Grids & Datums

Republic of Zimbabwe

BY Clifford J. Mugnier, CP, CMS, FASPRS

The Grids & Datums column has completed an exploration of every country on the Earth. For those who did not get to enjoy this world tour the first time, *PE&RS* is reprinting prior articles from the column. This month's article on the Republic of Zimbabwe was originally printed in 2003 but contains updates to their coordinate system since then.

The republic is populated primarily by the Bantu group of peoples and is divided into two major language groups. The Shona speaking Mashona constitute 75 percent of the population and the Sindebele speaking Ndebele constitute about 20 percent of the population. The latter group arrived in the southwest around Bulawayo within the last 150 years and is an offshoot of the South African Zulu. They maintained control over the Mashona until the European occupation in 1890. Stoneage implements have been found in Zimbabwe, and ruins suggest an early civilization. The "Great Zimbabwe" ruins are located near Masvingo, and evidence suggests that it was built between the 9th and 13th centuries by Africans that established trading contacts with commercial centers on the continent's southeastern coast. In 1888, Sir Cecil Rhodes obtained a concession for mineral rights from local chiefs and later the area was proclaimed a British sphere of influence. The British South Africa Company was chartered the following year and Salisbury (now Harare, the capital) was established in 1890. In 1895, the area was formally named Rhodesia in honor of Sir Cecil. The United Kingdom (*PE&RS*, October 2002) annexed Southern Rhodesia from the South Africa Company in 1923. A 1961 constitution was formulated that favored Caucasians in power. In 1965, the government declared Rhodesian independence, but the UK did not recognize the act and demanded more complete voting rights for the black majority in the country. United Nations sanctions and a guerilla uprising finally led to free elections in 1979 and independence as Zimbabwe in 1980. A land redistribution policy in 2000 has caused an exodus of white farmers, it has crippled the economy, and it has caused widespread shortages of basic commodities.

Zimbabwe is slightly larger than Montana, it is landlocked, and it is bordered by Botswana (813 km), South Africa (225 km), Zambia (797 km), and Moçambique (1,231 km), (*PE&RS*, September 1999). The terrain is mostly high plateau with a high veldt with mountains in the east. The lowest point is the junction of the Runde and Save Rivers at 162 m, and the highest point is Mount Inyangani (2,592 m).

In 1901, Alexander Simms completed a chain of quadrilaterals that spanned the west central part of the country. This chain started in the south near Bulawayo with the Inseza Base observed in 1898, it passed through Gwero, through Salisbury (now Harare) with the Gwibi Base observed in 1900, and it terminated in the north about 75 km east of where the Kariba Dam is now located on the Zambezi River. The geodetic coordinates of all the stations were referred to the origin point in Salisbury where: $\Phi_o = 17^o\ 50'\ 25.440''$ S and $\Lambda_o = 31^o\ 02'\ 19.000''$ E, with an azimuth to Mt. Hampden

Photogrammetric Engineering & Remote Sensing
Vol. 87, No. 10, October 2021, pp. 699-701.
0099-1112/21/699-701

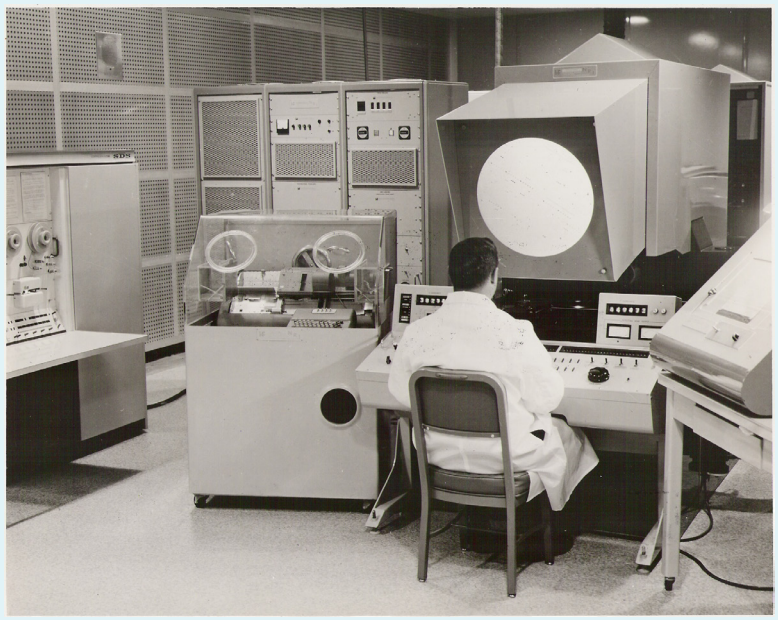
doi: 10.14358/PERS.87.10.699

THE SACR STORY

In regard to: "Spinor-Based Attitude Determination with Star Sensor Considering Depth" by Sheng, Q., *et al, PE&RS* Vol 87, No. 8, August 2021, pp. 551-556.

That article brought back some memories from long ago. In the late 1960s to early 1970s I was a commissioned officer (Topographic Engineer) at the U.S. Army Map Service (AMS) during the CORONA Program that utilized photographic products of military spy satellites. The systems used multiple star sensors to determine camera orientations similar to what is discussed by Sheng et al. Back then it was before the advent of digital imagery, so we used film that was physically returned from orbit. A special building was constructed at AMS to house the original film processing, duplicating, photogrammetric analyses, and cartographic stereocompilation of the final products.

Long ago, I was told a story about that building's design by my civilian supervisor and mentor, Mr. Zeno V. Kittrell. Seems that the architect was informed that the building was going to house special film measurement instruments called "comparators" that were being custom-built to be capable of ultra-high precision and would be mounted on special massive granite bases. These instruments were termed "Semi-Automatic Coordinate Readers" (SACRs) and were intended to measure stellar camera images from the satellites. With a multitude of stars being imaged on each 70mm film frame, multiple cameras photographed per each cartographic frame; the task was expected to be particularly arduous. Hence the "semi-automatic" feature was to be of great advantage. With particular attention to detail, the building's architect researched from which quarry the granite bases were to sourced, the weight of each finished base was computed, and the freight elevator load capacity for the building was then specified to be able to accommodate the SACR bases, one at a time. The room for the ultra-precise measurements of all imagery was "the Slab," excavated a couple stories below ground, and "the slab" was a monolithic slab of concrete separate from the building and was "floating" on a thick cushion of neoprene. The "slab" had filtered laminar flow air conditioning, and even had a seismograph to maintain a record of the stability of the instrumentation.



As Zeno told me, the momentous day arrived that the SACRs were to be delivered by a caravan of flat-bed 18-wheel trucks. When the first truck started backing up to the loading dock, the steel doors electrically opened, a half-dozen Federal Officers came out on the loading dock with loaded 12-gauge riot guns to stand guard (I guess in case one of the drivers was a Russian spy), and a heavy-duty forklift truck came out of the building to accept the first SACR granite base. The forklift picked up the SACR from the flat-bed truck, backed up on the loading dock, and then proceeded into the building to the special freight elevator so that the base could be taken down into the sub-basement and "The Slab." The forklift operator remained seated at the wheel, he reached up to the suspended elevator control box and had the safety doors close. He then pressed the "down" button, and the special freight elevator, the SACR base and the forklift truck instantly disappeared as the operator screamed as the elevator and all crashed down two floors. As Zeno related the catastrophe with tears running down his cheeks as he laughed, it seems the architect forgot to add the weight of the forklift truck to the freight elevator specifications! The rattled operator was given the rest of the day off, one of the guys in the machine shop ran the forklift truck for the Slab level, and another machinist got a second forklift to operate at the loading dock to load the freight elevator sans forklift. I'll bet those granite bases are still on the Slab and have not moved an inch in 50 years.

Zeno directed me to perform a sensitivity analysis on the stellar camera systems, and I published a classified paper in SCIF channels back in 1972. My guess is if it's still extant, it's still classified.

Notice the computer on the left side is an "SDS" mini-computer. That was built by Scientific Data Systems that later changed the name of the company to Digital Equipment Corporation (DEC). The reason was that "SDS" was also the abbreviation for "Student for a Democratic Society," an infamous radical left-wing group responsible for numerous violent conflicts with law enforcement back in the early 1970s. DEC was late purchased by Dell Computer Corp.

The operator in the picture is Mr. Scott Rae, a staff Mathematician that also worked for Zeno.

α_o = 273º 13′ 48.456″ and were fixed by interchange with the Royal Observatory at the Cape for longitude. After the work was published in 1905 in the *Geodetic Survey of South Africa, Volume iii*, little geodetic work was surveyed in Zimbabwe for about 25 years except by Capt. H.W. Gordon, R.E. (Prof. Charles L. Merry had some difficulty looking up those coordinates for me since his library had misplaced that volume!) Capt. Gordon connected Simms' system to the Transvaal system of South Africa in 1906-7. He was seriously handicapped by having a budget of only £1,600 for the task, but his work was of excellent quality. The Transvaal system had already been completed by Col. W.G. Morris, R.E., in 1905. Capt. Gordon also later ran a short chain westward from Simms' chain at about latitude 17° 10′ S to provide control for the Copper Queen mining area in 1928. The Eastern Circuit was started shortly thereafter; it ran from Harare (the capitol) eastward to the border with Moçambique, southward through Mutare to about latitude 20° S and then westward, joining Simms' chain again to the east of Bulawayo. Another short chain was run north from Bulawayo for about 70 km to the Lonely Mine area. In 1936, Gordon's connecting chain with the Transvaal was strengthened and re-observed as well as the new Nuanetsi Series was observed to the east that ran north-south from the Limpopo River to near the Zimbabwe ruins and to Rutenga. The Nuanetsi Series was completed in December 1937.

The result of Gordon's Connection showed a difference between the Transvaal chain and the Salisbury Datum of –3.503″ in latitude, –0.602″ in longitude, –8.89″ in azimuth at point Standhaus, and a difference of 40 feet in the mean between the vertical heights of the two systems. The work in both Zimbabwe and Zambia suggested that Gordon's connection had introduced a swing of some 9″ into the arc, from the northern Transvaal upwards. In 1930 at the Stockholm Conference of the International Union of Geodesy and Geophysics, a resolution was therefore passed recommending an examination of the Transvaal-Zimbabwe connecting chain.

In 1932, an astronomical determination of the azimuth Wedza–Standhaus was made with a Wild T-3 theodolite that gave the astro-geodetic difference in azimuth between the two systems of approximately 4.5″. In 1936, J.E.S. Bradford observed a connection series that widened and strengthened Gordon's chain, and all angles were re-observed. Heliographs were employed throughout for the re-observations (by repetition) of this chain except for two points in the Transvaal system. Those exceptions were direction angles observed by F.W.J. de Roes of the South African Trigonometrical Survey. The adjustment of the revised chain was made to the Transvaal system, which was an extension of the South African Cape Datum. The adjusted coordinates of the tie-point Standhaus changed to φ_o = 20º 21′ 54.654″ S and λ = 29º 35′ 54.631″ E, and the azimuth to station Filabusi changed to α = 273º 13′ 48.456″. The obsolete datum of Southern Rhodesia is now referred to as the "Old Circuit Datum" in Zimbabwe.

In 1944, D.R. Hendrikz of the South African Trigonometrical Survey wrote, "For the computation of the geographical coordinates of the stations of the Geodetic Survey, Sir David Gill adopted the numerical values of the semi-major and semi-minor axes of Clarke's 1880 figure or a = 20,926,202 ft and b = 20,854,895 ft. At that time this result was the most recent determination of the figure of the Earth. But, because the baselines were reduced to S.A.G. (*South African Geodetic – ed.*) feet, the computations were really carried out on a 'Modified Clarke 1880 Spheroid' defined by a = 6,378,249.145 326 int. metre and b = 6,356,514.966 721 int. metre. It may be remarked, in passing, that this value of the flattening for this spheroid is $^1/_f$ = 293.466 307 656, which differs slightly from the value 293.465 given by Clarke himself." Later in the document, Hendrikz went on to present relations of the "Geodetic Cape rood" = 12.396 S.A.G. feet, and 1 Cape morgen = 600 square Cape roods = 2.116 539 816 acres. Note that the acre was originally the amount of English land that could be plowed in one day, and the morgen was roughly the amount of German land that could be plowed in a morning. Hendrikz stated that 1 Rhynland morgen = 0.634 282 acres!

Thanks to Professor Charles L. Merry of the University of Cape Town, "The ellipsoid is the Clarke 1880, oriented using astronomic observations of latitude, longitude and azimuth at a point near Port Elizabeth in the late 1800s. The offset from the geocentre is about 350m. An unusual feature is that it is the so-called 'modified' Clarke 1880 ellipsoid, because the conversion factor 'yard-to-legal metre' was used to convert Clarke's values to international metres. The legal metre is based upon a defined relationship between the toise and the metre, not a physical standard, and is about 13ppm larger. Nevertheless, the official length standard is the international metre.

"Although local grid systems were common in the 19th and early 20th century, since the 1920s the Transverse Mercator (Gauss-Krüger) system has been exclusively used. It uses 2-degree wide panels, scale factor of unity on the central meridian and no false origin. The coordinate axes are directed South and West (no northings and eastings for us southerners!), and are labeled x and y respectively. It is a legal requirement for all cadastral surveys to use this grid system, and the large and medium scale national map series also uses it. The military use the UTM system, overprinted on the standard map sheets (false northing as well as false easting). …Contrary to what DMA (*now NIMA-ed.*) believe, they do not use the Arc datum. The Arc datum is used in parts of East Africa. It is based upon the same initial point near Port Elizabeth and the same ellipsoid (modified Clarke 1880), but uses a single chain of triangulation extracted from the national networks of South Africa, … and Zimbabwe, more or less along the 30th meridian. Close to Port Elizabeth, it is practically identical to the Cape datum, but diverges as one moves away. A GPS network is in place in Zimbabwe and the control networks are being re-adjusted. Although no final decision has been taken, it is likely that Zimbabwe will also convert to the WGS84 around the same time that South Africa does." (Personal communication, July 1997).

In April 1990, Professor Merry and J. Rens published a paper in *Survey Review* that described their solution for datum shift parameters in southern Africa that included Zimbabwe. The astronomic coordinates of the initial point of the Cape Datum near Port Elizabeth are for Buffelsfontein where Φ_o = 33º 59′ 32.000″ S and Λ_o = 25º 30′ 44.622″ E. With respect to Zimbabwe, Prof. Merry and Rens wrote, "The situation here is unique. Large rotations are evident and cannot be ignored. However, because of the relatively small size of Zimbabwe, these cannot be considered to represent a true misorientation of the Zimbabwean datum, but probably reflect regional distortions in the geodetic networks. Including the rotations in the transformation model reduces the standard deviation from near four metres to one metre – almost a fourfold reduction. Unlike the case in South Africa there is no significant scale factor. Nevertheless we recommend a full seven-parameter transformation – neglect of the scale factor would cause significant changes in the translation components shown …, due to the high correlation between them." Those parameters recommended are ΔX = –121.7 m ± 17.5 m, ΔY = –121.0 m ± 18.4 m, ΔZ = –258.5 m ± 21.2 m, R_x = +5.377″ ± 0.527″, R_y = +1.857″ ± 0.680, R_z = –2.989″ ± 0.636″, and Δs = +0.8′ 10^{-6} ± 2.3. The Hartebeesthoek 94 Datum is the official coordinate system of the Republic of South Africa and presumably also may someday be of the Republic of Zimbabwe.

Zimbabwe Update

"Recently, Zimbabwe recognized CORS technology as an integral component for the prompt acquisition of spatial data. Consequently, the country engaged the EU and UNDP to fund the process of establishing CORS in the country. Initially, five GNSS CORS will be established primarily focusing on expediting the process of boundary mapping of farms to support security of tenure thus ensuring food security in line with the Sustainable Development Goals. Having realized the urgent need for establishing CORS in Zimbabwe, the readiness of the stakeholders and institutions which use geospatial data is yet to be evaluated. Although the primary rationale for establishing CORS in Zimbabwe was motivated by the need to regularize the land reform program to ensure tenure security, it is apparent that other stakeholders besides cadastral surveyors will use this technology." Establishment of Continuously Operating Reference Stations (CORS) in Zimbabwe, Mlambo, R., Freeman, A., African Journal on Land Policy and Geospatial Sciences ISSN:2657-2664, Vol.3 No.3 (September 2020) 42.

The contents of this column reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the American Society for Photogrammetry and Remote Sensing and/or the Louisiana State University Center for GeoInformatics (C^4G).

This column was previously published in *PE&RS*.

In Memoriam

George Erio

1945-2021

George Erio passed away on August 8, 2021, after a battle with liver cancer. George was a lifelong supporter of ASPRS since the early 1970s where is served on the old Pacific Region Board as President.

George received his B.Sc. in Civil Engineering from the University of Illinois at Urbana-Champaign and worked as a surveyor in the summers. George then worked for California Department of Transportation (CALTRANS) as a Civil Engineer. George then took a year off work at CALTRANS and studied analytical photogrammetry under James Anderson and Frank Moffitt and received his M.Sc. in Photogrammetry in 1972. George's research was initially in camera calibration with Professor James Anderson. Later he put his knowledge of analytical photogrammetry into practice in developing an analytic bundle adjustment program which later became a commercial product and used by the federal government and private companies. After leaving CALTRANS George started Eriotech, LLC which provided aerotrigulation services and consulting.

George worked hard and played hard. When George wasn't working, he enjoyed his many hobbies including backpacking, camping, canoeing, target shooting, fishing, gardening and playing the guitar. He retired in Key Largo, Florida but remained interested in the Society and the profession.

George is survived by his wife, Vanneza Alverez Erio, his children Amy and William; brothers, Peter, Michael and Tom; sister, Mary; grandchildren, Isabella and Luke; and niece, Diana. He will be missed by his family, friends and colleagues.

George Erio's obituary can be viewed at www.butlerfuneralhomes.com/obituaries/George-William-Erio?obId=22010207#/obituaryInfo.