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NASA DIRECTORY OF OBSERVATION STATION LOCATIONS

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NASA DIRECTORY OF OBSERVATION STATION LOCATIONS

VOLUME 1

Third Edition

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ERRATA

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ABSTRACT

This directory contains geodetic information for NASA tracking stations and for observation stations cooperating in NASA geodetic satellite programs.

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.

The directory is in two volumes. Volume I covers the principal tracking facilities used by NASA, including the Spaceflight Tracking and Data Network, the Deep Space Network, and several large radio telescopes. Positions of these facilities are tabulated on their local or national datums, the Mercury Spheroid 1960, the Modified Mercury Datum 1968, and the Spaceflight Tracking and Data Network System. Volume II contains observation stations in the NASA Geodetic Satellites Program and includes stations participating in the National Geodetic Satellite Program. 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 in Volume I. It includes discussions of 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 third edition of the directory incorporates information received up to September 1973. Changes from the second edition may be identified by the date in the lower right corner of the data sheets. A few stations have been dropped for which useful tracking data are not and will not be on record. Many stations have been added. Indexes, maps, and tabulations have been revised to include the new data. The text has been reviewed to incorporate improved information.

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

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VOLUME I

PART A - BACKGROUND AND REFERENCE MATERIAL

PART B - NASA SATELLITE TRACKING FACILITIES

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 satellite tracking 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.

The directory is in two volumes. Volume I covers the NASA Network Facilities, the Cape Kennedy launch pads, the Deep Space Network, and radio telescopes cooperating in NASA programs. Volume II contains the observation stations participating in the NGSP, the NGP, and other programs. 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, National Ocean Survey BC-4 cameras, the Goddard Special Optical Network, international participants, and the Smithsonian Astrophysical Observatory optical network.

The directory is in 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 referred to in satellite tracking and geodetic programs. Part B contains a description of NASA tracking facilities, and the coordinate tables and Geodetic Data Sheets for them. Part C is separated in Volume II; it contains equipment descriptions, the coordinate tables, and Geodetic Data Sheets for observing stations participating in the satellite geodesy programs.

Positions of NASA tracking stations in Volume I are tabulated on their local datums, on the Mercury Spheroid 1960, on the Modified Mercury Datum 1968, and on the Spaceflight Tracking and Data Network 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. In 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. The shift constants are now outdated for worldwide tracking operations, but since the spheroid is still used for certain analytic programs within NASA, coordinate tabulations are given for it in this directory, but utilizing the shifts developed for the Modified Mercury Datum of 1968.

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 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 an interim system, pending establishment of a unified world geodetic system from the geodetic satellite programs.

Spaceflight Tracking and Data Network System (STDN). These are the official positions used by NASA for spaceflight operations. This is a worldwide geodetic system with transformations available to most major local geodetic datums. It is an outgrowth of the Mercury 1960 Datum, and is referenced to its spheroid (a = 6 378 166 meters, f = 1/298.3). Results from Apollo, Mariner-Mars, ERTS, GEOS, and other missions have contributed to the definition of the geodetic locations within the system. Continuing analysis of tracking and geodetic data may cause revisions to be made to this system as new tracking data are obtained and additional geodetic refinements are made.

Other coördinate reference systems are used by various tracking networks for specific spaceflight missions. 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

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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 triangulation network; 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 involved 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 surface on which field geodetic measurements are usually made.

The field 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 all external 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 in an anomalous and unpredictable manner 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 at least 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 over the years in determining accurate relative positions of tracking stations. Sea level itself, the best physical 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 virtually 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.

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 gravity vector and thus 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 much 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 mean position of the rotation axis of the earth. In this process, geometric geodesy utilizes space intersection, in which the satellite is considered a triangulation or trilateration target 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 or a laser retroreflector. Best results are likely to accrue from a combination of both.

In dynamic geodesy, the satellite is observed from widely separated ground stations at various times, and the forces acting on it are deduced from analysis of its motion. Observations must be sufficiently precise to develop a theory which will predict future positions at least as accurately as they can be observed. For this an extensive mathematical theory of the motion is required, as well as precise knowledge of such physical parameters as gravitational constants and air density, and the accurate geodetic position of the observing stations. Actually the observed position of the satellite will differ from the predicted one, and through analysis of 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 differences 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 distribution of the earth. There are, of course, other elements which affect the motion of the satellite, such as radiation pressure, magnetic effects, and attraction of other celestial bodies. If the satellite is at a high altitude and has large weight-to-surface ratio, atmospheric drag becomes insignificant compared to gravitational perturbations.

Both geometric and dynamical observations are used in the NASA Geodetic Satellites Program (see Part C) for 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 horizontal for the determination of latitude and longitude, or vertical for the determination of elevation. These two kinds of survey are conducted almost completely independently of one another, and each is based on a datum of its own.

1.4.1 Horizontal Geodetic Datums

There are differences of opinion, rather unimportant, among geodesists as to what should be included in defining a geodetic datum. Such a definition should include enough data to define uniquely the location of the origin, and permit computation of the extended control network. In an earth-centered system a geodetic datum may be defined by the position of a control point, designated as the origin, with respect to the earth's center of mass, usually expressed in rectangular space coordinates, X, Y, and Z. By convention the Z axis coincides with the earth's spin axis, positive north; the direction of the X and Y axes are respectively positive toward latitude and longitude 0°, 0°, and 0°, 90° East.

The geodetic coordinates, latitude, longitude, and height are analogous to the X, Y, and Z coordinates. They are based on an earth spheroid with specified equatorial radius and flattening, a and f. The classical geodetic datum may be defined by the coordinates ϕ_o, λ_o, and h_o for the origin, and the spheroidal constants. Here h_o is the height above the surface of the ellipsoid, and is equal to the elevation above the geoid plus the geoid height; it is absolute in an earth centered system but otherwise is of an arbitrary value.

Some definitions include the deflection components, ξ_o and η_o, and a geodetic azimuth from the origin to a nearby control point. However these quantities are all observable and not really basic. The deflection components at Meades Ranch, the origin of NAD 1927, were not known for a half century, and the geodetic azimuth from it to Waldo (not the Laplace azimuth) was reduced by nearly five seconds from Old NAD to NAD 1927. The only thing that set Meades Ranch apart from the other points in the network was that its coordinates remained unchanged in the 1927 adjustment. 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 unaccessible 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. For practical engineering purposes this is better anyway. 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. Development of the datum over a survey area is further complicated by continental instability and the fact that observed mean sea level varies with time. If a continental vertical datum is 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 parallel. 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.

These 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 on satellites affected by 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 solar-lunar 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. A readjustment of this network should improve its accuracy, and could result in elevation changes of decimeters.

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, which had been regional, were supplanted in 1971 by the new Australian Height Datum (AHD). Holding 30 tide gauges fixed at their mean sea level values, 757 sections of two-way leveling between 497 junction points entered the simultaneous adjustment.

1.6 DATUM CONNECTIONS

On most continents the horizontal geodetic control was started in separate regions using different origins and often 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 has been 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 directory 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: $E = 0.029\ K^{\frac{2}{3}}$, 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 $M^{\frac{1}{3}}$, 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, $E = 0.020\ K^{\frac{2}{3}}$.

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 now in progress. Electro-optical equipment (Geodimeter) is used for distance observations. Astronomic observations for latitude, longitude, and azimuth are made at every second station for orientation and the determination of geoid heights. These measurements approach the known accuracy of the speed of light, now estimated at one part in 10^6. Tests of the 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 over the lines at the time of measurement, 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 affect error estimates over great distances substantially.

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 500 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: $E = 1.8\ K^{\frac{2}{3}}$ 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: $E = 0.03\ K^{\frac{1}{2}}$, 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 sections 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 sections are based on existing triangulation arcs with their astronomic Laplace stations, which may be 100 or more kilometers apart. In the United States several thousand miles of surveys have been run specifically for geoidal section determination. The average spacing of these astro-geodetic deflections is twenty to twenty-five kilometers. The average correction to an observed geoid height difference is about 1.0 mm/km, and the maximum is 3 mm/km.

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 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 (0ʺ.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 these errors is not cumulative, but lack of awareness of them may give false confidence in the precision of the published values.

2.5 WORLD SYSTEMS

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, any distances or relative positions inferred from published geographic positions on different datums could be in error by several hundred meters, and for 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 DMA Topographic Command, Ohio State University, Goddard Space Flight Center, the National Ocean Survey, the Smithsonian Astrophysical Observatory, and the Naval Weapons Laboratory. Comparison of the transformation constants for the world geodetic systems indicates general agreement in the three components of the datum shifts and the spheroidal constants. It is reasonable to expect that a combined solution of the observational data from all the networks will soon yield determinations for these shifts 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.

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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 such as those established by Australia in the 1960s, or Shoran trilateration as established by Canada in the 1950s. 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 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 like 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 18th 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 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 to each other in a geodetic sense, although the astronomic latitudes were of high caliber.

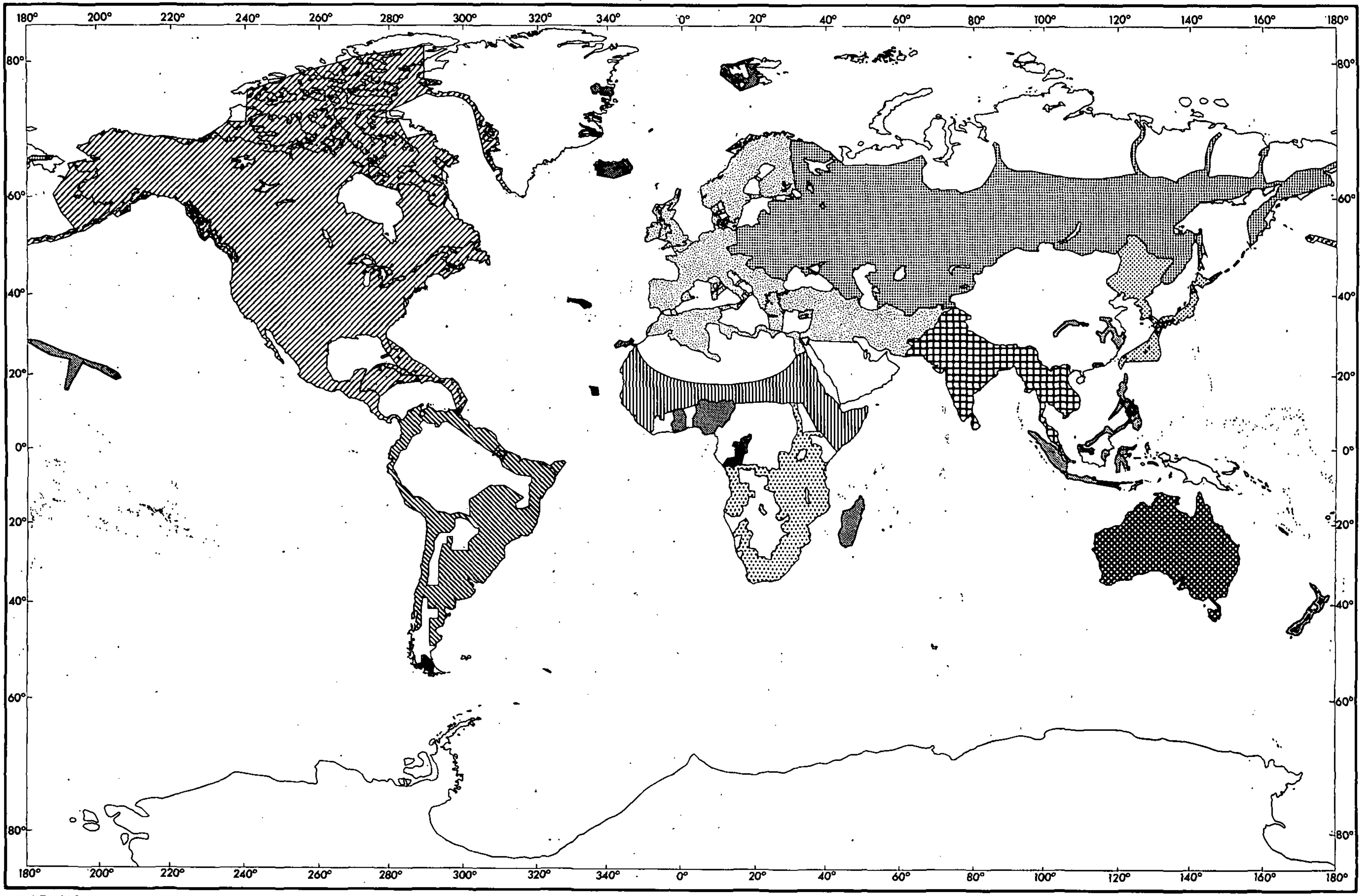
There was a slow trend toward accepting the Greenwich Meridian as the basis for longitude, and by 1940 practically all important geodetic networks were based on it. But there still remained the separate geodetic datums employing a variety of ellipsoids and methods for determining the coordinates of the 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.

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,



MAJOR GEODETIC DATUM BLOCKS

Figure 1.

and became known as the United States Standard Datum. A subsequent examination of the astro-geodetic 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 1940s. 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 than 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.) But revision of NAD 1927 is long overdue. Distortions of ten seconds in azimuth are known to exist, and closures within limited areas may be as poor as 1/20,000. An entirely new adjustment, which will include geodimeter and satellite observations, is needed. When completed it is expected to have an overall accuracy of $1/10^6$, with errors between adjacent stations no greater than $1/10^5$, an improvement in accuracy by a factor of three or four.

In summary the North American Datum of 1927 is defined by the following position and azimuth at Meades Ranch: latitude $39^\circ\ 13'\ 26''.686$ N, longitude $98^\circ\ 32'\ 30''.506$ W, azimuth to Waldo (from South) $75^\circ\ 28'\ 09''.64$.

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. 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 (EUROPE 50)

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 ground-work 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^{o} to 56^{o} North latitude and between 6^{o} and 27^{o} 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 astonomic 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 often 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 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° 41' 44".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".18. Thus the corrected longitude at the origin is 77° 39' 17".57 E. But since this was considered as the astronomic longitude, and a deflection of +2".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. Befo 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 the 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 N, longitude 139° 44' 40".9000 E, 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-1920s 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 1960s 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 it was adopted in April 1965 as the Australian National Spheroid, 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. Although 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 the Johnston Geodetic Station. These are: latitude 25° 56' 54".5515 S, longitude 133° 12' 30".0771 E. The geoid separation at this point is -6 meters, as of 1 November 1971.

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. Development of the geoid for the continent by 1971 showed its effect on the adjustment to be insignificant. 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.

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 referenc 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 origi 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 majo portion of the South American work was adjusted on the Provisional South American Datun 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 latitude 41^{o} 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 an 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 th the equatorial radius of the International Ellipsoid should be reduced by at least 100 mete (a subsequent change in the flattening inferred from satellite observations suggested anoth

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 exactly). Both CHUA and CAMPO INCHAUSPE, the National datum points of Brazil and Argentina, respectively, were assigned minimal geoid heights (zero and two meters). 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 now provides the basis for a homogeneous geodetic control system for the continent.

3.8 ARC DATUM (CAPE)

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 $33^{\circ}\ 59'\ 32''.000$ S, longitude $25^{\circ}\ 30'\ 44''.622$ E.

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 $59^{\circ} 46' 18''.55$ North, longitude $30^{\circ} 19' 42''.09$ 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]. Initially only the values of the first-order stations will be available on OSGB 1970 (SN). More accurate conversions to the European Datum will become available when Block 6 of the European readjustment is completed.

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

3.11 ADINDÂN DATUM

Between 1967 and 1970 a precise traverse was run across Africa roughly following the Twelfth Parallel North. Starting at the Chad-Sudan border, it extended 4654 kilometers of traverse length to Dakar, Senegal, passing through Nigeria, Niger, Upper Volta, and Mali. The portion in Nigeria was done by USDMATC in cooperation with the Nigerian Survey Department; the remainder was done by the French IGN under contract to DMATC, with the cooperation of the countries through which it passed.

All distances were measured with a Geodimeter and checked with a Tellurometer. First-order angles were used. Trig elevations carried between stations were referred frequently to first-order bench marks. Since first-order astronomic observations with a Wild T-4 were made at every other station (about 40-km spacing), a geoid profile across the continent made it possible to adjust the traverse to the spheroid. The final adjustment by DMATC [12] of April 1971 indicates an accuracy better than one part in 10^6, or nearly that of the U.S. precise transcontinental traverse.

All triangulation, trilateration, and traverse work in Sudan and Ethiopia has subsequently been computed in this datum. The Adindân base terminal Z_{Y} was chosen as the origin: latitude 22° 10′ 07.″1098 N, longitude 31° 29′ 21.″6079 E, with azimuth (from North) to Y_{Y} 58° 14′ 28.″45. The Clarke 1880 Spheroid is used (a 6 378 249.145, f 1/293.465). Z_{Y} is now about ten meters below the surface of Lake Nasser.

3.12 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^{0} East, and Z is positive toward North. The relationship between the X, Y, and Z coordinates and the conventional ellipsoidal coordinates of latitude, longitude, and height is expressed by relatively simple 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, were probably known within 300 meters, whereas the figure for North America and Tokyo was 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.

3.12.1 Mercury Datum (1960)

Before 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 the 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 [13].

AMS made three solutions in fitting the major geodetic datums into a single world geodetic system, using various combinations of data [14]. 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 were also available to transform positions of certain other datums - i.e., South American, Cape, and Indian - to the major datums, and through them to the Mercury Datum.

3.12.2 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 [15]. 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. Translation components for shifts of eighteen datums to the Modified Mercury Datum 1968 were published. Since then six other datum shifts have been added, and some of the original shifts modified.

3.12.3 Standard Earth, SAO

The Smithsonian Astrophysical Observatory has long been engaged in satellite observations. Their original twelve Baker-Nunn cameras are now supported with lasers at several stations. The several solutions published in the last few years have been based on increasing amounts and types of data. Orbital elements derived from single photographic observations were strengthened with paired observations for geometric support. Later lasers were installed at several of their stations, and data from them, as well as from Goddard and Centre National d'Etudes Spatiales laser stations, contributed to the results. In addition, data from the BC-4 camera network, from individual observatories, and from the Jet Propulsion Laboratory deep-space observations have been incorporated in the later solutions. Surface gravity data were utilized for the determinations of the geopotential.

These solutions, C5, C6, C7 [16, 17], and 1969 Standard Earth II, were followed in 1973 with Smithsonian Institution Standard Earth III [18]. The analysis of satellite data combined with surface measurements has resulted in a reference gravity field complete to 18th degree and order, and the coordinates of 90 satellite tracking sites.

The values adopted as the basis for scale and the reference ellipsoid are: a = 6 378 155 f = 1/298.257, GM = 3.986013×10^{20} cm^3/sec^2; c = $2.997\ 925 \times 10^{10}$ cm/sec.

3.12.4 NWL-8 Geodetic Parameters

The U.S. Naval Weapons Laboratory has conducted research in satellite geodesy since 1959 in the development of the Navy Navigation Satellite System. Objectives have included connecting the major datums and isolated sites into a unified world system, relating this system to a best-fitting earth-centered ellipsoid, refining the gravity field, and determining the motion of the pole. The system is now used routinely by other domestic and foreign agencies to position remote sites and for other geodetic projects.

Several types of solutions have been published. The latest (1973), NWL-9D [19], includes the positions of 40 stations with worldwide distribution, and the shifts of 26 datums to the system. The spheroid of the earlier NWL-8D was retained in this solution, in which a = 6 378 145 meters, and f = 1/298.25. GM is 398 601 Km^3/sec^2.

3.12.5 Summary of World Datum Relationships

Publication in 1974 of "The National Geodetic Satellite Program" (Government Printing Office, Washington, D.C.) will provide the results of the observations and analyses of the NGSP. Remarkable agreement among the principal participants has been achieved despite the different techniques employed. The shifts required to bring the major datums into a world system seldom differ by more than twenty meters, and a spheroid commanding general acceptance will probably be presented to the next assembly of the International Union of Geodesy and Geophysics in Grenoble in 1975. Continuing satellite observation programs indicate a shift of emphasis from geodesy to geophysics. The launch of the GEOS C satellite, now planned for June 1974, will make new data available, especially that from the laser altimeter. Within a few years it may reasonably be expected that the relative positions of points in the world network and the earth's center of mass will be known within one part in a million (standard error), or roughly between five and ten meters.

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:

$$X = (\nu + h) \cos\phi \cos\lambda = R \cos\psi \cos\lambda$$

$$Y = (\nu + h) \cos\phi \sin\lambda = R \cos\psi \sin\lambda$$

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

$$R = (X^2 + Y^2 + Z^2)^{\frac{1}{2}}$$

$$\psi = \tan^{-1} [Z/(\nu + h) \cos\phi]$$

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 [21]; some of the equations can be found in Molodenskiy [22] and Veis [23].

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

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

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

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

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

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.)

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

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

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 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 geodetic to rectangular coordinates (same spheroid):

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

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

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

From rectangular to geodetic coordinates ($\Delta\phi$ and $\Delta\lambda$ are in meters):

$$\Delta\phi = -\sin\phi \cos\lambda\, \Delta X - \sin\phi \sin\lambda\, \Delta Y + \cos\phi\, \Delta Z + 6.38 \cdot 10^6 \sin 2\phi \Delta f$$

$$\Delta\lambda = (-\sin\lambda\, \Delta X + \cos\lambda\, \Delta Y)/\cos\phi$$

$$\Delta H = \cos\phi \cos\lambda\, \Delta X + \cos\phi \sin\lambda\, \Delta Y + \sin\phi\, \Delta Z - \Delta a + 6.38 \cdot 10^6 \sin^2 \phi \Delta f$$

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 for $\Delta\phi$ and $\Delta\lambda$.

4.2 DATUM CONSTANTS

Table 1 lists the spheroidal constants, semi-major axis and flattening, of the spheroids now in common use. Table 2 lists the datums referred to in this directory, with the spheroid on which each is computed, and the name and location of the origin point.

TABLE 1
SPHEROID 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 2
REFERENCE DATUMS

DATUM	SPHEROID	ORIGIN	LATITUDE	LONGITUDE (E)
Adindân	Clarke 1880	STATION Z_{I}	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 Geodetic Station	-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
Cape Canaveral*	Clarke 1866	CENTRAL	28 29 32.364	279 25 21.230
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
Efate (New Hebrides)	International	BELLE VUE IGN	-17 44 17.400	168 20 33.250
European (Europe 50)	International	Helmertturm	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
Kourou (French Guiana)	International	POINT FONDAMENTAL	-05 15 53.699	-52 48 09.149
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
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 04.21
Ordnance Survey G.B. 1936	Airy	Herstmonceux	50 51 55.271	00 20 45.882
OSGB 1970 (SN)	Airy	Herstmonceux	50 51 55.271	00 20 45.882
Palmer Astro 1969 (Antarctica)	International	ISTS 050	-64 46 35.71	295 56 39.53
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	Helmertturm	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
Qornoq (Greenland)	International	No. 7008		
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	MONAVATU (latitude only)	-17 53 28.285	
		SUVA (longitude only)		178 25 35.835
Wake Island, Astronomic 1952	International	ASTRO 1952	19 17 19.991	166 38 46.294
White Sands*	Clarke 1866	KENT 1909	32 30 27.079	253 31 01.306
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 MERCURY SPHEROID 1960

In 1973 there is general agreement among satellite geodesists that the flattening of the spheroid is 1/298.25 with an error no greater than 0.05 in the denominator. But current estimates of the semi-major axis vary from about 6 378 128 meters to 6 378 145. To avoid repeated changes in their programs until a consensus is reached, some agencies continue to use older earth models with little loss of tracking effectiveness.

But the range of estimates of datum shifts has narrowed since 1960 although some large disagreements remain. To take advantage of this improvement, and to include such datums as the Australian and South American 1969 for which no shifts were available in 1960, the tabulation of positions on the Mercury Spheroid 1960 uses the shifts associated with the Modified Mercury Datum 1968, but retains the older spheroidal constants, 6 378 166 and 1/298.3.

4.4 TRANSFORMATION CONSTANTS FOR MODIFIED MERCURY DATUM 1968

The datum shifts listed below are from Army Map Service Technical Report No. 67, "A Modification of the Mercury Datum, Fischer 1968," June 1968, with additions and changes from DMATC up to 1 October 1973 (a = 6 378 150, f = 1/298.3).

Datum Shifts to Modified Mercury 1968

From	ΔX	ΔY	ΔZ
Adindân	-151m	- 28m	+220m
Australian	-107	- 42	+ 92
Arc	-128	-133	-274
American Samoa 62	- 93	+137	+375
Ascension 58	-208	+ 84	+ 52
Bermuda 57	- 65	+206	+308
Canton I. 63	+235	+244	-467
European	- 81	-104	-121
Guam	- 77	-238	+202
Johnston I. 61	+197	- 66	-211
NAD 1927	- 18	+145	+183
Old Hawaiian	+ 68	-278	-193
Pico de las Nieves (Canaries)	-308	-111	+149
SAD 1969	- 74	- 9	- 39
Tananarive	-180	-257	- 98
Tokyo	-162	+482	+671

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 an absolute accuracy of ten meters with respect to a reference system based on the earth's center of mass. To achieve this each station should be connected to its local horizontal and vertical datum within one meter. Developments in laser ranging, very long baseline interferometry, and improved radio tracking may demand more stringent requirements in the decimeter or even centimeter range. A 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. 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 kilometers 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 "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 referred to.

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

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 station. An explanation of the format and contents of the data sheet is provided just before the data sheets in Parts B and C of this directory.

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PART B - NASA SATELLITE TRACKING STATIONS

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SECTION 6

DESCRIPTION OF NASA TRACKING FACILITIES

6.1 INTRODUCTION

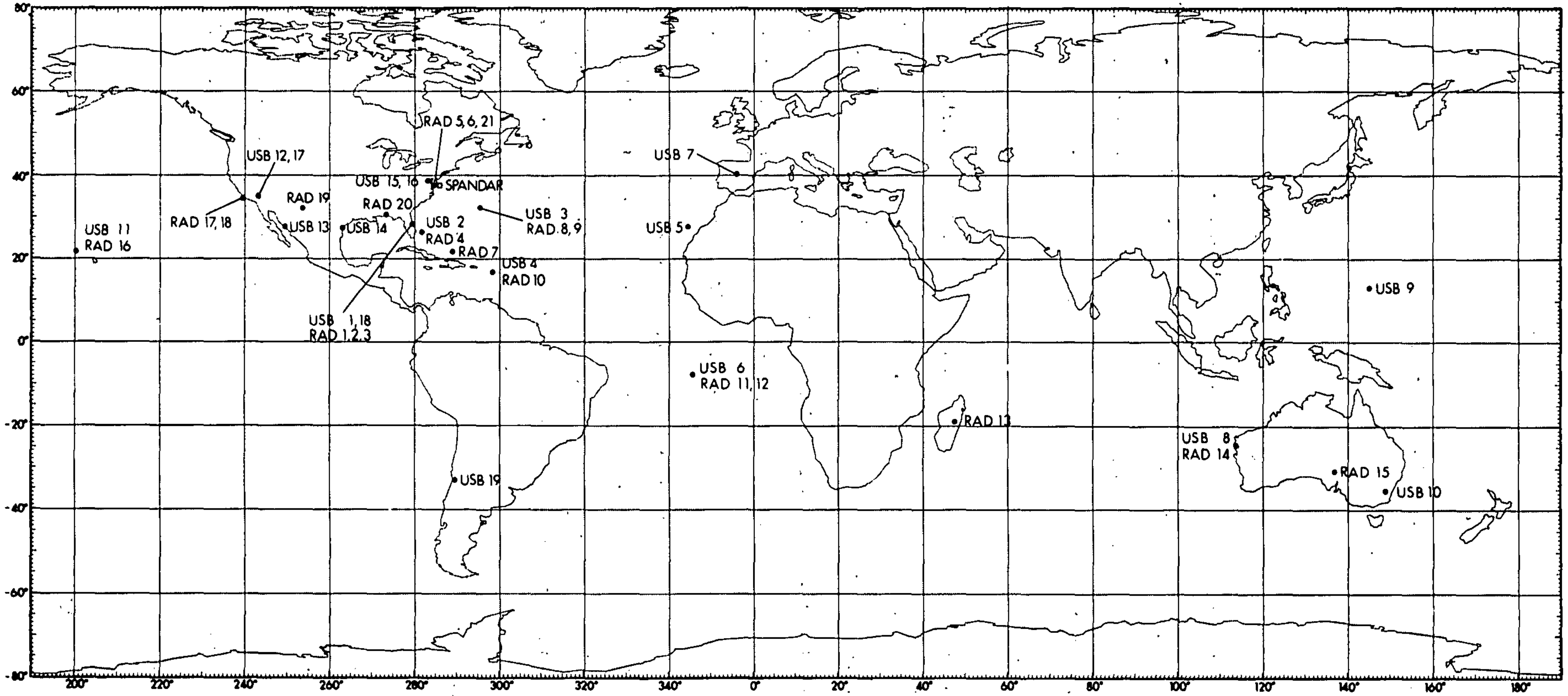
The antennas directly employed for spacecraft tracking by the National Aeronautics and Space Administration are in Volume 1 of this directory. Brief descriptions of the equipment at these stations are given in this section, with emphasis on the physical characteristics and orientation of the antennas. These have been summarized in Table 3 at the end of the section. Locations of the facilities are shown in Figures 2A, 2B, and 3.

6.2 UNIFIED S-BAND SYSTEM

The Unified S-Band Network was designed for the Apollo lunar program and will be used for subsequent space programs. It derives its name from the fact that it operates within the S-Band - approximately 2100 MHz uplink to the spacecraft and 2300 MHz downlink from the spacecraft - and the fact that all tracking functions are carried out by one unified system. Using a single carrier, the system performs the uplink functions of transmitting commands, data, and voice; the downlink functions of receiving telemetry data, voice, and television; and the functions of providing metric tracking data. Tracking is by a coherent Doppler and pseudo-random noise range system. Angle, range, and Doppler measurements are made, but the angle data, from antenna shaft encoders, is not precise enough for use as an independent data type. Two types of Cassegrain-feed antennas are used in the USB Network: three 26-meter antennas provide continous coverage of of lunar and deep space missions; twelve 9-meter antennas cover the earth-orbit portion of lunar missions, and back up the 26-meter antennas. Electronic equipment is similar for both types.

6.2.1 <u>USB 26-Meter Antenna</u>

The Apollo 26-meter Cassegrain antenna (Figure 4) consists of the main reflector, with 11-meter 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 individual panels which are adjustable to form a best-fit paraboloid. The hyperbolic subreflector is at the focal plane of the main reflector, and 6 meters from the top of the feed cone.

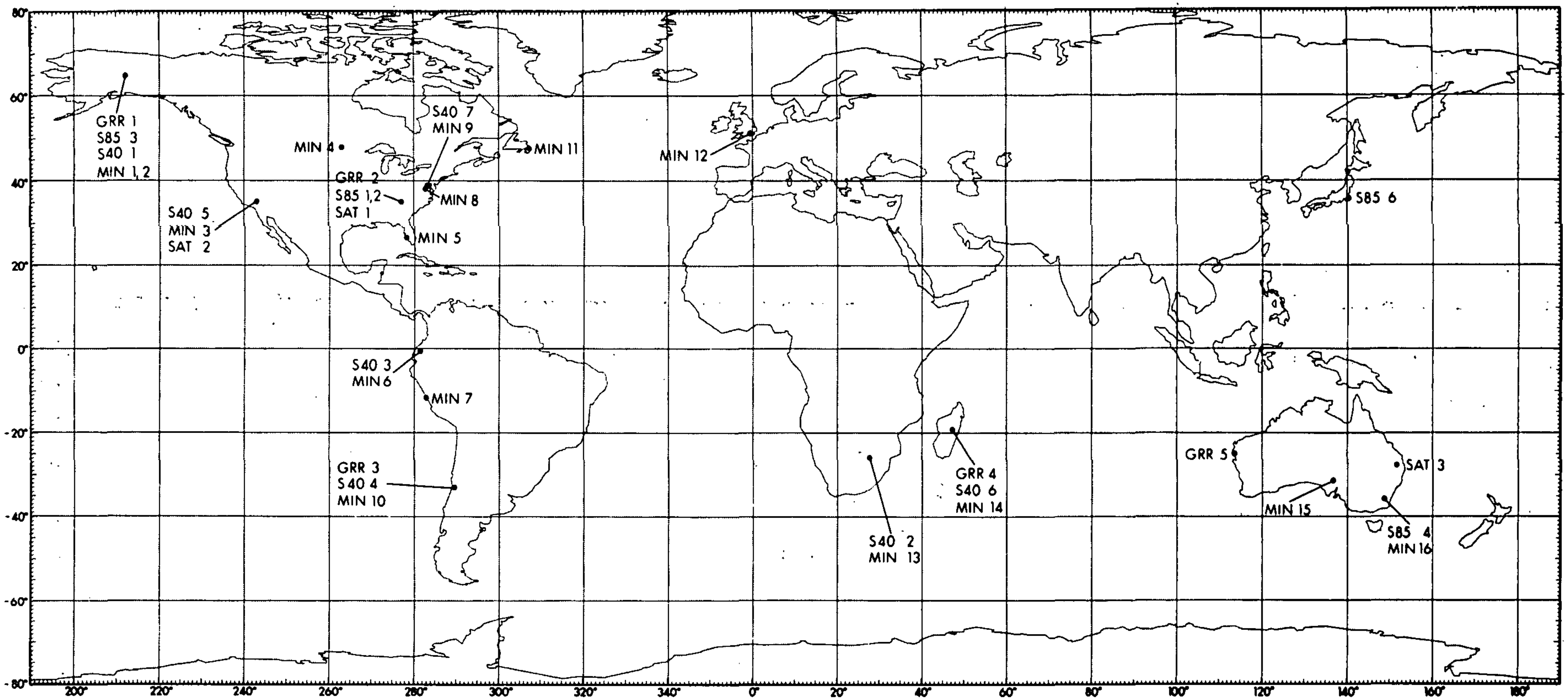


KEY

USB - Unified S-Band
RAD - C-Band Radar

NASA SATELLITE TRACKING SITES

Figure 2A.

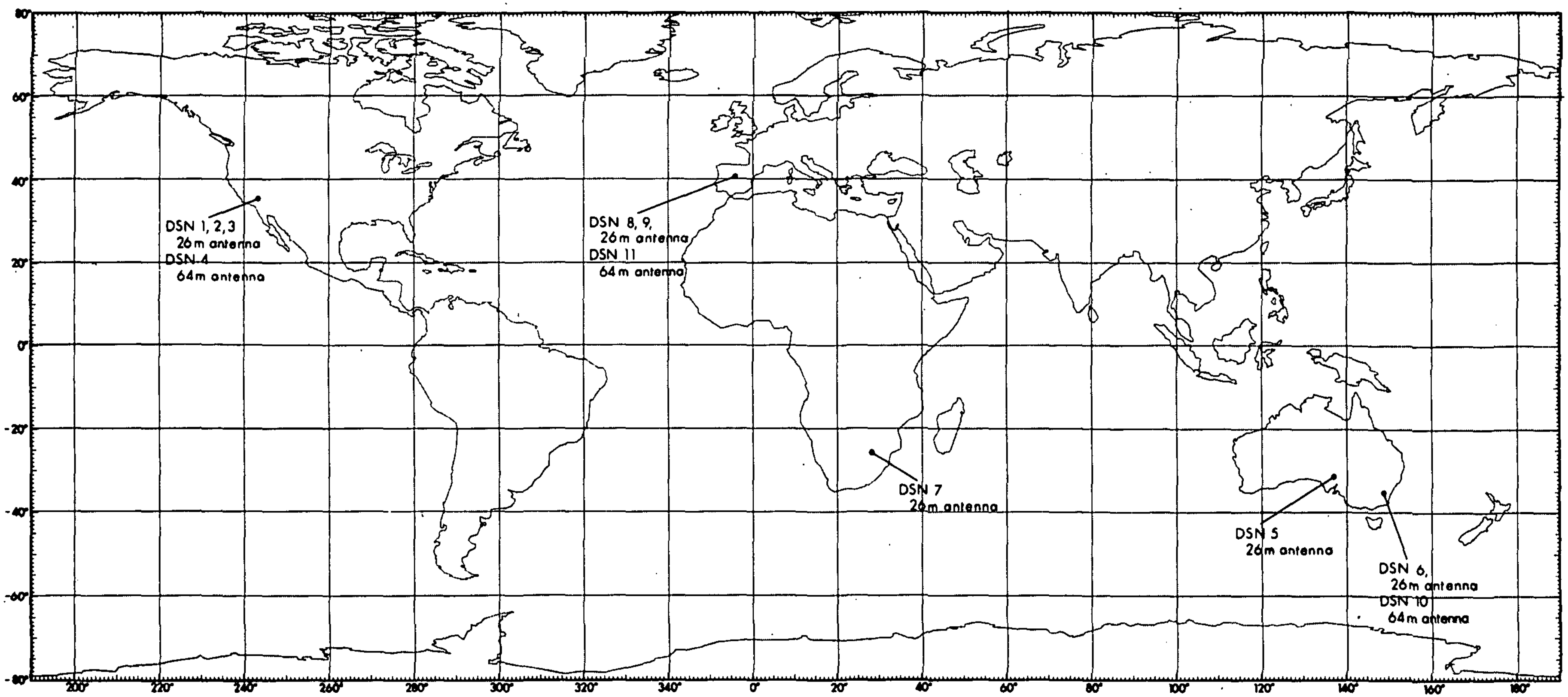


KEY

GRR - Goddard Range & Range-Rate
S85 - 26m Antenna
S40 - 12m Antenna
MIN - Minitrack
SAT - SATAN

NASA SATELLITE TRACKING SITES

Figure 2B.



KEY

DSN - Deep Space Network

DEEP SPACE NETWORK

Figure 3.

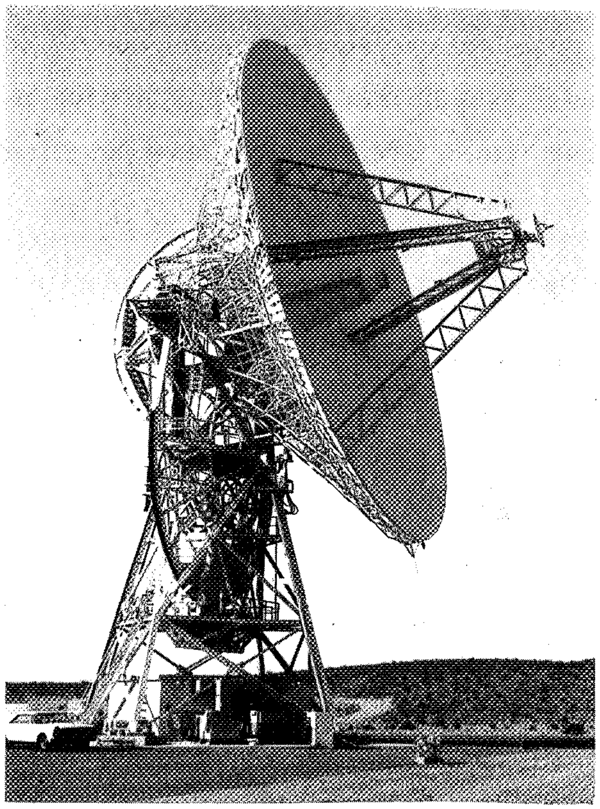


Figure 4. Unified S-Band 26-Meter Antenna

The axes of the X-Y mount are non-coplanar, with the upper Y axis separated 6.7 meters 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^{o} above the horizon except for semi-conical keyholes of 10^{o} radius at the horizon in the east and west.

6.2.2 USB 9-Meter Antenna

The 9-meter antenna structure (Figure 5) 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 9-meter circular aperture and a 3.7-m 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 (except for the two ERTS antennas) 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, 2.4 meters from the X axis (except USB 19, Santiago, which has the one-meter separation of axes of the GRARR mount) 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 $\pm 95^{o}$ (dead limit) from the zenith; the Y axis is limited to 82^{o} (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. Two of these antennas (USB 16, USB 17), used in the ERTS program, have the orientation of the USB 26-meter antennas.

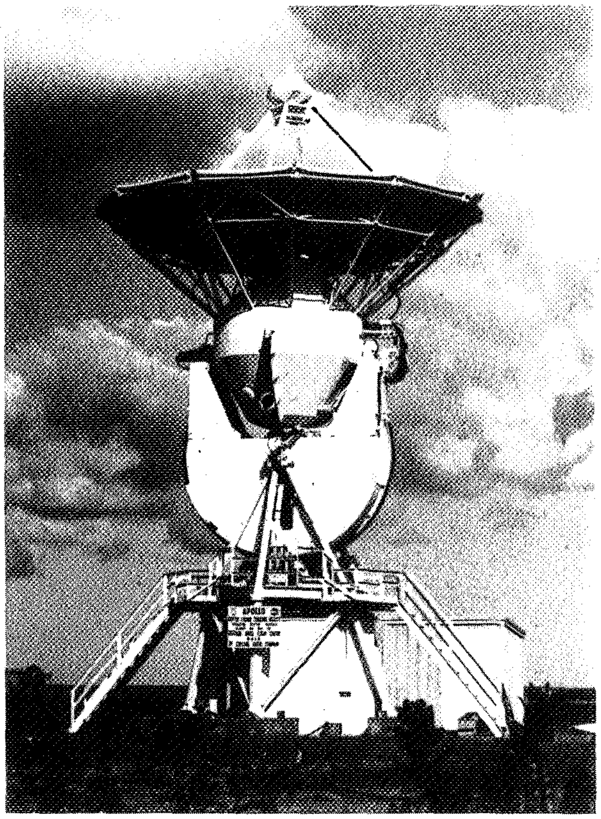


Figure 5. Unified S-Band 9-Meter Antenna

6.3 C-BAND RADARS

The C-Band radars are precision mono pulse 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 syste for Project Mercury and Project Gemini missions.

The radars are of two basic types: th 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 has a 3.7-meter diameter paraboloid reflector on an azimuth-elevatic pedestal (Figure 7). The reflector surface consists of wire mesh panels support by radia trusses. The pedestal is mounted on a reinforced concrete tower which is surrounded by building containing the electronic equipment. The antenna has a four-horn monopulse fee supported on a tetrapod located at the focal point of the reflector.

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. It has a 9-me diameter Cassegrain antenna with a five-horn monopulse feed (Figure 6). The main reflector is a solid-surface aluminum paraboloid. The feed assembly and 0.8 m hyperbolic subreflector are supported by a tripod. The antenna is mounted on a hydraulically driven azimuth-elevation pedestal.

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 <u>S-Band Radar (SPANDAR)</u>

This facility, located at the NASA Wallops Island Station, is a high-power conical scan tracking radar. The 18-meter paraboloid reflector is supported by an azimuth-elevation mounting on top of a 29-meter tower.

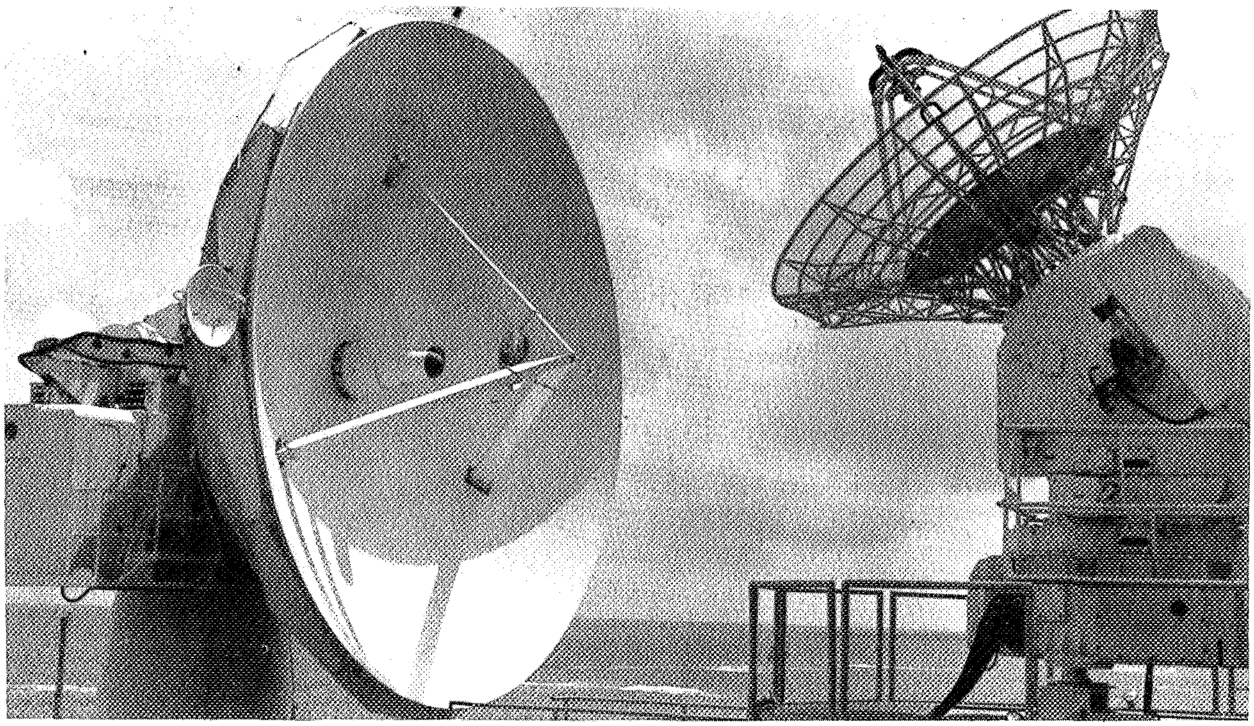


Figure 6. FPQ-6 and FPS-16 C-Band Radars

6.4 GODDARD RANGE AND RANGE-RATE SYSTEM

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, 76 to 122 meters apart, one operating at S-band frequency and the other at VHF, are used at most stations. 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 acqu sition 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 i use; the original Goddard Range and Range-Rate system (GRARR-1) at Rosman, Carnar-von, Santiago, and Tananarive, and a later system (GRARR-2) at Fairbanks. The S-ban systems at Rosman and Tananarive are compatible with USB frequencies.

6.4.1 GRARR-1 Facilities

The S-band system (Figure 7) consists of two identical Cassegrain-feed 4.3-mete diameter paraboloids with focal length of 2 meters. The parabolas are spaced 4.6 meter apart on the Y axis, with 30-cm clearance between reflector edges. The X and Y mounti of the VHF and S-band antennas are identical, 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; the Y axis is one meter above it. The original VHF antennas at these stations, monopulse-tracking phased arrays of 72 cavity-backed slots, have been replaced with 16-element sh backfire element arrays on 9 x 9 m expanded aluminum screens.

6.4.2 GRARR-2 Facilities

The S-band system consists of a single 9-meter Cassegrain antenna with a circul aperture solid surface parabolic reflector, a 1.14-meter solid hyperbolic subreflector,

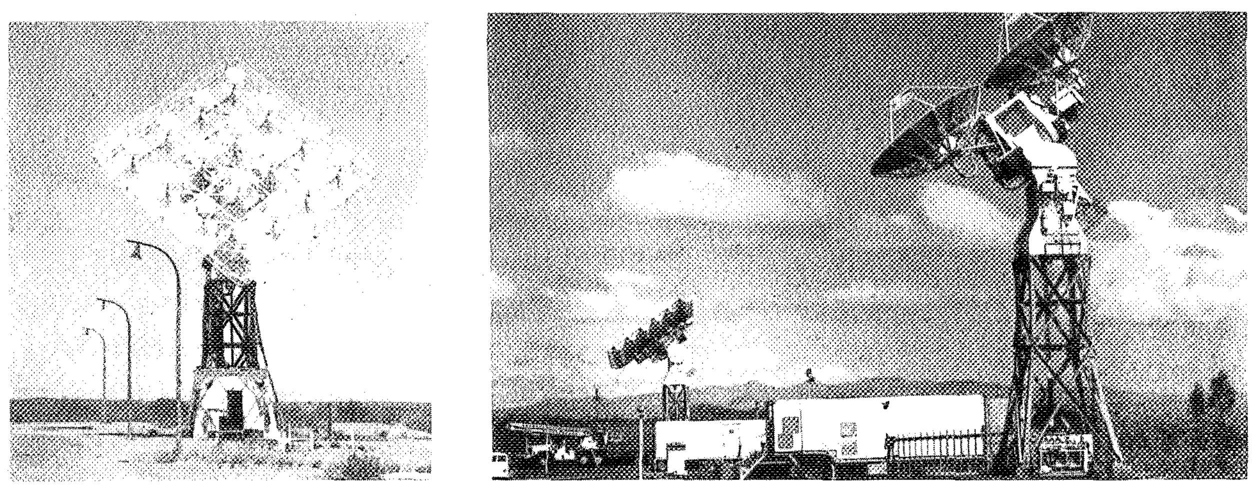


Figure 7. Goddard Range and Range-Rate Facility (GRARR-1)

and a monopulse feed mounted on an X-Y pedestal (Figure 8). The main reflector has a 3.7 meter focal length, and the subreflector has a 2-meter focal length. The VHF antenna has a 8.5 x 8.5-meter 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 9-meter Unified S-band (paragraph 6.2.2) in alignment and sky visibility. Both Fairbanks antennas are additionally restricted by keyholes up to 6^{o} above the horizon at the east and west points.

6.5 26-METER DATA ACQUISITION ANTENNAS

The 26-meter antennas provide tracking, data acquisition, and communications support for various satellite programs. They are instrumented for monopulse tracking in the 136, 400, and 1700 MHz bands. These antennas (Figure 9) have solid-surface aluminum paraboloid reflectors with circular apertures 26 meters in diameter. The focal length is 11 meters. Each section of the reflector surface is individually adjustable, with a surface tolerance of one mm. All these antennas have a focal-point feed system except the Rosman II antenna, which is also equipped with a removable 3.4-meter dichroic Cassegrain subreflector.

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

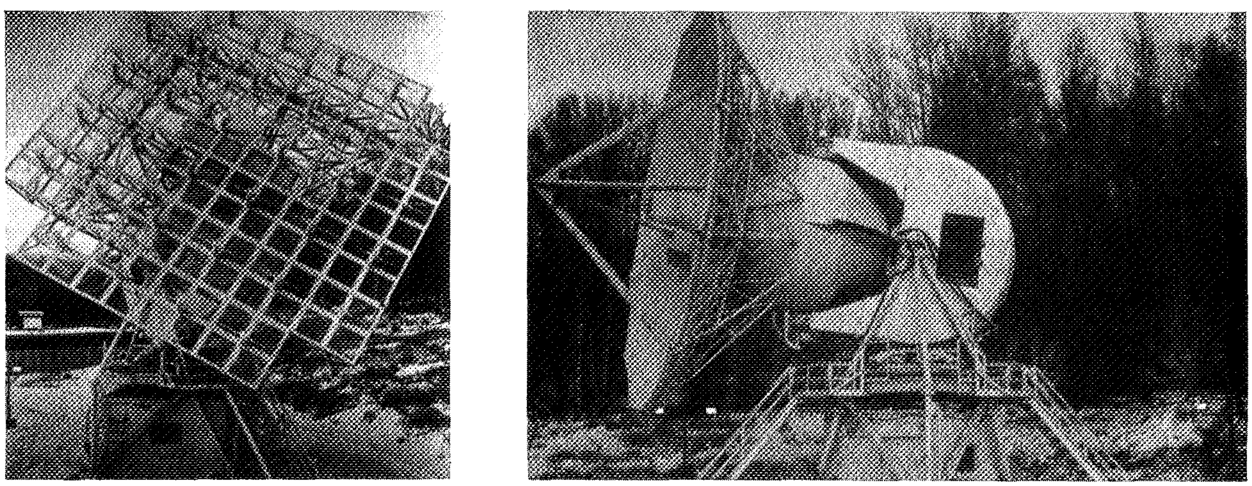


Figure 8. Goddard Range and Range-Rate Facility (GRARR-2)

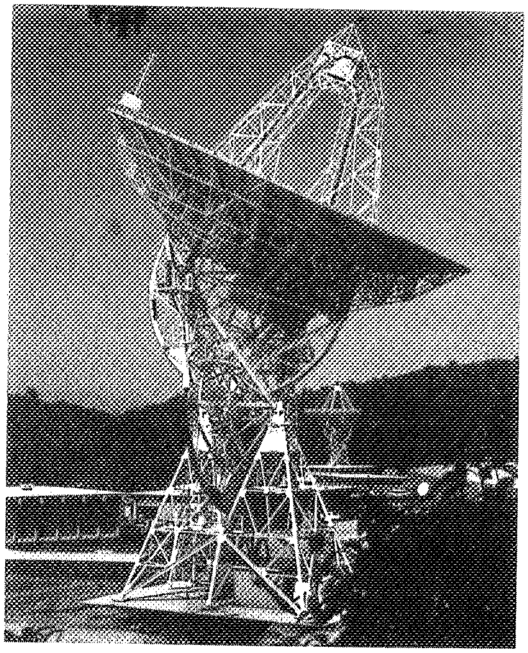


Figure 9. 26-Meter Data Acquisition Antenna

degrees above the horizon for ten degrees east and west of the 0^{o} and 180^{o} azimuth points. (Rosman II has somewhat greater, although similar, mechanical constraints on its field of view.) The entire antenna weighs about 270 metric tons and is about 37 meters high in the stow position.

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

6.6 12-METER DATA ACQUISITION ANTENNAS

The function and operation of these antennas are very similar to those of the 26-meter antennas. The 12-meter parabolic reflector is mounted on a coplanar X-Y pedestal (Figure 10). 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 5 meters). 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^{o} keyholes centered 12^{o} each side of north and south. The antenna is 17 meters high in the stow position, and its overall weight is 49 metric tons.

The 12-meter 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.

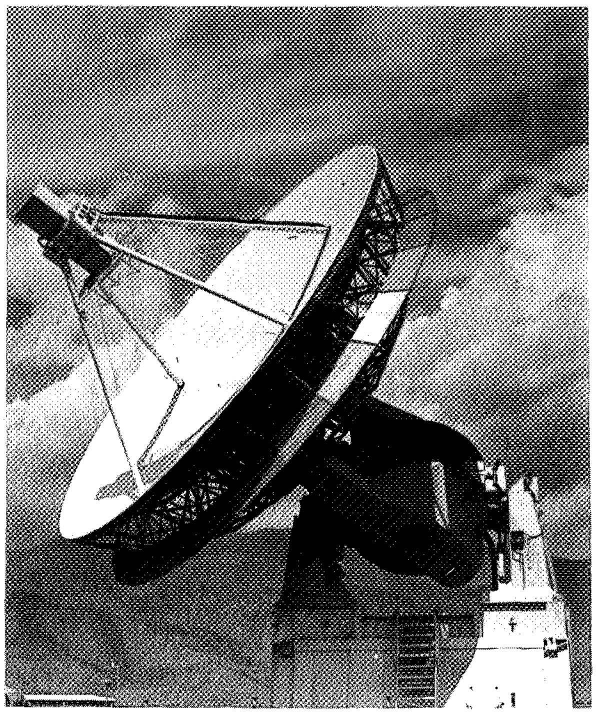


Figure 10. 12-Meter Data Acquisition Antenna

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 $1\frac{1}{2}$ meters above the ground on pedestals (Figure 11). The system operates in the 136-138 MHz band.

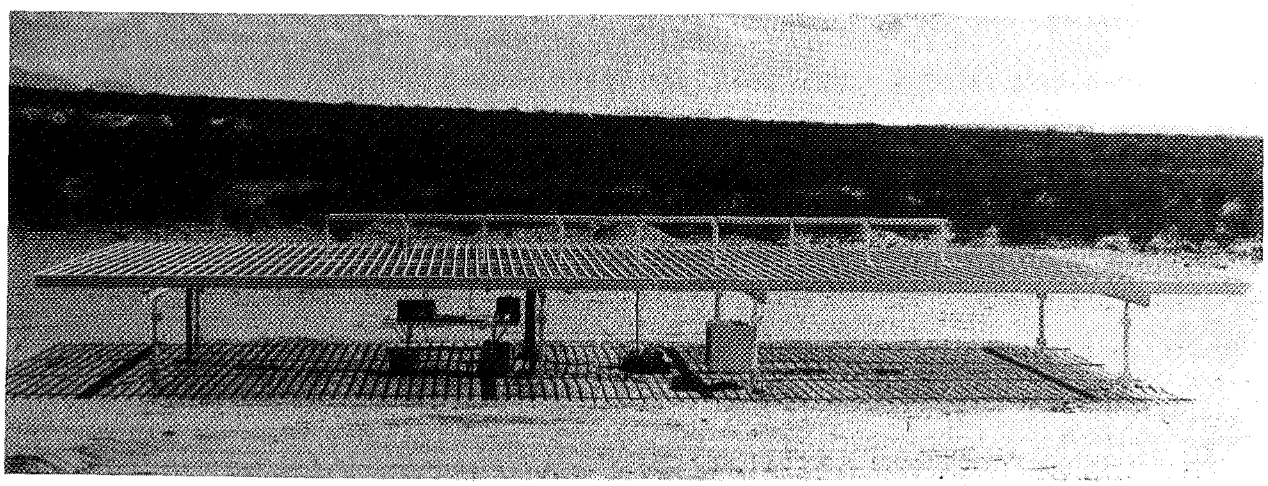


Figure 11. Minitrack Antenna

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.

6.8 SATAN ANTENNAS

The Satellite Automatic Tracking Antenna (SATAN) is a wideband yagi designed to complement the data acquisition and command functions of the 12- and 26-meter antennas. It operates in the 136- to 138-MHz frequency range. The SATAN telemetry and command (T&C) antennas listed in the directory are either 9- or 16-element arrays. The 9-element array, at Toowoomba, Australia, is mounted on an azimuth-over-elevation pedestal. The antenna can be positioned $\pm 270^{\circ}$ in azimuth and $\pm 80^{\circ}$ from zenith in elevation. The 16-element array, at Rosman and Goldstone, is mounted on an X-Y pedestal. The Y-axis supports the antenna platform and is aligned in the East-West direction. Each axis of the pedestal can be rotated $\pm 83^{\circ}$ from zenith.

6.9 DEEP SPACE NETWORK

This network was established by NASA under the management and technical direction of the Jet Propulsion Laboratory, California Institute of Technology, by whom it was designed and implemented. It is designed primarily for the support of planetary and interplanetary exploration, but has supported, in collaboration with the Spaceflight Tracking and Data Network, the Apollo 8 through 17 flights. It is continually improved to reflect developments in telecommunications, and is much used for radio science investigations. Seven 26-m antennas are involved in tracking spacecraft and acquiring data. These stations are connected through the NASA Communication (NASCOM) system and the local Ground Communication Facilities (GCF) to the Network Control Center at JPL, Pasadena. The first of three 64-m diameter antennas has been in operation at Goldstone for several years; the other two are (1973) in final stages of construction at Madrid, Spain and Canberra, Australia. Two additional antennas at Goldstone are a 26-m azimuth-elevation mounted antenna used for research and development of new capabilities before their entry into the operating network, and a 9-m diameter antenna for radio science development. In recent years the latter has also operated as part of a network time synchronization system at X-band, which uses the moon as the reflecting surface for signals to the overseas deep space stations.

6.9.1 26-m Diameter Hour Angle-Declination Mount

The antenna in most common use at the deep space stations is the 26-m diameter paraboloid with polar mount (Figure 12). The seven stations mentioned above are of this type and are essentially identical except in the number of legs (three for the earlier models). These stations operate in the S-band range with transmitters at 2110/2120MHz and receivers at 2290/2300MHz. The stations generate angle, doppler, and ranging metric data. They are equipped with electronics to receive, record, demodulate, decode, and format spacecraft telemetry data for retransmission to the control centers. They have command modulators and associated digital equipment to transmit commands to the spacecraft.

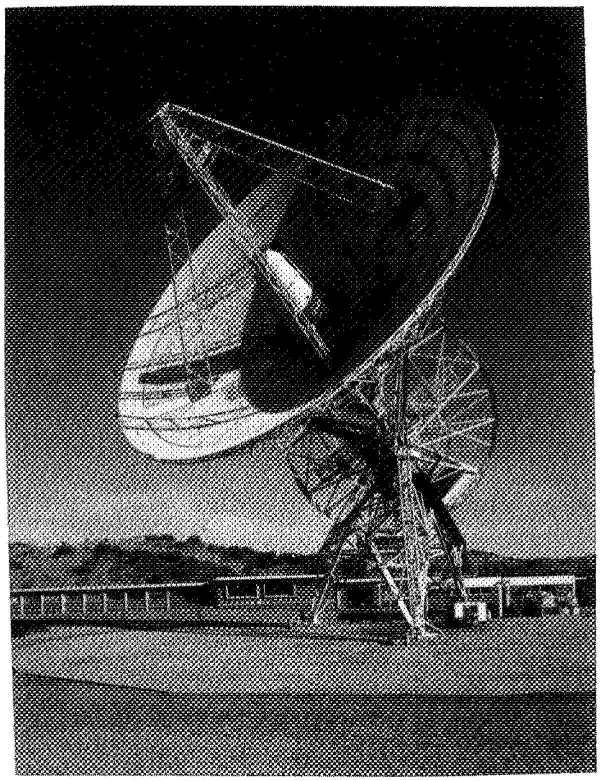


Figure 12. DSN 26-Meter Antenna

6.9.2 26-m Diameter Antenna (Venus Station) AZ-EL Mounted

This station, as noted above, is the research and development facility for introducing new capability into the operating network. It has the appropriate transmitting and receiving electronics.

6.9.3 64-Meter Antenna

The 64-meter Advanced Antenna System (Figure 13) was placed in operation at the Goldstone Mars station in 1966. Two antennas almost identical to it 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 64-meter diameter paraboloid has a focal length of 27.109 meters. The reflector is constructed of 1200 aluminum sheeted panels 2 mm thick. The surface is solid out to half the radius; the surface for the outer half of the radius is perforated with 6-mm holes for 50% porosity. The Cassegrain feed cone, at the vertex of the primary reflector, is divided into four 3-meter modules. The 6-meter 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 26-meter antenna.

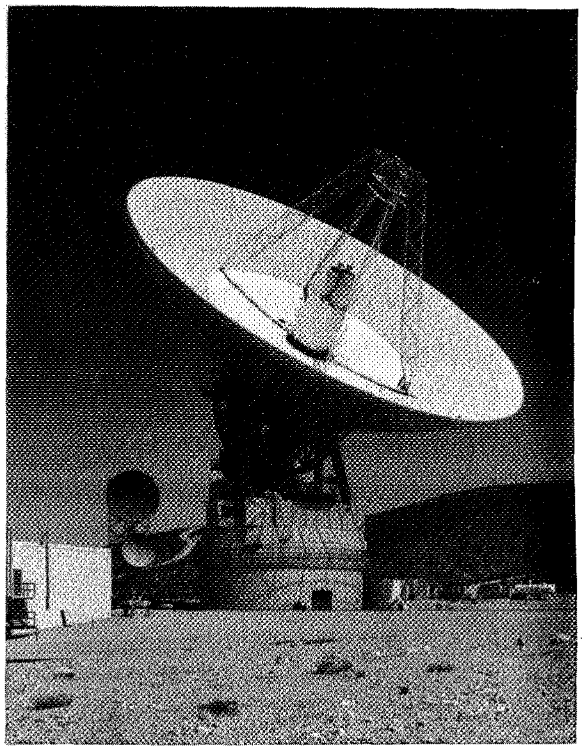


Figure 13. DSN 64-Meter Antenna

The azimuth-elevation mount is designed to track at 0.5° a second with a dead-load RMS error of 6 mm. 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 73 meters high in the zenith-pointing position, and weighs about 7000 metric tons, 2300 of these being in the moving part

6.10 RADIO TELESCOPES

The following facilities, primarily devoted to studies in radio astronomy, are not NASA facilities, but are listed for their past or potential cooperation with NASA satellite programs.

6.10.1 Jodrell Bank 76-Meter Telescope

The large telescope at Jodrell Bank, England, is famous for its use in tracking the early Russian and American satellites. The 76-meter telescope is a fully steerable paraboloid (alt-azimuth mounted) with a focal length of 19 meters. The reflector surface originally consisted of 7100 one-meter square sections of sheet steel which were welded together. The surface lining was modified in 1971 with adjustable solid panels which allow the surface to be maintained as a paraboloid to within 2.5 mm. 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.

6.10.2 Parkes 64-Meter 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 at S-band frequencies. The 64-meter diameter paraboloid has a focal length of 26.2 meters. 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 9 meter 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 $\pm 225^{\circ}$. The supporting tower structure, 12 meters in diameter and about 12 meters high, houses the control system and radio frequency equipment.

6.10.3 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 11 to

3 cm wavelength range. 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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"Space Tracking and Data Acquisition Network Manual." Report No. X-530-70-454, NASA Goddard Space Flight Center, December 1970.

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

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

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

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

TABLE 3
ANTENNA CHARACTERISTICS

Directory Group		Equipment	Antenna Type	Main Reflector Diameter m	Main Reflector Focal Length m	Approx. Overall Height m	Axes Orientation	Reference Axis Height m	Axes Separation m	Angle Readings	Sky Coverage[3]
Unified S-Band		USB 9 m	Cassegrain	9	3.6	15	X: N-S[1]	6[2]	2.4	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
		USB 26 m	Cassegrain	26	11	37	X: E-W	14[2]	7	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	9	2.7	12	Az-El	6[3]	0	Az: 0° at North El: 0° at horizon	Zenith to 2° below horizon except zenith keyhole of 5° radius
		FPS-16	Prime Focus	3.7	1.3	6		2.4[3]	0		Zenith to 10° below horizon except zenith keyhole of 5° radius
Goddard Range And Range Rate	1	VHF-Slotted	Planar Array	9x9	-	15	X: N-S	10.7[2]	1.0	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
		S-band Paired 4 m	Cassegrain	4.3	2						
	2	VHF-Dipole	Planar Array	8.5x8.5	-	15		6[2]	2.4		Zenith to horizon except N-S keyhole of 10° width and 5° height
		S-band 9 m	Cassegrain	9	3.7						
Data Acquisition		26 m X-Y	Prime Focus[5]	26	11	37	X: N-S	13[2]	7	X: +90°(E) to -90°(W) Y: +90°(N) to -90°(S)	Zenith to horizon except N-S keyhole of 20° width, 12° height
		26 m Az-El	Cassegrain	26	11	36	Az-El	22[3]	0	Az: 0° at North El: 0° at horizon	5° beyond zenith to 1° below horizon
		12 m X-Y	Prime Focus[6]	12	5	17	X: N-S	7[2]	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		26 m HA-Dec	Cassegrain	26			HA-Dec	12-15			
		26 m Az-El	Cassegrain	26		27	Az-El	11	3		
		64 m Az-El	Cassegrain	64	27	72		34	0		

NOTES:
Dimensions shown may vary somewhat with individual antennas, because of local conditions and/or hardware modifications.
1- Except the two ERTS antennas, which are oriented like the USB 26-m.
2- Height of X-axis above foundation. X-axis is lower, fixed axis.
3- Height of elevation axis above foundation.
4- Limitation of keyhole (gimbal lock) shown as maximum width and height of a usually elliptical zone; additional limitations of horizon profile not shown.
5- Except for Rosman II, which is equipped for either prime focus or Cassegrain feed.
6- Except for Goldstone, which is Cassegrain.

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Station Index

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STATION INDEX

NASA SATELLITE TRACKING STATIONS

Station	Location	Antenna
Unified S-Band		
USB 1	Merritt Island, Florida	9-meter
USB 2*	Grand Bahama Island	9-meter
USB 3	Bermuda	9-meter
USB 4*	Antigua, West Indies Assoc. States	9-meter
USB 5	Canary Islands	9-meter
USB 6	Ascension Island	9-meter
USB 7	Madrid, Spain	26-meter
USB 8	Carnarvon, Australia	9-meter
USB 9	Guam	9-meter
USB 10	Canberra, Australia	26-meter
USB 11	Kauai, Hawaii	9-meter
USB 12	Goldstone, California	26-meter
USB 13*	Guaymas, Mexico	9-meter
USB 14	Corpus Christi, Texas	9-meter
USB 15	Greenbelt, Maryland	9-meter
USB 16	Greenbelt, Maryland	9-meter
USB 17	Goldstone, California	9-meter
USB 18	Merritt Island, Florida	9-meter
USB 19	Santiago, Chile	9-meter
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, West Indies Assoc. States	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

*Removed or not operational

Station	Location	Antenna
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

Goddard Range and Range-Rate

GRR 1S	Fairbanks, Alaska	S-Band 9-meter
GRR 1V	Fairbanks, Alaska	VHF
GRR 2S	Rosman, North Carolina	S-Band Paired 4.3-meter
GRR 2V	Rosman, North Carolina	VHF
GRR 3S*	Santiago, Chile	S-Band 9-meter
GRR 3V	Santiago, Chile	VHF
GRR 4S	Tananarive, Madagascar	S-Band Paired 4.3-meter
GRR 4V	Tananarive, Madagascar	VHF
GRR 5S	Carnarvon, Australia	S-Band Paired 4.3-meter
GRR 5V	Carnarvon, Australia	VHF

26-meter Antennas

S85 1	Rosman, North Carolina
S85 2	Rosman, North Carolina
S85 3	Fairbanks, Alaska
S85 4	Orroral, Australia
S85 6	Kashima, Japan

12-meter Antennas

S40 1	Gilmore Creek, Alaska
S40 2	Johannesburg, South Africa
S40 3	Quito, Ecuador
S40 4	Santiago, Chile
S40 5	Goldstone, California
S40 6	Tananarive, Madagascar
S40 7	Greenbelt, Maryland

Station	Location	Antenna
Minitrack		
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, Canada	
MIN 12	Winkfield, England	
MIN 13	Johannesburg, South 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	26-meter HA-Dec
DSN 2	Goldstone, California	26-meter HA-Dec
DSN 3	Goldstone, California	26-meter Az-El
DSN 4	Goldstone, California	64-meter Az-El
DSN 5	Woomera, Australia	26-meter HA-Dec
DSN 6	Tidbinbilla, Australia	26-meter HA-Dec
DSN 7	Johannesburg, South Africa	26-meter HA-Dec
DSN 8	Madrid, Spain	26-meter HA-Dec
DSN 9	Madrid, Spain	26-meter HA-Dec
DSN 10	Tidbinbilla, Australia	64-meter HA-Dec
DSN 11	Madrid, Spain	64-meter HA-Dec

Station	Location		Antenna
Radio Telescopes			
RTE 1	Jodrell Bank, England		76-meter
RTE 2	Parkes, Australia		64-meter
RTE 3	Bonn, West Germany		100-meter
RTE 4	Green Bank, West Virginia		43-meter
Launch Sites			
LPD 1	Cape Kennedy, Florida	Stand 12	
LPD 2	Cape Kennedy, Florida	Stand 13	
LPD 3	Cape Kennedy, Florida	Stand 14	
LPD 4	Cape Kennedy, Florida	Stand 19	
LPD 5	Cape Kennedy, Florida	Stand 34	
LPD 6	Cape Kennedy, Florida	Stand 37A	
LPD 7	Cape Kennedy, Florida	Stand 37B	
LPD 8	Cape Kennedy, Florida	Stand 39A	

Positions on Local or Major Datums

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POSITIONS ON LOCAL OR MAJOR DATUMS

STATION		GEODETIC COORDINATES				ELEV	GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	MSL(M)	X(M)	Y(M)	Z(M)
UNIFIED S-BAND ANTENNAS									
USB 1	MERRITT ISLAND	NAD27	28° 30' 28".22	279° 18' 22".93	19.2	9.2	907 084.1	-5 535 373.4	3 025 921.7
USB 2	GRAND BAHAMA	NAD27	26 37 56.45	281 45 43.47	19.4	11.4	1 163 031.9	-5 585 586.8	2 841 708.6
USB 3	BERMUDA	BER57	32 20 59.50	295 20 30.55	22.6	22.6	2 308 527.7	-4 874 516.5	3 393 100.6
USB 4	ANTIGUA	NAD27	17 0 57.13	298 14 48.51	40.4	34.4	2 887 328.8	-5 374 298.3	1 854 412.1
USB 5	GRAND CANARY	PICO	27 45 46.18	344 22 4.52	160.4	160.4	5 439 468.7	-1 522 010.4	2 953 389.3
USB 6	ASCENSION	ASC58	-7 57 19.04	345 40 20.72	544.2	544.2	6 121 441.4	-1 563 474.2	-876 968.1
USB 7	MADRID	EUROP	40 27 23.85	355 49 58.23	763.1	785.1	4 847 912.1	-353 214.8	4 117 260.5
USB 8	CARNARVON	AUSTR	-24 54 27.43	113 43 27.17	50.6	44.5	-2 328 873.5	5 299 235.8	-2 669 827.1
USB 9	GUAM	GUAM	13 18 33.28	144 44 3.89	92.1	92.1	-5 068 819.1	3 584 355.2	1 458 650.5
USB10	CANBERRA	AUSTR	-35 35 5.05	148 58 35.68	1138.7	1129.7	-4 450 939.6	2 676 871.4	-3 691 493.2
USB11	KAUAI	OLDHW	22 7 45.93	200 19 55.38	1150.9	1150.9	-5 543 898.0	-2 054 276.3	2 387 988.1
USB12	GOLDSTONE	NAD27	35 20 29.63	243 7 38.04	951.0	973.0	-2 354 748.4	-4 646 935.7	3 669 204.5
USB13	GUAYMAS	NAD27	27 57 45.96	249 16 46.28	14.9	23.9	-1 994 697.0	-5 273 111.6	2 972 702.7
USB14	CORPUS CHRISTI	NAD27	27 39 11.78	262 37 17.92	17.3	12.3	-726 063.6	-5 606 962.9	2 942 368.8
USB15	GREENBELT	NAD27	38 59 54.30	283 9 24.85	54.7	53.7	1 129 808.8	-4 833 314.8	3 992 018.5
USB16	GREENBELT	NAD27	38 59 53.58	283 9 27.83	61.2	60.2	1 129 883.0	-4 833 316.9	3 992 005.3
USB17	GOLDSTONE	NAD27	35 20 29.63	243 7 40.46	945.6	967.6	-2 354 692.0	-4 646 959.4	3 669 201.3
USB18	MERRITT ISLAND	NAD27	28 30 26.34	279 18 22.93	19.1	9.1	907 088.5	-5 535 400.6	3 025 870.8
USB19	SANTIAGO	SAD69	-33 9 2.73	289 20 3.25	731.9	705.7	1 769 938.7	-5 044 486.2	-3 468 381.4
RADARS									
RAD 1	MERRITT ISLAND	NAD27	28 25 27.93	279 20 7.38	21.2	11.2	910 601.9	-5 539 262.9	3 017 796.0
RAD 2	PATRICK AFB	NAD27	28 13 33.99	279 24 1.77	24.9	14.9	918 599.8	-5 548 515.5	2 998 451.5
RAD 3	CAPE KENNEDY	NAD27	28 28 52.79	279 25 23.77	23.6	13.6	918 605.9	-5 534 897.6	3 023 342.0
RAD 4	GRAND BAHAMA	NAD27	26 38 9.02	281 43 55.31	19.9	11.9	1 160 067.7	-5 586 026.5	2 842 054.7
RAD 5	WALLOPS ISLAND	NAD27	37 51 36.51	284 29 25.24	13.0	15.0	1 261 620.1	-4 881 717.1	3 893 013.3
RAD 6	WALLOPS ISLAND	NAD27	37 50 28.39	284 30 52.38	10.4	12.4	1 264 004.8	-4 882 429.1	3 891 353.4
RAD 7	GRAND TURK	NAD27	21 27 43.49	288 52 3.05	42.0	36.0	1 920 453.1	-5 619 579.8	2 318 962.7
RAD 8	BERMUDA	BER57	32 20 48.03	295 20 46.32	19.9	19.9	2 308 980.3	-4 874 508.7	3 392 800.9
RAD 9	BERMUDA	BER57	32 20 47.53	295 20 46.53	21.1	21.1	2 308 989.3	-4 874 514.8	3 392 788.5
RAD10	ANTIGUA	NAD27	17 8 34.78	298 12 24.47	48.3	42.3	2 881 625.8	-5 372 678.7	1 867 862.1
RAD11	ASCENSION	ASC58	-7 58 22.78	345 35 53.90	125.4	125.4	6 118 749.3	-1 571 220.8	-878 849.3
RAD12	ASCENSION	ASC58	-7 57 6.29	345 35 14.63	92.3	92.3	6 118 733.5	-1 572 458.6	-876 517.5
RAD13	TANANARIVE	TANAN	-19 0 .99	47 18 54.19	1338.3	1338.3	4 091 046.6	4 435 762.4	-2 063 839.5

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STATION		GEODETIC COORDINATES				ELEV	GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	MSL(M)	X(M)	Y(M)	Z(M)
RADARS									
RAD14	CARNARVON	AUSTR	-24° 53' 50".76	113° 42' 57".76	55.1	49.0	-2 328 310.7	5 300 006.6	-2 668 805.3
RAD15	WOOMERA	AUSTR	-30 49 11.00	136 50 13.12	123.2	124.7	-3 998 907.1	3 750 369.9	-3 248 819.4
RAD16	KAUAI	OLDHW	22 7 35.83	200 19 53.96	1155.0	1155.0	-5 544 025.4	-2 054 280.2	2 387 701.8
RAD17	VANDENBERG AFB	NAD27	34 39 57.14	239 25 10.43	89.0	123.0	-2 671 836.2	-4 521 351.1	3 607 304.8
RAD18	PT. ARGUELLO	NAD27	34 34 57.95	239 26 21.97	627.5	661.5	-2 673 156.8	-4 527 170.1	3 600 023.9
RAD19	WHITE SANDS	NAD27	32 21 28.62	253 37 50.66	1232.8	1234.0	-1 520 195.1	-5 175 429.1	3 394 506.3
RAD20	EGLIN AFB	NAD27	30 25 17.06	273 12 6.44	36.8	27.8	307 463.1	-5 496 301.3	3 210 588.3
RAD21	WALLOPS ISLAND	NAD27	37 51 16.74	284 29 11.61	28.8	30.8	1 261 394.2	-4 882 174.6	3 892 541.8
GODDARD R/RR STATIONS									
GRR1S	FAIRBANKS	NAD27	64 58 20.89	212 29 22.41	348.6	346.6	-2 282 482.4	-1 453 517.0	5 756 536.4
GRR1V	FAIRBANKS	NAD27	64 58 19.19	212 29 28.12	348.6	346.6	-2 282 482.3	-1 453 605.7	5 756 514.1
GRR2S	ROSMAN	NAD27	35 11 45.05	277 7 26.23	880.3	873.9	647 213.2	-5 178 486.4	3 655 962.8
GRR2V	ROSMAN	NAD27	35 11 41.10	277 7 26.23	879.9	873.9	647 221.8	-5 178 555.8	3 655 863.0
GRR3S	SANTIAGO	SAD69	-33 9 2.73	289 20 3.25	731.9	705.7	1 769 938.7	-5 044 486.2	-3 468 381.4
GRR3V	SANTIAGO	SAD69	-33 9 5.21	289 20 3.25	732.2	706.0	1 769 925.0	-5 044 447.1	-3 468 445.4
GRR4S	TANANARIVE	TANAN	-19 1 9.33	47 18 12.56	1399.0	1399.0	4 091 516.4	4 434 475.6	-2 065 846.4
GRR4V	TANANARIVE	TANAN	-19 1 11.80	47 18 12.56	1399.0	1399.0	4 091 499.6	4 434 457.4	-2 065 918.2
GRR5S	CARNARVON	AUSTR	-24 54 14.96	113 42 54.94	44.0	37.9	-2 328 107.9	5 299 742.1	-2 669 476.3
GRR5V	CARNARVON	AUSTR	-24 54 18.92	113 42 54.94	44.0	37.9	-2 328 087.3	5 299 695.1	-2 669 586.8
85-FOOT ANTENNAS									
S85 1	ROSMAN	NAD27	35 12 .05	277 7 40.57	898.0	892.0	647 542.0	-5 178 191.4	3 656 350.8
S85 2	ROSMAN	NAD27	35 11 55.68	277 7 27.45	894.0	888.0	647 221.8	-5 178 306.4	3 656 238.3
S85 3	FAIRBANKS	NAD27	64 58 37.71	212 29 5.58	309.0	307.0	-2 282 188.6	-1 453 068.1	5 756 720.9
S85 4	ORRORAL	AUSTR	-35 37 52.85	148 57 20.91	945.9	937.6	-4 447 254.2	2 676 850.7	-3 695 586.2
S85 6	KASHIMA	TOKYO	35 57 3.20	140 39 57.83	48.1	45.1	-3 997 747.3	3 276 074.2	3 723 440.1
40-FOOT ANTENNAS									
S40 1	GILMORE CREEK	NAD27	64 58 36.93	212 28 54.00	299.0	297.0	-2 282 285.2	-1 452 949.5	5 756 701.6
S40 2	JOHANNESBURG	ARC	-25 53 9.16	27 42 27.93	1545.0	1537.0	5 084 811.9	2 670 464.3	-2 768 140.6
S40 3	QUITO	SAD69	-0 37 22.11	281 25 11.28	3594.3	3570.0	1 263 488.1	-6 255 046.3	-68 904.5
S40 4	SANTIAGO	SAD69	-33 9 4.07	289 19 56.40	728.5	702.3	1 769 762.7	-5 044 521.1	-3 468 414.0
S40 5	GOLDSTONE	NAD27	35 19 53.97	243 6 47.76	918.0	940.0	-2 356 156.4	-4 646 904.5	3 668 288.8

POSITIONS ON LOCAL OR MAJOR DATUMS

STATION		GEODETIC COORDINATES				ELEV	GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	MSL(M)	X(M)	Y(M)	Z(M)
40-FOOT ANTENNAS									
S40 6	TANANARIVE	TANAN	-19° 0' 34".40	47° 18' 5".66	1385.2	1385.2	4 091 893.2	4 434 586.3	-2 064 826.2
S40 7	GREENBELT	NAD27	38 59 59.64	283 9 29.96	55.7	54.7	1 129 905.1	-4 833 186.6	3 992 147.3
MINITRACK STATIONS									
MIN 1	FAIRBANKS	NAD27	64 52 19.72	212 9 47.17	164.7	162.7	-2 299 237.8	-1 445 840.3	5 751 628.7
MIN 2	FAIRBANKS	NAD27	64 58 38.60	212 28 40.90	291.6	289.6	-2 282 335.2	-1 452 777.6	5 756 716.8
MIN 3	GOLDSTONE	NAD27	35 19 48.09	243 6 2.73	907.1	929.1	-2 357 214.3	-4 646 475.6	3 668 134.6
MIN 4	EAST GRAND FORKS	NAD27	48 1 21.40	262 59 21.56	255.4	252.6	-521 679.0	-4 242 198.1	4 718 543.9
MIN 5	FORT MYERS	NAD27	26 32 51.89	278 8 3.93	20.5	4.8	807 883.1	-5 652 136.6	2 833 327.5
MIN 6	QUITO	SAD69	-0 37 20.62	281 25 17.94	3592.9	3568.6	1 263 689.9	-6 255 004.7	-68 858.8
MIN 7	LIMA	SAD69	-11 46 34.98	282 51 1.63	59.2	49.9	1 388 896.3	-6 088 429.6	-1 293 212.9
MIN 8	BLOSSOM POINT	NAD27	38 25 49.63	282 54 48.22	6.8	5.8	1 118 061.2	-4 876 472.0	3 942 793.4
MIN 9	GREENBELT	NAD27	38 59 56.73	283 9 37.31	51.8	50.8	1 130 089.5	-4 833 198.4	3 992 074.8
MIN10	SANTIAGO	SAD69	-33 8 57.24	289 19 56.40	719.6	693.4	1 769 798.3	-5 044 622.6	-3 468 232.9
MIN11	ST. JOHN'S	NAD27	47 44 29.74	307 16 43.37	106.0	69.0	2 602 802.4	-3 419 301.2	4 697 477.3
MIN12	WINKFIELD	EUROP	51 26 49.11	359 18 14.10	61.0	67.4	3 983 199.1	-48 394.1	4 964 832.6
MIN13	JOHANNESBURG	ARC	-25 52 58.86	27 42 27.93	1530.3	1522.3	5 084 922.6	2 670 522.4	-2 767 849.0
MIN14	TANANARIVE	TANAN	-19 0 27.10	47 18 .46	1377.9	1377.9	4 092 050.0	4 434 531.9	-2 064 611.5
MIN15	WOOMERA	AUSTR	-31 23 30.07	136 52 11.02	128.5	129.5	-3 977 143.9	3 725 688.8	-3 303 119.5
MIN16	ORRORAL	AUSTR	-35 37 37.50	148 57 10.71	939.5	931.2	-4 447 353.6	2 677 210.2	-3 695 197.9
SATAN ANTENNAS									
SAT 1	ROSMAN	NAD27	35 12 6.12	277 7 26.36	940.2	934.2	647 176.1	-5 178 163.1	3 656 528.1
SAT 2	GOLDSTONE	NAD27	35 19 53.97	243 6 42.39	914.7	936.7	-2 356 276.3	-4 646 840.7	3 668 286.9
SAT 3	COOBY CREEK	AUSTR	-27 23 50.69	151 56 17.15	551.6	550.0	-5 001 023.6	2 666 026.1	-2 917 646.3
DEEP SPACE NETWORK									
DSN 1	GOLDSTONE	NAD27	35 23 22.35	243 9 5.26	1014.3	1036.3	-2 351 415.0	-4 645 227.9	3 673 582.3
DSN 2	GOLDSTONE	NAD27	35 17 59.85	243 11 43.41	966.9	988.9	-2 350 428.2	-4 652 127.3	3 665 447.0
DSN 3	GOLDSTONE	NAD27	35 14 51.79	243 12 21.57	1071.5	1093.5	-2 351 115.0	-4 655 626.4	3 660 775.0
DSN 4	GOLDSTONE	NAD27	35 25 33.34	243 6 40.85	1009.8	1031.8	-2 353 607.0	-4 641 490.8	3 676 870.6
DSN 5	WOOMERA	AUSTR	-31 22 59.43	136 53 10.12	147.3	148.3	-3 978 581.8	3 724 895.9	-3 302 323.7

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STATION		GEODETIC COORDINATES				ELEV	GEOCENTRIC COORDINATES		
NO.	LOCATION	DATUM	LATITUDE	LONGITUDE(E)	H(M)	MSL(M)	X(M)	Y(M)	Z(M)
DEEP SPACE NETWORK									
DSN 6	TIDBINBILLA	AUSTR	-35° 24′ 8″.04	148° 58′ 48″.19	664.1	655.8	-4 460 847.4	2 682 461.6	-3 674 729.2
DSN 7	JOHANNESBURG	ARC	-25 53 21.15	27 41 8.53	1399.0	1391.0	5 085 580.4	2 668 370.8	-2 768 408.9
DSN 8	MADRID	EUROP	40 25 47.72	355 45 8.28	766.4	788.4	4 849 331.9	-360 171.9	4 115 005.8
DSN 9	MADRID	EUROP	40 27 15.27	355 38 .57	716.3	738.3	4 846 789.6	-370 090.3	4 117 029.0
DSN10	TIDBINBILLA	AUSTR	-35 24 14.34	148 58 48.19	678.0	669.7	-4 460 760.6	2 682 409.5	-3 674 895.4
DSN11	MADRID	EUROP	40 26 3.93	355 45 9.13	774.0	796.0	4 849 015.7	-360 128.3	4 115 391.3
RADIO TELESCOPES									
RTE 1	JODRELL BANK	EUROP	52 14 14.66	357 41 34.39	124.6	128.6	3 911 202.8	-157 576.6	5 019 221.0
RTE 2	PARKES	AUSTR	-33 0 .04	148 15 44.15	395.1	391.8	-4 554 090.2	2 816 808.7	-3 454 186.6
RTE 3	BONN	*							
RTE 4	GREEN BANK	NAD27	38 26 15.41	280 9 50.39	883.9	880.9	882 895.2	-4 924 679.3	3 943 961.4
LAUNCH SITES									
LPD 1	PAD 12	NAD27	28 28 49.13	279 27 28.05	25.0	15.0	921 949.7	-5 534 397.4	3 023 243.4
LPD 2	PAD 13	NAD27	28 29 8.13	279 27 19.22	25.0	15.0	921 667.0	-5 534 161.6	3 023 757.7
LPD 3	PAD 14	NAD27	28 29 27.14	279 27 10.39	25.0	15.0	921 384.2	-5 533 925.7	3 024 272.1
LPD 4	PAD 19	NAD27	28 30 24.15	279 26 43.70	19.7	9.7	920 530.0	-5 533 214.2	3 025 811.8
LPD 5	PAD 34	NAD27	28 31 17.51	279 26 19.11	25.0	15.0	919 742.6	-5 532 555.1	3 027 257.7
LPD 6	PAD 37A	NAD27	28 31 59.42	279 25 53.98	27.6	17.6	918 967.9	-5 532 061.4	3 028 392.6
LPD 7	PAD 37B	NAD27	28 31 53.13	279 26 5.39	27.6	17.6	919 289.1	-5 532 101.9	3 028 222.3
LPD 8	PAD 39A	NAD27	28 36 28.78	279 23 44.34	38.9	28.9	914 845.1	-5 528 735.4	3 035 680.2

* INSUFFICIENT DATA

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Positions on Modified Mercury Datum 1968

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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
UNIFIED S-BAND ANTENNAS									
USB 1	MERRITT ISLAND	28° 30' 29".15	279° 18' 23".14	-20.1	907 066.1	-5 535 228.4	3 026 104.7	6 373 290.4	28° 20' 49".22
USB 2	GRAND BAHAMA	26 37 57.62	281 45 43.90	-20.6	1 163 013.9	-5 585 441.8	2 841 891.6	6 373 861.3	26 28 43.66
USB 3	BERMUDA	32 21 4.60	295 20 31.68	-5.8	2 308 462.7	-4 874 310.5	3 393 408.6	6 372 058.1	32 10 39.28
USB 4	ANTIGUA	17 0 59.75	298 14 50.29	-.5	2 887 310.8	-5 374 153.3	1 854 595.1	6 376 331.9	16 54 33.17
USB 5	GRAND CANARY	27 45 51.97	344 21 57.58	211.4	5 439 160.7	-1 522 121.4	2 953 538.3	6 373 751.6	27 36 22.06
USB 6	ASCENSION	-7 57 17.53	345 40 21.69	553.0	6 121 233.4	-1 563 390.2	-876 916.1	6 378 296.6	-7 54 8.29
USB 7	MADRID	40 27 19.38	355 49 53.58	827.2	4 847 831.1	-353 318.8	4 117 139.5	6 370 018.6	40 15 55.90
USB 8	CARNARVON	-24 54 24.57	113 43 31.26	25.4	-2 328 980.5	5 299 193.8	-2 669 735.1	6 374 408.9	-24 45 36.58
USB 9	GUAM	13 18 36.73	144 44 11.82	109.7	-5 068 896.1	3 584 117.2	1 458 852.5	6 377 135.1	13 13 27.32
USB10	CANBERRA	-35 35 1.19	148 58 39.30	1150.9	-4 451 046.6	2 676 829.4	-3 691 401.2	6 372 101.1	-35 24 6.47
USB11	KAUAI	22 7 34.26	200 20 5.30	1130.9	-5 543 830.0	-2 054 554.3	2 387 795.1	6 376 269.2	21 59 32.18
USB12	GOLDSTONE	35 20 29.38	243 7 34.81	934.0	-2 354 766.4	-4 646 790.8	3 669 387.5	6 371 969.3	35 9 36.57
USB13	GUAYMAS	27 57 46.71	249 16 43.78	-9.9	-1 994 715.0	-5 272 966.6	2 972 885.7	6 373 469.5	27 48 14.07
USB14	CORPUS CHRISTI	27 39 12.76	262 37 16.59	-18.5	-726 081.6	-5 606 817.9	2 942 551.8	6 373 555.7	27 29 44.35
USB15	GREENBELT	38 59 54.24	283 9 25.49	18.1	1 129 790.8	-4 833 169.8	3 992 201.5	6 369 743.3	38 48 37.23
USB16	GREENBELT	38 59 53.52	283 9 28.47	24.6	1 129 865.0	-4 833 171.9	3 992 188.3	6 369 749.8	38 48 36.51
USB17	GOLDSTONE	35 20 29.38	243 7 37.23	928.6	-2 354 710.0	-4 646 814.4	3 669 384.3	6 371 963.9	35 9 36.57
USB18	MERRITT ISLAND	28 30 27.28	279 18 23.14	-20.2	907 070.5	-5 535 255.6	3 026 053.8	6 373 290.5	28 20 47.35
USB19	SANTIAGO	-33 9 3.97	289 20 .45	748.7	1 769 864.7	-5 044 495.2	-3 468 420.4	6 372 542.0	-32 58 30.67
RADARS									
RAD 1	MERRITT ISLAND	28 25 28.87	279 20 7.59	-18.1	910 583.9	-5 539 117.9	3 017 979.0	6 373 318.4	28 15 50.04
RAD 2	PATRICK AFB	28 13 34.96	279 24 1.99	-14.5	918 581.8	-5 548 370.5	2 998 634.5	6 373 383.4	28 3 58.77
RAD 3	CAPE KENNEDY	28 28 53.73	279 25 23.99	-15.7	918 587.9	-5 534 752.6	3 023 525.0	6 373 303.1	28 19 14.15
RAD 4	GRAND BAHAMA	26 38 10.20	281 43 55.74	-20.1	1 160 049.7	-5 585 881.5	2 842 237.7	6 373 860.9	26 28 56.17
RAD 5	WALLOPS ISLAND	37 51 36.51	284 29 26.01	-23.2	1 261 602.1	-4 881 572.1	3 893 196.3	6 370 114.8	37 40 25.84
RAD 6	WALLOPS ISLAND	37 50 28.40	284 30 53.15	-25.8	1 263 986.8	-4 882 284.1	3 891 536.4	6 370 118.9	37 39 17.84
RAD 7	GRAND TURK	21 27 45.40	288 52 4.09	.1	1 920 435.1	-5 619 434.7	2 319 145.7	6 375 308.1	21 19 54.85
RAD 8	BERMUDA	32 20 53.13	295 20 47.44	-8.5	2 308 915.3	-4 874 302.7	3 393 108.9	6 372 056.5	32 10 27.86
RAD 9	BERMUDA	32 20 52.63	295 20 47.66	-7.3	2 308 924.3	-4 874 308.7	3 393 096.5	6 372 057.7	32 10 27.36
RAD10	ANTIGUA	17 8 37.37	298 12 26.25	7.5	2 881 607.8	-5 372 533.7	1 868 045.1	6 376 313.5	17 2 8.26
RAD11	ASCENSION	-7 58 21.26	345 35 54.86	134.2	6 118 541.2	-1 571 136.8	-878 797.3	6 377 875.9	-7 55 11.60
RAD12	ASCENSION	-7 57 4.78	345 35 15.59	101.1	6 118 525.5	-1 572 374.6	-876 465.5	6 377 845.0	-7 53 55.61
RAD13	TANANARIVE	-19 0 5.41	47 18 52.76	1304.2	4 090 866.6	4 435 505.4	-2 063 937.5	6 377 204.2	-18 53 .17

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STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
RADARS									
RAD14	CARNARVON	-24° 53' 47".89	113° 43' 1".85	29.9	-2 328 417.7	5 299 964.6	-2 668 713.3	6 374 416.3	-24° 45' ".06
RAD15	WOOMERA	-30 49 7.51	136 50 17.03	127.5	-3 999 014.1	3 750 327.9	-3 248 727.4	6 372 699.8	-30 38 59.01
RAD16	KAUAI	22 7 24.16	200 20 3.88	1135.0	-5 543 957.4	-2 054 558.2	2 387 508.8	6 376 274.0	21 59 22.13
RAD17	VANDENBERG AFB	34 39 56.85	239 25 6.92	76.6	-2 671 854.3	-4 521 206.1	3 607 487.8	6 371 348.1	34 29 9.58
RAD18	PT. ARGUELLO	34 34 57.67	239 26 18.47	615.1	-2 673 174.8	-4 527 025.1	3 600 206.9	6 371 915.6	34 24 11.17
RAD19	WHITE SANDS	32 21 28.91	253 37 48.44	1205.1	-1 520 213.1	-5 175 284.1	3 394 689.3	6 373 266.7	32 11 3.65
RAD20	EGLIN AFB	30 25 17.76	273 12 6.07	-1.5	307 445.1	-5 496 156.3	3 210 771.3	6 372 700.2	30 15 13.89
RAD21	WALLOPS ISLAND	37 51 16.74	284 29 12.38	-7.4	1 261 376.2	-4 882 029.6	3 892 724.8	6 370 132.5	37 40 6.11
GODDARD R/RR STATIONS									
GRR1S	FAIRBANKS	64 58 19.25	212 29 12.35	346.6	-2 282 500.4	-1 453 372.0	5 756 719.4	6 360 968.1	64 49 27.11
GRR1V	FAIRBANKS	64 58 17.55	212 29 18.06	346.6	-2 282 500.3	-1 453 460.7	5 756 697.1	6 360 968.2	64 49 25.40
GRR2S	ROSMAN	35 11 45.28	277 7 26.23	842.9	647 195.2	-5 178 341.4	3 656 145.8	6 371 929.3	35 0 53.64
GRR2V	ROSMAN	35 11 41.32	277 7 26.23	842.5	647 203.8	-5 178 410.8	3 656 046.0	6 371 929.3	35 0 49.69
GRR3S	SANTIAGO	-33 9 3.97	289 20 .45	748.7	1 769 864.7	-5 044 495.2	-3 468 420.4	6 372 542.0	-32 58 30.67
GRR3V	SANTIAGO	-33 9 6.44	289 20 .45	749.0	1 769 851.0	-5 044 456.1	-3 468 484.4	6 372 542.1	-32 58 33.14
GRR4S	TANANARIVE	-19 1 13.75	47 18 11.13	1365.0	4 091 336.4	4 434 218.6	-2 065 944.4	6 377 260.7	-18 54 8.16
GRR4V	TANANARIVE	-19 1 16.22	47 18 11.13	1365.0	4 091 319.6	4 434 200.4	-2 066 016.2	6 377 260.5	-18 54 10.61
GRR5S	CARNARVON	-24 54 12.10	113 42 59.03	18.8	-2 328 214.9	5 299 700.1	-2 669 384.3	6 374 403.3	-24 45 24.17
GRR5V	CARNARVON	-24 54 16.06	113 42 59.03	18.8	-2 328 194.3	5 299 653.1	-2 669 494.8	6 374 403.0	-24 45 28.11
85-FOOT ANTENNAS									
S85 1	ROSMAN	35 12 .27	277 7 40.58	860.6	647 524.0	-5 178 046.4	3 656 533.7	6 371 945.5	35 1 8.60
S85 2	ROSMAN	35 11 55.90	277 7 27.46	856.6	647 203.8	-5 178 161.4	3 656 421.3	6 371 942.0	35 1 4.24
S85 3	FAIRBANKS	64 58 36.07	212 28 55.52	307.0	-2 282 206.6	-1 452 923.1	5 756 903.9	6 360 927.2	64 49 44.00
S85 4	ORRORAL	-35 37 48.99	148 57 24.53	958.0	-4 447 361.2	2 676 808.7	-3 695 494.2	6 371 891.6	-35 26 53.88
S85 6	KASHIMA	35 57 14.57	140 39 47.05	59.8	-3 997 909.3	3 276 556.2	3 724 111.1	6 370 879.1	35 46 16.88
40-FOOT ANTENNAS									
S40 1	GILMORE CREEK	64 58 35.29	212 28 43.93	297.1	-2 282 303.2	-1 452 804.5	5 756 884.6	6 360 917.3	64 49 43.21
S40 2	JOHANNESBURG	-25 53 10.67	27 42 25.84	1539.1	5 084 683.9	2 670 331.2	-2 768 414.6	6 375 640.9	-25 44 7.83
S40 3	QUITO	-0 37 23.38	281 25 8.87	3598.9	1 263 414.1	-6 255 055.3	-68 943.5	6 381 746.2	-0 37 8.37
S40 4	SANTIAGO	-33 9 5.30	289 19 53.59	745.3	1 769 688.7	-5 044 530.1	-3 468 453.0	6 372 538.5	-32 58 32.00
S40 5	GOLDSTONE	35 19 53.72	243 6 44.53	901.0	-2 356 174.4	-4 646 759.5	3 668 471.8	6 371 939.7	35 9 .99

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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 6	TANANARIVE	-19° 0' 38".82	47° 18' 4".22	1351.2	4 091 713.2	4 434 329.3	-2 064 924.2	6 377 249.0	-18° 53' 33".41
S40 7	GREENBELT	38 59 59.58	283 9 30.60	19.1	1 129 887.1	-4 833 041.6	3 992 330.3	6 369 743.8	38 48 42.57
MINITRACK STATIONS									
MIN 1	FAIRBANKS	64 52 18.05	212 9 37.12	163.2	-2 299 255.8	-1 445 695.3	5 751 811.7	6 360 813.6	64 43 24.34
MIN 2	FAIRBANKS	64 58 36.96	212 28 30.83	289.7	-2 282 353.2	-1 452 632.6	5 756 899.8	6 360 909.7	64 49 44.89
MIN 3	GOLDSTONE	35 19 47.84	243 5 59.50	890.1	-2 357 232.3	-4 646 330.6	3 668 317.6	6 371 929.4	35 8 55.11
MIN 4	EAST GRAND FORKS	48 1 21.02	262 59 19.85	220.1	-521 697.0	-4 242 053.1	4 718 726.9	6 366 597.6	47 49 52.02
MIN 5	FORT MYERS	26 32 53.09	278 8 4.02	-20.0	807 865.1	-5 651 991.6	2 833 510.5	6 373 887.1	26 23 40.34
MIN 6	QUITO	-0 37 21.89	281 25 15.54	3597.5	1 263 615.9	-6 255 013.7	-68 897.8	6 381 744.9	-0 37 6.89
MIN 7	LIMA	-11 46 36.23	282 50 59.18	69.5	1 388 822.3	-6 088 438.6	-1 293 251.9	6 377 335.7	-11 42 .30
MIN 8	BLOSSOM POINT	38 25 49.60	282 54 48.84	-29.8	1 118 043.2	-4 876 327.0	3 942 976.4	6 369 901.7	38 14 35.62
MIN 9	GREENBELT	38 59 56.67	283 9 37.95	15.2	1 130 071.5	-4 833 053.4	3 992 257.8	6 369 740.1	38 48 39.65
MIN10	SANTIAGO	-33 8 58.47	289 19 53.59	736.4	1 769 724.3	-5 044 631.6	-3 468 271.9	6 372 530.2	-32 58 25.19
MIN11	ST. JOHN'S	47 44 28.99	307 16 46.89	81.2	2 602 784.4	-3 419 156.2	4 697 660.3	6 366 563.1	47 32 59.31
MIN12	WINKFIELD	51 26 45.71	359 18 8.66	97.0	3 983 118.1	-48 498.1	4 964 711.6	6 365 213.5	51 15 30.05
MIN13	JOHANNESBURG	-25 53 .38	27 42 25.84	1524.4	5 084 794.6	2 670 389.4	-2 768 123.0	6 375 627.0	-25 43 57.58
MIN14	TANANARIVE	-19 0 31.52	47 17 59.03	1343.8	4 091 870.0	4 434 274.9	-2 064 709.5	6 377 242.3	-18 53 26.14
MIN15	WOOMERA	-31 23 26.58	136 52 14.95	131.8	-3 977 250.9	3 725 646.8	-3 303 027.5	6 372 515.9	-31 13 11.60
MIN16	ORRORAL	-35 37 33.64	148 57 14.33	951.6	-4 447 460.6	2 677 168.2	-3 695 105.9	6 371 886.8	-35 26 38.57
SATAN ANTENNAS									
SAT 1	ROSMAN	35 12 6.35	277 7 26.37	902.8	647 158.1	-5 178 018.1	3 656 711.1	6 371 987.2	35 1 14.67
SAT 2	GOLDSTONE	35 19 53.72	243 6 39.16	897.7	-2 356 294.3	-4 646 695.7	3 668 469.9	6 371 936.4	35 9 .99
SAT 3	COOBY CREEK	-27 23 46.83	151 56 20.33	584.8	-5 001 130.6	2 665 984.1	-2 917 554.3	6 374 237.2	-27 14 22.05
DEEP SPACE NETWORK									
DSN 1	GOLDSTONE	35 23 22.09	243 9 2.03	997.2	-2 351 433.0	-4 645 082.9	3 673 765.3	6 372 015.7	35 12 28.90
DSN 2	GOLDSTONE	35 17 59.61	243 11 40.19	949.8	-2 350 446.2	-4 651 982.3	3 665 630.0	6 371 999.6	35 7 7.13
DSN 3	GOLDSTONE	35 14 51.55	243 12 18.35	1054.4	-2 351 133.0	-4 655 481.4	3 660 958.0	6 372 122.6	35 3 59.51
DSN 4	GOLDSTONE	35 25 33.08	243 6 37.61	992.8	-2 353 625.0	-4 641 345.7	3 677 053.6	6 371 998.3	35 14 39.60
DSN 5	WOOMERA	-31 22 55.94	136 53 14.05	150.6	-3 978 688.8	3 724 853.9	-3 302 231.8	6 372 537.6	-31 12 41.06

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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 6	TIDBINBILLA	-35° 24' 4".18	148° 58' 51".80	676.7	-4 460 954.4	2 682 419.6	-3 674 637.2	6 371 691.0	-35° 13' 10".86
DSN 7	JOHANNESBURG	-25 53 22.66	27 41 6.43	1393.1	5 085 452.4	2 668 237.8	-2 768 682.9	6 375 494.0	-25 44 19.76
DSN 8	MADRID	40 25 43.25	355 45 3.63	830.7	4 849 250.9	-360 275.9	4 114 884.8	6 370 032.1	40 14 19.87
DSN 9	MADRID	40 27 10.80	355 37 55.91	780.7	4 846 708.6	-370 194.3	4 116 908.0	6 369 973.1	40 15 47.33
DSN10	TIDBINBILLA	-35 24 10.48	148 58 51.80	690.6	-4 460 867.6	2 682 367.5	-3 674 803.4	6 371 704.3	-35 13 17.14
DSN11	MADRID	40 25 59.46	355 45 4.48	838.3	4 848 934.7	-360 232.3	4 115 270.3	6 370 038.1	40 14 36.07
RADIO TELESCOPES									
RTE 1	JODRELL BANK	52 14 11.27	357 41 28.74	161.0	3 911 121.8	-157 680.6	5 019 100.0	6 364 990.2	52 3 .07
RTE 2	PARKES	-32 59 56.20	148 15 47.69	411.7	-4 554 197.2	2 816 766.7	-3 454 094.6	6 372 256.7	-32 49 24.37
RTE 3	BONN	*							
RTE 4	GREEN BANK	38 26 15.39	280 9 50.71	846.8	882 877.2	-4 924 534.3	3 944 144.4	6 370 775.8	38 15 1.46
LAUNCH SITES									
LPD 1	PAD 12	28 28 50.06	279 27 28.27	-14.3	921 931.7	-5 534 252.4	3 023 426.4	6 373 304.8	28 19 10.49
LPD 2	PAD 13	28 29 9.07	279 27 19.44	-14.3	921 649.0	-5 534 016.6	3 023 940.7	6 373 303.2	28 19 29.43
LPD 3	PAD 14	28 29 28.08	279 27 10.61	-14.3	921 366.2	-5 533 780.7	3 024 455.1	6 373 301.5	28 19 48.37
LPD 4	PAD 19	28 30 25.08	279 26 43.92	-19.6	920 512.0	-5 533 069.2	3 025 994.8	6 373 291.2	28 20 45.17
LPD 5	PAD 34	28 31 18.44	279 26 19.33	-14.3	919 724.6	-5 532 410.1	3 027 440.7	6 373 291.9	28 21 38.32
LPD 6	PAD 37A	28 32 .35	279 25 54.20	-11.7	918 949.9	-5 531 916.4	3 028 575.6	6 373 290.9	28 22 20.08
LPD 7	PAD 37B	28 31 54.06	279 26 5.61	-11.7	919 271.1	-5 531 956.9	3 028 405.3	6 373 291.5	28 22 13.81
LPD 8	PAD 39A	28 36 29.70	279 23 44.56	-.3	914 827.1	-5 528 590.4	3 035 863.2	6 373 278.9	28 26 48.45

* INSUFFICIENT DATA

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Positions on Mercury Spheroid 1960

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POSITIONS ON MERCURY SPHEROID 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".16	279° 18' 23".14	-36.1	907 066.1	-5 535 228.4	3 026 104.7	6 373 290.4	28° 20' 49".22
USB 2	GRAND BAHAMA	26 37 57.63	281 45 43.90	-36.6	1 163 013.9	-5 585 441.8	2 841 891.6	6 373 861.3	26 28 43.65
USB 3	BERMUDA	32 21 4.60	295 20 31.68	-21.8	2 308 462.7	-4 874 310.5	3 393 408.6	6 372 058.1	32 10 39.29
USB 4	ANTIGUA	17 0 59.75	298 14 50.29	-16.5	2 887 310.8	-5 374 153.3	1 854 595.1	6 376 331.9	16 54 33.17
USB 5	GRAND CANARY	27 45 51.98	344 21 57.58	195.4	5 439 160.7	-1 522 121.4	2 953 538.3	6 373 751.6	27 36 22.06
USB 6	ASCENSION	-7 57 17.53	345 40 21.69	537.0	6 121 233.4	-1 563 390.2	-876 916.1	6 378 296.6	-7 54 8.29
USB 7	MADRID	40 27 19.39	355 49 53.58	811.2	4 847 831.1	-353 318.8	4 117 139.5	6 370 018.6	40 15 55.90
USB 8	CARNARVON	-24 54 24.57	113 43 31.26	9.4	-2 328 980.5	5 299 193.8	-2 669 735.1	6 374 408.9	-24 45 36.58
USB 9	GUAM	13 18 36.73	144 44 11.82	93.7	-5 068 896.1	3 584 117.2	1 458 852.5	6 377 135.1	13 13 27.32
USB10	CANBERRA	-35 35 1.19	148 58 39.30	1134.9	-4 451 046.6	2 676 829.4	-3 691 401.2	6 372 101.1	-35 24 6.47
USB11	KAUAI	22 7 34.26	200 20 5.30	1114.9	-5 543 830.0	-2 054 554.3	2 387 795.1	6 376 269.2	21 59 32.18
USB12	GOLDSTONE	35 20 29.38	243 7 34.81	918.0	-2 354 766.4	-4 646 790.8	3 669 387.5	6 371 969.3	35 9 36.57
USB13	GUAYMAS	27 57 46.71	249 16 43.78	-25.9	-1 994 715.0	-5 272 966.6	2 972 885.7	6 373 469.5	27 48 14.07
USB14	CORPUS CHRISTI	27 39 12.76	262 37 16.59	-34.4	-726 081.6	-5 606 817.9	2 942 551.8	6 373 555.7	27 29 44.35
USB15	GREENBELT	38 59 54.24	283 9 25.49	2.2	1 129 790.8	-4 833 169.8	3 992 201.5	6 369 743.3	38 48 37.23
USB16	GREENBELT	38 59 53.52	283 9 28.47	8.7	1 129 865.0	-4 833 171.9	3 992 188.3	6 369 749.8	38 48 36.51
USB17	GOLDSTONE	35 20 29.38	243 7 37.23	912.6	-2 354 710.0	-4 646 814.4	3 669 384.3	6 371 963.9	35 9 36.56
USB18	MERRITT ISLAND	28 30 27.28	279 18 23.14	-36.2	907 070.5	-5 535 255.6	3 026 053.8	6 373 290.5	28 20 47.35
USB19	SANTIAGO	-33 9 3.97	289 20 .45	732.8	1 769 864.7	-5 044 495.2	-3 468 420.4	6 372 542.0	-32 58 30.67
RADARS									
RAD 1	MERRITT ISLAND	28 25 28.87	279 20 7.59	-34.1	910 583.9	-5 539 117.9	3 017 979.0	6 373 318.4	28 15 50.04
RAD 2	PATRICK AFB	28 13 34.96	279 24 1.99	-30.5	918 581.8	-5 548 370.5	2 998 634.5	6 373 383.4	28 3 58.77
RAD 3	CAPE KENNEDY	28 28 53.73	279 25 23.99	-31.7	918 587.9	-5 534 752.6	3 023 525.0	6 373 303.1	28 19 14.15
RAD 4	GRAND BAHAMA	26 38 10.20	281 43 55.74	-36.1	1 160 049.7	-5 585 881.5	2 842 237.7	6 373 860.9	26 28 56.17
RAD 5	WALLOPS ISLAND	37 51 36.51	284 29 26.01	-39.2	1 261 602.1	-4 881 572.1	3 893 196.3	6 370 114.8	37 40 25.84
RAD 6	WALLOPS ISLAND	37 50 28.40	284 30 53.15	-41.8	1 263 986.8	-4 882 284.1	3 891 536.4	6 370 118.9	37 39 17.84
RAD 7	GRAND TURK	21 27 45.41	288 52 4.09	-15.9	1 920 435.1	-5 619 434.7	2 319 145.7	6 375 308.1	21 19 54.85
RAD 8	BERMUDA	32 20 53.14	295 20 47.44	-24.5	2 308 915.3	-4 874 302.7	3 393 108.9	6 372 056.5	32 10 27.86
RAD 9	BERMUDA	32 20 52.63	295 20 47.66	-23.3	2 308 924.3	-4 874 308.7	3 393 096.5	6 372 057.7	32 10 27.36
RAD10	ANTIGUA	17 8 37.37	298 12 26.25	-8.5	2 881 607.8	-5 372 533.7	1 868 045.1	6 376 313.5	17 2 8.26
RAD11	ASCENSION	-7 58 21.27	345 35 54.86	118.2	6 118 541.2	-1 571 136.8	-878 797.3	6 377 875.9	-7 55 11.60
RAD12	ASCENSION	-7 57 4.78	345 35 15.59	85.1	6 118 525.5	-1 572 374.6	-876 465.5	6 377 845.0	-7 53 55.61
RAD13	TANANARIVE	-19 0 5.41	47 18 52.76	1288.2	4 090 866.6	4 435 505.4	-2 063 937.5	6 377 204.2	-18 53 .17

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POSITIONS ON MERCURY SPHEROID 1960

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
RADARS									
RAD14	CARNARVON	-24° 53' 47".89	113° 43' 1".85	13.9	-2 328 417.7	5 299 964.6	-2 668 713.3	6 374 416.3	-24° 45' ".06
RAD15	WOOMERA	-30 49 7.51	136 50 17.03	111.5	-3 999 014.1	3 750 327.9	-3 248 727.4	6 372 699.8	-30 38 59.01
RAD16	KAUAI	22 7 24.16	200 20 3.88	1119.0	-5 543 957.4	-2 054 558.2	2 387 508.8	6 376 274.0	21 59 22.13
RAD17	VANDENBERG AFB	34 39 56.85	239 25 6.92	60.6	-2 671 854.3	-4 521 206.1	3 607 487.8	6 371 348.1	34 29 9.58
RAD18	PT. ARGUELLO	34 34 57.67	239 26 18.47	599.1	-2 673 174.8	-4 527 025.1	3 600 206.9	6 371 915.6	34 24 11.17
RAD19	WHITE SANDS	32 21 28.91	253 37 48.44	1189.1	-1 520 213.1	-5 175 284.1	3 394 689.3	6 373 266.7	32 11 3.65
RAD20	EGLIN AFB	30 25 17.77	273 12 6.07	-17.5	307 445.1	-5 496 156.3	3 210 771.3	6 372 700.2	30 15 13.89
RAD21	WALLOPS ISLAND	37 51 16.75	284 29 12.38	-23.4	1 261 376.2	-4 882 029.6	3 892 724.8	6 370 132.5	37 40 6.11
GODDARD R/RR STATIONS									
GRR1S	FAIRBANKS	64 58 19.25	212 29 12.35	330.7	-2 282 500.4	-1 453 372.0	5 756 719.4	6 360 968.1	64 49 27.10
GRR1V	FAIRBANKS	64 58 17.55	212 29 18.06	330.7	-2 282 500.3	-1 453 460.7	5 756 697.1	6 360 968.2	64 49 25.40
GRR2S	ROSMAN	35 11 45.28	277 7 26.23	826.9	647 195.2	-5 178 341.4	3 656 145.8	6 371 929.3	35 0 53.64
GRR2V	ROSMAN	35 11 41.33	277 7 26.23	826.5	647 203.8	-5 178 410.8	3 656 046.0	6 371 929.3	35 0 49.69
GRR3S	SANTIAGO	-33 9 3.97	289 20 .45	732.8	1 769 864.7	-5 044 495.2	-3 468 420.4	6 372 542.0	-32 58 30.67
GRR3V	SANTIAGO	-33 9 6.44	289 20 .45	733.1	1 769 851.0	-5 044 456.1	-3 468 484.4	6 372 542.1	-32 58 33.14
GRR4S	TANANARIVE	-19 1 13.75	47 18 11.13	1349.0	4 091 336.4	4 434 218.6	-2 065 944.4	6 377 260.7	-18 54 8.16
GRR4V	TANANARIVE	-19 1 16.22	47 18 11.13	1349.0	4 091 319.6	4 434 200.4	-2 066 016.2	6 377 260.5	-18 54 10.61
GRR5S	CARNARVON	-24 54 12.10	113 42 59.03	2.8	-2 328 214.9	5 299 700.1	-2 669 384.3	6 374 403.3	-24 45 24.17
GRR5V	CARNARVON	-24 54 16.06	113 42 59.03	2.8	-2 328 194.3	5 299 653.1	-2 669 494.8	6 374 403.0	-24 45 28.11
85-FOOT ANTENNAS									
S85 1	ROSMAN	35 12 .28	277 7 40.58	844.6	647 524.0	-5 178 046.4	3 656 533.7	6 371 945.5	35 1 8.60
S85 2	ROSMAN	35 11 55.91	277 7 27.46	840.6	647 203.8	-5 178 161.4	3 656 421.3	6 371 942.0	35 1 4.24
S85 3	FAIRBANKS	64 58 36.07	212 28 55.52	291.1	-2 282 206.6	-1 452 923.1	5 756 903.9	6 360 927.2	64 49 44.00
S85 4	ORRORAL	-35 37 48.99	148 57 24.53	942.0	-4 447 361.2	2 676 808.7	-3 695 494.2	6 371 891.6	-35 26 53.88
S85 6	KASHIMA	35 57 14.57	140 39 47.05	43.8	-3 997 909.3	3 276 556.2	3 724 111.1	6 370 879.1	35 46 16.88
40-FOOT ANTENNAS									
S40 1	GILMORE CREEK	64 58 35.29	212 28 43.93	281.1	-2 282 303.2	-1 452 804.5	5 756 884.6	6 360 917.3	64 49 43.21
S40 2	JOHANNESBURG	-25 53 10.68	27 42 25.84	1523.1	5 084 683.9	2 670 331.2	-2 768 414.6	6 375 640.9	-25 44 7.83
S40 3	QUITO	-0 37 23.38	281 25 8.87	3582.9	1 263 414.1	-6 255 055.3	-68 943.5	6 381 746.2	-0 37 8.37
S40 4	SANTIAGO	-33 9 5.30	289 19 53.59	729.4	1 769 688.7	-5 044 530.1	-3 468 453.0	6 372 538.5	-32 58 32.00
S40 5	GOLDSTONE	35 19 53.72	243 6 44.53	885.0	-2 356 174.4	-4 646 759.5	3 668 471.8	6 371 939.7	35 9 .99

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POSITIONS ON MERCURY SPHEROID 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 6	TANANARIVE	-19° 0' 38".82	47° 18' 4".22	1335.2	4 091 713.2	4 434 329.3	-2 064 924.2	6 377 249.0	-18° 53' 33".41
S40 7	GREENBELT	38 59 59.59	283 9 30.60	3.2	1 129 887.1	-4 833 041.6	3 992 330.3	6 369 743.8	38 48 42.57
MINITRACK STATIONS									
MIN 1	FAIRBANKS	64 52 18.05	212 9 37.12	147.2	-2 299 255.8	-1 445 695.3	5 751 811.7	6 360 813.6	64 43 24.34
MIN 2	FAIRBANKS	64 58 36.96	212 28 30.83	273.7	-2 282 353.2	-1 452 632.6	5 756 899.8	6 360 909.7	64 49 44.89
MIN 3	GOLDSTONE	35 19 47.84	243 5 59.50	874.1	-2 357 232.3	-4 646 330.6	3 668 317.6	6 371 929.4	35 8 55.11
MIN 4	EAST GRAND FORKS	48 1 21.02	262 59 19.85	204.2	-521 697.0	-4 242 053.1	4 718 726.9	6 366 597.6	47 49 52.02
MIN 5	FORT MYERS	26 32 53.09	278 8 4.02	-36.0	807 865.1	-5 651 991.6	2 833 510.5	6 373 887.1	26 23 40.34
MIN 6	QUITO	-0 37 21.89	281 25 15.54	3581.5	1 263 615.9	-6 255 013.7	-68 897.8	6 381 744.9	-0 37 6.89
MIN 7	LIMA	-11 46 36.23	282 50 59.18	53.5	1 388 822.3	-6 088 438.6	-1 293 251.9	6 377 335.7	-11 42 .30
MIN 8	BLOSSOM POINT	38 25 49.61	282 54 48.84	-45.8	1 118 043.2	-4 876 327.0	3 942 976.4	6 369 901.7	38 14 35.62
MIN 9	GREENBELT	38 59 56.67	283 9 37.95	-.7	1 130 071.5	-4 833 053.4	3 992 257.8	6 369 740.1	38 48 39.65
MIN10	SANTIAGO	-33 8 58.48	289 19 53.59	720.5	1 769 724.3	-5 044 631.6	-3 468 271.9	6 372 530.2	-32 58 25.19
MIN11	ST. JOHN'S	47 44 28.99	307 16 46.89	65.2	2 602 784.4	-3 419 156.2	4 697 660.3	6 366 563.1	47 32 59.31
MIN12	WINKFIELD	51 26 45.71	359 18 8.66	81.1	3 983 118.1	-48 498.1	4 964 711.6	6 365 213.5	51 15 30.05
MIN13	JOHANNESBURG	-25 53 .38	27 42 25.84	1508.4	5 084 794.6	2 670 389.4	-2 768 123.0	6 375 627.0	-25 43 57.58
MIN14	TANANARIVE	-19 0 31.52	47 17 59.03	1327.9	4 091 870.0	4 434 274.9	-2 064 709.5	6 377 242.3	-18 53 26.14
MIN15	WOOMERA	-31 23 26.58	136 52 14.95	115.8	-3 977 250.9	3 725 646.8	-3 303 027.5	6 372 515.9	-31 13 11.60
MIN16	ORRORAL	-35 37 33.64	148 57 14.33	935.7	-4 447 460.6	2 677 168.2	-3 695 105.9	6 371 886.8	-35 26 38.57
SATAN ANTENNAS									
SAT 1	ROSMAN	35 12 6.35	277 7 26.37	886.8	647 158.1	-5 178 018.1	3 656 711.1	6 371 987.2	35 1 14.67
SAT 2	GOLDSTONE	35 19 53.72	243 6 39.16	881.7	-2 356 294.3	-4 646 695.7	3 668 469.9	6 371 936.4	35 9 .99
SAT 3	COOBY CREEK	-27 23 46.83	151 56 20.33	568.8	-5 001 130.6	2 665 984.1	-2 917 554.3	6 374 237.2	-27 14 22.05
DEEP SPACE NETWORK									
DSN 1	GOLDSTONE	35 23 22.09	243 9 2.03	981.2	-2 351 433.0	-4 645 082.9	3 673 765.3	6 372 015.7	35 12 28.90
DSN 2	GOLDSTONE	35 17 59.61	243 11 40.19	933.8	-2 350 446.2	-4 651 982.3	3 665 630.0	6 371 999.6	35 7 7.13
DSN 3	GOLDSTONE	35 14 51.55	243 12 18.35	1038.4	-2 351 133.0	-4 655 481.4	3 660 958.0	6 372 122.6	35 3 59.51
DSN 4	GOLDSTONE	35 25 33.08	243 6 37.61	976.8	-2 353 625.0	-4 641 345.7	3 677 053.6	6 371 998.3	35 14 39.60
DSN 5	WOOMERA	-31 22 55.94	136 53 14.05	134.6	-3 978 688.8	3 724 853.9	-3 302 231.8	6 372 537.6	-31 12 41.06

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POSITIONS ON MERCURY SPHEROID 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 6	TIDBINBILLA	-35° 24' 4".18	148° 58' 51".80	660.7	-4 460 954.4	2 682 419.6	-3 674 637.2	6 371 691.0	-35° 13' 10".86
DSN 7	JOHANNESBURG	-25 53 22.66	27 41 6.43	1377.1	5 085 452.4	2 668 237.8	-2 768 682.9	6 375 494.0	-25 44 19.76
DSN 8	*MADRID*	*40 25 43.25*	*355 45 3.63*	*814.7*	*4 849 250.9*	*-360 275.9*	*4 114 884.8*	*6 370 032.1*	*40 14 19.87*
DSN 9	MADRID	40 27 10.80	355 37 55.91	764.7	4 846 708.6	-370 194.3	4 116 908.0	6 369 973.1	40 15 47.33
DSN10	TIDBINBILLA	-35 24 10.48	148 58 51.80	674.6	-4 460 867.6	2 682 367.5	-3 674 803.4	6 371 704.3	-35 13 17.14
DSN11	MADRID	40 25 59.46	355 45 4.48	822.3	4 848 934.7	-360 232.3	4 115 270.3	6 370 038.1	40 14 36.07
RADIO TELESCOPES									
RTE 1	JODRELL BANK	52 14 11.27	357 41 28.74	145.1	3 911 121.8	-157 680.6	5 019 100.0	6 364 990.2	52 3 .07
RTE 2	PARKES	-32 59 56.20	148 15 47.69	395.7	-4 554 197.2	2 816 766.7	-3 454 094.6	6 372 256.7	-32 49 24.37
RTE 3	BONN	*							
RTE 4	GREEN BANK	38 26 15.40	280 9 50.71	830.9	882 877.2	-4 924 534.3	3 944 144.4	6 370 775.8	38 15 1.47
LAUNCH SITES									
LPD 1	PAD 12	28 28 50.07	279 27 28.27	-30.3	921 931.7	-5 534 252.4	3 023 426.4	6 373 304.8	28 19 10.49
LPD 2	PAD 13	28 29 9.07	279 27 19.44	-30.3	921 649.0	-5 534 016.6	3 023 940.7	6 373 303.2	28 19 29.43
LPD 3	PAD 14	28 29 28.08	279 27 10.61	-30.3	921 366.2	-5 533 780.7	3 024 455.1	6 373 301.5	28 19 48.37
LPD 4	PAD 19	28 30 25.09	279 26 43.92	-35.6	920 512.0	-5 533 069.2	3 025 994.8	6 373 291.2	28 20 45.17
LPD 5	PAD 34	28 31 18.44	279 26 19.33	-30.3	919 724.6	-5 532 410.1	3 027 440.7	6 373 291.9	28 21 38.32
LPD 6	PAD 37A	28 32 .36	279 25 54.20	-27.7	918 949.9	-5 531 916.4	3 028 575.6	6 373 290.9	28 22 20.09
LPD 7	PAD 37B	28 31 54.06	279 26 5.61	-27.7	919 271.1	-5 531 956.9	3 028 405.3	6 373 291.5	28 22 13.81
LPD 8	PAD 39A	28 36 29.70	279 23 44.56	-16.3	914 827.1	-5 528 590.4	3 035 863.2	6 373 278.9	28 26 48.45

* INSUFFICIENT DATA

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Positions on Spaceflight Tracking and Data Network System

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POSITIONS ON SPACEFLIGHT TRACKING AND DATA NETWORK SYSTEM

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".77	279° 18' 23".85	-54.4	907 081.1	-5 535 200.4	3 026 112.7	6 373 272.1	28° 20' 49".84
USB 3	BERMUDA	32 21 5.00	295 20 31.94	-33.8	2 308 461.7	-4 874 292.5	3 393 412.6	6 372 046.1	32 10 39.68
USB 5	GRAND CANARY	27 45 51.62	344 21 57.87	167.1	5 439 143.7	-1 522 108.4	2 953 515.3	6 373 723.4	27 36 21.70
USB 6	ASCENSION	-7 57 17.37	345 40 22.57	528.4	6 121 232.4	-1 563 362.2	-876 910.1	6 378 287.9	-7 54 8.13
USB 7	MADRID	40 27 19.65	355 49 53.60	807.7	4 847 823.1	-353 317.8	4 117 143.5	6 370 015.1	40 15 56.17
USB 8	CARNARVON	-24 54 23.52	113 43 32.08	3.0	-2 329 004.5	5 299 191.8	-2 669 703.1	6 374 402.6	-24 45 35.53
USB 9	GUAM	13 18 38.27	144 44 12.52	116.0	-5 068 917.1	3 584 106.2	1 458 903.5	6 377 157.3	13 13 28.84
USB10	CANBERRA	-35 34 59.74	148 58 40.10	1125.3	-4 451 072.6	2 676 821.4	-3 691 359.2	6 372 091.6	-35 24 5.02
USB11	KAUAI	22 7 34.46	200 20 5.44	1139.7	-5 543 848.0	-2 054 565.3	2 387 810.1	6 376 294.0	21 59 32.37
USB12	GOLDSTONE	35 20 29.64	243 7 35.04	918.7	-2 354 759.4	-4 646 789.8	3 669 394.5	6 371 970.1	35 9 36.83
USB14	CORPUS CHRISTI	27 39 13.04	262 37 16.96	-46.3	-726 069.6	-5 606 804.9	2 942 553.8	6 373 543.8	27 29 44.63
USB15	GREENBELT	38 59 54.81	283 9 26.23	-2.1	1 129 804.8	-4 833 151.7	3 992 212.5	6 369 739.0	38 48 37.80
USB16	GREENBELT	38 59 54.09	283 9 29.21	4.4	1 129 879.0	-4 833 153.9	3 992 199.3	6 369 745.5	38 48 37.08
USB17	GOLDSTONE	35 20 29.64	243 7 37.46	913.3	-2 354 703.0	-4 646 813.4	3 669 391.3	6 371 964.6	35 9 36.82
USB18	MERRITT ISLAND	28 30 27.90	279 18 23.85	-54.5	907 085.5	-5 535 227.6	3 026 061.8	6 373 272.1	28 20 47".96
USB19	SANTIAGO	-33 9 3.59	289 20 1.06	706.6	1 769 874.7	-5 044 475.2	-3 468 396.4	6 372 515.9	-32 58 30.29
RADARS									
RAD 1	MERRITT ISLAND	28 25 29.49	279 20 8.30	-52.5	910 598.9	-5 539 089.9	3 017 987.0	6 373 299.9	28 15 50.66
RAD 2	PATRICK AFB	28 13 35.57	279 24 2.70	-48.9	918 596.8	-5 548 342.5	2 998 642.5	6 373 364.9	28 3 59.38
RAD 3	CAPE KENNEDY	28 28 54.35	279 25 24.70	-50.0	918 602.9	-5 534 724.6	3 023 533.0	6 373 284.7	28 19 14.76
RAD 4	GRAND BAHAMA	26 38 10.79	281 43 56.48	-54.3	1 160 064.7	-5 585 853.5	2 842 245.7	6 373 842.6	26 28 56.76
RAD 5	WALLOPS ISLAND	37 51 37.07	284 29 26.74	-43.5	1 261 616.1	-4 881 554.1	3 893 207.3	6 370 110.5	37 40 26.40
RAD 6	WALLOPS ISLAND	37 50 28.96	284 30 53.89	-46.0	1 264 000.8	-4 882 266.1	3 891 547.4	6 370 114.6	37 39 18.39
RAD 7	GRAND TURK	21 27 45.90	288 52 4.89	-33.1	1 920 450.1	-5 619 406.7	2 319 153.7	6 375 290.9	21 19 55.35
RAD 8	BERMUDA	32 20 53.54	295 20 47.70	-36.5	2 308 914.3	-4 874 284.7	3 393 112.9	6 372 044.4	32 10 28.25
RAD 9	BERMUDA	32 20 53.03	295 20 47.92	-35.2	2 308 923.3	-4 874 290.8	3 393 100.5	6 372 045.8	32 10 27.76
RAD10	ANTIGUA	17 8 37.79	298 12 27.15	-22.9	2 881 622.8	-5 372 505.8	1 868 053.1	6 376 299.0	17 2 8.67
RAD11	ASCENSION	-7 58 21.11	345 35 55.74	109.5	6 118 540.2	-1 571 108.8	-878 791.3	6 377 867.2	-7 55 11.45
RAD12	ASCENSION	-7 57 4.62	345 35 16.47	76.4	6 118 524.5	-1 572 346.6	-876 459.5	6 377 836.2	-7 53 55.45
RAD13	TANANARIVE	-19 0 5.54	47 18 53.49	1307.7	4 090 862.6	4 435 532.4	-2 063 947.5	6 377 223.7	-18 53 .30
RAD14	CARNARVON	-24 53 46.84	113 43 2.67	7.5	-2 328 441.7	5 299 962.6	-2 668 681.3	6 374 410.0	-24 44 59.01
RAD15	WOOMERA	-30 49 5.97	136 50 17.99	99.7	-3 999 042.1	3 750 318.9	-3 248 680.4	6 372 688.1	-30 38 57.46

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POSITIONS ON SPACEFLIGHT TRACKING AND DATA NETWORK SYSTEM

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″.36	200° 20′ 4″.02	1143.8	-5 543 975.4	-2 054 569.2	2 387 523.8	6 376 298.8	21° 59′ 22″.33
RAD17	VANDENBERG AFB	34 39 57.12	239 25 7.14	60.9	-2 671 847.3	-4 521 205.1	3 607 494.8	6 371 348.4	34 29 9.85
RAD18	PT. ARGUELLO	34 34 57.94	239 26 18.69	599.4	-2 673 167.8	-4 527 024.1	3 600 213.9	6 371 915.9	34 24 11.44
RAD19	WHITE SANDS	32 21 29.24	253 37 48.74	1176.8	-1 520 201.1	-5 175 271.1	3 394 691.3	6 373 254.3	32 11 3.98
RAD21	WALLOPS ISLAND	37 51 17.30	284 29 13.11	-27.7	1 261 390.2	-4 882 011.6	3 892 735.8	6 370 128.2	37 40 6.66
GODDARD R/RR STATIONS									
GRR1S	FAIRBANKS	64 58 19.20	212 29 13.38	339.1	-2 282 497.4	-1 453 386.0	5 756 726.4	6 360 976.6	64 49 27.05
GRR1V	FAIRBANKS	64 58 17.50	212 29 19.08	339.1	-2 282 497.3	-1 453 474.7	5 756 704.1	6 360 976.7	64 49 25.35
GRR2S	ROSMAN	35 11 45.98	277 7 26.96	810.4	647 210.2	-5 178 313.4	3 656 153.8	6 371 912.6	35 0 54.33
GRR2V	ROSMAN	35 11 42.02	277 7 26.96	810.0	647 218.8	-5 178 382.8	3 656 054.0	6 371 912.6	35 0 50.38
GRR3S	SANTIAGO	-33 9 3.59	289 20 1.06	706.6	1 769 874.7	-5 044 475.2	-3 468 396.4	6 372 515.9	-32 58 30.29
GRR3V	SANTIAGO	-33 9 6.07	289 20 1.06	706.9	1 769 861.0	-5 044 436.1	-3 468 460.4	6 372 515.9	-32 58 32.76
GRR4S	TANANARIVE	-19 1 13.88	47 18 11.85	1368.4	4 091 332.4	4 434 245.6	-2 065 954.4	6 377 280.1	-18 54 8.28
GRR4V	TANANARIVE	-19 1 16.35	47 18 11.85	1368.4	4 091 315.6	4 434 227.4	-2 066 026.2	6 377 279.9	-18 54 10.74
GRR5S	CARNARVON	-24 54 11.05	113 42 59.84	-3.6	-2 328 238.9	5 299 698.1	-2 669 352.3	6 374 397.0	-24 45 23.12
GRR5V	CARNARVON	-24 54 15.01	113 42 59.84	-3.6	-2 328 218.2	5 299 651.1	-2 669 462.8	6 374 396.7	-24 45 27.06
85-FOOT ANTENNAS									
S85 1	ROSMAN	35 12 .97	277 7 41.30	828.1	647 539.0	-5 178 018.4	3 656 541.8	6 371 928.9	35 1 9.29
S85 2	ROSMAN	35 11 56.60	277 7 28.18	824.1	647 218.8	-5 178 133.4	3 656 429.3	6 371 925.4	35 1 4.93
S85 3	FAIRBANKS	64 58 36.02	212 28 56.54	299.5	-2 282 203.6	-1 452 937.1	5 756 910.9	6 360 935.6	64 49 43.95
S85 4	ORRORAL	-35 37 47.54	148 57 25.34	932.3	-4 447 387.2	2 676 800.7	-3 695 452.2	6 371 882.1	-35 26 52.43
S85 6	KASHIMA	35 57 14.49	140 39 46.93	62.7	-3 997 920.2	3 276 569.2	3 724 120.1	6 370 898.0	35 46 16.80
40-FOOT ANTENNAS									
S40 1	GILMORE CREEK	64 58 35.23	212 28 44.96	289.5	-2 282 300.2	-1 452 818.5	5 756 891.6	6 360 925.7	64 49 43.16
S40 2	JOHANNESBURG	-25 53 11.03	27 42 26.98	1542.0	5 084 679.9	2 670 365.2	-2 768 432.6	6 375 659.9	-25 44 8.18
S40 3	QUITO	-0 37 23.52	281 25 9.44	3546.7	1 263 424.1	-6 255 016.3	-68 947.5	6 381 710.0	-0 37 8.51
S40 4	SANTIAGO	-33 9 4.93	289 19 54.21	703.2	1 769 698.7	-5 044 510.1	-3 468 429.0	6 372 512.4	-32 58 31.62
S40 5	GOLDSTONE	35 19 53.98	243 6 44.76	885.7	-2 356 167.4	-4 646 758.5	3 668 478.8	6 371 940.5	35 9 1.25
S40 6	TANANARIVE	-19 0 38.95	47 18 4.95	1354.6	4 091 709.2	4 434 356.3	-2 064 934.2	6 377 268.4	-18 53 33.54
S40 7	GREENBELT	39 0 .15	283 9 31.34	-1.1	1 129 901.1	-4 833 023.6	3 992 341.3	6 369 739.5	38 48 43.14
MINITRACK STATIONS									
MIN 2	FAIRBANKS	64 58 36.91	212 28 31.86	282.2	-2 282 350.2	-1 452 646.6	5 756 906.8	6 360 918.2	64 49 44.84

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POSITIONS ON SPACEFLIGHT TRACKING AND DATA NETWORK SYSTEM

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
MINITRACK STATIONS									
MIN 3	MOJAVE	35° 19' 48".10	243° 5' 59".73	874.8	-2 357 225.3	-4 646 329.6	3 668 324.6	6 371 930.1	35° 8' 55".38
MIN 5	FORT MYERS	26 32 53.69	278 8 4.70	-55.3	807 880.1	-5 651 963.6	2 833 518.5	6 373 867.7	26 23 40.94
MIN 6	QUITO	-0 37 22.03	281 25 16.10	3545.3	1 263 625.9	-6 254 974.7	-68 901.8	6 381 708.6	-0 37 7.03
MIN 7	LIMA	-11 46 36.23	282 50 59.93	43.1	1 388 842.3	-6 088 423.6	-1 293 249.9	6 377 325.4	-11 42 .30
MIN 9	GREENBELT	38 59 57.24	283 9 38.69	-5.0	1 130 085.5	-4 833 035.4	3 992 268.8	6 369 735.7	38 48 40.22
MIN10	SANTIAGO	-33 8 58.10	289 19 54.21	694.3	1 769 734.3	-5 044 611.6	-3 468 247.9	6 372 504.1	-32 58 24.82
MIN11	ST. JOHN'S	47 44 29.24	307 16 47.73	44.7	2 602 786.4	-3 419 130.2	4 697 650.2	6 366 542.6	47 32 59.56
MIN12	WINKFIELD	51 26 46.11	359 18 9.13	86.6	3 983 112.1	-48 489.1	4 964 723.6	6 365 219.0	51 15 30.45
MIN13	JOHANNESBURG	-25 53 .73	27 42 26.99	1527.3	5 084 790.6	2 670 423.4	-2 768 141.0	6 375 645.9	-25 43 57.93
MIN14	TANANARIVE	-19 0 31.64	47 17 59.75	1347.3	4 091 866.0	4 434 301.9	-2 064 719.5	6 377 261.7	-18 53 26.27
MIN15	WOOMERA	-31 23 25.04	136 52 15.92	103.5	-3 977 278.9	3 725 637.8	-3 302 980.5	6 372 503.8	-31 13 10.07
MIN16	ORRORAL	-35 37 32.19	148 57 15.13	925.9	-4 447 486.6	2 677 160.2	-3 695 063.9	6 371 877.2	-35 26 37.12
DEEP SPACE NETWORK									
DSN 1	GOLDSTONE	35 23 22.35	243 9 2.26	982.0	-2 351 426.0	-4 645 081.9	3 673 772.3	6 372 016.4	35 12 29.16
DSN 2	GOLDSTONE	35 17 59.87	243 11 40.42	934.5	-2 350 439.2	-4 651 981.3	3 665 637.0	6 372 000.3	35 7 7.39
DSN 3	GOLDSTONE	35 14 51.81	243 12 18.58	1039.1	-2 351 126.0	-4 655 480.4	3 660 965.0	6 372 123.3	35 3 59.76
DSN 4	GOLDSTONE	35 25 33.34	243 6 37.84	977.5	-2 353 618.0	-4 641 344.7	3 677 060.6	6 371 999.1	35 14 39.86
DSN 5	WOOMERA	-31 22 54.40	136 53 15.02	122.3	-3 978 716.8	3 724 844.9	-3 302 184.7	6 372 525.4	-31 12 39.52
DSN 6	TIDBINBILLA	-35 24 2.73	148 58 52.61	651.2	-4 460 980.4	2 682 411.6	-3 674 595.2	6 371 681.6	-35 13 9.41
DSN 7	JOHANNESBURG	-25 53 23.02	27 41 7.58	1396.0	5 085 448.4	2 668 271.8	-2 768 700.9	6 375 512.8	-25 44 20.11
DSN 8	MADRID	40 25 43.52	355 45 3.64	811.2	4 849 242.9	-360 274.9	4 114 888.8	6 370 028.6	40 14 20.14
DSN 9	MADRID	40 27 11.07	355 37 55.93	761.2	4 846 700.6	-370 193.3	4 116 912.0	6 369 969.6	40 15 47.59
DSN10	TIDBINBILLA	-35 24 9.03	148 58 52.61	665.1	-4 460 893.6	2 682 359.5	-3 674 761.4	6 371 694.8	-35 13 15.70
DSN11	MADRID	40 25 59.73	355 45 4.49	818.8	4 848 926.7	-360 231.3	4 115 274.3	6 370 034.4	40 14 36.34
C-BAND RADAR AND OPTICAL CALIBRATION SITES									
4050	PRETORIA	-25 56 37.19	28 21 29.07	1588.8	5 051 627.7	2 726 629.7	-2 774 161.1	6 375 689.9	-25 47 33.50
4450	BARKING SANDS	22 1 19.74	200 13 16.16	1.0	-5 550 988.6	-2 044 693.5	2 376 700.0	6 375 182.3	21 53 19.37
4690	ELY	39 18 31.11	244 54 48.06	2779.6	-2 096 141.1	-4 477 497.5	4 020 669.9	6 372 407.4	39 7 12.85
SPECIAL OPTICAL NETWORK									
7050	GREENBELT	39 1 14.18	283 10 19.42	-.9	1 130 700.2	-4 831 360.9	3 994 115.2	6 369 732.1	38 49 57.06

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POSITIONS ON SPACEFLIGHT TRACKING AND DATA NETWORK SYSTEM

STATION		GEODETIC COORDINATES			GEOCENTRIC COORDINATES				
NO.	LOCATION	LATITUDE	LONGITUDE(E)	H(M)	X(M)	Y(M)	Z(M)	R(M)	LATITUDE
SPECIAL OPTICAL NETWORK									
7051	ROSMAN	35°11' 47".52	277° 7' 26".96	815.8	647 207.3	-5 178 290.6	3 656 195.7	6 371 917.8	35° 0' 55".87
7052	WALLOPS ISLAND	37 51 36.00	284 29 24.84	-49.9	1 261 575.0	-4 881 580.6	3 893 177.1	6 370 104.2	37 40 25.32
7054	CARNARVON	-24 54 15.99	113 42 58.79	-10.0	-2 328 183.9	5 299 646.0	-2 669 487.6	6 374 390.2	-24 45 28.04
7055	MOUNT HOPKINS	31 41 7.70	249 7 19.00	2314.0	-1 936 730.8	-5 077 630.9	3 332 037.5	6 374 616.4	31 30 49.70
7056	MOUNT HOPKINS	31 41 7.61	249 7 18.60	2313.9	-1 936 741.2	-5 077 628.4	3 332 035.0	6 374 616.4	31 30 49.61
7058	ROMULUS	42 42 5.18	283 10 18.23	182.2	1 069 775.3	-4 571 154.1	4 303 332.4	6 368 558.5	42 30 34.99
7059	GREENBELT	39 1 15.85	283 10 18.70	-2.5	1 130 675.8	-4 831 332.1	3 994 154.2	6 369 730.3	38 49 58.73
7060	GUAM	13 18 33.60	144 44 14.01	109.8	-5 068 964.9	3 584 085.2	1 458 762.6	6 377 151.4	13 13 24.21
SAO OPTICAL NETWORK									
9001	ORGAN PASS	32 25 24.92	253 26 49.59	1606.0	-1 535 726.6	-5 167 005.3	3 401 053.0	6 373 661.5	32 14 59.03
9002	OLIFANTSFONTEIN	-25 57 35.70	28 14 53.02	1549.0	5 056 128.0	2 716 535.1	-2 775 763.1	6 375 645.3	-25 48 31.76
9004	SAN FERNANDO	36 27 46.88	353 47 37.59	47.9	5 105 593.3	-555 206.2	3 769 684.0	6 370 702.8	36 16 45.44
9005	TOKYO	35 40 22.38	139 32 17.71	76.9	-3 946 727.8	3 366 269.6	3 698 831.8	6 371 011.5	35 29 26.85
9006	NAINI TAL	29 21 33.73	79 27 28.19	1844.0	1 018 176.7	5 471 114.6	3 109 599.1	6 374 902.6	29 11 42.99
9007	AREQUIPA	-16 27 56.38	288 30 25.15	2468.4	1 942 805.2	-5 804 080.7	-1 796 913.7	6 378 929.6	-16 21 41.05
9008	SHIRAZ	29 38 13.93	52 31 12.14	1549.2	3 376 857.5	4 403 994.9	3 136 265.4	6 374 519.4	29 26 19.70
9009	CURACAO	12 5 25.19	291 9 45.34	-30.3	2 251 863.5	-5 816 911.4	1 327 175.9	6 377 204.9	12 0 42.34
9010	JUPITER	27 1 14.61	279 53 13.98	-48.2	976 309.1	-5 601 377.7	2 880 255.2	6 373 733.6	26 51 55.07
9011	VILLA DOLORES	-31 56 34.36	294 53 37.18	609.8	2 280 608.8	-4 914 574.4	-3 355 398.6	6 372 826.4	-31 46 13.41
9012	MAUI	20 42 26.11	203 44 33.91	3047.5	-5 466 068.6	-2 404 302.6	2 242 196.5	6 378 559.5	20 34 49.30
9023	WOOMERA	-31 23 25.78	136 52 43.92	111.9	-3 977 781.0	3 725 094.7	-3 303 004.5	6 372 512.1	-31 13 10.81
9028	ADDIS ABABA	8 44 51.35	38 57 33.93	1895.5	4 903 752.6	3 965 234.1	963 874.0	6 379 570.8	8 41 23.85
9427	JOHNSTON ISLAND	16 44 39.09	190 29 10.26	-7.0	-6 007 391.4	-1 111 905.8	1 825 750.1	6 376 397.8	16 38 17.98
9901	ORGAN PASS	32 25 24.92	253 26 49.59	1605.9	-1 535 726.6	-5 167 005.3	3 401 053.0	6 373 661.4	32 14 59.03
9902	OLIFANTSFONTEIN	-25 57 35.70	28 14 53.02	1548.8	5 056 127.8	2 716 535.0	-2 775 763.0	6 375 645.1	-25 48 31.76
9907	AREQUIPA	-16 27 56.38	288 30 25.15	2468.8	1 942 805.3	-5 804 081.1	-1 796 913.6	6 378 929.9	-16 21 41.05
9921	MOUNT HOPKINS	31 41 3.40	249 7 18.99	2333.3	-1 936 761.7	-5 077 711.1	3 331 934.8	6 374 636.1	31 30 45.41
9929	NATAL	-5 55 40.29	324 50 7.79	18.8	5 186 481.3	-3 653 850.1	-654 328.9	6 377 958.4	-5 53 18.46
9930	DIONYSOS	38 4 42.42	23 55 57.84	498.2	4 595 226.7	2 039 465.8	3 912 630.2	6 370 573.2	37 53 30.51
9991	DIONYSOS	38 4 44.30	23 55 59.23	493.3	4 595 176.7	2 039 480.7	3 912 672.8	6 370 568.1	37 53 32.38

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NOTES FOR THE GEODETIC DATA SHEETS

The Geodetic Data Sheets give a summary description of surveys performed and data gathered in positioning and orienting equipment at each site. This information is for site personnel in checking geodetic references, for operations and planning personnel in preparing, changing, or adding observation instruments at existing sites, and for analysis personnel in assessing positional accuracies and future geodetic needs.

The sheet describes the procedures and results of the local tie of the equipment to the geodetic datum. It is intended to answer questions to date and reliability, 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 effort by identifying fixed survey monuments at or near the site. It should aid in establishing the latest or most accurate information, reducing the common problem of having contradictory positions without date or source.

Station Number and Name - The station numbers in Volume 1 are arbitrary, and for cross-reference in this directory only. Official designations for these stations are given, when available, under "Other Codes". Station numbers and code names in Volume 2 are those adopted by the Geodetic Satellite Data Service at the National Space Science Data Center. "Station" refers to a fixed point of reference for a particular piece of equipment. If equipment is moved to a new position, a new code name and number must be assigned. Different types of equipment occupying the same point have different numbers and names.

Other Codes - COSPAR, DoD, or other 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, 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 are listed. 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 spheroid, usually 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. Distanc 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.

More detailed survey information will usually be retained by the agency which performed the survey.

Accuracy Assessment - The accuracy assessments to local control attempt to indicate whether a one-meter criterion has been met. More precise estimates are often given when furnished by the reporting agency. 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. Information was also obtained from other sources as noted on the data sheets. These 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:

DoD GEOSAT Records Center, DMATC

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

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

Eastern Test Range, Patrick AF Base

USAF Space and Missile Test Center, Vandenberg AF Base

Defense Mapping Agency Hydrographic Center

First Geodetic Survey Squadron, DMAAC

Inter-American Geodetic Survey, DMATC

Jet Propulsion Laboratory

Foreign Sources have included:

Australia:	Division of National Mapping, Department of Minerals and Energy
Canada:	Dominion Geodesist, Ottawa
Denmark:	Geodetic Institute
Finland:	Finnish Geodetic Institute
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
S. 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 unless otherwise specified:

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

National Mapping Technical Report 13: The Geoid in Australia 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 given by DMATC in their Geodetic Summary for each station. Heights are referred to a zero geoid separation at station CHUA.

Abbreviations and symbols used in the directory are:

Organizations etc.

ACIC*	Aeronautical Chart and Information Center (U.S. Air Force)
AFB	Air Force Base
AFETR	U.S. Air Force Eastern Test Range
AFWTR	U.S. Air Force Western Test Range (now SAMTEC)
AGU	American Geophysical Union (National Committee of the U.S. for the IUGG)
AIG	Association Internationale de Geodesie (IAG)
AMS*	U.S. Army Map Service (now DMATC)
ATS	Applications Technology Satellite
C&GS**	U.S. Coast and Geodetic Survey (now National Geodetic Survey)
CE	U.S. Corps of Engineers
CERG	Centre d'Etudes et de Recherches en Geodynamique et Astronomie
CNES	Centre National d'Etudes Spatiales (France)
COSPAR	Committee for Space Research (International Council of Scientific Unions)
CSC	Computer Sciences Corporation
CSIRO	Commonwealth Scientific and Industrial Organization (Australia)
DMA*	Defense Mapping Agency
DMAAC*	DMA Aerospace Center (formerly ACIC)
DMAHC*	DMA Hydrographic Center (formerly USNOO)
DMATC*	DMA Topographic Center (formerly TOPOCOM)
DOS	Directorate of Overseas Surveys (Great Britain)
DSIF	Deep Space Instrumentation Facility, JPL (now DSN)
DSN	Deep Space Network (JPL)
EPSOC	European Physics Satellite Observation Campaign
ERTS	Earth Resources Technology Satellite
ESLD	Engineering Survey Liaison Detachment (1381st)
FFB	Field Facilities Branch (now Physical Plant Engineering Branch), GSFC
GRGS	Groupe de Recherches de Geodesie Spatiale
GSC	Geodetic Survey of Canada
GSFC	Goddard Space Flight Center (Greenbelt, Maryland)
IAG	International Association of Geodesy (AIG)
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
NGO	Norwegian Geographic Office
NGP	NASA Geodetic Satellites Program
NGS**	National Geodetic Survey (formerly USC&GS)
NGSP	National Geodetic Satellite Program
NITR	National Institute for Telecommunication Research (S. Africa)
NOAA**	National Oceanic and Atmospheric Administration
NOS**	National Ocean Survey (formerly USC&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
SAMTEC	USAF Space and Missile Test Center, Vandenberg AFB Calif (formerly AFWTR)
SAO	Smithsonian Astrophysical Observatory
STDN	Spaceflight Tracking and Data Network (GSFC)
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
USNHO*	U.S. Navy Hydrographic Office
USNOO*	U.S. Naval Oceanographic Office
VLBI	Very Long Baseline Interferometry
WEST	West European Satellite Triangulation Program
WSMR	U.S. Army White Sands Missile Range (New Mexico)

*Names and abbreviations of U.S. Government surveying and mapping agencies in this directory do not always reflect current use by these organizations. The Army Map Service (AMS) was integrated January 15, 1969, into the newly formed U.S. Army Topographic Command (TOPOCOM). On January 1, 1972, the Defense Mapping Agency (DMA) was established to include the Air Force Aeronautical Chart and Information Center (ACIC), part of the Naval Oceanographic Office (NOO - the Navy Hydrographic Office, NHO, before 1962), and TOPOCOM. The last is now designated the DMA Topographic Center (DMATC), and includes the Inter-American Geodetic Survey.

**In July 1965 the Coast and Geodetic Survey, the Weather Bureau, and a small portion of the Bureau of Standards were joined to form the Environmental Science Services Administration (ESSA), Department of Commerce. On October 3, 1970, ESSA joined with other organizations, such as the Bureau of Commercial Fisheries and the Lake Survey, to form the National Oceanic and Atmospheric Administration (NOAA), still under

Commerce. Under NOAA, the Coast and Geodetic Survey was redesignated the National Ocean Survey (NOS). In June 1971, what had been the Geodesy Division C&GS (since 1915) was designated the National Geodetic Survey (NGS) under NOS.

Equipment

B-N	Baker-Nunn camera
MOTS	Minitrack Optical Tracking System
R/RR	Range and Range-Rate
SECOR	Sequential Collation of Range
STADAN	Satellite Tracking and Data Acquisition Network (now in Spaceflight Tracking and Data Network - 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
AHD	Australian Height Datum (1971)

Geodetic Terms

A-G	astronomic minus geodetic
Az Mk	azimuth mark
BM	bench mark (an elevation station)
GM	gravitational constant times earth mass
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 zenith is north of geodetic
η	deflection in the prime vertical, plus if astronomic zenith is east of geodetic
$<$	less than

GLOSSARY OF GEODETIC TERMS

The terms defined here are selected as having special relevance to this directory. More extended discussion and definitions of geodetic terms may be found in the references. A sketch 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 90° east longitude.

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 a 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 measurec clockwise from North.

Geodetic azimuths are generally carried through the triangulation, but are initially established and subsequently controlled by a pattern of Laplace azimuths.

Geodetic Datum - A survey network of points whose positions are fixed with respect to each other and to the earth. It is defined by a spheroid and the relationship between the spheroid and a point (or points) on the topographic surface established as the origin of datum. This relationship is defined generally (but not necessarily) by the geodetic latitude, longitude, and the geodetic height of the origin, the 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 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.

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 to the reference spheroid to the geoid measured outward along the normal to the spheroid. (The phrase is used by some to designate the height of a point above the geoid, which is here called elevation.)

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.

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

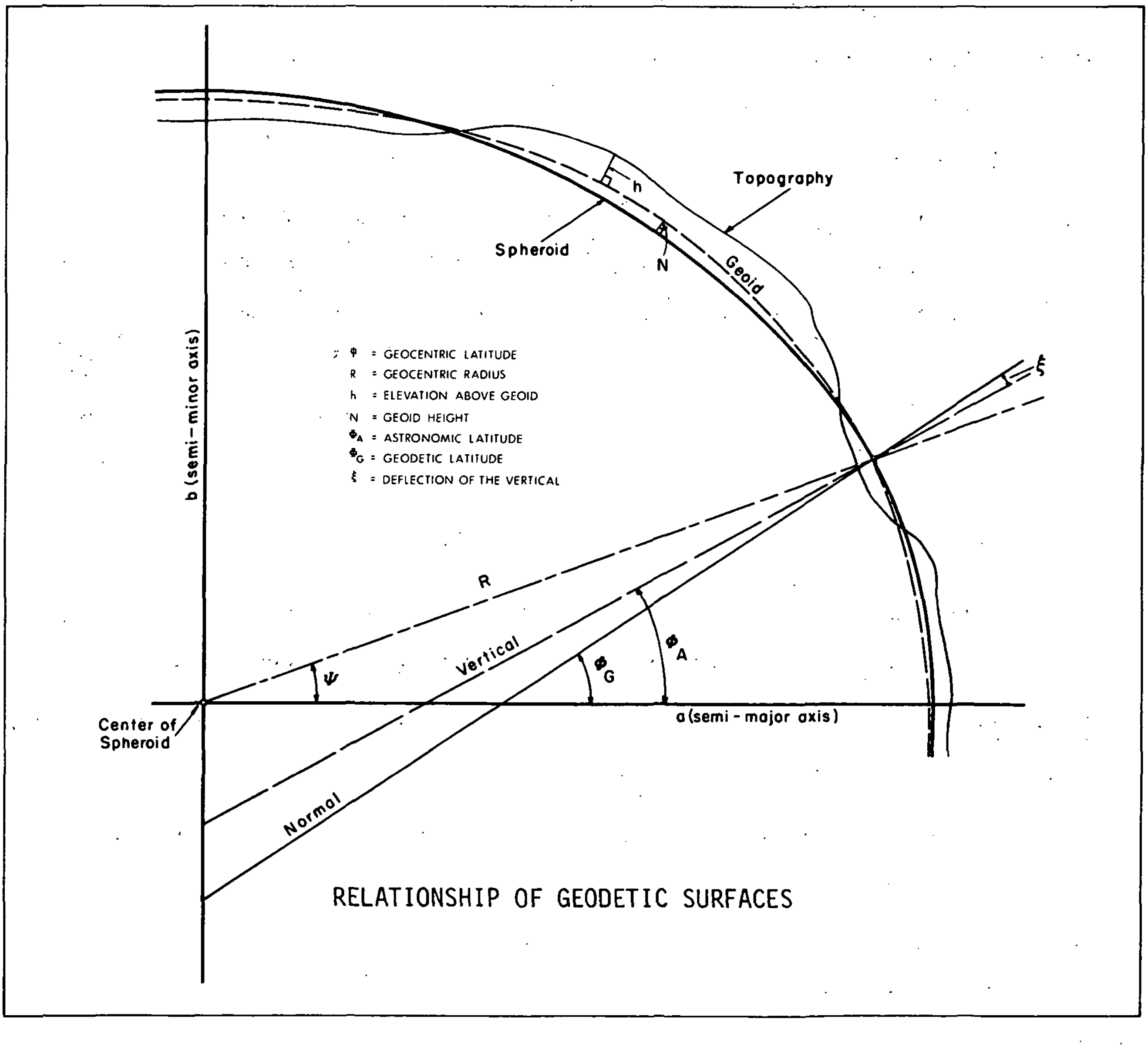
Normal - The line perpendicular to the spheroid at any point. The normal seldom coincides with the vertical at the point.

Spheroid - The 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 gi˙ ı as the length of the semi-major axis, a, and the flattening, f = -ᵃ where b is the length of the semi-minor axis.

Vertical - The ˙ ˏ ʚendicular to the geoid at any point. It is the direction of the force of ɑt that point.

Ver ɑtum - 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.



RELATIONSHIP OF GEODETIC SURFACES

GEODETIC DATA SHEETS

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Unified S-Band Antennas

Station No. USB 1

Code Name ____________

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 193301 STDN MIL 3

Location Merritt Island, Florida

Equipment Unified S-Band 9-meter (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 from 4-mile station

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

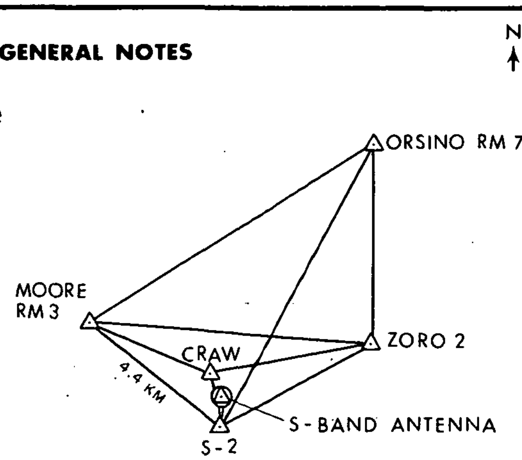
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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 STDN GBM 3

Location Grand Bahama Island, British West Indies   Equipment Unified S-Band 9-meter (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.

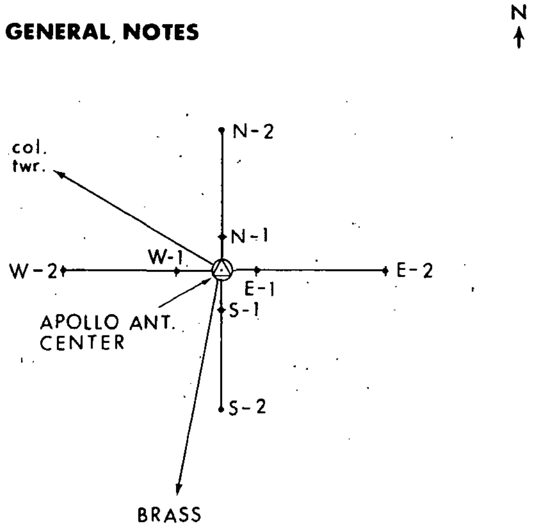
Surveyed by Facility Construction Branch, GSFC, in October 1966. Station APOLLO ANTENNA CENTER is marked by a tablet at the center of the concrete foundation of the antenna (elev. 4.83 m).

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 STDN BDA 3

Location Bermuda

Equipment Unified S-Band 9-meter (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 ∆ SOLD, 660 m distant

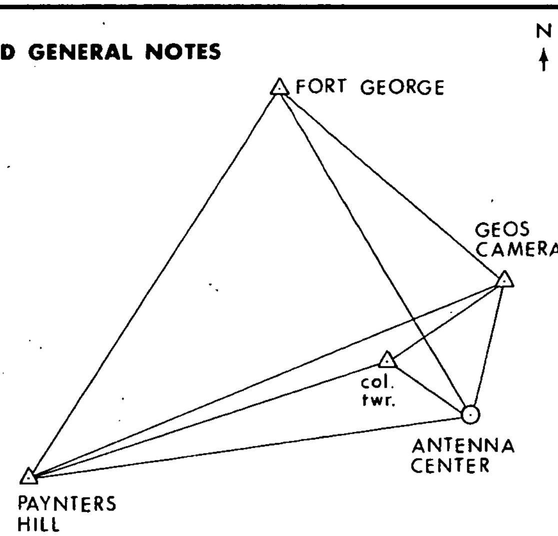
Elevation above mean sea level 22.594 meters   Geoid height ______ meters   Height above ellipsoid ______ meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	∆ ANTENNA CENTER	∆ PAYNTERS HILL	4432.43	250° 04' 19".1
Geodetic	∆ ANTENNA CENTER	∆ 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.



DATE July 1973

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

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes STDN ANG 3

Code Name

Location Antigua, West Indies Associated States

Equipment Unified S-Band 9-meter (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

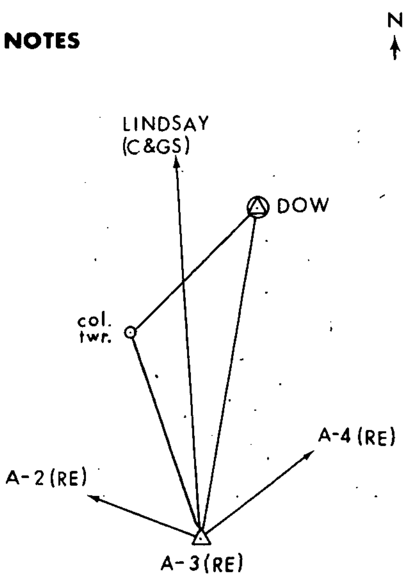
This antenna has been moved to Greenbelt, Md.

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

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes STDN CYI 3

Location Gran Canaria, Canary Islands

Equipment Unified S-Band 9-meter (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

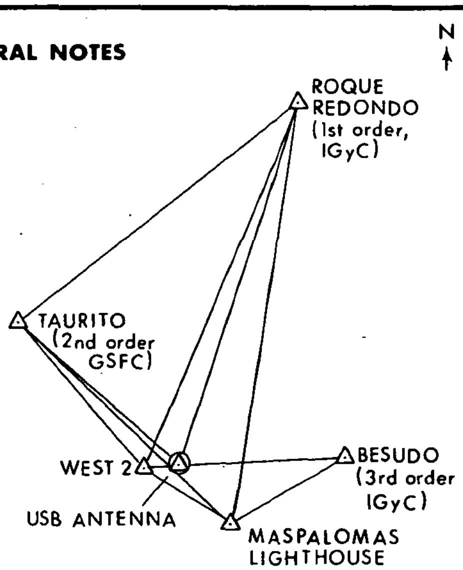
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes STDN ACN 3

Code Name

Location Ascension Island

Equipment Unified S-Band 9-meter (30-foo

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

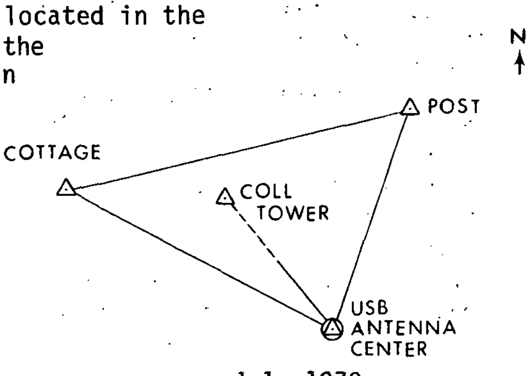
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ USB ANT CTR	Δ COLL. TOWER	1274.708	317° 38' 55".4
Geodetic	Δ USB ANT CTR	Δ POST	1355.4	358 47 49

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 STDN MAD 8

Location Madrid, Spain

Equipment Unified S-Band 26-meter (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

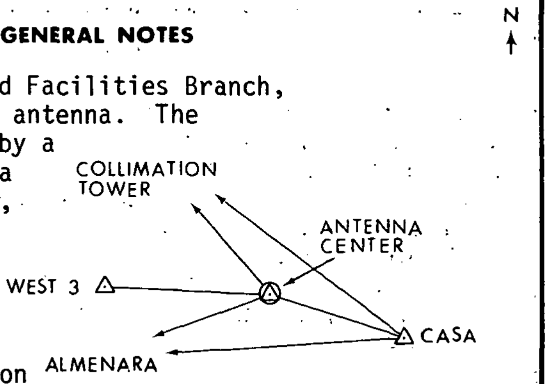
AZIMUTH DATA

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 STDN CRO 3

Location Carnarvon, Australia

Equipment Unified S-Band 9-meter (30-fo

Agency NASA-Goddard Space Flight Center

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 1964 at Δ GC 18A, 1.1 km from site

Elevation above mean sea level 44.5 meters

Geoid height + 6.1 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, WA, 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.

The elevation is referred to AHD.

Geoid height from National Mapping Technical Report 13, 1971.

DATE April 1972

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.05 meters	6 meters
Vertical	0.5 meters	1 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia - Carnarvon, Div. of National Mapping, Canberra, March 1972.

Station No. USB 9

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes STDN GWM 3

Location GUAM

Equipment Unified S-Band 9-meter (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

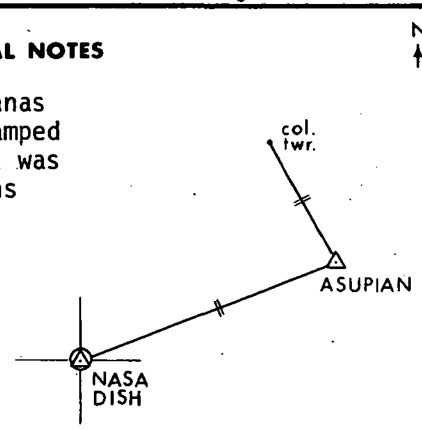
AZIMUTH DATA

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 STDN HSK 8

Location Canberra, Australia

Equipment Unified S-Band 26-meter (85-

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 1129.66 meters   Geoid height + 9.0 meters   Height above ellipsoid 1139 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 AHD.

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 National Mapping Technical Report 13, 1971.

DATE April 1972

ACCURACY ASSESSMENT

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

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, March 1972.

Station No. USB 11

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes SAMTEC 337601
STDN HAW 3

Location Kauai, Hawaii

Equipment Unified S-Band 9-meter (30-foot)

Agency NASA-Goddard Space Flight Center

USB 11

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	22° 07' 45".928	Latitude	ξ = + 7"
Longitude (E)	200 19 55.379	Longitude (E)	η = - 11
Datum	Old Hawaiian	Based on	second-order obs C&GS 1961 at Δ MANU, 300 m distant

Elevation above mean sea level 1150.9 meters

Geoid height ______ meters

Height above ellipsoid ______ meters

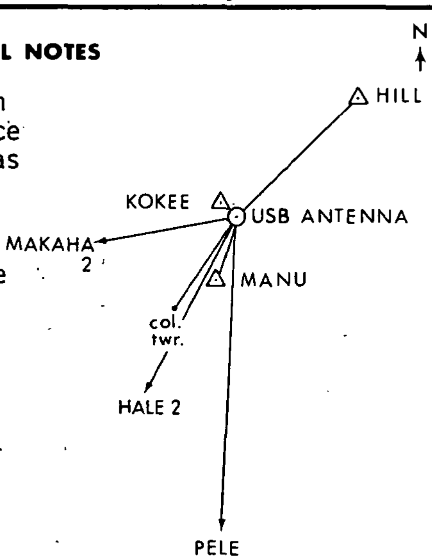
AZIMUTH DATA

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, FFB, GSFC.

Station No. USB 12

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes STDN GDS 8

Location Goldstone, California

Equipment Unified S-Band 26-meter (85-fo

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

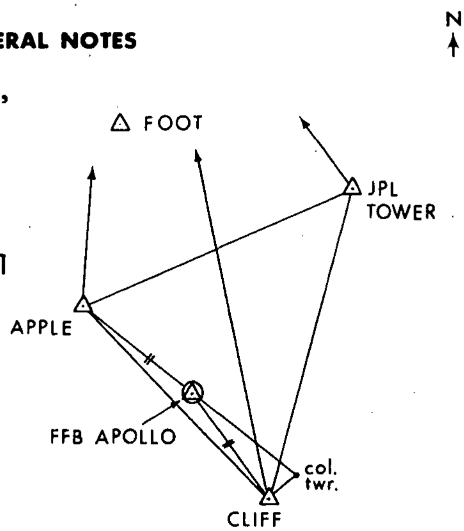
Surveyed by Field Facilities Branch, GSFC in 1965, before antenna construction. The station, probably destroyed later, was marked by a bronze disk at ground level stamped FFB-APOLLO.

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 STDN GYM 3

Location Guaymas, Mexico

Equipment Unified S-Band 9-meter (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	

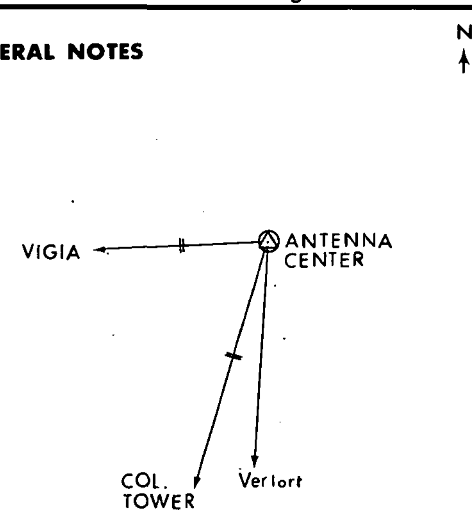
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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 STDN TEX 3

Location Corpus Christi, Texas

Equipment Unified S-Band 9-meter (30-f

Agency NASA-Goddard Space Flight Center

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

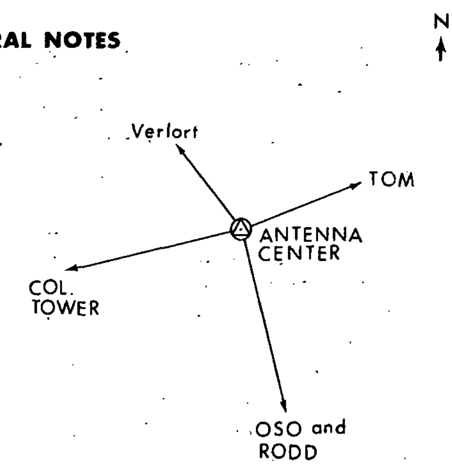
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANTENNA CENTER	Δ OSO	1559.467	170° 06' 14".6
Geodetic	Δ ANTENNA CENTER	Δ COL. TOWER	731.479	252 32 32
	center Y-axis	subreflectors	728.010 slant range	

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

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes STDN ETC 3

Location Greenbelt, Maryland

Equipment Unified S-Band 9-meter (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

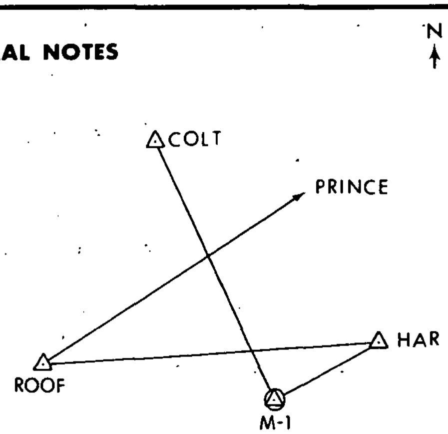
Elevation above mean sea level 53.7 meters   Geoid height + 1 meters   Height above ellipsoid 55 meters

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 STDN ENTA

Location Greenbelt, Maryland

Equipment Unified S-Band 9-meter (30-foo

Agency NASA-Goddard Space Flight Center

USB 16

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). Elevation is on the Washington Suburban Sanitary Datum, which is within a few centimeters of SLD 1929.

(The orientation of the two ERTS antennas USB 16 and USB 17 is like that of the USB 85-foot antennas, rotated 90°, that is, from other USB 30-foot antennas.)

Geoid height from TOPCOCOM geoid charts 1967.

DATE June 1973

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 STDN EGDA

Location Goldstone, California

Equipment Unified S-Band 9-meter (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).

(The orientation of the two ERTS antennas USB 16 and USB 17 is like that of the USB 85-foot antennas, rotated 90°, that is, from other USB 30-foot antennas.)

Geoid height from TOPOCOM geoid charts 1967.

DATE June 1973

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 STDN MIX 3

Location Merritt Island, Florida

Equipment Unified S-Band 9-meter (30-fo

Agency NASA-Goddard Space Flight Center

USB 18

Point referred to center of X-axis

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	28° 30' 26".34	Latitude	
Longitude (E)	279 18 22.93	Longitude (E)	
Datum	NAD 1927	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 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 June 1973

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.

Station No. USB 19

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: STDN SAN3

Code Name

Location: Santiago, Chile

Equipment: Unified S-Band 9-meter (30-foot)

Agency: NASA-Goddard Space Flight Center

USB 19

Point referred to: center of X-axis

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	USB 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 to revise this preliminary position slightly.

This GR&RR antenna (GRR 3S) was converted for use in the USB network.

Geoid height from CHUA base, TOPOCOM 1971.

DATE: August 1973

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	1 meters	7 meters
Vertical	2 meters	3 meters

REFERENCES

Memo: Networks Operations Div., GSFC, to Geonautics, 24 June 1966; Geodetic Summary USATOPOCOM August 1971; telecon NOD 12 July 1973.

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C-Band 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.

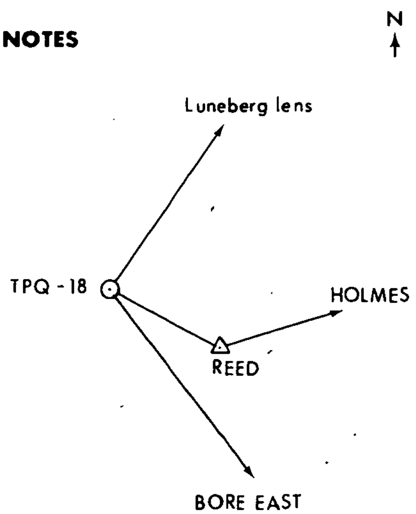
Elevation by USC&GS first-order levels Mar 1964.

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.

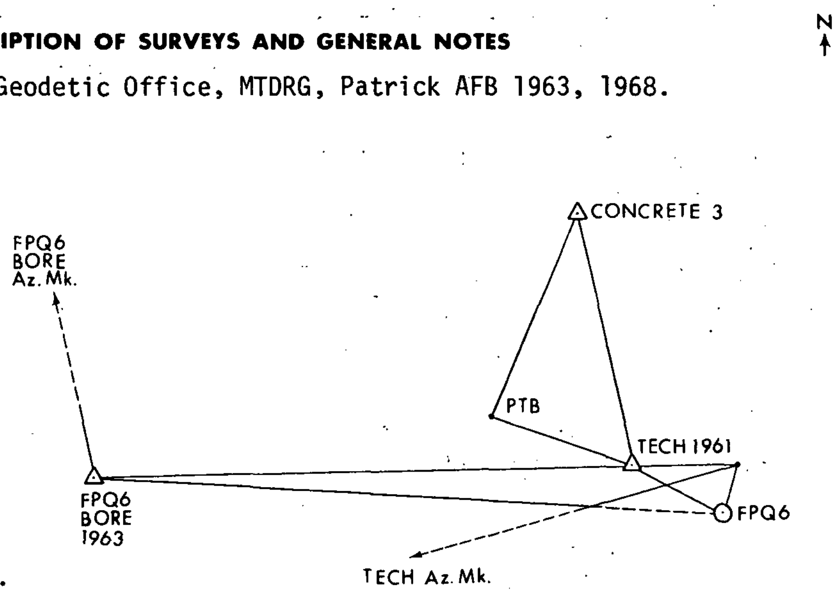
Position was fixed by first-order class I horizontal surveys (adjusted).

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

Location Cape Kennedy, Florida

Equipment FPS-16 radar

Agency USAF-Eastern Test Range

RAD 3

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.

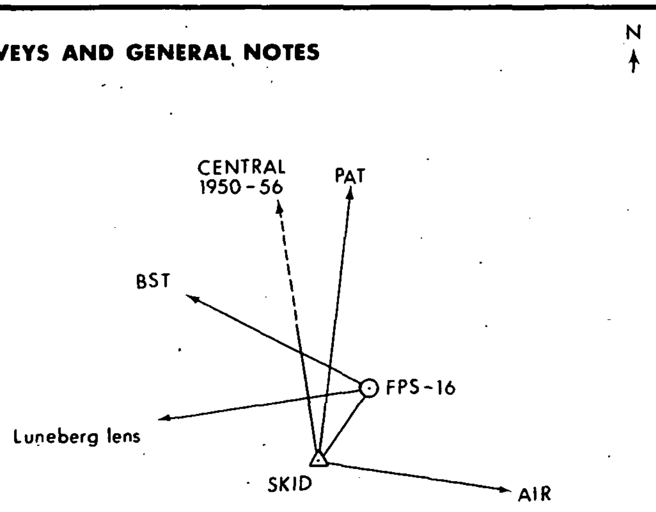
Position was fixed by first-order class I horizontal surveys (not adjusted).

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

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: AFETR 031801; APOLLO GBIT

Code Name

Location: Grand Bahama Island — Equipment: TPQ-18 radar

Agency: USAF-Eastern Test Range

RAD 4

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

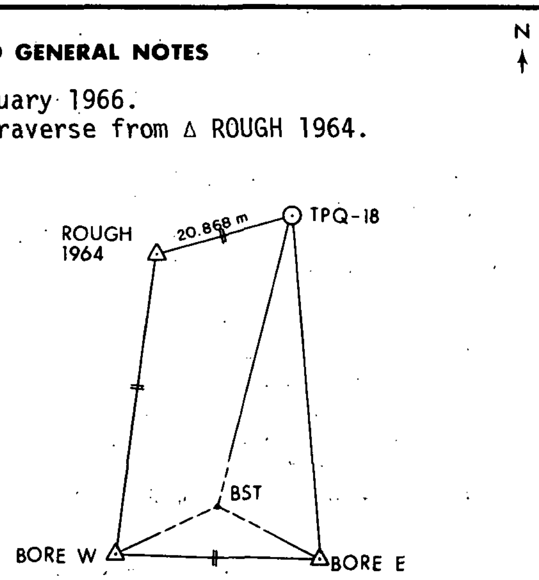
AZIMUTH DATA

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

RAD 5

Point referred to: center of rotation of antenna axes

GEODETIC COORDINATES

Latitude: 37° 51' 36".509

Longitude (E): 284 29 25.236

Datum: NAD 1927

ASTRONOMIC COORDINATES

Latitude:

Longitude (E):

Based on:

Elevation above mean sea level: 14.953 meters

Geoid height: - 2 meters

Height above ellipsoid: 13 meters

AZIMUTH DATA

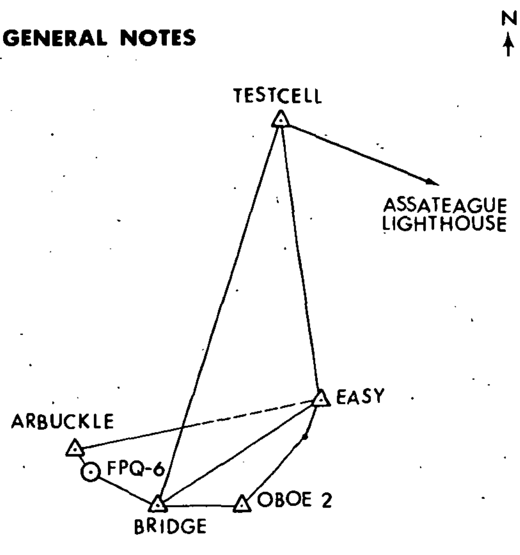
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center of rotation	Δ BRIDGE	1908.898	117° 59' 02".43
Geodetic	center of rotation	Δ ARBUCKLE	696.22	339 56 42.39

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

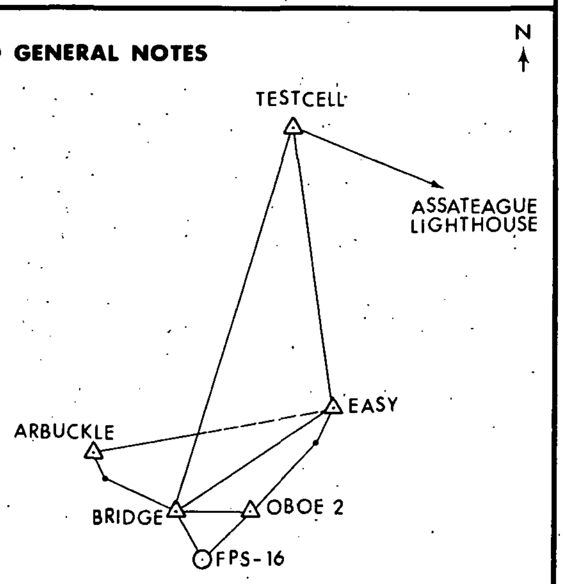
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	center of rotation	Δ BRIDGE	1283.715	339° 43' 55".75
Geodetic	center of rotation	Δ OBOE 2	1849.616	50 37 49.15

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

Latitude: 21° 27' 43".487

Longitude (E): 288 52 03.051

Datum: NAD 1927

ASTRONOMIC COORDINATES

Latitude: 21° 27' 57".02

Longitude (E): 288 52 12.18

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

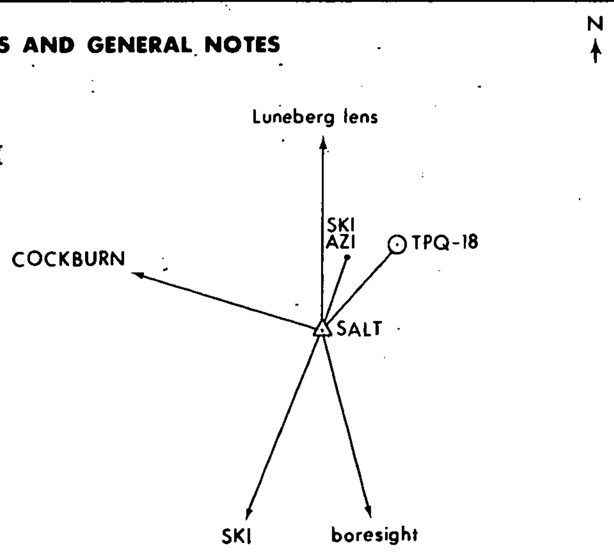
Surveys performed by USC&GS 1963, and USAF ETR 1968.

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

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

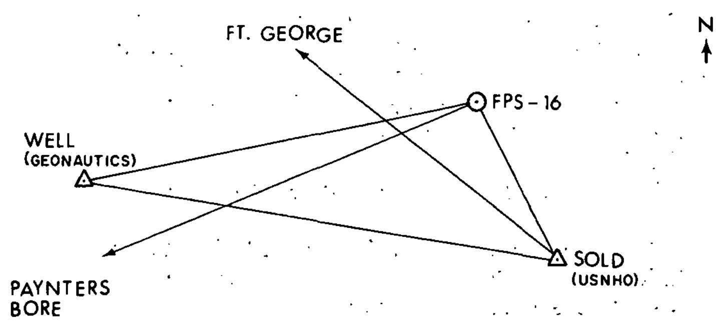
*slant range

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.

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



DATE July 1973

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

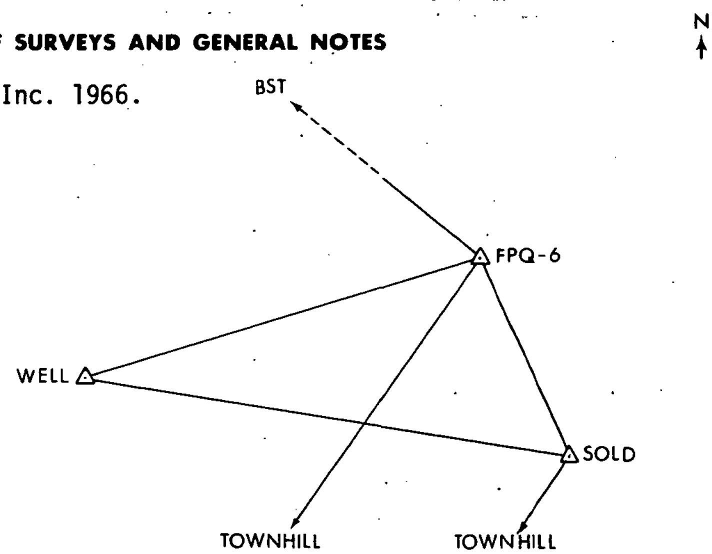
Surveys performed by Geonautics, Inc. 1966.

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.



DATE July 1973

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

Point referred to intersection of axes of rotation

GEODETIC COORDINATES

Latitude 17° 08' 34".777

Longitude (E) 298 12 24.472

Datum NAD 1927 (CC)

ASTRONOMIC COORDINATES

Latitude 17° 08' 40".1

Longitude (E) 298 12 37.2

Based on first-order obs C&GS 1963 at △ 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	△ HARRIS	50.045	185 33 38

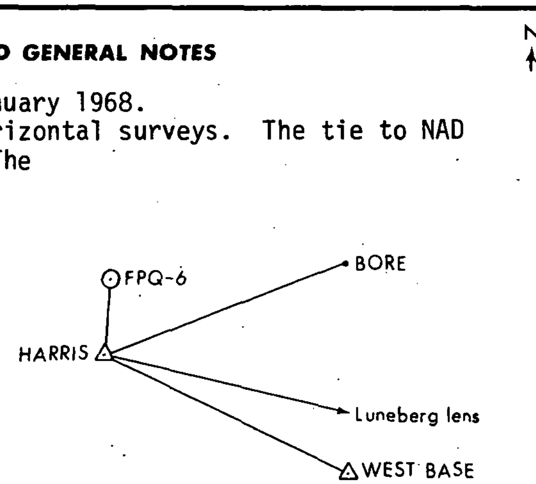
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

Code Name ______

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

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		ASTRONOMIC COORDINATES	
Latitude	- 07° 58' 22".7786	Latitude	ξ = - 2".3 ± 0".2
Longitude (E)	345 35 53.8981	Longitude (E)	η = - 4.2 ± 0.2
Datum	Ascension Island 1958	Based on	C&GS gravimetric/topographic determination at Δ CON, 121 m from antenna

Elevation above mean sea level: 125.378 meters Geoid height: ______ meters 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

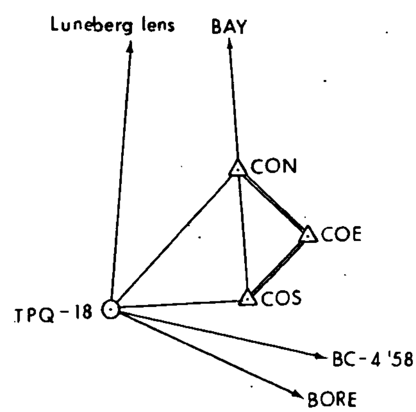
This station is no longer in operation.

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.



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*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

Point referred to: center of rotating base

GEODETIC COORDINATES

Latitude: - 07° 57' 06".2898

Longitude (E): 345 35 14.6257

Datum: Ascension Island 1958

ASTRONOMIC COORDINATES

Latitude: ξ = + 3".19 ± 0".2

Longitude (E): η = - 6.64 ± 0.2

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

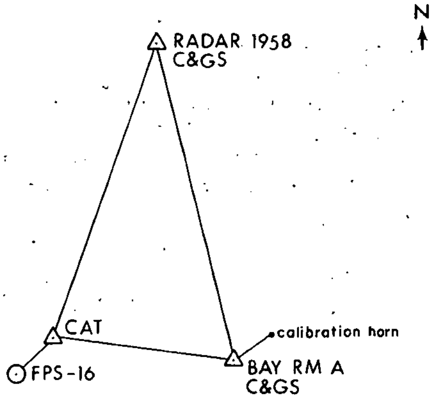
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

Location Tananarive, Madagascar

Equipment FPS-16 (Capri) radar

Agency NASA-Goddard Space Flight Center

RAD 13

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

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 Dept. Lands and Surveys WA 1964 at Δ GC 18A, 400 m from antenna

Elevation above mean sea level 49.0 meters   Geoid height + 6.1 meters   Height above ellipsoid 55 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

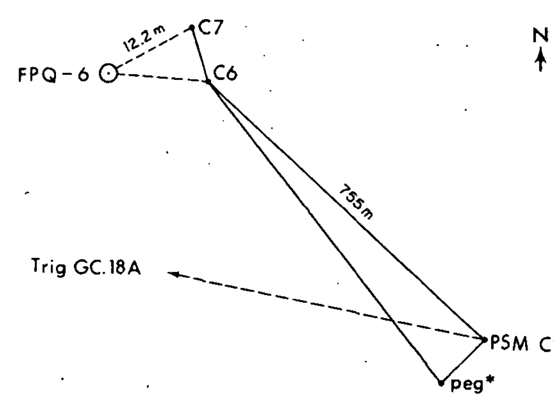
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

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

The elevation is referred to AHD.

Geoid height from National Mapping Technical Report 13, 1971.



*Peg is 45.0 m below center of boresight horn, 767.769 m from the point of reference at geodetic azimuth 138° 28' 48".93.

DATE April 1972

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 National Mapping, March 1972.

Station No. RAD 15

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes APOLLO WOMF
NGSP 4946

Code Name

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 124.71 meters
Geoid height - 1.5 meters
Height above ellipsoid 123 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

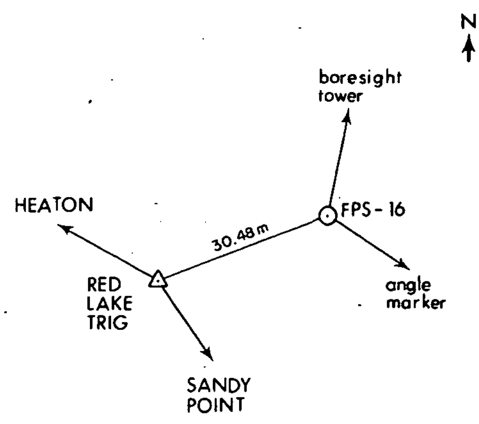
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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.

The elevation is referred to AHD.

Geoid height from National Mapping Technical Report 13, 1971.



DATE April 1972

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.1 meters	2 meters
Vertical	0.5 meters	1 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of National Mapping, March 1972.

Station No. RAD 16

Code Name ______

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes	
SAMTEC	333001
APOLLO	HAWF
NGSP	4742

Location Kauai, Hawaii

Equipment FPS-16 radar

Agency NASA-Goddard Space Flight Center

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)	

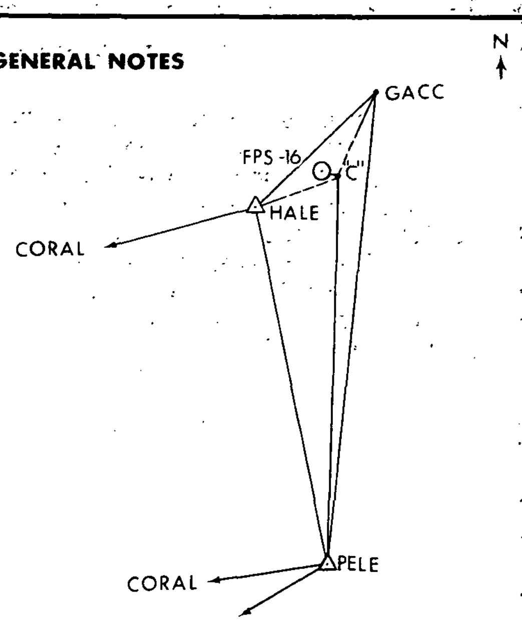
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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	
SAMTEC	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		ASTRONOMIC COORDINATES	
Latitude	34° 39' 57".1404	Latitude	ξ = - 2".1
Longitude (E)	239 25 10.4275	Longitude (E)	η = - 6.9
Datum	NAD 1927	Based on	SAMTEC G.C.M

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.A.F. 1968.

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

Geoid height from TOPOCOM geoid charts 1967.

DATE April 1972

ACCURACY ASSESSMENT

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

REFERENCES

SAMTEC Geodetic Coordinates Manual, Part I, USAF Space and Missile Test Center, Vandenburg AFB California, February 1972.

Station No. RAD 18

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: SAMTEC 023001; APOLLO CALF

Location: Point Arguello, California

Equipment: FPS-16 radar (No. 1)

Agency: USAF-Western Test Range

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

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	34° 34' 57".950	Latitude	ξ = - 4".2
Longitude (E)	239 26 21.970	Longitude (E)	η = - 9.3
Datum	NAD 1927	Based on	SAMTEC G.C.M.

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; resurvey by USAF, 1968.

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 First Geodetic Survey Squadron.

Geoid height from TOPOCOM geoid charts 1967.

DATE April 1972

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; SAMTEC Geodetic Coordinates Manual, February 1972.

ation No. RAD 19

de Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

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

cation: White Sands, New Mexico

Equipment: FPS-16 radar

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

RAD 19

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: - 1.2 meters

Height above ellipsoid: 1232.8 meters

AZIMUTH DATA

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

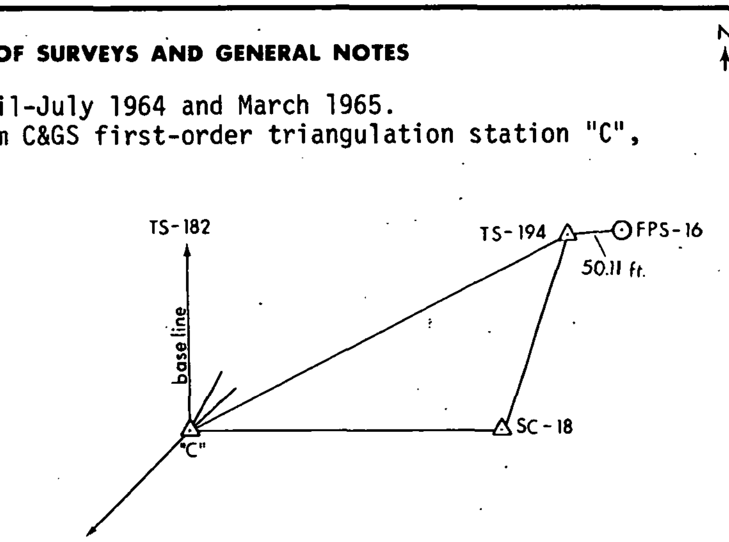
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

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 + 8.9 meters — Height above ellipsoid 36.8 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

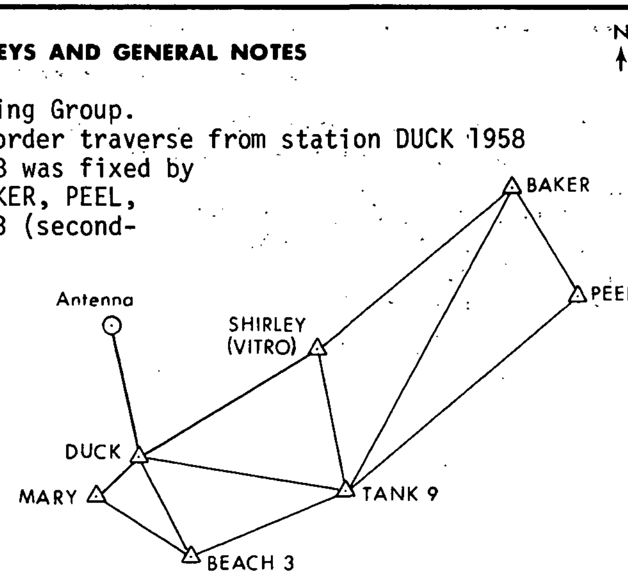
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Code Name

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: 28.8 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.

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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 9-meter (30-foot)

Agency NASA-Goddard Space Flight Center

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.

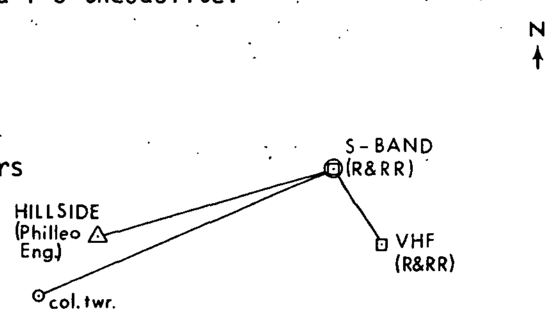
Field surveys by Field Facilities Branch, GSFC, 1965. This third-order field position is based on a Geodimeter traverse from Δ HILLSIDE (Philleo Engineering Company) using a Model 4D Geodimeter and a Wild T-3 theodolite.

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.

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Station No. GRR 1V

Code Name -

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

Location Rosman, North Carolina

Equipment Goddard Range and Range Rate S-Band paired 4.3 meter (14-foot)

Agency NASA-Goddard Space Flight Center

GRR 2S

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 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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Code Name

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

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

GRR 3S

Location: Santiago, Chile

Equipment: Goddard Range and Range Rate S-Band 9-meter (30-foot)

Agency: NASA-Goddard Space Flight Center

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

GEODETIC COORDINATES

Latitude: - 33° 09' 02".734

Longitude (E): 289 20 03.255

Datum: South American 1969

ASTRONOMIC COORDINATES

Latitude: - 33° 09' 13".4

Longitude (E): 289 19 38.8

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.

This antenna has been converted for use in the USB network.

Geoid height from CHUA base, TOPOCOM 1971.

DATE: September 1973

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

Location: Santiago, Chile

Equipment: Goddard Range and Range Rat
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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NGSP 1123

Code Name

Location Tananarive, Madagascar

Equipment Goddard Range and Range Rate S-Band paired 4.3 meter (14-foot)

Agency NASA-Goddard Space Flight Center

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: ø - 19° 01' 13".32, λ 47° 18' 09".45, elevation 1402.7 m. When at this location it had NGSP No. 1122 (MADGAR).

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 4.3 meter (14-foot)

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 Dept. Lands & Surveys WA, 400 m from station

Elevation above mean sea level 37.9 meters

Geoid height + 6.1 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

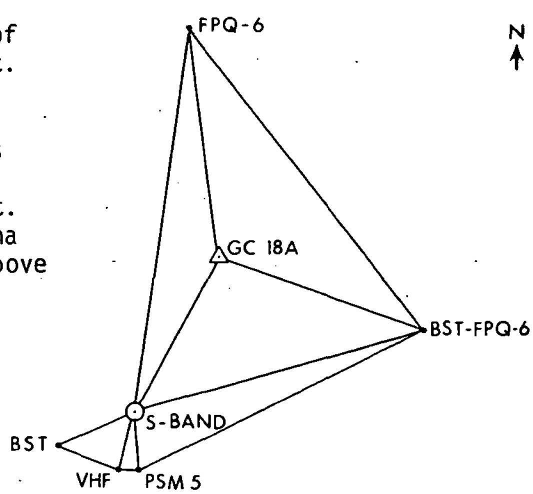
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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.

Elevations are referred to AHD.

Geoid height from National Mapping Technical Report 13, 1971.



DATE April 1972

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 National Mapping, March 1972.

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		ASTRONOMIC COORDINATES	
Latitude	- 24° 54' 18".923	Latitude	- 24° 54' 17".56
Longitude (E)	113 42 54.937	Longitude (E)	113 42 55.73
Datum	Australian Geodetic	Based on	first-order obs 1964 by Dept. Lands & Surveys WA, 400 m from station

Elevation above mean sea level: 37.9 meters Geoid height: + 6.1 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.

Elevation is referred to AHD.

Geoid height from National Mapping Technical Report 13, 1971.

DATE April 1972

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 National Mapping, March 1972

26-Meter Data Acquisition Antennas

Station No. S85 1

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes NASA Rosman I

Code Name

Location Rosman, North Carolina

Equipment 26-meter X-Y antenna (85-foot)

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

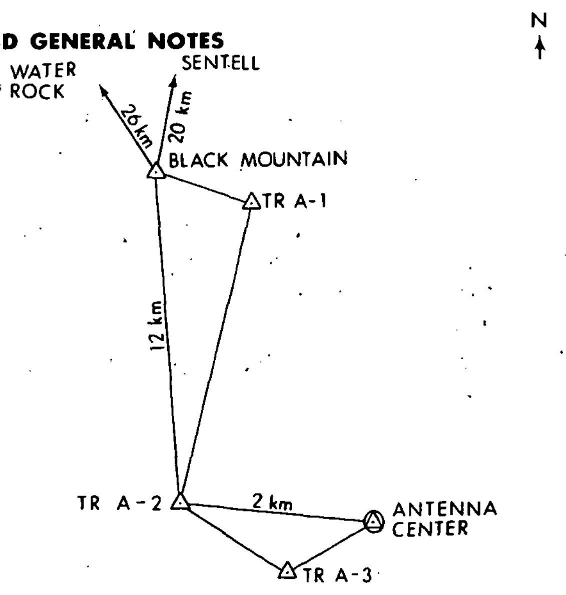
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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 26-meter X-Y antenna (85-foot

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

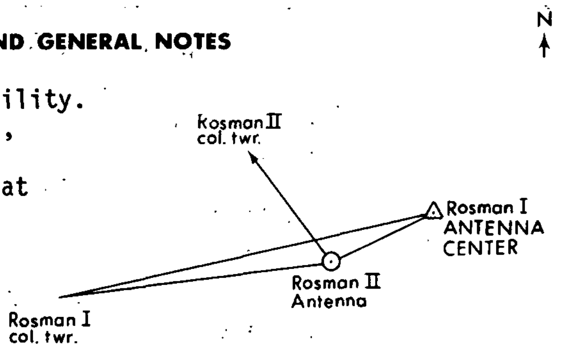
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ ANT CTR (RII)	Δ ANT CTR (RI)	358.206	67° 54' 43"
Geodetic	Δ ANT CTR (RII)	col. twr. (RII)	6836.20	319 03 08.40

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

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: NASA ULASKA

Code Name

Location: Fairbanks, Alaska

Equipment: 26-meter X-Y antenna (85-foot)

Agency: NASA-Goddard Space Flight Center

S85 3

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

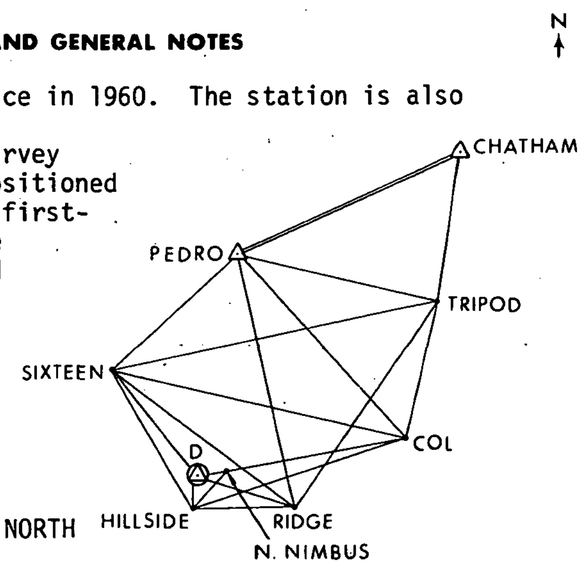
Surveyed by Philleo Engrg. and Arch. Service in 1960. The station is also called Gilmore Center or Ulaska.

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

Location: Orroral, Australian Capital Territory

Equipment: 26-meter X-Y antenna (85-fo

Agency: NASA-Goddard Space Flight Center

Point referred to: center of x-axis

GEODETIC COORDINATES

Latitude: - 35° 37' 52".8542

Longitude (E): 148 57 20.9076

Datum: Australian Geodetic

Elevation above mean sea level: 937.61 meters

Geoid height: + 8.3 meters

ASTRONOMIC COORDINATES

Latitude: - 35° 37' 47".22

Longitude (E): 148 57 31.95

Based on: second-order obs 1964/5 by Div. of Nat. Mapping at Δ OR.LAP. 76.4 m South of antenna

Height above ellipsoid: 946 meters

AZIMUTH DATA

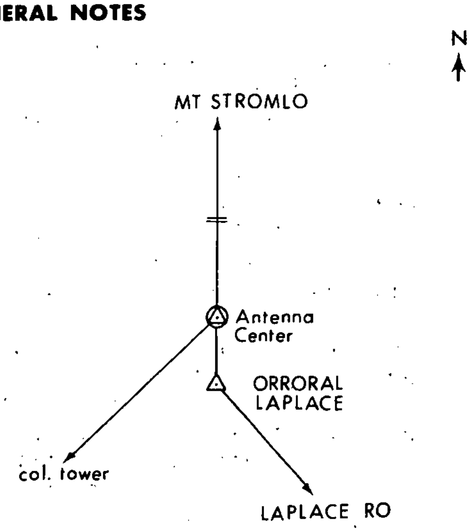
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ Antenna Center	Δ col. tower	1753.0	245° 09' 50".47
Laplace	Δ ORRORAL LAPLACE	Δ LAPLACE RO	2987.07	156 32 46.32
Astronomic	Δ ORRORAL LAPLACE	Δ LAPLACE RO		156 32 40.19

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by the Survey Branch, Department of Interior, Canberra, April-July 1965. 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 AHD.
The X-axis is about 13 m above the base.

Geoid height from National Mapping Technical Report 13, 1971.



DATE: April 1972

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, March 1972.

ation No. S85 6

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

de Name

cation Kashima, Japan

Equipment 26-meter Az-El antenna (85-foot)

gency 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.

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12-Meter Data Acquisition Antennas

Station No. S40 1

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Gilmore Creek, Alaska

Equipment 12-meter antenna (40-foot)

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.

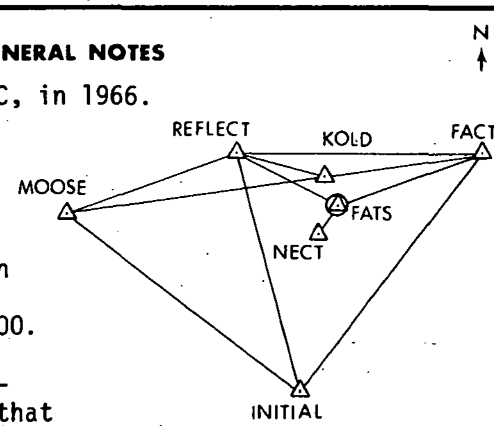
The station is marked by a punch hole at the center of an etched cross on a NASA-GSFC brass tablet stamped "FATS 1966," in the concrete floor at the center of the foundation of the antenna.

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: 12-meter antenna (40-foot)

Agency: NASA-Goddard Space Flight Center

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: +8 meters

Height above ellipsoid: 1545 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.

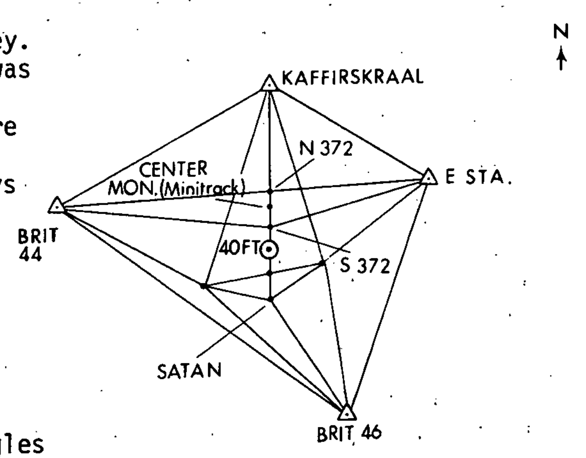
Elevation of the monument is given as 1530 ± 3 m. The height to X-axis from foundation for this type of antenna is 7 m.

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.

Geoid height from DMATC.



DATE July 1973

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

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes

Location Quito, Ecuador

Equipment 12-meter antenna (40-foot)

Agency NASA-Goddard Space Flight Center

S40 3

Point referred to center of X-axis

GEODETIC COORDINATES

Latitude - 00° 37' 22".109

Longitude (E) 281 25 11.277

Datum South American 1969

Elevation above mean sea level 3570 meters

ASTRONOMIC COORDINATES

Latitude - 00° 37' 21".90 ± 0".1

Longitude (E) 281 25 03.40 ± 0.2

Based on first-order IAGS obs 1956 200 m from antenna

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

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Santiago, Chile

Equipment: 12-meter antenna (40-foot)

Agency: NASA-Goddard Space Flight Center

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 12-meter antenna (40-foot)

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

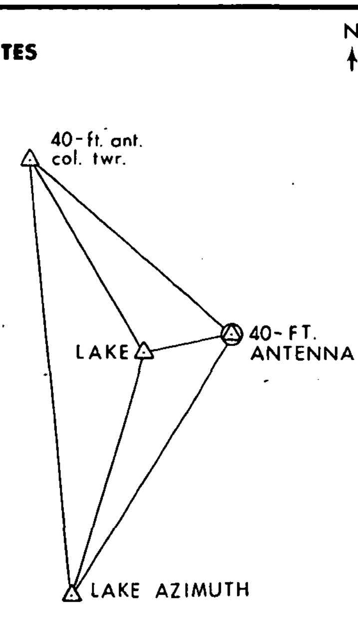
This is an Applied Technology Satellite facility.

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

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location Tananarive, Madagascar

Equipment 12-meter antenna (40-foot)

Agency NASA-Goddard Space Flight Center

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

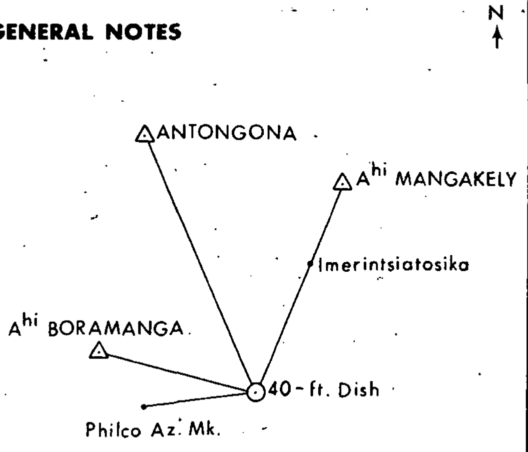
Surveyed by Institut Geographique National, Paris, Annexe de Tananarive (H. Monge), 1966.

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

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

S40 7

Location Greenbelt, Maryland

Equipment 12 meter antenna (40-foot)

Agency NASA-Goddard Space Flight Center

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

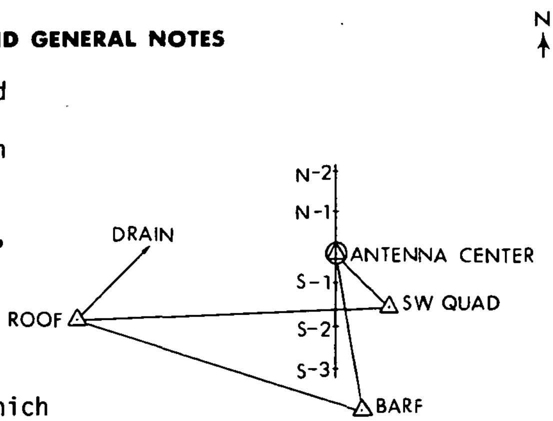
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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.

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Minitrack Stations

tation No. MIN 1

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: COSPAR 13; NGSP 1013

ode Name

ocation Fairbanks, Alaska

Equipment Minitrack

gency 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.

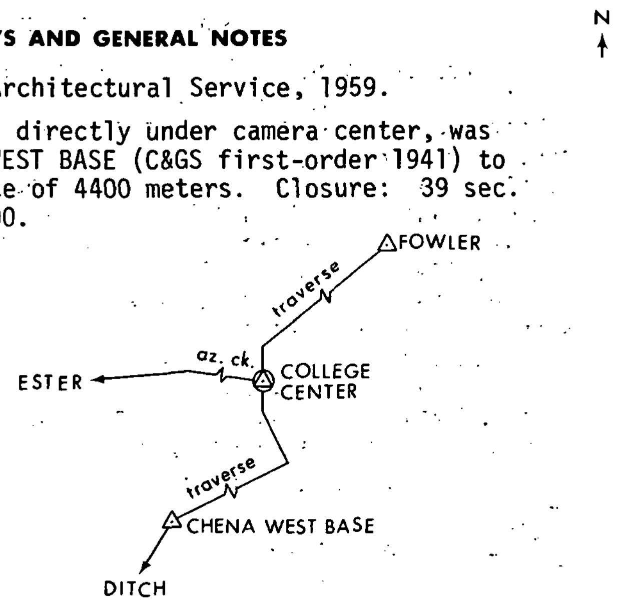
Position of survey mon. COLLEGE CENTER, directly under camera center, was established by taped traverse from CHENA WEST BASE (C&GS first-order 1941) to FOWLER (C&GS second-order 1944), a distance of 4400 meters. Closure: 39 sec. in azimuth, 0.4 m in length; ratio 1:10,700.

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.

This station was moved in 1966. See No. MIN 2.



DATE April 1972

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 SAO 4041

Location Fairbanks, Alaska

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 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.

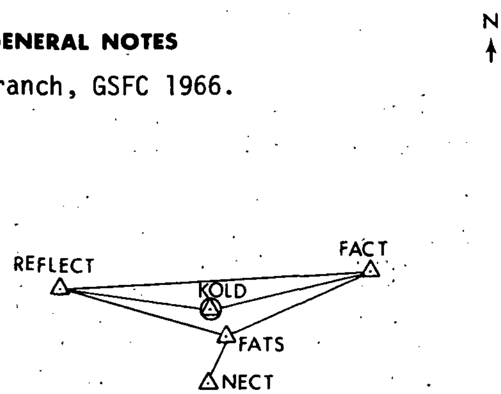
Elevation was by spirit levels to Δ ULASKA, which was tied earlier to C&GS bench marks.

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.

This is the position of the station after 1966. The earlier position was No. MIN 1.



DATE April 1972

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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Code Name

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 - 21.9 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).

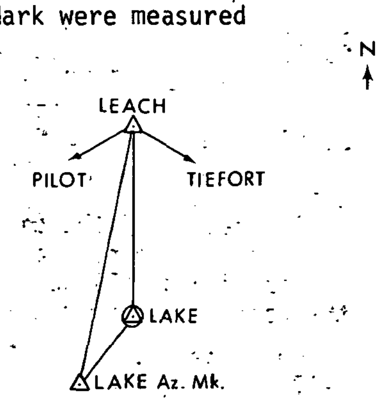
Elevation of LAKE was determined by vertical angles from trig. elevation of LEACH with p.e. less than one meter.

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.

This station is not operating but is in caretaker status. Station is also known as Mojave.



DATE July 1973

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

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 +2.8 meters

Height above ellipsoid 255.4 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; SAO 4021; 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: + 15.7 meters

Height above ellipsoid: 20.5 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

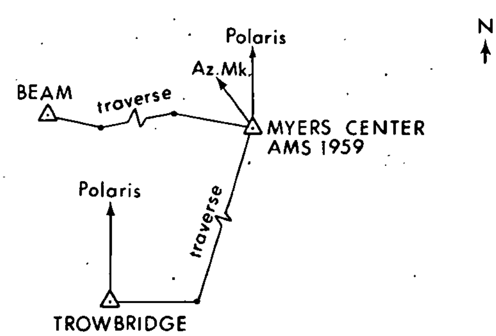
Surveys performed by Army Map Service, September, 1959.

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.

This station was closed in February 1972.

DATE July 1973

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; SAO 4800; 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

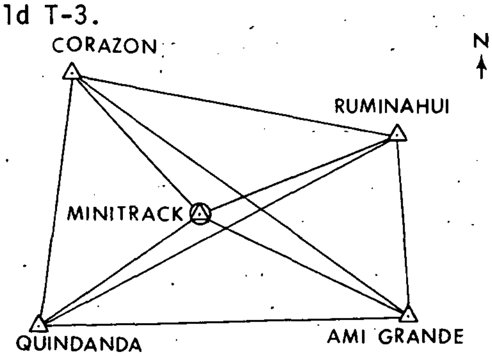
Surveys performed by IAGS and IGM Ecuador in 1957.

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.

tation No. MIN 7

ode Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 6; NGSP 1006

ocation: Lima, Peru — Equipment: Minitrack

gency: 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

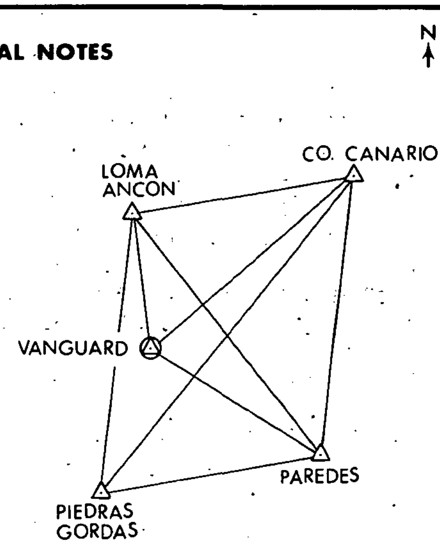
Surveys performed by IAGS and IGM Peru 1956.

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

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

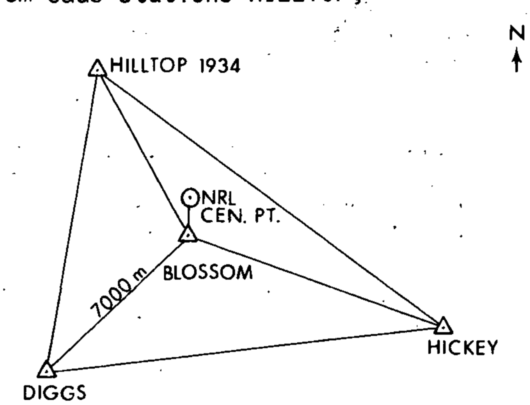
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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.

This station has been removed.



DATE July 1973

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

MIN 9

Location Greenbelt, Maryland

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 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.

This station is not operating but is in caretaker status.

DATE July 1973

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

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: COSPAR 8; SAO 4802; NGSP 1008

Location: Santiago, Chile   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 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

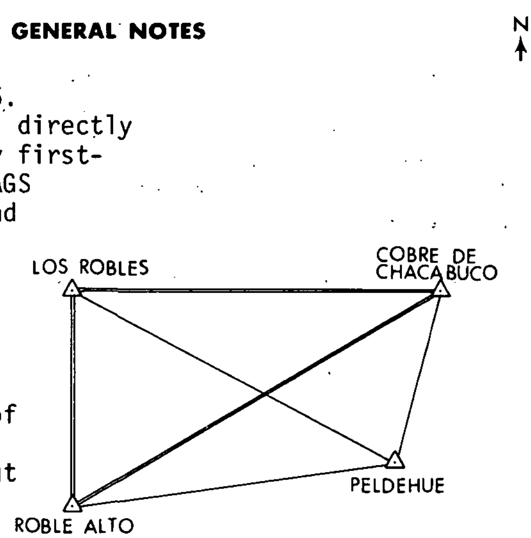
Surveys performed by IAGS and IGM Chile, 1956.

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

Code Name ____

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: COSPAR 12; NGSP 1012

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

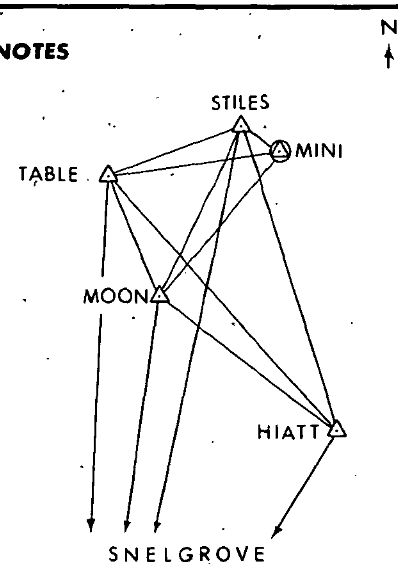
Surveys performed by Geodetic Survey of Canada, 1959.

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.

This station closed 31 March 1970.

Geoid height from TOPOCOM geoid charts 1967.



DATE April 1972

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

Code Name

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: COSPAR 15; SAO 4652; NGSP 1015

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"

This station is not operating but is in caretaker status.

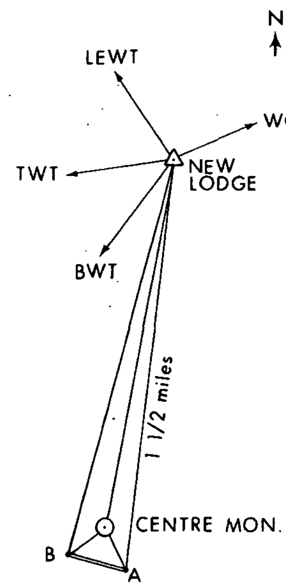
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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 1973

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; SAO 4401; 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 +8 meters Height above ellipsoid 1530 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"

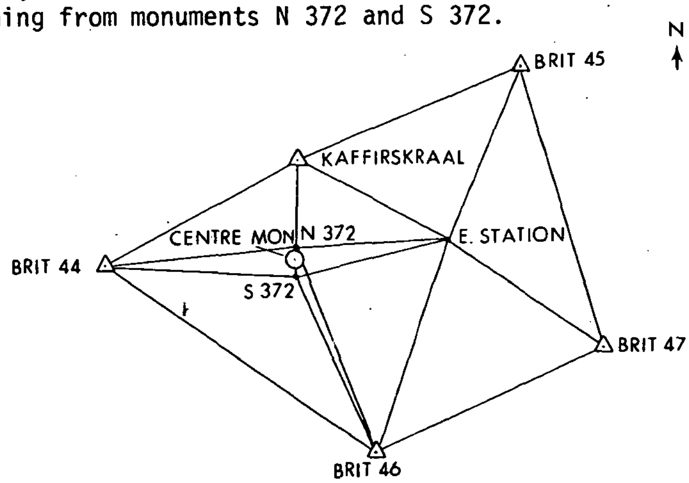
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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.

Geoid height from DMATC.



DATE July 1973

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; SAO 4714

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

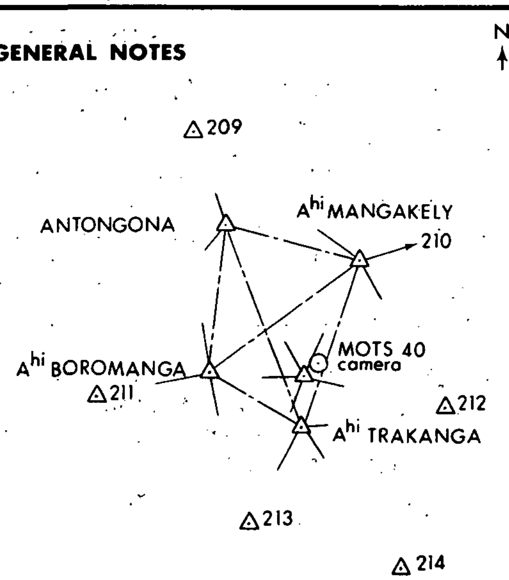
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

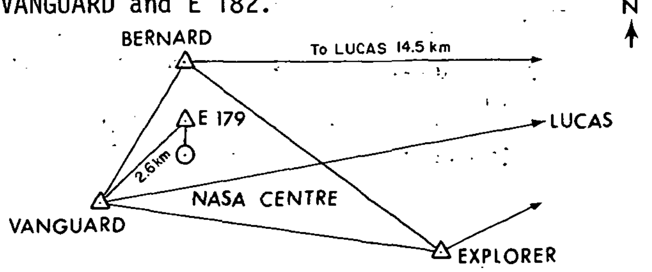
Elevation above mean sea level 129.51 meters — Geoid height -1.0 meters — Height above ellipsoid 129 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Astronomic	Δ THE KNOLL	Δ CAMPBELL RISE		85° 36' 28".96
Laplace	Δ THE KNOLL	Δ CAMPBELL RISE		85 36 28.29
Geodetic	Δ THE KNOLL	Δ CAMPBELL RISE		85 36 27.23

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Station is also referred to as "Island Lagoon."
This station was moved to Orroral (see Station No. 1038) in 1966.
Survey performed by Dept. of Interior Survey Section, Woomera 1960.
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.
Geoid height from National Mapping Technical Report 13, 1971.



DATE April 1972

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 National Mapping, March 1972.

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 931.25 meters

Geoid height + 8.3 meters

Height above ellipsoid 940 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 National Geodetic Survey was at MOUNT STROMLO, some 40 Km to the north, by closed loops of second order Tellurometer traverse.

The height of the ground screen is 2.243 m above the survey monument.

The elevation is referred to AHD.

Geoid height from National Mapping Technical Report 13, 1971.

From Δ ORRORAL LAPLACE to ORRORAL LAPLACE RO,

The Astronomic Azimuth is 156° 32' 40".19,
The Laplace azimuth is 156 32 46.32,
The Geodetic azimuth is 156 32 46.75.

DATE April 1972

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 National Mapping, March 1972.

SATAN Antennas

ation No. SAT 1

ode Name

ocation Rosman, North Carolina

gency NASA-Goddard Space Flight Center

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Equipment SATAN Antenna

SAT 1

Point referred to center of X-axis

GEODETIC COORDINATES

Latitude 35° 12' 06".124

Longitude (E) 277 07 26.363

Datum NAD 1927

Elevation above mean sea level 934.2 meters

ASTRONOMIC COORDINATES

Latitude ξ = -9".3

Longitude (E) η = +9.1

Based on first-order obs AMS 1962 at ROSMAN I, 400 m SE of the SATAN

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

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 $\xi = -2'' \pm 2''$

Longitude (E) $\eta = -4 \pm 3$

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 for USB 12, Field Facilities Branch, GSFC, April 1965.

tation No. SAT 3

ode Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

ocation Cooby Creek, Australia — Equipment SATAN antenna

gency 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 + 1.6 meters — Height above ellipsoid 552 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 National Mapping Technical Report 13, 1971.

DATE April 1972

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.

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Station No. DSN 1

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL DSS 11; APOLLO GDSW; COSPAR GOLDSTONE II

Code Name ______

Location: Goldstone, California

Equipment: 26-meter HA-Dec: Pioneer (85-foot)

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

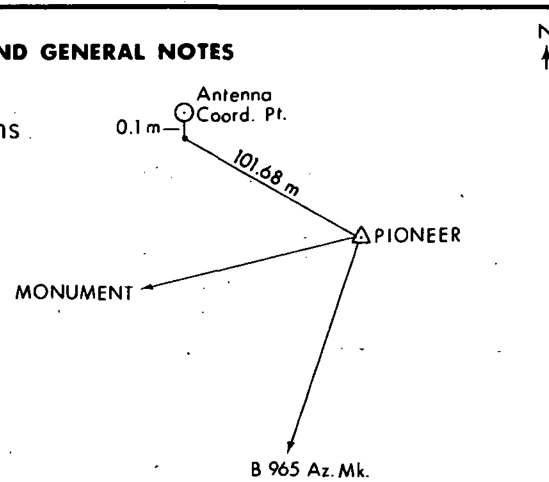
AZIMUTH DATA

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 DSS 12; COSPAR GOLDSTONE I

Location: Goldstone, California

Equipment: 26-meter HA-Dec: Echo (85-foo

Agency: Jet Propulsion Laboratory, California Institute of Technology

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: - 21.6 meters

Height above ellipsoid: 967.3 meters

AZIMUTH DATA

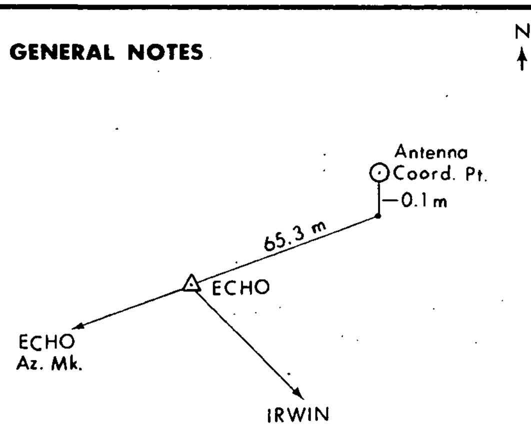
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic (third-order)	Δ ECHO	Δ ECHO AZ MK	720 ±	251° 56' 10"

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 DSS 13

Location: Goldstone, California

Equipment: 26-meter Az-El: Venus (85-foot)

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 Δ VENUS

Elevation above mean sea level: 1093.5 meters | Geoid height: - 21.6 meters | Height above ellipsoid: 1072 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ VENUS	Δ VENUS AZ MK	800 ±	67° 15' 40"*
Geodetic	Δ VENUS	center of az axis	71.382	317 49 04

*third-order

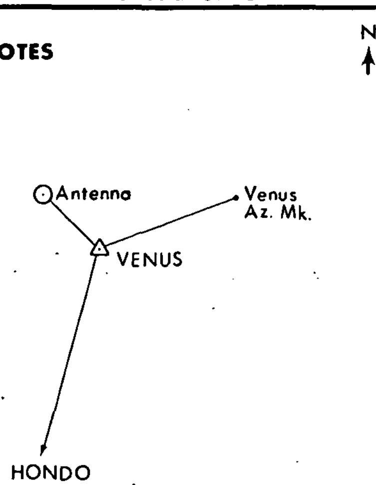
DESCRIPTION OF SURVEYS AND GENERAL NOTES

This Station is used for research and development.

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 Δ VENUS to the antenna were made by Jet Propulsion Laboratory in 1964.

The elevation axis is 9.44 m above Δ 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 DSS 14

Code Name

Location: Goldstone, California

Equipment: 64-meter Az-El: Mars (210-fo

Agency: Jet Propulsion Laboratory, California Institute of Technology

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

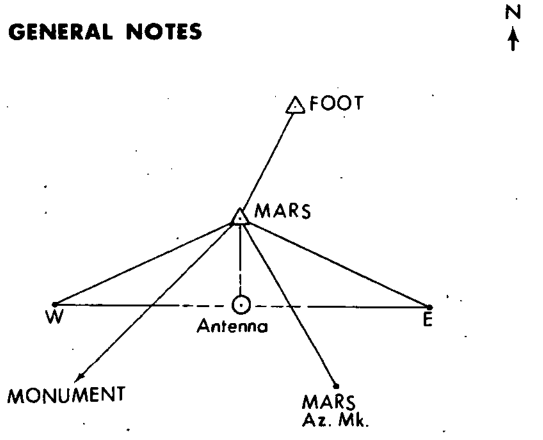
*third-order

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.

tation No. DSN 5

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL DSS 41; COSPAR 34

ode Name ______

ocation: Woomera, Australia Equipment: 26-meter HA-Dec (85-foot)

gency: 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° 22' 58".25 ± 0".6
Longitude (E)	136 53 10.1244	Longitude (E)	136 53 09.84 ± 0.6
Datum	Australian Geodetic	Based on	second-order obs by Dept. of Interior Woomera at Δ E172 in 1963

Elevation above mean sea level 148.28 meters Geoid height -1.0 meters Height above ellipsoid 147 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
Astronomic	antenna center	col. twr.	141	27 53 11

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The station is referred to as Island Lagoon.

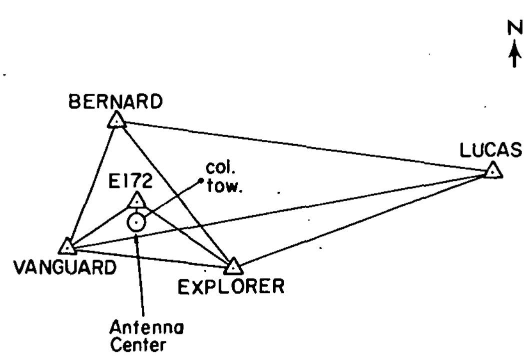
The site was surveyed by the Survey Section, Dept. of Interior, Woomera in September 1960. The geodetic control consists of the first-order scheme shown in sketch. It is based on first-order stations BERNARD and LUCAS of the Australian Army Survey.

The elevation is referred to AHD.

This survey was to a point in space 15 m above the center of the dish footings. The correction of 1.23 m in elev. and 0".0711 in latitude to the reference point was by JPL.

Geoid height from National Mapping Technical Report 13, 1971.

The position of the center of the dish footings is lat. - 31° 22' 59".3594, long. 136° 53' 10".1244.



DATE April 1972

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, March 1972 and JPL Memo 14 March 1969.

Station No. DSN 6

Code Name

GEODETIC DATA SHEET

GEODETIC SATELLITE OBSERVATION STATION

Other Codes: JPL DSS 42; APOLLO HSKW

Location: Tidbinbilla, Australian Capital Territory

Equipment: 26-meter HA-Dec (85-foot)

Agency: Jet Propulsion Laboratory, California Institute of Technology

Point referred to: intersection of the polar axis and the plane of the declination axis in the direction of the polar wheel

GEODETIC COORDINATES

Latitude: -35° 24' 08".0422

Longitude (E): 148 58 48.1909

Datum: Australian Geodetic

ASTRONOMIC COORDINATES

Latitude: -35° 24' 02".16 ± 0".31

Longitude (E): 148 58 51.49 ± 0.41

Based on: second-order obs. 1964 by Div. of Natl. Mapping at △TIDBINBILLA LAPLACE

Elevation above mean sea level: 655.78 meters

Geoid height: + 8.3 meters

Height above ellipsoid: 664 meters

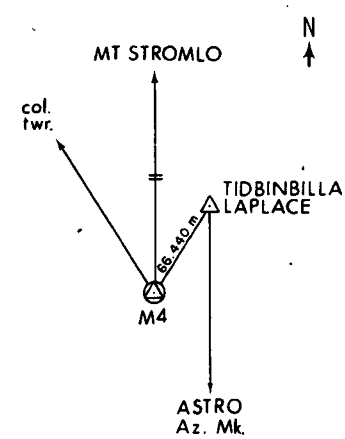
AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	△ M4 (Ant. Ctr.)	col. tower	3577.819	312° 11' 28"
Geodetic	△ TID. LAPLACE	△ ASTRO AZ MK	581	180 00 00.91

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The site was surveyed by the Survey Branch, now in the Dep. of Services and Property, Canberra, in August 1964 and extended in July 1972. 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 △ MT STROMLO of the National Geodetic Survey.

The elevation is referred to AHD. The reference point is 15.075 m above △ M4 (elev. about 650 m).



Geoid height from National Mapping Technical Report 13, 1971.

DATE March 1973

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	<1 meters	5 meters
Vertical	0.5 meters	2 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Division of National Mapping, Canberra, March 1973.

Station No. DSN 7

Code Name -

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL DSS 51; COSPAR 51

DSN 7

Location: Johannesburg, South Africa

Equipment: 26-meter HA-Dec (85-foot)

Agency: Jet Propulsion Laboratory, California Institute of Technology

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 +8 meters   Height above ellipsoid 1399 meters

AZIMUTH DATA

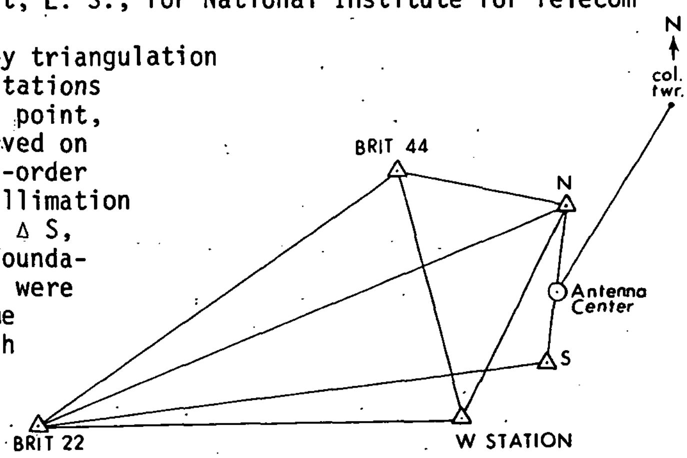
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	antenna center	center col. tower (survey mark)	1561.37	28° 09' 23".0
Geodetic	antenna center	col. tower (dish)	1559.51	28 09 30.6

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.

Geoid height from DMATC.



DATE July 1973

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 DSS 61; APOLLO MADW

Code Name

Location: Madrid, Spain

Equipment: 26-meter HA-Dec (85-foot)

Agency: Jet Propulsion Laboratory, California Institute of Technology

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

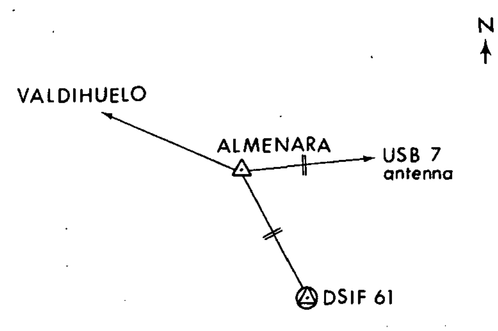
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: JPL DSS 62

Code Name

Location: Madrid, Spain

Equipment: 26-meter HA-Dec (85-foot)

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

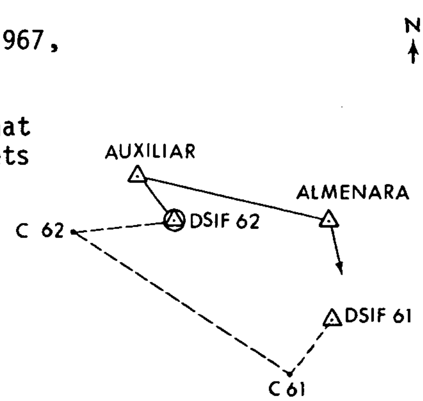
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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 DSS 43

Code Name ____

Location: Tidbinbilla, Australia

Equipment: 64-meter HA-Dec (210-foot)

Agency: Jet Propulsion Laboratory, California Institute of Technology

Point referred to: intersection of elevation axis and plane of elevation wheel

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	-35° 24' 14"3407	Latitude	-35° 24' 08"46 ± 0"31
Longitude (E)	148 58 48.1908	Longitude (E)	148 58 51.49 ± 0.41
Datum	Australian Geodetic	Based on	second-order obs. 1964 by DNM at △ TIDBINBILLA LAPLACE 260 m N. of sta.

Elevation above mean sea level 669.73 meters; Geoid height 8.3 meters; Height above ellipsoid 678.0 meters

AZIMUTH DATA

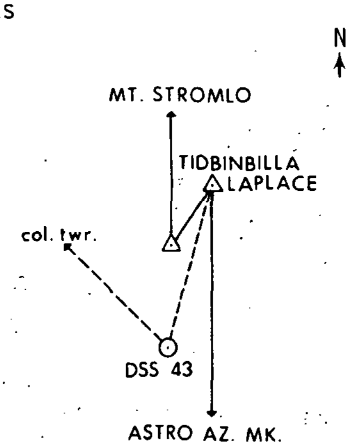
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	point of reference	col. twr.	3710.95	314° 24' 44"
Geodetic	△ TID. LAPLACE	△ ASTRO AZ. MK.	581	180 00 00.91

DESCRIPTION OF SURVEYS AND GENERAL NOTES

The local surveys were made in August 1964 and extended in July 1972 by the Survey Branch, now in the Dep. of Service and Property, and by the Div. of Nat. Mapping. The position was by closed Tellurometer survey to △ MOUNT STROMLO of the Nat. Geodetic Survey.

The elevation is referred to AHD.

Geoid height from Nat. Mapping Technical Report 13, 1971.



DATE March 1973

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	< 1 meters	5 meters
Vertical	0.5 meters	2 meters

REFERENCES

Geodetic Information for Space Tracking Stations in Australia, Div. of Nat. Mapping, Canberra, March 1973.

Station No. DSN 11

Code Name ______

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes JPL DSS 63

Location Madrid, Spain

Equipment 64-meter HA-Dec (210-foot)

Agency Jet Propulsion Laboratory, California Institute of Technology

DSN 11

Point referred to intersection of elevation axis and plane of elevation wheel

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	40° 26' 03".93	Latitude	
Longitude (E)	355 45 09.13	Longitude (E)	
Datum	European	Based on	

Elevation above mean sea level 796 meters   Geoid height -22 meters   Height above ellipsoid 774 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH

DESCRIPTION OF SURVEYS AND GENERAL NOTES

Preliminary position.

Geoid height from G. Bomford's geoid chart of Europe, etc., February 1971.

DATE July 1973

ACCURACY ASSESSMENT	To Local Control	To Datum Origin
Horizontal	______ meters	______ meters
Vertical	______ meters	______ meters

REFERENCES

Telecon Networks Operations Division, GSFC, 5 June 1973.

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.

Station No. RTE 2

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Location: Parkes, NSW, Australia

Equipment: 64-meter radio telescope

Agency: C.S.I.R.O. Radiophysics Laboratory

Point referred to: intersection of axes of antenna

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	- 33° 00' 00".036	Latitude	- 32° 59' 59".58
Longitude (E)	148 15 44.147	Longitude (E)	148 15 41.67
Datum	Australian Geodetic	Based on	first-order obs July 1963 by Div. Nat. Mapping 18.3 m SW of the antenna center

Elevation above mean sea level 391.77 meters; Geoid height + 3.3 meters; Height above ellipsoid 395 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 National 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 AHD.

Geoid height from National Mapping Tehnnical Report 13, 1971

DATE April 1972

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, Div. of National Mapping, March 1972.

Station No. RTE 3

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes

Code Name

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.

Station No. RTE 4

Code Name

GEODETIC DATA SHEET

GEODETIC SATELLITE OBSERVATION STATION

Other Codes

Location: Green Bank, West Virginia

Equipment: 43-meter radio telescope

Agency: National Radio Astronomy Observatory

Point referred to: center of top of 6.35 cm diameter pipe protruding from feedhorn in zenith position

GEODETIC COORDINATES		ASTRONOMIC COORDINATES	
Latitude	38° 26' 15".409	Latitude	38° 26' 12".45 ±0".35
Longitude (E)	280 09 50.387	Longitude (E)	280 09 53.64 0.08
Datum	NAD 1927	Based on	mod. first-order obs. 1970 by 1 GSSq at site

Elevation above mean sea level: 880.870 meters — Geoid height: +3.0 meters — Height above ellipsoid: 883.9 meters

AZIMUTH DATA

ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ SITE	Δ GEONAUTICS 5	240.408	238° 56' 41".3
Astronomic	Δ SITE	Δ GEONAUTICS 5		238 56 43.8

DESCRIPTION OF SURVEYS AND GENERAL NOTES

N ↑

The position was determined by a first-order electronic loop traverse by the First Geodetic Survey Squadron in 1970 from C&GS first-order station PADDYS KNOB 1878, 1957, 19 Km SSE of the site. Two ref. marks provided initial azimuth, and two astro-longitudes were used to convert the observed first-order astro-azimuths to geodetic. Second-order C&GS Δ BANK 1957 was used as a check. All distances were measured at least twice with a Mod 8 Laser Geodimeter. Directions were observed with a Wild T3, using 16 positions. Permanent station SITE 1970 was set about 100 m east of the telescope building and used for local control. The antenna feed-horn pipe was intersected from four stations while in zenith position for each of the four horizontal quadrants.

First-order spirit levels were run to the site (11 Km) from three C&GS first-order benchmarks. Vertical angles were observed to the tip of the feed-horn from four stations in three positions each.

Geoid height from AMS geoid charts 1967.

DATE: August 1973

ACCURACY ASSESSMENT

	To Local Control	To Datum Origin
Horizontal	0.2 meters	4.2 meters
Vertical	0.3 meters	<1 meters

REFERENCES

Final Survey Data, AF Project 71-1, 1st Geodetic Survey Squadron USAF, 30 November 1970.

Launch Sites

ation No. LPD 1

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: AFETR 015012

ode Name

ocation: Cape Kennedy, Florida

Equipment: Stand 12 (Atlas-Agena)

gency: NASA-John F. Kennedy Space Center

LPD 1

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

GEODETIC COORDINATES

Latitude: 28° 28' 49".1255

Longitude (E): 279 27 28.0486

Datum: NAD 1927 (CC)*

Elevation above mean sea level: 14.973 meters

Geoid height: + 10 meters

ASTRONOMIC COORDINATES

Latitude: ξ = + 0".91

Longitude (E): η = + 2.16

Based on: first-order obs C&GS 1956 at Δ 12 NW, 216 m distant

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

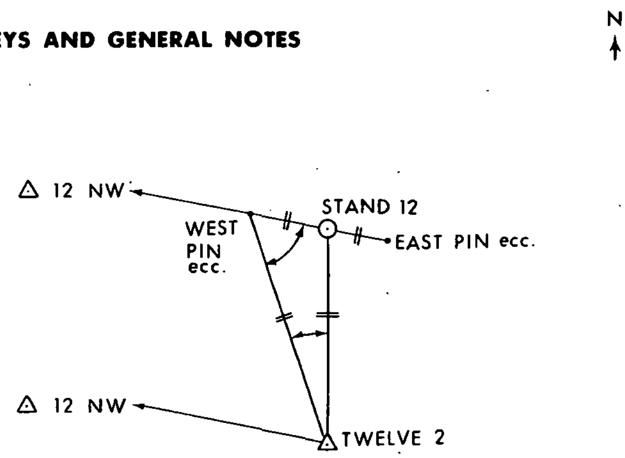
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes: AFETR 015013

Code Name

Location: Cape Kennedy, Florida

Equipment: Stand 13 (Atlas-Agena)

Agency: NASA-John F. Kennedy Space Center

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	NAC 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

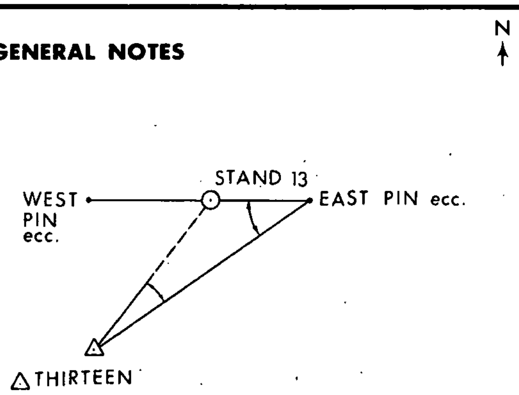
ASTRONOMIC OR GEODETIC	FROM	TO	DISTANCE meters	AZIMUTH FROM NORTH
Geodetic	Δ THIRTEEN	Δ AIR		233° 51' 24".60

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.

tation No. LPD 3

GEODETIC DATA SHEET
SATELLITE TRACKING STATION

Other Codes: AFETR 015014

ode Name

ocation: Cape Kennedy, Florida

Equipment: Stand 14 (Atlas-Agena)

gency: 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

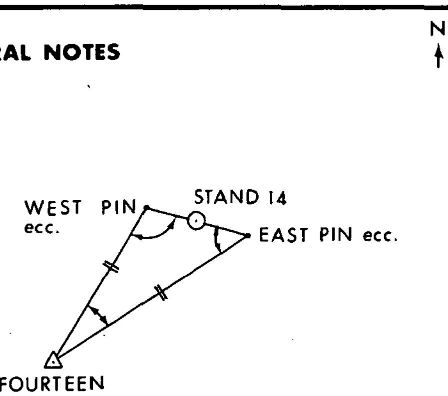
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

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: + 9.9 meters

Height above ellipsoid: 19.6 meters

AZIMUTH DATA

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

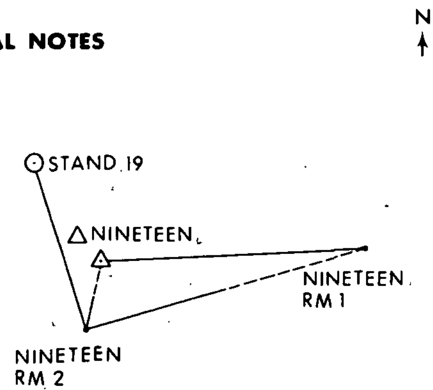
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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"

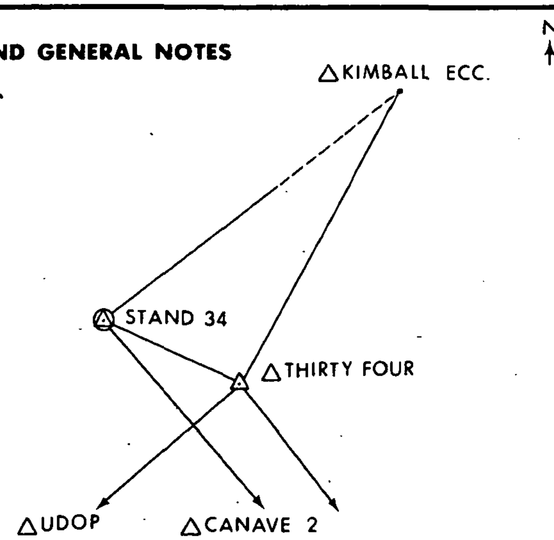
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

Code Name

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 015037

Location Cape Kennedy, Florida — Equipment Stand 37A

Agency NASA-John F. Kennedy Space Center

LPD 6

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 + 9.9 meters — Height above ellipsoid 27.5 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

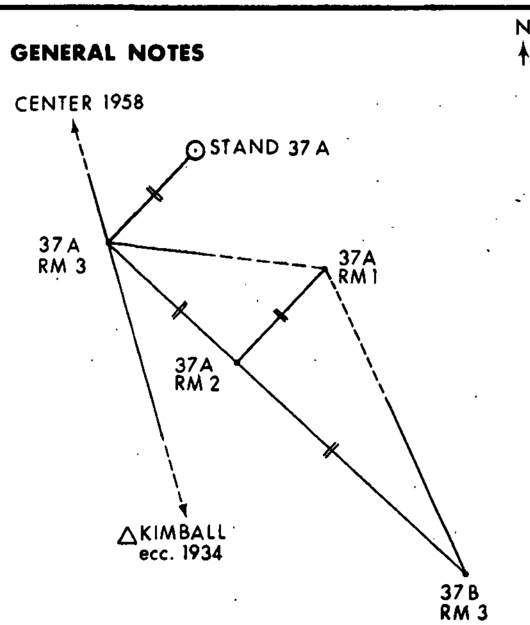
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 015037

Code Name

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 + 9.9 meters — Height above ellipsoid 27.5 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

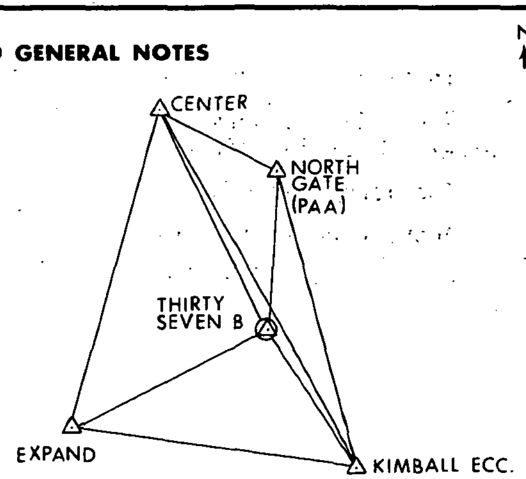
DESCRIPTION OF SURVEYS AND GENERAL NOTES

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

GEODETIC DATA SHEET

SATELLITE TRACKING STATION

Other Codes AFETR 335039

Code Name

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 (base of launch arms)

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.

NASA DIRECTORY OF
OBSERVATION STATION
LOCATIONS

EDGE INDEX

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