65162

UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

Distr.
LIMITED

E/CN.14/CART/310
10 October 1972

Original: ENGLISH

ECONOMIC COMMISSION FOR AFRICA

Third Regional Cartographic Conference
for Africa

Addis Ababa (Ethiopia) 30 October - 10 November 1972
Provisional agenda item 7(b)

AFRICA ON A WORLD GEODETIC DATUM*

Submitted by the Government of the United States of America

The need for a unified world geodetic datum has become paramount during the past few years. With the rapid advances in technology in such areas as gravity, plate tectonics, crustal movement, and orbital mechanics, there is a requirement that such a datum be determined and adopted by the world community. To satisfy this need, a method was established whereby precise positioning of selected stations on major land masses and islands throughout the world could be obtained. The use of artificial earth satellites provided a means for establishing this common geodetic datum.

The Worldwide Geometric Satellite Programme, as part of the United States National Geodetic Satellite Programme, utilized the passive (sun-reflective) satellite PAGEOS to afford an observation target for use in spanning intercontinental and oceanic distances. The goal of the programme was the establishment of a precise spatial network of control stations on the earth's surface whose positions are defined relative to a cartesian co-ordinate system in inertial space, having one axis parallel to a specific pole, and meeting the accuracy requirements of $\pm$ 10 metres. This, of course, depends on the accuracy of the measured scale lines, which should be of an accuracy of 1:500,000 or, preferably, 1:1,000,000.

The geometric principle underlying the programme was proposed by Yrjö Vaisala in 1946. It states that two conjugate rays emanating from the ends of a line form a plane in space. The intersection of two such planes, established from the same two points, establishes a base line between the two points. Simultaneous photographic observations of a satellite oriented against a star background will produce these rays and establish the planes. The spatial orientation of the

* By Joseph D. D'Onofrio, Chief, Satellite and Altimetry Branch, Satellite and Marine Applications Division, National Geodetic Survey.

planes can thus be determined giving the orientation of the resultant chord through the earth's surface. Observations from adjoining stations will therefore result in a network of triangles extended over the entire earth.

Planning for such a programme had begun in the late 1950's and the camera systems were used in the early and mid-1960's in a programme to provide geodetic control throughout North America. This programme used the satellites ECHO I and ECHO II which, due to their relatively low altitude, were not suitable for spanning intercontinental distances. Thus, with the launch of PAGEOS on June 23, 1966, came the opportunity for establishing a worldwide network of observing stations.

This network will provide a worldwide reference net to which all geodetic, topographic, and navigational data can be related. Also, it will afford the replacement of the classic, time-consuming, long-arc, triangulation methods of determining the size and shape of the earth by a more economical and theoretically superior approach. Finally, it will allow the establishment of a network of geodetically related satellite tracking stations providing more accurate determination of satellite orbits. This will in turn provide data ideally suited for analyzing gravimetric and related geophysical parametres leading to a determination of the position of the centre of mass and the overall shape of the gravitational field of the earth.

The programme represents the co-operative efforts of NASA, which designed and launched the satellite; the Department of Defense, US Army Topographic Centre, which provided four field teams, equipment and transportation; 27 host countries, which provided personnel and logistic support in varying degrees; and NOAA, National Ocean Survey, which was responsible for the technical direction of the field operations. The National Ocean Survey also had responsibility for plate measurement, processing and geodetic computations.

The observation portion of the programme was undertaken utilizing the Wild BC-4 ballistic camera with modifications for "chopping" the star and satellite trails to obtain imagery suitable for measurement on high precision comparators. Instrumentation was used to maintain precise epoch timing and to relate this timing to the respective star and satellite imagery. The equipment was so designed that it enabled observations to be taken in Tromsø, Norway at -48°C and in Ft. Lamy, Chad at $+45^{\circ}$C. The final observation for the programme was observed on November 20, 1970.

The network consisted of 45 stations around the world encompassing virtually every major land mass (Figure 1). It included four stations on the African Continent. The first of the four African BC-4 observation stations was established in Dakar, Senegal, at Yoff International Airport in January 1968. In February 1968, the stations in Ft. Lamy, Chad and Johannesburg, South Africa were established. The former was located at the Ft. Lamy International Airport, and the latter at the US NASA STADAN Site near Johannesburg. In May 1968, the Ethiopian station was established at Debre Zeit, about 50 kilometres southeast of Addis Ababa. Figures 2 and 3 show the observation stations at the above sites.

The following table lists the observational results obtained at each of the stations:

TABLE 1

STATIONS	042 Ethiopia	063 Senegal	064 Chad	068 South Africa
OCCUPATION DATES	7/5/68 - 16/6/70	30/1/68 - 16/12/68	10/2/68 - 17/2/69	20/2/68 - 2/11/69
TOTAL OBSERVATIONS SCHEDULED	437	318	352	410
SINGLE STATION OBSERVATIONS OBTAINED	119	71	136	176
SIMULTANEOUS OBSERVATIONS OBTAINED	95	57	92	91

A total of 502, or 33 per cent, of all scheduled observations were obtained. Of this number, 335, or 67 per cent, were successful simultaneous observations with one or more other stations in the network. The African network provided direct ties to European, Asian, South American and Antarctic observing stations as well as several islands in the Atlantic and Indian oceans (Figure 4).

Six base lines were established throughout the network connecting the respective observation stations. These scale lines were measured in the United States between stations 002 Beltsville, Maryland, and 003 Moses Lake, Washington; in Europe between stations 006 Tromsø, Norway, and 065 Hohenpeissenberg, Germany, and between 065 and 016 Catania, Sicily; in Australia between stations 032 Perth and 060 Culgoora, and between 060 and 023 Thursday Island; and in Africa between stations 063 Dakar and 064 Ft. Lamy. The African scale line was measured through Chad, Cameroon, Niger, Nigeria, Upper Volta, Mali and Senegal as part of the Twelfth Parallel Survey. A portion of the survey was accomplished through contractual co-operation with France's IGN (Institut Geographique National), and that portion within Nigeria by the Federal Survey Department of Nigeria with technical assistance from the United States.

Thus, the final results for the network were based upon the following data obtained from 45 stations: A total of 1,064 simultaneous satellite observations were measured. These represented 856 two-station simultaneous events, 194 three-station events and 14 four-station events. In all, there were 2,350 plates measured. Additionally, the six scale lines listed previously were incorporated into the reduction.

The mean errors for the x, y and z components of the four stations in Africa were approximately 5.4 metres, 4.9 metres and 6.4 metres respectively. The resultant geocentric RMS error of ± 5.6 metres for these stations (which varied from ± 5.1 to ± 6.3 m) corresponds very favourably to the overall RMS error for the entire network of approximately ± 4.9 metres.

The direct benefits to Africa of the completed Worldwide Satellite Triangulation Network will be many. Probably the most important contribution will be derived from the precise determination of the four Africa based satellite triangulation stations which will provide an excellent starting point for an intracontinental densification network. This, in turn, will contribute to a more accurate control system for any local surveying and mapping performed by individual nations in Africa. There are currently nine datums operational in Africa, of which three are considered major datums used in mapping. An intracontinental densification network would be an invaluable aid towards providing control which could eventually eliminate the need for so many datums; and, instead, geodesists could rely on a unified continental datum based on the Worldwide Satellite Triangulation System. Satellite positioning methods of developing a densification network will also be of great value in overcoming many of the obstacles presented by the extended wilderness terrain over the continent.

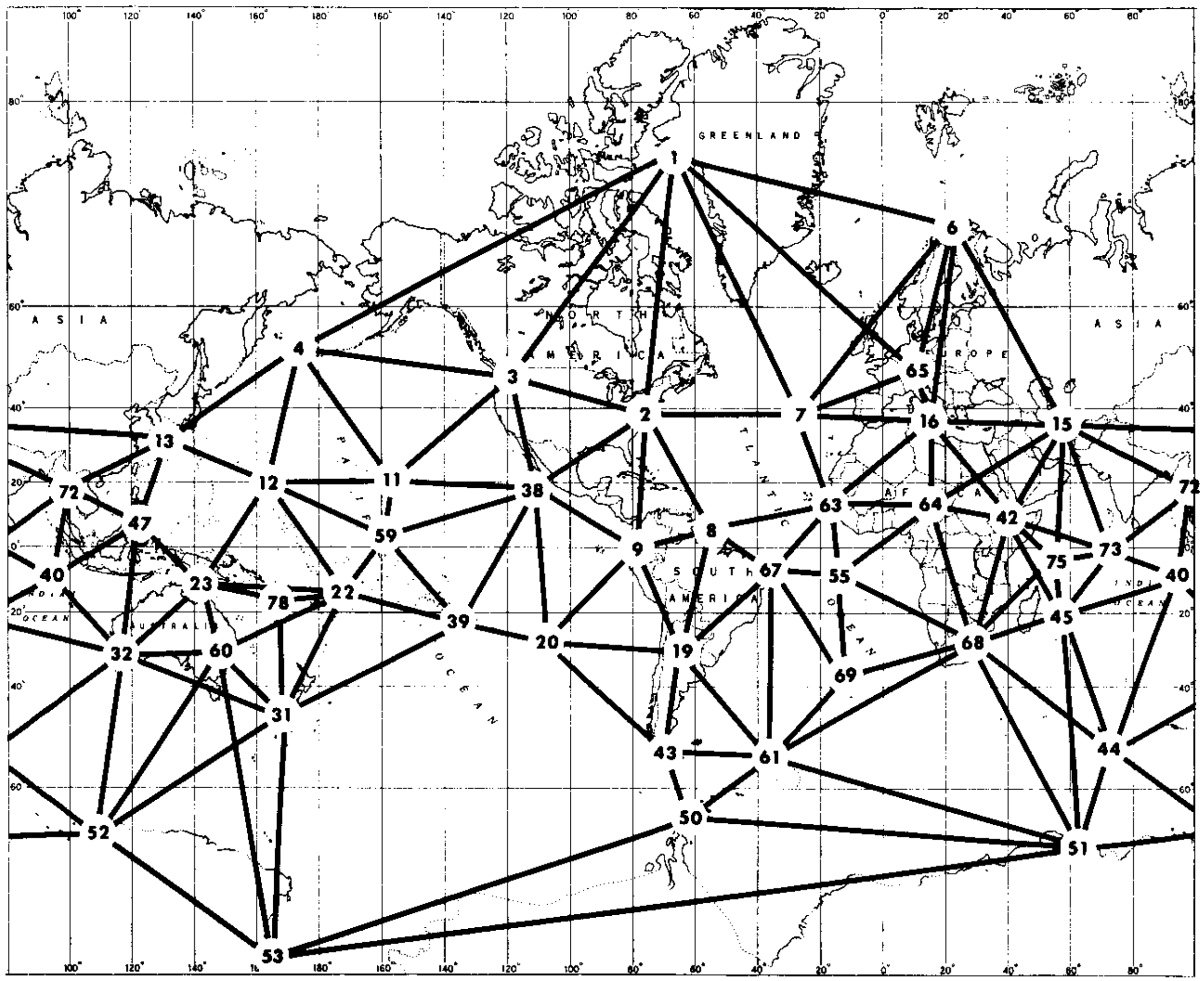
A second important benefit is a large step towards investigation of historical trends of ground motion drift enabling scientists to develop improved identification of the location and degree of earthquake hazards.

One method of establishing an intracontinental densification network, currently being investigated, is the use of satellite doppler techniques in the precise positioning of network stations, utilizing the Geoceiver system, originally developed by the Applied Physics Laboratory of the Johns Hopkins University.

This system provides several unique capabilities. Utilizing the existing network of BC-4 stations in Africa, such an intracontinental network could be completed in a relatively short time, with normally no more than two weeks required to perform observations at any station. Due to the small size of the Geoceiver and auxiliary equipment, it could be deployed virtually anywhere on the continent. The accuracies indicated through tests and observations indicate very accurate geodetic results. Thus, the potential for extending such a unified datum throughout Africa exists in instrumentation which has been developed and suitably tested.

In closing, it should be noted that since the Second United Nations Cartographic Conference for Africa held in Tunis in 1966, the African geodetic community has been provided first with a plan to incorporate the continent into a worldwide geodetic network. Secondly, it has seen the successful completion of field observations, and the reduction and analysis of the observational data. Now participants at this third conference, here in Addis Ababa can see the next opportunity, which is the extension and expansion of this basic BC-4 geodetic network. Hopefully, the next conference will see a similarly large advance in further unifying the geodetic network of Africa.

WORLD GEOMETRIC SATELLITE NETWORK



001 Greenland, Denmark
002 Maryland
003 Washington
004 Alaska
006 Norway
007 Azores, Portugal
008 Surinam
009 Ecuador
011 Hawaii
012 Wake Island, USA
013 Japan
015 Iran
016 Italy
019 Argentina
020 Easter I., Chile
022 American Samoa
023 Australia
031 New Zealand
032 Australia
038 Socorro I., Mexico
039 Pitcairn I., U.K.
040 Cocos I., Australia
042 Ethiopia
043 Chile
044 Heard I., Australia
045 Mauritius
047 Philippines
050 Palmer, Antarctica
051 Mawson, Antarctica
052 Casey, Antarctica
053 McMurdo, Antarctica
055 Ascension I., U.K.
059 Christmas I.
060 Australia
061 South Georgia Is.
063 Senegal
064 Chad
065 West Germany
067 Brazil
068 South Africa
069 Tristan da Cunha Is., U.K.
072 Thailand
073 Chagos Island, U.K.
075 Mahé Island, U.K.
078 New Hebrides, U.K.

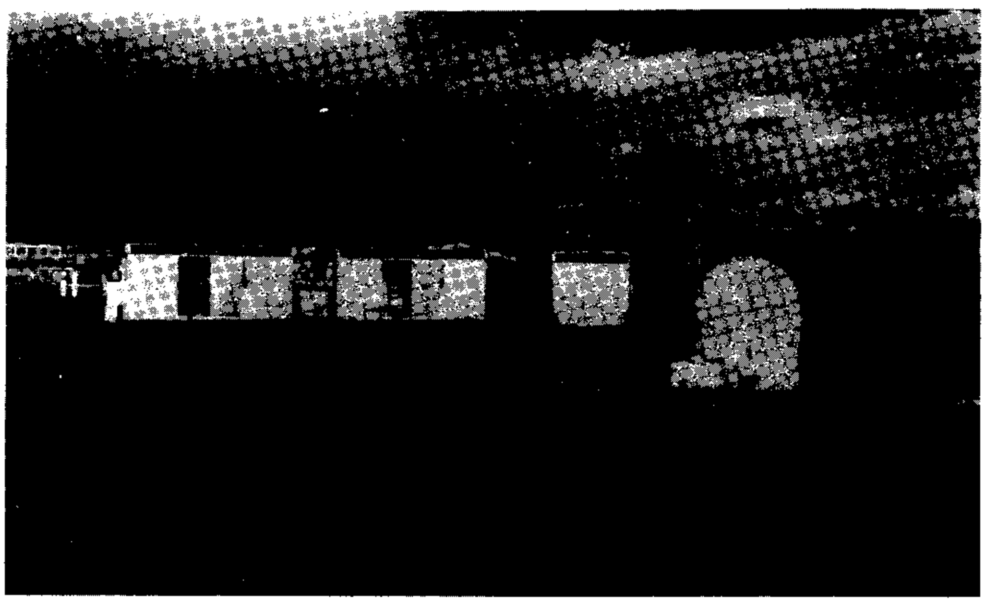
Figure 1

042 Ethiopia

063 Senegal

Figure 2

064 Chad



068 South Africa

Figure 3

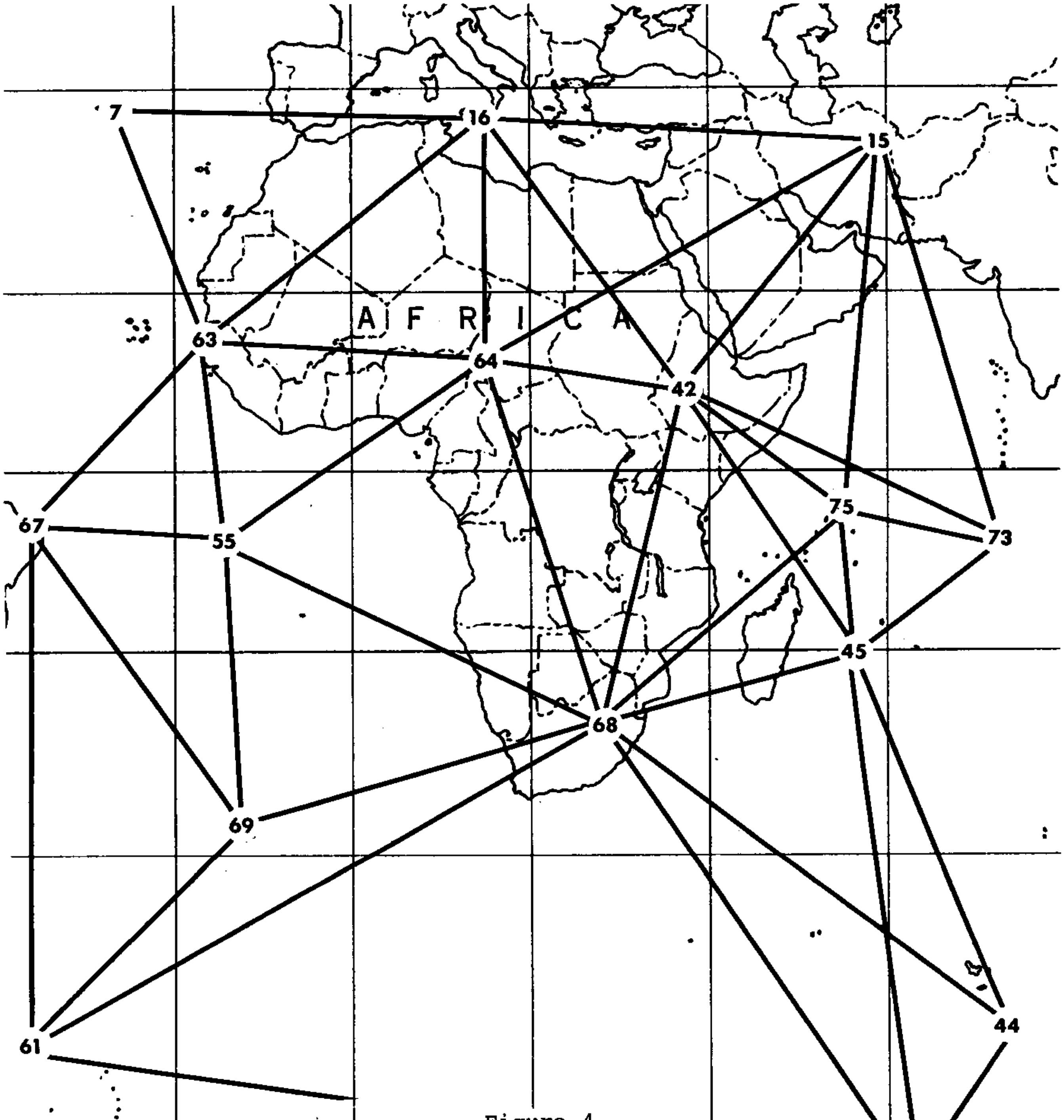


Figure 4

072-648