ANNEX

BASIC ELEMENTS OF THE GEODETIC PROBLEM

A. Origin of the Problem

1. Geodetic Systems End at Coast Lines

Ground control points on the Earth's surface conventionally are established by measurement from a pre-selected initial point to other points by means of triangulation (distances between points of triangles are calculated through the measurement of angles). Since this procedure is impossible over ocean areas, continental geodetic systems stop at coast lines. Limited ocean spaces can be covered by direct measurement of sides of triangles (trilateration) from continent-to islands-to continent, using electronic techniques. This is called HIRAN. Europe has been tied with North America through Canada with an estimated uncertainty of plus or minus 240 feet. Such ties were made in the Far East and are now being undertaken to interconnect Australia, New Guinea, the Marshalls, and other islands farther east. No HIRAN connection between the Tokyo and North American datums is possible.

B. Sources of Errors

1. Size and Shape of the Earth; Datums

Computing relationships of control points for small areas (property surveys) is easy because computations are made on a plane surface. For large areas where earth curvature is involved, however, computations are made on a curved surface of a near-sphere with predetermined dimensions. Such a figure, the ellipsoid of reference, has definite estimated lengths of the equatorial and polar axes and a ratio between the two that defines the flattening. Because none of these can be measured directly, they have throughout the history of geodesy been differently estimated by geodesists of various countries. The ellipsoid of reference plus the initial point of a geodetic network defines a distinctive datum. Any change or difference in any one of the dimensions of an ellipsoid or in the initial point changes the datum and the resultant geodetic system. The joining of two or more datums creates discrepancies at points common to the datums, as at a border between countries. The US uses the North American Datum, 1927,

based on the Clarke ellipsoid of 1866. The Soviets use the Pulkovo Datum, 1942, based on the Krasovskiy ellipsoid of 1940. The joining of the datums of continents is further complicated by the lack of intervening triangulation over bodies of water (now corrected with HIRAN ties by the USAF), thus giving rise to errors in computing distances and directions between widely separated launch and target points for ICBM operations.

2. Fitting of the Ellipsoid to the Geoid

Because the earth is not a true sphere, and hence not a smoothed surface, mathematical difficulties (and discrepancies) arise in fitting the ellipsoid of reference, a mathematical approximation to the earth, to the geoid, a generalized, undulating representation of the sea-level earth surface. The latter cannot be observed directly but must be deduced from astronomic observations or from the measurement of random variations in the force of gravity from point to point on the earth's surface. Of these, only gravity can be measured on both land and sea; astronomic determinations at sea cannot be measured within better than a 1-mile error. The unknown angular separation between a geoid and an ellipsoid leads to angular errors -- deflection of the vertical -- since the plumb bob of surveying instruments is perpendicular to the geoid and not to the ellipsoid on which all computations are made. For very small countries it has been sufficient to assume that the geoid and ellipsoid were coincident; for others the errors could in some cases be corrected by astronomic methods. But, for a country as broad as the USSR, the errors were found to be inadmissible, amounting "to 40-50 times the errors of field work." In the 1930's the Soviets learned that the German ellipsoid then in use (Bessel) and the conventional western method of computation (development method) gave an error of some 900 meters (3,000 feet) in the positions of common points. As a result, a new ellipsoid was computed in 1940, and a new method of computation was adopted (projection method), in which points are projected perpendicular to the ellipsoid. The Soviets now assert that the inferiority of the development method will be felt sharply in the future when adjoining nets are connected and that divergencies will make cartographic unification impossible. Essential to the projection method are gravity data, for which the Soviets began systematic surveys in 1932. The technique of this method is similar to that used by the USAF in positioning Ascension Island to Cape Canaveral, in which an accuracy of plus or minus 500 feet is claimed. The method is being used by the Soviets to establish geodetic positions in Antarctica on the Soviet ellipsoid, a part of the development of a Soviet world geodetic system.

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3. USAF-ACIC

The USAF has also been engaged in the derivation of a USAF World Geodetic System based on a gravimetric approach. For this it has undertaken independent programs for establishing intercontinental ties (HIRAN, solar eclipse programs, etc.). Within the past year the Army and USAF World Geodetic Systems have coordinated their results into a Defense World Geodetic System (DWGS). Major problems still exist, nevertheless, to make the DWGS fruitful for ICBM system requirements.

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