S40 7

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Code Name

Location Greenbelt, Maryland

Equipment 40-foot antenna

Agency NASA-Goddard Space Flight Center

S40 7

Point referred to intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	38° 59' 59".645	Latitude	ξ = -1".5
Longitude (E)	283 09 29.959	Longitude (E)	η = +6.2
Datum	NAD 1927	Based on	first-order obs. by NOS 1962 at Δ Goddard, 3 km N of antenna

Elevation above mean sea level 54.69 meters — Geoid height + 1 meters — Height above ellipsoid 52 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ 40-ft.Ant.Cen.	Δ North 2	145.464	359° 59' 59".5
Geodetic	Δ 40-ft.Ant.Cen.	Δ BARF	407.108	173 36 34.85
Astronomic	Δ 40-ft.Ant.Cen.	Δ BARD		173 36 32.85

DESCRIPTION OF SURVEYS AND GENERAL NOTES

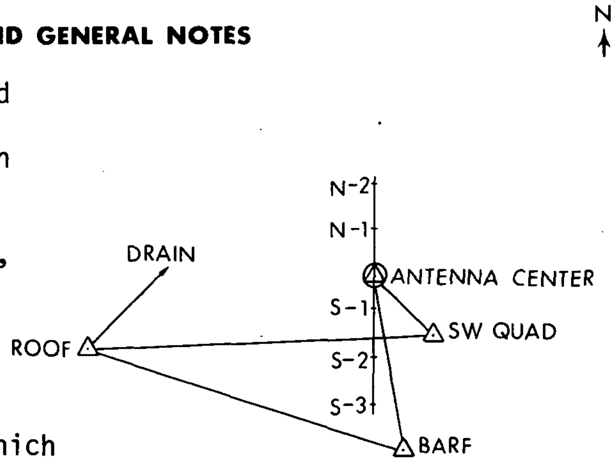
This antenna is at the GSFC Network Test and Training facilities (NTTF).

The position is marked by a punch hole in an etched cross in a brass tablet 3.240 m directly below the intersection of the X-Y axis.

The local survey by Field Facilities Branch, GSFC, in September 1966, was based on third-order control established by USNOO. The local survey was done to first-order standards in expectation that the area control will soon be upgraded.

Elevation was taken from Δ MICRO (USNOO), which is believed to be of third-order accuracy, and is referred to the WSSD datum (elev. of survey tablet in base of antenna is 51.446 m).

Geoid height from TOPOCOM geoid charts 1967.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	< 1 meters	1 meters

REFERENCES

Geodetic Survey Report, Field Facilities Branch, GSFC, September 1968.

Minitrack Stations

Station No. MIN 1

Code Name ______

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 13; NGSP 1013

Location: Fairbanks, Alaska

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 1

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1033)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	64° 52' 19".721	Latitude	
Longitude (E)	212 09 47.168	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level: 162.7 meters

Geoid height: + 2 meters

Height above ellipsoid: 165 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

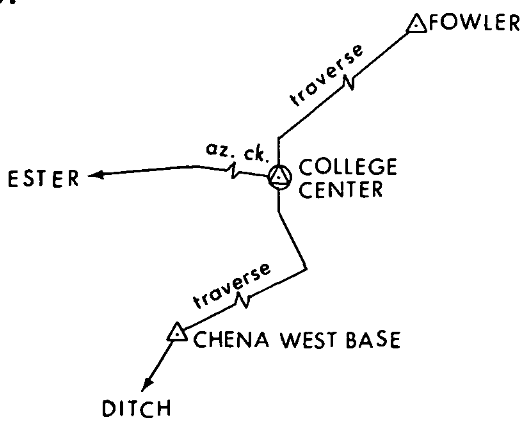
Surveys performed by Philleo Engr'g & Architectural Service, 1959.

Position of survey mon. COLLEGE CENTER, directly under camera center, was established by taped traverse from CHENA WEST BASE (C&GS first-order 1941) to FOWLER (C&GS second-order 1944), a distance of 4400 meters. Closure: 39 sec. in azimuth, 0.4 m in length; ratio 1:10,700.

Station is marked by 2 inch brass disk in top of 1.5 inch pipe.

The camera axis is 2.18 meters above the center monument.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	11 meters
Vertical	1 meters	2 meters

REFERENCES

Geodetic and Astronomic Positions for NASA Satellite Tracking Stations, AMS 9/63.

Station No. MIN 2

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NGSP 1036

Location Fairbanks, Alaska Equipment Minitrack

Agency NASA-Goddard Space Flight Center

MIN 2

Point referred to center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1036)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	64° 58' 38".600	Latitude	
Longitude (E)	212 28 40.898	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 289.55 meters Geoid height + 2 meters Height above ellipsoid 292 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ KOLD	Δ REFLECT	3668.295	286° 44' 44".92
Geodetic	Δ KOLD	Δ NORTH AZ		359 59 57.63

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Facilities Construction Branch, GSFC 1966.

Gilmore and Rose Creek area, near Fairbanks.

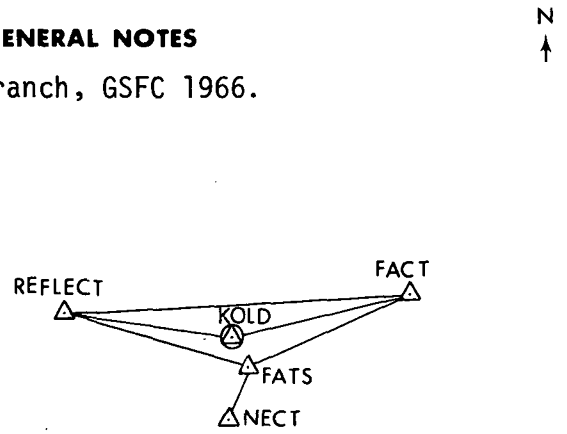
Station is marked by punched hole at center of etched cross on NASA brass tablet stamped "KOLD." Position was by closed Geodimeter traverse from NASA stations REFLECT and FACT, which were in turn set by triangulation from first-order C&GS stations INITIAL and MOOSE.

Elevation was by spirit levels to Δ ULASKA, which was tied earlier to C&GS bench marks.

The center of the camera axes is 3.5 m above the reference monument.

Permafrost will degrade the accuracy of the positions within a few years.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.13 meters	11 meters
Vertical	< 1 meters	< 1 meters

REFERENCES

Geodetic Survey Report for Alaska STADAN, Field Facilities Branch, GSFC 1966.

Station No. MIN 3

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 17; NGSP 1017

Location: Goldstone, California

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 3

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1030)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 19' 48".088	Latitude	
Longitude (E)	243 06 02.730	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 929.1 meters

Geoid height - 22 meters

Height above ellipsoid 907 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ LAKE	azimuth mark	3530.55	197° 27' 21".02

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by AMS for NASA in 1960.

Station LAKE, directly under the camera, was established from LEACH (C&GS first-order 1926) with azimuth from TIEFORT and PILOT (both C&GS first-order 1926). Three sides of triangle to LAKE and LAKE Azimuth Mark were measured by Tellurometer (28 fine readings). Sixteen directions were observed for each angle with a Wild T-3. Eighteen additional alignment markers were set.

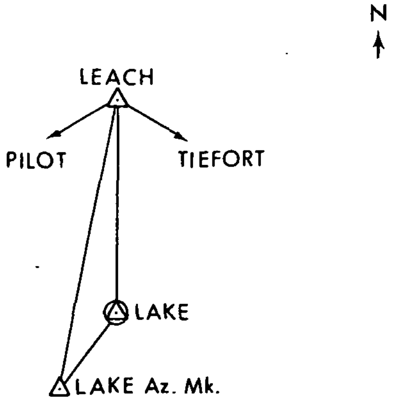
All azimuths are within two seconds of accuracy, and positions within 1:75,000 (AMS).

Elevation of LAKE was determined by vertical angles from trig. elevation of LEACH with p.e. less than one meter.

Station is marked by C of E disc stamped "LAKE," set in 8-inch diameter concrete post flush with ground.

The camera center is 1.71 meters above the center monument.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	< 1 meters	2 meters

REFERENCES

Geodetic and Astronomic Positions for NASA Satellite Tracking Stations, AMS 9/63.

Station No. MIN 4

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 14; NGSP 1014

Location East Grand Forks, Minnesota

Equipment Minitrack

Agency NASA-Goddard Space Flight Center

MIN 4

Point referred to center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1034 and 7034)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	48° 01' 21".403	Latitude	
Longitude (E)	262 59 21.561	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 252.58 meters

Geoid height + 3 meters

Height above ellipsoid 256 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ NORTHLAND	azimuth mark	800	251° 03' 40".38
Geodetic	Δ NORTHLAND	Δ S372	113.603	180 00 00

DESCRIPTION OF SURVEYS AND GENERAL NOTES

See Station No. 7034. This station was transferred to the Special Optical Network, 1 September 1966.

Geoid height from TOPOCOM geoid charts 1967.

DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	3 meters
Vertical	< 1 meters	1 meters

REFERENCES

Geodetic and Astronomic Positions for NASA Satellite Tracking Stations, AMS 9/63.

Station No. MIN 5

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 3; NGSP 1003

Location: Fort Myers, Florida

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 5

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1022)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	26° 32' 51".891	Latitude	26° 32' 54".21 ± 0".37
Longitude (E)	278 08 03.926	Longitude (E)	278 08 05.63 ± 0.63
Datum	NAD 1927	Based on	second-order obs AMS 1959 at station

Elevation above mean sea level: 4.81 meters   Geoid height: + 16 meters   Height above ellipsoid: 21 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Astronomic	Δ MYERS CENTER	azimuth mark	300	314° 17' 29".12
Laplace	Δ MYERS CENTER	azimuth mark		314 17 28.36

DESCRIPTION OF SURVEYS AND GENERAL NOTES

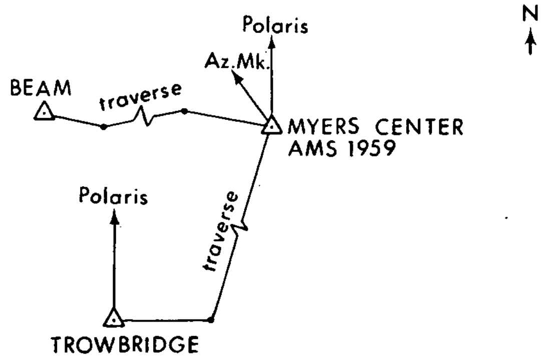
Surveys performed by Army Map Service, September, 1959.

Position of station MYERS CENTER, directly under the camera center, was established by third-order traverse from Δ TROWBRIDGE (C&GS first-order 1934) to Δ BEAM (C&GS second-order 1955), a distance of 8200 m. Azimuth closure from Polaris observation at Δ TROWBRIDGE to C&GS azimuth at Δ BEAM was 20 seconds, linear error 0.1 m, closure ratio 1:103,000.

Elevation of survey station was established by AMS (fourth-order).

The center monument is a CE disk stamped Δ MYERS CENTER AMS 1959. It is flush with the concrete platform. The camera axis is 1.23 m above the center monument. Azimuth mark is CE disk in concrete five inches above ground.

Sixteen additional orientation monuments were set by AMS at this time.



Geoid height from TOPOCOM geoid charts 1967.

DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	6 meters
Vertical	1 meters	1 meters

REFERENCES

Geodetic and Astronomic Positions for NASA Satellite Tracking Stations, AMS 9/63.

Station No. MIN 6

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes COSPAR 5
NGSP 1005

Location Quito, Ecuador

Equipment Minitrack

Agency NASA-Goddard Space Flight Center

Point referred to center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1025)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 00° 37' 20".621	Latitude	- 00° 37' 20".41 ± 0".10
Longitude (E)	281 25 17.939	Longitude (E)	281 25 10.06 ± 0.16
Datum	South American 1969	Based on	first-order obs IAGS 1956 at station

Elevation above mean sea level 3568.6 meters

Geoid height + 24.3 meters

Height above ellipsoid 3593 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ MINITRACK	Δ RUMINAHUI	7122.404	75° 05' 04".4

DESCRIPTION OF SURVEYS AND GENERAL NOTES

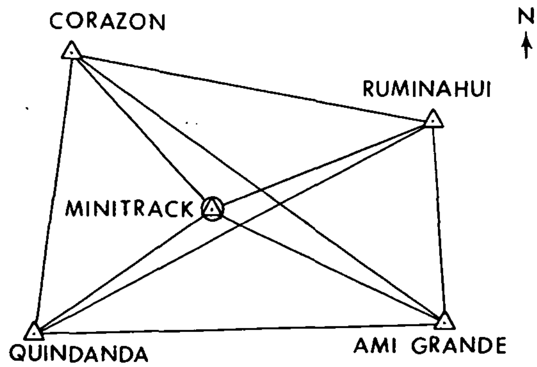
Surveys performed by IAGS and IGM Ecuador in 1957.

Position of mon. MINITRACK was fixed by first-order triangulation from first-order stations of the IGM-IAGS triangulation network of Ecuador. A center-point figure was formed from stations CORAZON, RUMINAHUI, QUINDANDA, and AMI GRANDE; 16 directions were observed for each station with a Wild T-3.

Elevation, determined by vertical angles from trig elevations of the four base stations, is within one meter with respect to local control, and within two meters referred to mean sea level.

Station and azimuth mark are marked by IAGS bronze disks in concrete blocks flush with ground, stamped "MINITRACK ECUADOR 1956" and "MINITRACK AZIMUTH 1956 ECUADOR" respectively. Camera center is 1.21 m above center monument MINITRACK.

Geoid height from CHUA base, TOPOCOM 1971.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	8 meters
Vertical	1 meters	2 meters

REFERENCES

Geodetic Information Report and Summary, USATOPOCOM May 1971.

Station No. MIN 7

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 6; NGSP 1006

Location: Lima, Peru

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 7

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1026)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 11° 46' 34".982	Latitude	- 11° 46' 44".49 ± 0".07
Longitude (E)	282 51 01.627	Longitude (E)	282 50 27.76 ± 0.12
Datum	South American 1969	Based on	first-order IAGS obs 1956 at station

Elevation above mean sea level: 49.9 meters

Geoid height: + 9.3 meters

Height above ellipsoid: 59 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ VANGUARD	Δ PAREDES	6893.930	115° 04' 51".61
Astronomic	Δ VANGUARD	Δ PAREDES		115 04 58.52

DESCRIPTION OF SURVEYS AND GENERAL NOTES

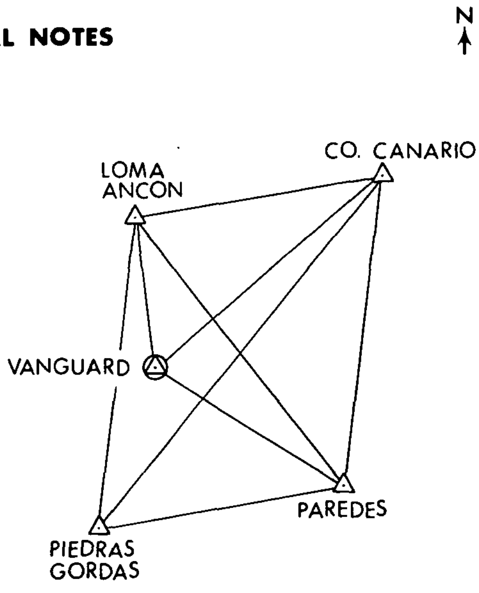
Surveys performed by IAGS and IGM Peru 1956.

Position of center monument VANGUARD was fixed by first-order triangulation from first-order stations of IGM-IAGS triangulation network of Peru. From base stations CO. CANARIO and PIEDRAS GORDAS 16 directions were observed with a Wild T-3 at each station for two quadrilaterals.

Mark for station was cross in nail-head in wooden stake, to be replaced by permanent mark after construction. Four reference marks (IAGS bronze discs) were set 5 to 12 m from VANGUARD.

Elevation was determined by vertical angles from trigonometric elevations of the base stations. The camera axis is 1.21 m above the center monument.

Geoid height from CHUA base, TOPOCOM 1971.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	7 meters
Vertical	1.2 meters	2 meters

REFERENCES

Geodetic Information Report and Summary, USATOPOCOM May 1971.

Station No. MIN 8

Code Name 1BPOIN

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 1; NGSP 1001

Location: Blossom Point, Maryland

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 8

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1021)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	38° 25' 49".628	Latitude	
Longitude (E)	282 54 48.225	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level 5.76 meters

Geoid height + 1 meters

Height above ellipsoid 7 meters

AZIMUTH DATA

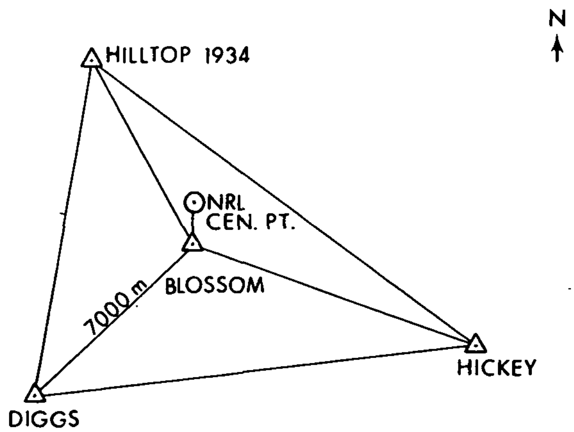
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Astronomic	Δ BLOSSOM	azimuth mark	305	20° 36' 21".76
Laplace	Δ BLOSSOM	azimuth mark		20 36 17.10
Geodetic	Δ BLOSSOM	Δ DIGGS	6998.21	228 12 05.91

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Survey by C&GS 1956. Monument NRL CENTER POINT 1956 (1.23 m directly below camera axis) was set from first-order C&GS station BLOSSOM (500 feet away). Δ BLOSSOM was set by first-order triangulation from C&GS stations HILLTOP, HICKEY and DIGGS.

Elevation by AMS third-order levels to USED BM 1460, about two miles south of the Minitrack center.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	< 1 meters	1 meters

REFERENCES

Vanguard Positions, AMS report (undated).

Station No. MIN 9

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Greenbelt, Maryland

Equipment Minitrack

Agency NASA-Goddard Space Flight Center

MIN 9

Point referred to center of array at elevation of ground screen (coincident with center of camera axes - NGSP 7077)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	38° 59' 56".73	Latitude	ξ = - 1.5
Longitude (E)	283 09 37.31	Longitude (E)	η = + 6.2
Datum	NAD 1927	Based on	first-order obs C&GS 1962 at Δ GODDARD 3 km north of station

Elevation above mean sea level 50.85 meters — Geoid height + 1 meters — Height above ellipsoid 52 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ MICRO	Δ HAR	80.7	225° 05' 13".6
Geodetic	Δ MICRO	Δ ROOF	852.2	264 33 26.6

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Naval Oceanographic Office, November 1966. The position of survey monument MICRO (1.11 meters below the center of the ground screen) was determined by third-order triangulation and traverse based on stations ROOF (NOO), CEDAR 2, ORDNANCE, RENO, and the Washington Monument. The elevation of Δ MICRO is 163.19 feet on the Washington Suburban Sanitary Datum, which is within a few cm of SLD 1929.

Geoid height from TOPOCOM geoid charts 1967.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	< 1 meters	1 meters

REFERENCES

Naval Oceanographic Office survey sta. card No. 306295.

Station No. MIN 10

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 8; NGSP 1008

Code Name

Location: Santiago, Chile

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 10

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1028)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 33° 08' 57".242	Latitude	- 33° 09' 07".87 ± 0".10
Longitude (E)	289 19 56.402	Longitude (E)	289 19 31.99 ± 0.10
Datum	South American 1969	Based on	first-order obs IAGS 1956 at station

Elevation above mean sea level 693.4 meters | Geoid height + 26.2 meters | Height above ellipsoid 720 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ PELDEHUE	Azimuth mark	1000 ±	324° 08' 24".1
Astronomic	Δ PELDEHUE	Azimuth mark		324 08 38.37

DESCRIPTION OF SURVEYS AND GENERAL NOTES

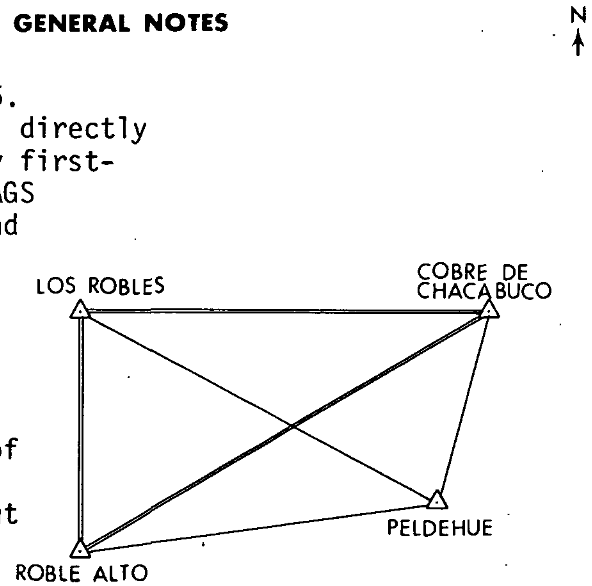
Surveys performed by IAGS and IGM Chile, 1956.

The position of the center monument PELDEHUE, directly below the center of the camera axis, was fixed by first-order triangulation from three first-order IGM-IAGS triangulation stations, ROBLE ALTO, LOS ROBLES and COBRE DE CHACABUCO. Sixteen directions were observed at each station with a Wild T-3.

Elevation was determined by vertical angles from three horizontal control stations. The camera axis is 1.23 m above the center mon. (elev. 692.2 m).

Station is marked by IGM bronze disk in top of concrete block, and is stamped "PELDEHUE 1956." IGM bronze plugs in concrete blocks were set about 28 m distant at the cardinal points, and as a subsurface mark.

Geoid height from CHUA base, USATOPOCOM 1971.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.43 meters	7 meters
Vertical	1.3 meters	2 meters

REFERENCES

Geodetic Information Report and Summary, USATOPOCOM August 1971.

Station No. MIN 11

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 12; NGSP 1012

Code Name

Location: St. John's, Newfoundland, Canada

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 11

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1032)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	47° 44' 29".739	Latitude	
Longitude (E)	307 16 43.369	Longitude (E)	
Datum	NAD 1927	Based on	

Elevation above mean sea level: 69 meters

Geoid height: + 37 meters

Height above ellipsoid: 106 meters

AZIMUTH DATA

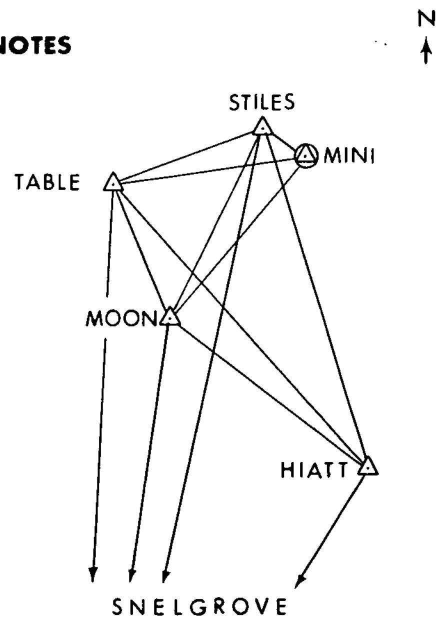
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ HIATT	Δ STILES	6500	344° 54' 25".40
Astronomic	Δ HIATT	Δ STILES	6500	344 54 32.57±0".49

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Geodetic Survey of Canada, 1959.

Triangulation for MINI, a survey mon. 1.95 m below the camera center, was based on two secondary occupied positions, SNELGROVE (GSC) and HIATT (USC&GS 1942) in a local network which included three additional observation stations, TABLE, STILES and MOON. All lines shown on the diagram were read from both ends; twelve pointings were made for each direction. The maximum correction required in the reduction of the directions was 1.4 seconds. A supporting astronomic azimuth was observed on the line HIATT-STILES, with a seven-second discrepancy which is ascribed to deflection of the vertical. MINI is marked by a bronze tablet set in a 12-inch diameter metal-sheathed concrete monument at ground level.

Elevation was by trigonometric leveling.



Geoid height from TOPOCOM geoid charts 1967.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	8 meters
Vertical	1 meters	3 meters

REFERENCES

Ltr. Defense Construction (1951) Limited, Ottawa to NASA, 10/1/59; Ltr. Dominion Geodesist to GSFC 5/28/64.

Station No. MIN 12

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 15; NGSP 1015

Code Name

Location: Winkfield, England

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1035)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	51° 26' 49".11	Latitude	
Longitude (E)	359 18 14.10	Longitude (E)	
Datum	European	Based on	

Elevation above mean sea level 67.37 meters | Geoid height - 6.4 meters | Height above ellipsoid 61 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ CENTRE MON.	Pillar "B"	115.60	225° 48' 14"

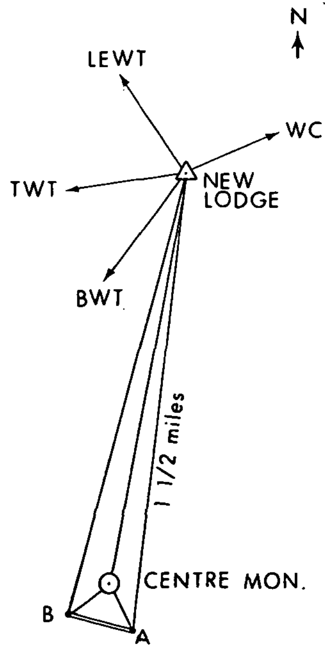
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by Ordnance Survey, June 1960.

Azimuth from NEW LODGE, a triangulation station of the Ordnance Survey, to Δ CENTRE MON. was set by 16 measurements from TILEHURST WTR TWR (16 mi) and LAND END WTR TWR (12-1/2 mi), secondary stations (positions better than 0.1 m). The distance of Δ CENTRE MON. to Δ NEW LODGE was measured by Tellurometer four times. Station N372 was set from Δ CENTRE MON. on four arcs from Δ NEW LODGE; the 11 other main line Minitrack points were referenced to N372 (2 arcs). Distance measurements were made with base line equipment and care to .001 ft accuracy. Reference pillars A and B were set about 450 ft from Δ CENTRE MON. and each other. A to B was measured as a base line and angles on four arcs were turned to and from Δ NEW LODGE, Δ CENTRE MON., A and B. Conversion to European Datum by AMS.

The camera center is 1.71 m above the center monument. Leveling was from bench marks about 400 yards away to normal Ordnance Survey standards.

Geoid height from G. Bomford's geoid chart of Europe, N. Africa and S.W. Asia, February, 1971.



DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	3 meters
Vertical	< 1 meters	1 meters

REFERENCES

"Winkfield Survey," Director General, Ordnance Survey 6/21/60.

Station No. MIN 13

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 16; NGSP 1016

Location: Johannesburg, Republic of South Africa

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 13

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1031)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 25° 52' 58".862	Latitude	
Longitude (E)	27 42 27.931	Longitude (E)	
Datum	Cape (Arc)	Based on	

Elevation above mean sea level 1522.3 meters   Geoid height ______ meters   Height above ellipsoid ______ meters

AZIMUTH DATA

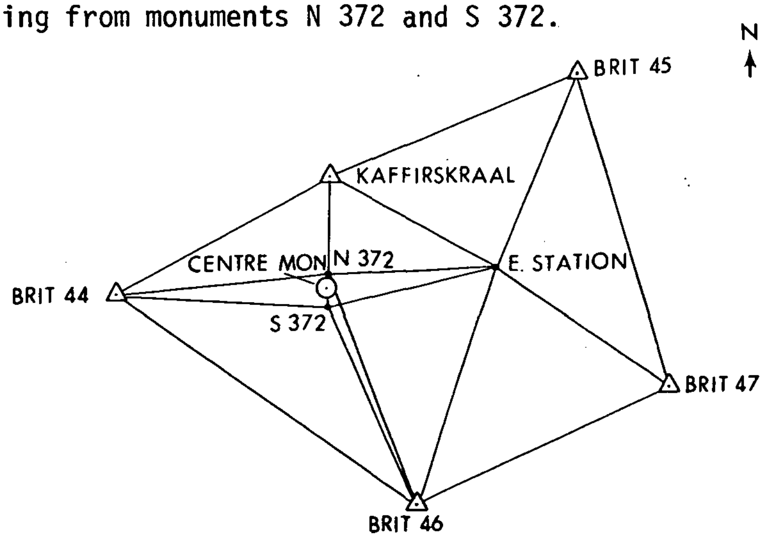
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ CENTRE MON.	Δ N 372	113.60	0° 0' 0"
Astronomic	Δ CENTRE MON.	Δ N 372		0 0 01 ± 2"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by I. B. Watt, LS., 1961 for Nat. Inst. for Telecom. Research. Position was fixed by precise chaining from monuments N 372 and S 372. These were fixed by intersection from one secondary (KAFFIRSKRAAL) and four tertiary stations of the basic Trig Survey net, and an additional point, E STATION. This survey is directly connected with surveys for adjacent Deep Space stations of NASA-JPL.

Elevation was determined by vertical angles from trigonometric elevations of the five stations.

The camera center is 1.73 m above the center monument.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	3 meters
Vertical	3 meters	4 meters

REFERENCES

Ltr. Halberstadt, Dent & Course, J'bg. to Nat'l Inst. for Telecommunications Res., J'bg. RSA 1/15/64.

Station No. MIN 14

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NGSP 1023

Code Name

Location Tananarive, Madagascar Equipment Minitrack

Agency NASA-Goddard Space Flight Center

MIN 14

Point referred to center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1043)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	-19° 00' 27".097	Latitude	
Longitude (E)	47 18 00.461	Longitude (E)	
Datum	Tananarive	Based on	

Elevation above mean sea level 1377.94 meters Geoid height ___ meters Height above ellipsoid ___ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

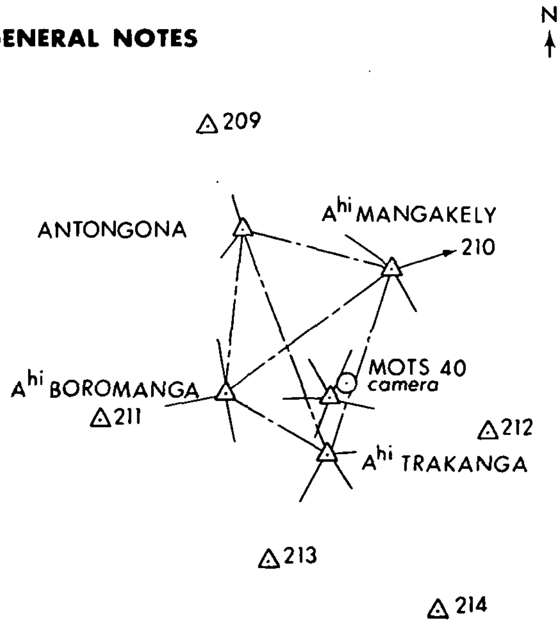
DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveys performed by H. Monge, Institut Geographique National, Paris, Annexe de Tananarive.

Location details are not available; survey sketch is given. H. Monge's notes mention use of a Tellurometer and a Wild T-3 theodolite.

Madagascar is not connected geodetically to a major datum. The local datum is based on a single astronomic observation at Tananarive Observatory.

The camera axis is about one meter above a brass tablet, MINITRACK CENTER.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	1 meters
Vertical	< 1 meters	1 meters

REFERENCES

Memo Plant Engineering Section to Facilities Construction Branch, GSFC 9/26/66. Rept. IGN, Paris, Annexe de Tan., July 1966.

Station No. MIN 15

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 18; NGSP 1018

Code Name

Location: Woomera, Australia

Equipment: Minitrack

Agency: NASA-Goddard Space Flight Center

MIN 15

Point referred to: center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1024)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 31° 23' 30".069	Latitude	- 31° 23' 28".4
Longitude (E)	136 52 11.022	Longitude (E)	136 52 11.0
Datum	Australian Geodetic	Based on	second-order obs 1963 by Div. of Nat. Mapping at Δ E148,650 m from station

Elevation above mean sea level: 132.81 meters   Geoid height: - 1.1 meters   Height above ellipsoid: 132 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ THE KNOLL	Δ CAMPBELL RISE		85° 36' 27".23
Astronomic	Δ THE KNOLL	Δ CAMPBELL RISE		85 36 28.96
Laplace	Δ THE KNOLL	Δ CAMPBELL RISE		85 36 28.29

DESCRIPTION OF SURVEYS AND GENERAL NOTES

This station was moved to Orroral (see Station No. 1038) in 1966.

Survey performed by Dept. of Interior Survey Section, Woomera 1960.

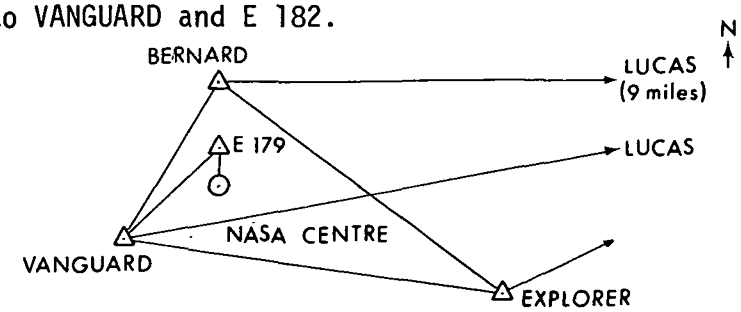
Station is also referred to as "Island Lagoon."

Based on stations BERNARD and LUCAS of first-order triangulation chain of the Australian Army Survey, station VANGUARD was set by a braced quadrilateral to first-order standards. Δ VANGUARD to E 179 was observed to first-order standards, the distance measured by Tellurometer.

Permanent survey marks (brass plugs in concrete) for the Minitrack system were set by precise invar chaining and angle observation. Azimuth is based on repeated astro-azimuth observations from E 179 to VANGUARD and E 182.

Station NASA CENTRE, at the center of the Minitrack array, is 1.71 m below the center of the camera axis. It is 21.00 ft south of Δ E 179 on the astronomic meridian to the azimuth mark, Δ E 182.

MSL at Port Augusta is dubious. Standard error of local levels is about 1 foot. Geoid height from Mather et al, IUGG Moscow 1971.



DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	2 meters
Vertical	< 1 meters	2 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, August 1969.

Station No. MIN 16

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NGSP 1121

Location Orroral, Australia

Equipment Minitrack

Agency NASA-Goddard Space Flight Center

MIN 16

Point referred to center of array at elevation of ground screen (coincident with center of camera axes - NGSP 1038)

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 35° 37' 37".501	Latitude	- 35° 37' 31".9
Longitude (E)	148 57 10.705	Longitude (E)	148 57 21.7
Datum	Australian Geodetic	Based on	second-order obs. by Div. of Nat. Mapping 1964/5 at Δ OR.LAPLACE, 700 m SSE.

Elevation above mean sea level 931.6 meters

Geoid height + 9.3 meters

Height above ellipsoid 941 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	camera center	azimuth mark	655.789	179° 59' 59".81

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Local surveys by Survey Branch, Dept. of Interior, Canberra, October 1966.

The connection to the Nat'l. Geodetic Survey was at MOUNT STROMLO, some 25 miles to the north, by closed loops of second order Tellurometer traverse.

The height of the declination pivot point is 2.243 m above the survey monument.

The elevation is referred to Canberra City Datum.

Geoid height from Mather et al, IUGG Moscow 1971.

DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	< 1 meters	2 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, August 1969.

SATAN Antennas

Station No. SAT 1

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Code Name

Other Codes

Location Rosman, North Carolina Equipment SATAN Antenna

Agency NASA-Goddard Space Flight Center

SAT 1

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 12' 06".124	Latitude	ξ = -9".3
Longitude (E)	277 07 26.363	Longitude (E)	η = +9.1
Datum	NAD 1927	Based on	first-order obs AMS 1962 at ROSMAN I, 400 m SE of the SATAN

Elevation above mean sea level 934.2 meters Geoid height + 6 meters Height above ellipsoid 940 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center of rotation	ATS SATAN col.twr	60.96	115° 25' 00"
Geodetic	center of rotation	Δ N-1 (Ros I)	360.283	86 02 23

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The survey is not described. The position and elevation are given as third-order.

Elevation of the slab is 925.07 m. The X-axis is 9.17 m above the slab, the Y-axis is 9.72 m above the slab.

The data were compiled by Field Facilities Branch, GSFC. (See Station No. S85 1.)

Geoid height from TOPOCOM geoid charts, 1967.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	4 meters
Vertical	1 meters	1 meters

REFERENCES

Position and description sheet, Field Facilities Branch, GSFC, September 1966.

Station No. SAT 2

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Goldstone Lake, California

Equipment: SATAN antenna

Agency: NASA-Goddard Space Flight Center

SAT 2

Point referred to: center of X-axis

GEODETIC COORDINATES

Latitude: 35° 19' 53".973

Longitude (E): 243 06 42.387

Datum: NAD 1927

ASTRONOMIC COORDINATES

Latitude: ξ = -2" ± 2"

Longitude (E): η = -4 ± 3

Based on: mean of deflections at DSN Pioneer and Echo antennas.

Elevation above mean sea level: 936.7 meters

Geoid height: - 22 meters

Height above ellipsoid: 915 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ FFB ATS	Δ N372 (Minitrack)	1003.852	266° 07' 34"
Geodetic	Δ FFB ATS	Δ W-2	114.417	277 00 00

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The position is given as third-order. The survey is not described.

Station FFB ATS was set at the center of the antenna before construction, and was destroyed. Reference marks W-1, W-2, and E-1 are aluminum tablets set in concrete.

Elevation of the center monument (fourth order) was 927.49 m. The X-axis is approximately 9.2 m above it.

Geoid height from TOPOCOM geoid charts, 1967.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control		To Datum Origin	
Horizontal	< 1	meters	4	meters
Vertical	1	meters	1	meters

REFERENCES

Position and description sheet, Field Facilities Branch, GSFC, April 1965.

Station No. SAT 3

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Cooby Creek, Australia

Equipment: SATAN antenna

Agency: NASA-Goddard Space Flight Center

SAT 3

Point referred to: center of rotation

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 27° 23' 50".694	Latitude	
Longitude (E)	151 56 17.151	Longitude (E)	
Datum	Australian Geodetic	Based on	

Elevation above mean sea level: 550 meters | Geoid height: + 1 meters | Height above ellipsoid: 551 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center of rotation	40-foot antenna	28.101	282° 31' 43".2

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The SATAN T&C antenna was the ATS VHF antenna at the facility at Toowoomba, Queensland (now closed).

The position was taken from the site plan, which shows the antenna to be 20 feet south and 90 feet east of the TGS 40-foot mobile antenna. The elevation given is the design elevation of an unidentified point.

Geoid height from Mather et al, IUGG Moscow, 1971.

DATE: September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	5 meters
Vertical	5 meters	5 meters

REFERENCES

Position and description sheet, Physical Plant Engineering Branch, GSFC, June 1971.

Station No. DSN 1

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL 11; APOLLO GDSW; COSPAR GOLDSTONE II

Location: Goldstone, California

Equipment: 85-foot HA-Dec: Pioneer

Agency: Jet Propulsion Laboratory, California Institute of Technology

DSN 1

Point referred to: intersection of axes of rotation

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 23' 22".346	Latitude	ξ = - 1".04 ± 0".17
Longitude (E)	243 09 05.262	Longitude (E)	η = - 6.42 ± 0.15
Datum	NAD 1927	Based on	obs by C&GS 1964 at Δ PIONEER, 100 m from antenna

Elevation above mean sea level 1036.3 meters Geoid height - 22 meters Height above ellipsoid 1014 meters

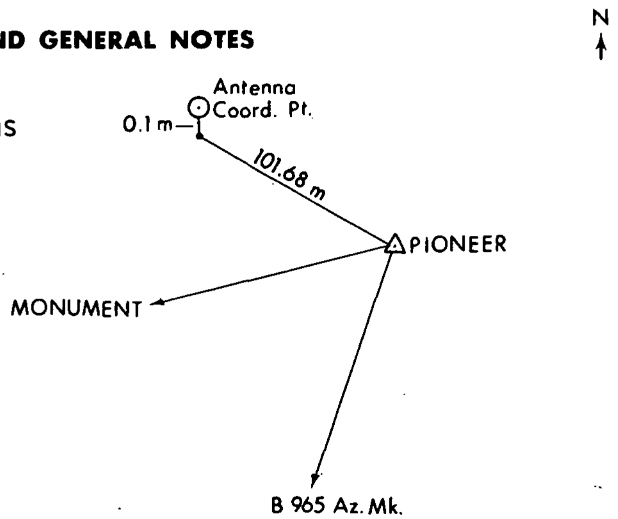
AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic (third-order)	Δ PIONEER	Δ PIONEER AZ MK (= BM B965)	960 ±	198° 04' 27"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The basic first-order triangulation net at Goldstone Test Station, which includes stations PIONEER, BM B965, and MONUMENT, was done by the USC&GS in 1963. C&GS also ran precise leveling over most of the stations. Traverse and level ties from Δ PIONEER to the antenna were made by the Jet Propulsion Laboratory in 1964. The antenna coordinate point is 11.8 meters above Δ PIONEER.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	4 meters
Vertical	0.5 meters	1 meters

REFERENCES

USC&GS records, and JPL Report dated 22 April 1964.

Station No. DSN 2

Code Name ________

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL 12; COSPAR GOLDSTONE III

Location: Goldstone, California

Equipment: 85-foot HA-Dec: Echo

Agency: Jet Propulsion Laboratory, California Institute of Technology

DSN 2

Point referred to: intersection of axes of rotation

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 17' 59".854	Latitude	35° 17' 56".89 ± 0".11
Longitude (E)	243 11 43.414	Longitude (E)	243 11 41.97 ± 0.08
Datum	NAD 1927	Based on	first-order obs C&GS 1964 at Δ ECHO

Elevation above mean sea level: 988.9 meters

Geoid height: - 22 meters

Height above ellipsoid: 967 meters

AZIMUTH DATA

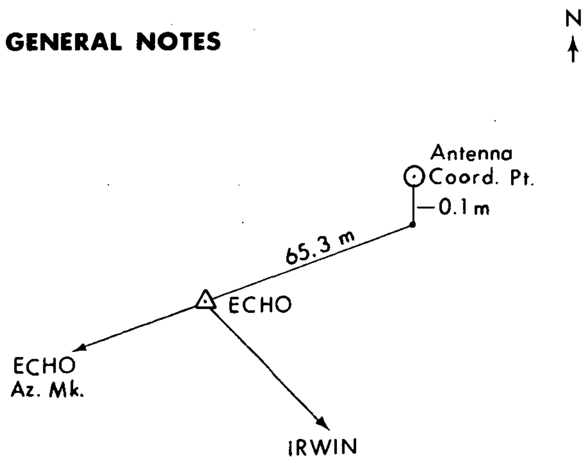
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic (third-order)	Δ ECHO	Δ ECHO AZ MK	720 ±	251° 56' 10"

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The basic first-order triangulation net at the Goldstone Test Station, which included stations ECHO (with its azimuth mark) and IRWIN, was done by USC&GS in 1963. C&GS also ran precise leveling over most of the stations. The traverse and level ties from Δ ECHO to the coordinate point of the antenna were made by the Jet Propulsion Laboratory in 1964.

The antenna coordinate point is 11.7 m above Δ ECHO.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	4 meters
Vertical	0.5 meters	1 meters

REFERENCES

USC&GS records and JPL Report dated 22 April 1964.

Station No. DSN 3

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes JPL 13

Location Goldstone, California

Equipment 85-foot Az-El: Venus

Agency Jet Propulsion Laboratory, California Institute of Technology

DSN 3

Point referred to center of azimuth axis at height of elevation axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 14' 51".788	Latitude	35° 14' 49".04 ± 0".14
Longitude (E)	243 12 21.573	Longitude (E)	243 12 21.24 ± 0.12
Datum	NAD 1927	Based on	first-order obs C&GS 1964 at △ VENUS

Elevation above mean sea level 1093.5 meters

Geoid height - 22 meters

Height above ellipsoid 1072 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	△ VENUS	△ VENUS AZ MK	800 ±	67° 15' 40"*
Geodetic	△ VENUS	center of az axis	71.382	317 49 04

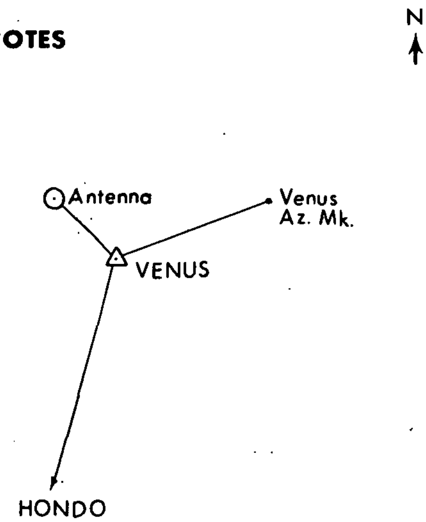
*third-order

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The basic first-order triangulation net at the Goldstone Test Station, which included stations VENUS (with its azimuth mark) and HONDO, was done by the USC&GS in 1963. C&GS also ran precise leveling over most of the stations. The traverse and level ties from △ VENUS to the antenna were made by Jet Propulsion Laboratory in 1964.

The elevation axis is 9.44 m above △ VENUS.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	4 meters
Vertical	0.5 meters	1 meters

REFERENCES

USC&GS records and JPL Report dated 22 April 1964.

Station No. DSN 4

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes JPL 14

Code Name

Location Goldstone, California

Equipment 210-foot Az-El: Mars

Agency Jet Propulsion Laboratory, California Institute of Technology

DSN 4

Point referred to intersection of azimuth and elevation axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	35° 25' 33".340	Latitude	ξ = - 4".8
Longitude (E)	243 06 40.850	Longitude (E)	η = - 5.3
Datum	NAD 1927	Based on	first-order obs C&GS 1964 at Δ MARS

Elevation above mean sea level 1031.8 meters

Geoid height - 22 meters

Height above ellipsoid 1010 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ MARS	Δ MARS AZ MK	1600 ±	169° 52' 26"*
Geodetic	Δ MARS	antenna center	199.67	180 53 18

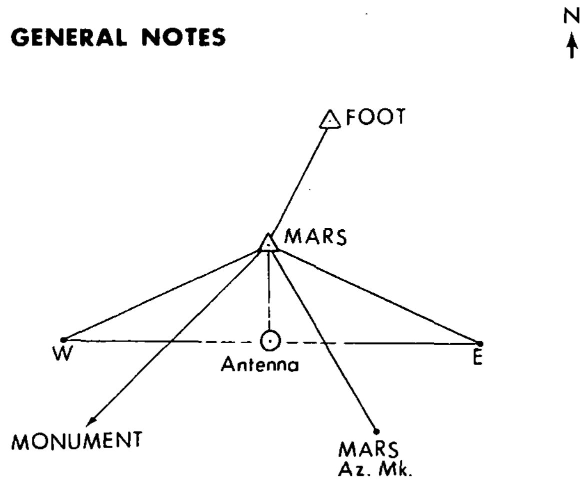
*third-order

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The basic first-order triangulation net at the Goldstone Test Station, which included stations MARS (with its azimuth mark), FOOT, and MONUMENT (USGS), was done by the USC&GS in 1963. C&GS also ran precise leveling over most of the stations. The traverse ties from Δ MARS to the antenna and the two auxiliary marks E and W were made by Teledyne Inc., Geotronics Division, in 1966. The latter organization also determined the elevation of the antenna by vertical-angle observations.

The elevation axis of the antenna is 15.5 m above Δ MARS.

Geoid height from TOPOCOM geoid charts 1967.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.3 meters	4 meters
Vertical	0.5 meters	1 meters

REFERENCES

USC&GS records and report of Teledyne Inc. entitled, "Position of the DSS-14 Antenna," April 11, 1968.

Station No. DSN 5

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL 41; COSPAR 34

Location: Woomera, Australia

Equipment: 85-foot HA-Dec

Agency: Jet Propulsion Laboratory, California Institute of Technology

DSN 5

Point referred to: intersection of polar axis with hour angle gear

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 31° 22' 59".4305	Latitude	- 31° 23' 58".18 ± 0".6
Longitude (E)	136 53 10.1244	Longitude (E)	136 53 09.56 ± 0.6
Datum	Australian Geodetic	Based on	second-order obs by Dept. of Interior at Δ E172.

Elevation above mean sea level 151.59 meters — Geoid height - 1.1 meters — Height above ellipsoid 150 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	antenna center	BS dish center	1392.7*	27° 53' 10"
Geodetic	antenna center	E172	38.80	0 00 01

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The station is referred to as Island Lagoon.

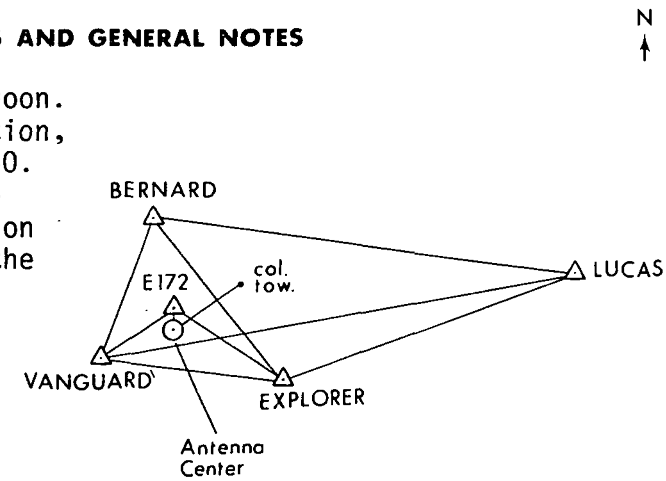
The site was surveyed by the Survey Section, Dept. of Interior, Woomera in September 1960. The geodetic control consists of the first-order scheme shown in sketch. It is based on first-order stations BERNARD and LUCAS of the Australian Army Survey.

The elevation of Δ E172 (137.84 m) is based on railway leveling carried from Port Augusta. The quality of both the leveling and the datum is uncertain.

*Slant range from center of dish foundations to center of dish on boresight tower = 1395.40 m.

Geoid height from Mather et al, IUGG Moscow 1971.

The position of the center of the dish footings is lat. - 31° 22' 59".3594, long. 136° 53' 10".1244.



DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.5 meters	3 meters
Vertical	1 meters	2 meters

REFERENCES Geodetic Information for Space Tracking Stations in Australia, Director Nat. Mapping, Sept. 1969, and JPL Memo 14 March 1969.

Station No. DSN 6

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL 42; APOLLO HSKW

Location: Tidbinbilla, Australian Capital Territory

Equipment: 85-foot HA-Dec

Agency: Jet Propulsion Laboratory, California Institute of Technology

DSN 6

Point referred to: intersection of the polar axis and the plane of the declination axis in the direction of the polar wheel

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 35° 24' 08".0381	Latitude	- 35° 24' 02".24 ± 0".31
Longitude (E)	148 58 48.2057	Longitude (E)	148 58 51.54 ± 0.41
Datum	Australian Geodetic	Based on	second-order obs 1964 by Div. of Natl. Mapping at Δ TIDBINBILLA LAPLACE

Elevation above mean sea level 656.08 meters

Geoid height + 8.4 meters

Height above ellipsoid 664 meters

AZIMUTH DATA

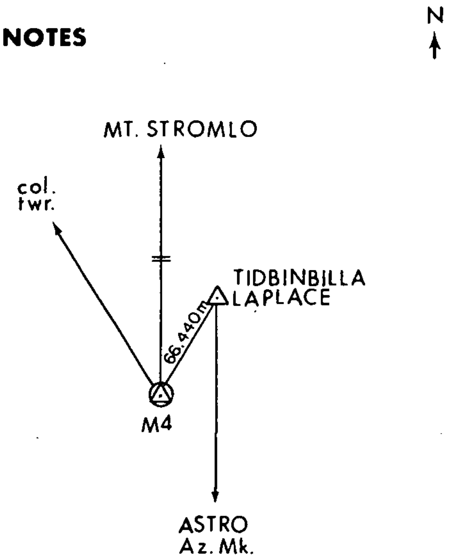
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ M4 (Ant. Ctr.)	col. tower	3577.819	312° 11' 26".29
Geodetic	Δ TID. LAPLACE	Δ ASTRO AZ MK	581	180 00 00.54

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by the Survey Branch, Department of Interior, in August 1964. The center of the antenna is marked by a brass disk, designated M4, 15.075 m directly below the reference point. The geodetic position of this station was determined by closed Tellurometer traverse from Δ MT STROMLO of the National Geodetic Survey.

The elevation is based on the Canberra City Datum. The reference point is 15.075 m above Δ M4 (elev. about 640 m).

Geoid height from Mather et al, IUGG Moscow 1971.



DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	5 meters
Vertical	1 meters	2 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Division of National Mapping, Canberra, July 1969.

Station No. DSN 7

Code Name ______

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL 51; COSPAR 51

Location: Johannesburg, South Africa

Equipment: 85-foot HA-Dec

Agency: Jet Propulsion Laboratory, California Institute of Technology

DSN 7

Point referred to: center of the antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 25° 53' 21"15	Latitude	- 25° 53' 14"
Longitude (E)	27 41 08.53	Longitude (E)	27 41 05
Datum	Cape (Arc)	Based on	low order obs 1960 at site

Elevation above mean sea level: 1391 meters; Geoid height: ______ meters; Height above ellipsoid: ______ meters

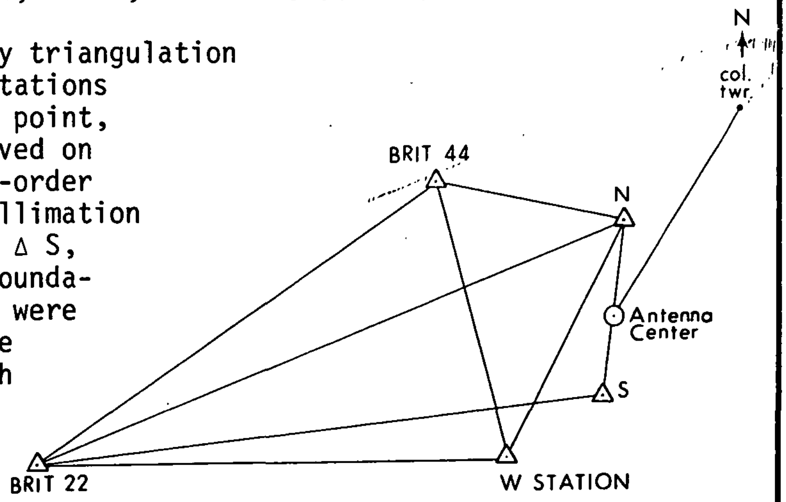
AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	antenna center	center col. tower (survey mark)	1561.37	28° 09' 23"0
Geodetic	antenna center	col. tower (dish)	1559.51	28 09 30.6

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by I. B. Watt, L. S., for National Institute for Telecom Research, October 1960-June 1961.

Stations N and S were positioned by triangulation based on two TrigSurvey third-order stations BRIT 22 and BRIT 44, and an auxiliary point, W STATION. All rays were fully observed on four arcs with a Wild T-2, with third-order closures. Control for antenna and collimation tower were carefully set from Δ N and Δ S, which are 3600 feet apart. Antenna foundations, collimation tower and its dish were located after construction in the same survey. Height of center of main dish was not verified; the center of the antenna is reported to be 13 m above the survey point.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	3 meters
Vertical	3 meters	4 meters

REFERENCES

Survey results of I. B. Watt, 1961; letter JPL to GSFC 20 June 1963; JPL memo 8 April 1968.

Station No. DSN 8

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL 61; APOLLO MADW

Code Name

Location: Madrid, Spain

Equipment: 85-foot HA-Dec

Agency: Jet Propulsion Laboratory, California Institute of Technology

DSN 8

Point referred to: intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	40° 25' 47".717	Latitude	40° 25' 32".21 ± 0".28
Longitude (E)	355 45 08.278	Longitude (E)	355 45 11.77 ± 0.27
Datum	European Datum	Based on	obs at site by IGyC in 1965 with Zeiss Ni II astrolabe-level

Elevation above mean sea level: 788.4 meters
Geoid height: - 22 meters
Height above ellipsoid: 766 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ DSIF 61	Δ ALMENARA	2318.436	345° 16' 17".6

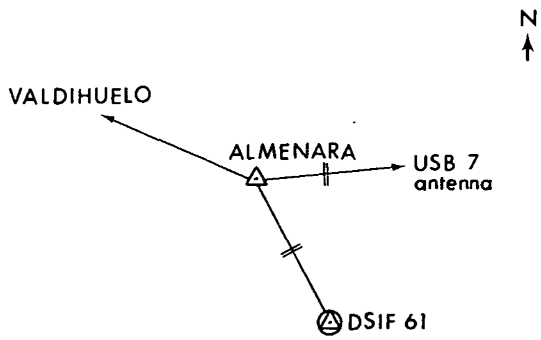
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The geodetic survey at Robledo de Chavela was made by the Instituto Geografico y Catastral in 1965. The survey station in the base of the antenna is not described.

Horizontal observations were based on IGyC first-order stations ALMENARA and VALDIHUELO. Direction observations were made with a Wild T-3 (24 circle positions) at Δ ALMENARA. Distances were measured to the two antenna sites with Electrotapes DM20, 6 times in each direction. The instruments were later calibrated at the Geophysical Laboratory at Toledo.

Elevations were extended about 2.5 km from the railroad leveling between Madrid and Avila (believed to be third order) by double-run spirit leveling. Elevations are based on MSL at Alicante. The intersection of the axes is 14.6 m above the survey mark (elev. 773.8 m).

Geoid height from G. Bomford's geoid chart of Europe, N. Africa and S.W. Asia, February,1971.



DATE: August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	5 meters
Vertical	0.5 meters	1 meters

REFERENCES

Report on geodetic work for DSIF-61 and Apollo at Robledo de Chavela, IGyC, July 1965.

Station No. DSN 9

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes JPL 62

Location Madrid, Spain

Equipment 85-foot HA-Dec

Agency Jet Propulsion Laboratory, California Institute of Technology

DSN 9

Point referred to intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	40° 27' 15".273	Latitude	40° 27' 03".01 ± 0".18
Longitude (E)	355 38 00.572	Longitude (E)	355 38 04.81 ± 0.19
Datum	European	Based on	obs by IGyC (1965) with Zeiss Ni II astrolabe-level at site

Elevation above mean sea level 738.3 meters Geoid height - 22 meters Height above ellipsoid 716 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ AUXILIAR	Δ DSIF 62	57.050	164° 44' 56"
Geodetic	Δ AUXILIAR	Δ ALMENARA	9518.04	93 03 23.93

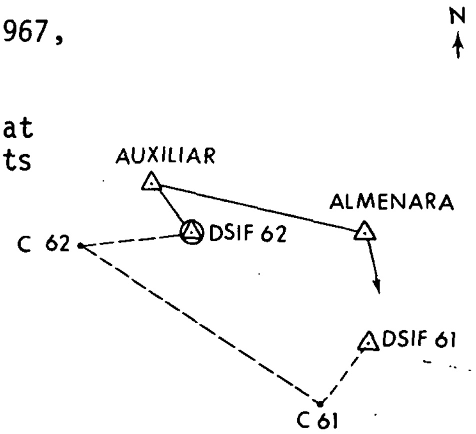
DESCRIPTION OF SURVEYS AND GENERAL NOTES

The position is marked by a brass spike under the main antenna. This site is called Cebreros.

The survey, by Instituto Geografico y Catastral in 1967, was a two-leg traverse from Δ ALMENARA, a first-order station in the European Adjustment. Azimuth was based on the direction to DSIF 61, from the 1965 survey of that station. The angle at Δ ALMENARA was measured in 24 sets with a Wild T-3. Because of poor weather this angle has a probable error of 0".53. The angle at Δ AUXILIAR was measured with the T-3 in six sets. Vertical angles (reciprocal but not simultaneous) were observed at all three stations. Distances were measured repeatedly with two calibrated DM-20 Electrotapes. A third-order check traverse was run from DSIF 62 to DSIF 61.

Elevation was based on third-order geodetic leveling nearby. The intersection of axes is about 15 m above the ground mark (elev. 723.3 m).

Geoid height from G. Bomford's geoid chart of Europe, N. Africa and S.W. Asia, February, 1971



DATE August 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	5 meters
Vertical	0.5 meters	1 meters

REFERENCES

Report by IGyC of Geodetic Work NASA/INTA Installations, at El Quexigal, Madrid, February 1967.

Station No. DSN 10

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes JPL 71

Code Name

Location Merritt Island, Florida

Equipment 6-foot Az-El

Agency Jet Propulsion Laboratory, California Institute of Technology

Point referred to intersection of axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 28' 45".038	Latitude	ξ = + 1".0
Longitude (E)	279 26 00.772	Longitude (E)	η = + 1.9
Datum	NAD 1927 (CC)*	Based on	C&GS first-order obs at Δ SOUPAD, 500 m NW

Elevation above mean sea level 12.847 meters Geoid height + 10 meters Height above ellipsoid 23 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	rotation center	front center of collimation dish	70.938**	150° 19' 58"
Geodetic	rotation center	Δ BRYANT	9.588	139 55 55
Geodetic	Δ BRYANT	Δ CENTRAL	1820.44	323 32 51.6

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by USC&GS in March 1966.

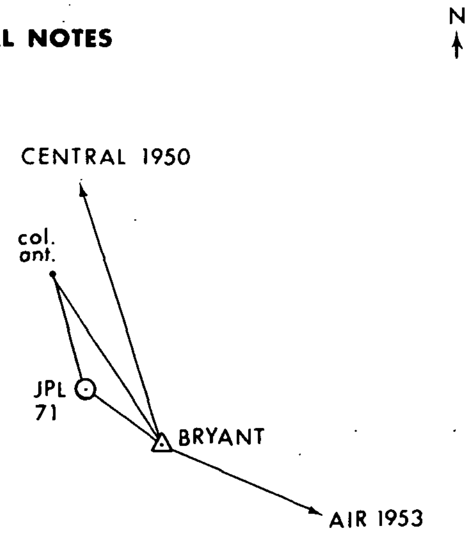
The geographic position was determined by first-order Class I triangulation and traverse from first-order C&GS stations CENTRAL and AIR. Station BRYANT was set in this survey.

Elevation was determined by C&GS first-order levels from first-order lines.

Geoid height from TOPOCOM geoid charts 1967.

*Cape Canaveral Datum is within a few centimeters of NAD 1927 in this area.

**Slant range = 71.022 meters.



DATE July 1970

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.05 meters	6 meters
Vertical	0.1 meters	0.2 meters

REFERENCES

USC&GS GP List, March 1966. Letter C&GS-Patrick AFB to Geonautics, 28 May 1966.

Station No. DSN 11

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes JPL 72

Location Ascension Island

Equipment 30-foot Az-El

Agency Jet Propulsion Laboratory, California Institute of Technology

DSN 11

Point referred to center of elevation axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 07° 57' 17".058	Latitude	ξ = - 0".1 ± 3"
Longitude (E)	345 40 20.716	Longitude (E)	η = + 14.5 ± 3
Datum	Ascension Island 1958	Based on	C&GS gravity/topo. analysis 1966

Elevation above mean sea level 541.5 meters   Geoid height ____ meters   Height above ellipsoid ____ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ JPL ANT CTR	Δ COL. TOWER	1230.349	315° 44' 07"
Geodetic	Δ JPL ANT CTR	Δ POST	1294.5	358 44 24.8

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Surveyed by Facilities Construction Branch, GSFC, in 1965, prior to construction. The survey for the USB 30-foot antenna was made at the same time.

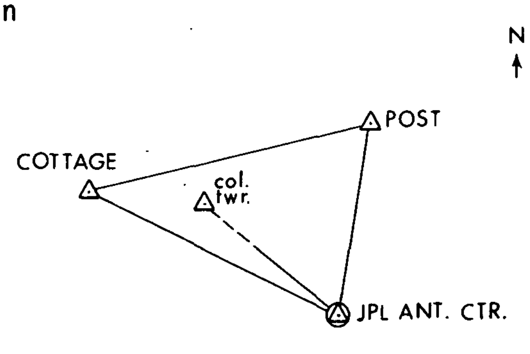
The survey point is an unmarked brass disk set in center of bottom of antenna foundation well. Disk will be obscured when equipment is installed.

The horizontal control consisted of a first-order triangle based on two USC&GS stations, COTTAGE and POST.

Terrain permitted only 6 alignment marks to be established: N1, N2, E1, E2, W1, and a station designated "MIDPOINT" halfway between this antenna and the USB antenna to the south.

The island MSL datum is based on an 11-month series of tidal observations at Georgetown. The center line of the elevation axis is 7.8 m above the base of the pedestal (elev. 533.7 m).

This station was transferred to MSFN in July 1968 and has since been dismantled.



DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	0.3 meters
Vertical	1 meters	1 meters

REFERENCES

Geodetic Survey Report for USB Antenna and JPL DSN Antenna at Ascension Island, Facil. Constr. Br., GSFC; and GSFC letter dated 16 Sept. 1966 to GSFC.

Radio Telescopes

Station No. RTE 1

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Jodrell Bank, England

Equipment 76-meter radio telescope (Mark 1A)

Agency Nuffield Radio Astronomy Laboratories

RTE 1

Point referred to intersection of telescope axes

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	52° 14' 14".656	Latitude	
Longitude (E)	357 41 34.387	Longitude (E)	
Datum	European	Based on	

Elevation above mean sea level 128.56 meters   Geoid height - 4 meters   Height above ellipsoid 125 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The position was surveyed by Ordnance Survey in 1969 to an accuracy of about 10 cm on OSGB 1936 Datum. The point coordinated was at ground level in the center of the inner rail track of the telescope. The position above was derived from the engineering drawings. The position on European Datum was by Bomford's graphical conversion. Modification of the telescope in 1971 from its Mark 1 to Mark 1A designation did not change the position of the reference point.

The elevation of the ground point is 78.267 m above Ordnance Datum at Newlyn. The intersection of axes is 50.29 m above this point.

Geoid height from G. Bomford's geoid chart of Europe, N. Africa and SW Asia, February 1971.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	3 meters
Vertical	0.02 meters	< 1 meters

REFERENCES

Letter J. Kelsey, Ordnance Survey, to CSC, 1 July 1971.

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Station No. RTE 2

Code Name

Other Codes

Location Parkes, NSW, Australia

Equipment 64-meter radio telescope

Agency C.S.I.R.O. Radiophysics Laboratory

RTE 2

Point referred to intersection of axes of antenna

GEODETIC COORDINATES

Latitude - 33° 00' 00".036

Longitude (E) 148 15 44.147

Datum Australian Geodetic

Elevation above mean sea level 391.9 meters

ASTRONOMIC COORDINATES

Latitude - 32° 59' 59".58

Longitude (E) 148 15 41.67

Based on first-order obs July 1963 by Div. Nat. Mapping 18.3 m SW of the antenna center

Geoid height + 4 meters

Height above ellipsoid 396 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Astronomic	Astro pillar	Δ EAST PILLAR		90° 00' 59".85
Laplace	Astro pillar	Δ EAST PILLAR		90 00 58.50
Geodetic	Astro pillar	Δ EAST PILLAR		90 00 57.97

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The local surveys were by the Div. of Nat. Mapping in March 1966.

The connection between the antenna and the Australian Geodetic Survey at stations BOOR and KADINA was by a closed Tellurometer traverse.

The elevation is referred to the New South Wales standard datum based on mean sea level Sydney.

Geoid height from Mather et al, IUGG Moscow 1971.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	0.5 meters	< 1 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Division of National Mapping, June 1969.

Station No. RTE 3

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Bonn, West Germany

Equipment: 100-meter radio telescope

Agency: Max-Planck-Institut für Radioastronomie

RTE 3

Point referred to: center of elevation axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	50° 31' 33"8	Latitude	50° 31' 32"3
Longitude (E)	06 53 03.7	Longitude (E)	06 52 59.2
Datum	not specified	Based on	(estimated accuracy 3")

Elevation above mean sea level 369 meters

Geoid height + 0.6 meters

Height above ellipsoid 370 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

This radio telescope is at Effelsberg, 40 km west of Bonn. The datum is probably Potsdam. The information now available is preliminary.

The rail of the telescope is 319.0 m above NN (msl). The center of the elevation axis is 50 m higher.

Geoid height from G. Bomford's geoid chart of Europe, N. Africa and S.W. Asia, February 1971.

Insufficient data for accuracy assessment.

DATE September 1971

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	meters	meters
Vertical	meters	meters

REFERENCES

Letter Max-Planck-Institut für Radioastronomie to CSC, 30 July 1971.

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