Oriental Republic Of Uruguay

The region was originally inhabited by Charrúa Indians and was visited by the Spanish explorer Juan Díaz de Solís in 1516. Colonia was founded by the Portuguese in 1680 and Montevideo was founded in 1726. Long associated with Brazil, the former Banda Oriental, Cisplatine Province gained independence on 25 August 1825. Uruguay is slightly smaller than the state of Washington, and is the second-smallest country in South America after Suriname. Most (three-fourths) of the low-lying portion of the country is grassland, which is ideal for raising cattle and sheep. The coastline is 660 km long and Uruguay shares borders with Argentina and Brazil. The lowest point is the Atlantic Ocean (0 m) on the eastern border and the highest point is Cerro Catedral (514 m). The economy of Uruguay is one of the two strongest of all of the South America countries.

The initial classical triangulations with Bamburg broken elbow astronomical theodolites and Huetz direction theodolites were performed in the central portion of the republic corresponding to the Durazno and Tacuarembó provinces in 1908. The *Servicio Geográfico Militar* (SGM) was founded in May of 1913 and was based in Montevideo. The following year, a triangulation network plan was designed, including four meridian arcs and five parallel chains. The classical triangulation net would take another 50+ years to complete. The Clarke 1880 ellipsoid was chosen for an initial figure of reference where a = 6,378,249.145 m and $1/f$ = 293.465. The grid system chosen in 1924 was based on the Polyhedric projection (same as Argentina, *PE&RS*, December 1999) and the centesimal angle system of grads. The Bonne projection was considered too cumbersome for survey computations. The initial reference system was called "Cerro de Montevideo," and it was considered a reconnaissance-quality system intended mainly for military purposes. This series of maps were produced at 1:100,000 scale. The initial instrument of choice for detailed cadastral observations was the Schraeder Tacheograph, a European instrument intended for cadastral surveys. The instrument intended to provide third- and fourth-order control was the Schasselons (sic) theodolite. Lt. Col. Silvestre Mato, Commander of the SGM estimated (optimistically) in 1924 that the initial mapping of the republic would take six brigades of Geographic Engineers 21 years to complete.

From 1912 to 1918, the International Laguna (lagoon) Merím chain was observed along the southern border with Brazil. At about the same time, the metropolitan area of Montevideo was observed between 1915 and 1917. Subsequently, the western border with Argentina along the Uruguay River was observed in a chain of figures from 1918 to 1937, and the eastern border north of the Laguna Merím chain with Brazil was observed from 1920 to 1940 to its junction with the Argentine border. During the 1930s, the coastal area was triangulated from the Laguna Merím chain to connect with the southern chain of the metropolitan area of Montevideo. In 1939, observations were made at what was to become the origin point for the national datum at Yacaré, in the northernmost Department of Artigas. In 1946, the SGM decided to change the reference figure to the International ellipsoid of 1930 where a = 6,378,388 m and $1/f$ = 297. My guess is that Col. Floyd Hough of the U.S. Army Corps of Engineers Army Map Service had something to do with that. It was his urgings to the Pan American Institute of Geography and History in the late 1940s that prompted all of Latin America to eventually adopt the UTM Grid for military mapping along with the International Ellipsoid. The founding of the Inter-American Geodetic Survey School in the Panama Canal Zone and the cooperative geodetic observation campaigns and military assistance programs implemented those changes. The República Oriental del Uruguay – U.S. Army Map Service (ROU-USAMS) adjustment of 1965 used the origin point at Yacaré where $\Phi_o = 30° 35' 53.68''$ South, $\Lambda_o = 57° 25' 01.30''$ West of Greenwich, and the defining azimuth from Yacaré to La Quisilla is $\alpha_o = 87° 34' 26.28''$ (from south). The deflection of the vertical is defined to be zero at the origin point. This adjustment included 248 vertices, eight Laplace Astro stations, 325 triangles, and 15 geodetic bases at Oeste (Uruguaiana), Guavitu, Tambores, Sudeste, Ubajay-Mudry, Molles, Cerro Chato, Artibas, Cerro Colorado, Florida, Agraciada, Tararidas, Carrasco, Maldonado, and Cerro. This ROU-USAMS adjustment has commonly been called Yacaré Datum outside of Uruguay. The new national (civil) grid system associated with this datum is based on the Gauss-Krüger Transverse Mercator projection with a central meridian $\lambda_o = 55° 48' (62^G)$ West of Greenwich.

In 1969, Dr. Irene Fischer of the U.S. Army Map Service published the results of the South American Datum of 1969 (SAD69). A total of 36 common stations along the Brazil-Uruguay border were included in the adjustment, and this datum is the exclusive reference system used by the Uruguay-Brazil Boundary Demarcation Commission. The SAD69 origin is in Brazil at station Chuá where $\Phi_o = 19° 45' 41.6527''$ South, $\Lambda_o = 48° 06' 04.0639''$ West of Greenwich, and the defining azimuth from Chuá to Uberaba is $\alpha_o = 271° 30' 04.05''$. The orthometric elevation H_o = 763.28 m, the deflection of the vertical at the origin is defined as $\xi_o = 0.31''$ and $\eta_o = -3.52''$, and ellipsoid height h_o = 0 m. The ellipsoid of reference is the International 1967 where a = 6,378,160 m and $1/f$ = 298.25.

By 1990, the geodetic net of Uruguay was comprised of 420 first order stations and some 3,000 stations of second, third, and fourth orders; all determined by various instruments and densification methods. Satellite surveying began in 1993 for topographic densification in Uruguay, and in 1995 geodetic-quality GPS receivers were used to participate in the South American Geocentric Reference System (SIRGAS) project. According to M.Sc.T.L.Eng. Barbato, F.D. of the University of the Republic, three Laplace stations were initially occupied along with five other first-order stations in Uruguay. In 1997, three more stations in Uruguay were added to the SIRGAS campaign. The software used to initially process the GPS data was that developed by the University of Bern. Additional solutions were performed with the Berneese package and also with the Geomatics Canada package, "Geodetic adjustment using Helmert blocking of Space and Terrestrial data" (GHOST) and using geoidal heights from GeoidUru 1994 and GEMT2 models. The final República Oriental Uruguay 1998 (ROU 98) net adjustment was comprised of three SIRGAS-weighted position equations, 417 geodetic stations with geoid heights including 11 observed with GPS, 2337 horizontal directions, 66 distances, 11 astronomic azimuths, etc., resulting in a vari-

continued on page 1141

GRIDS and Datums, *continued from page 1127*
ance of unit weight of 1.65. (That's very good!) According to Prof. Fabián Barbato, the general trend of the position change vectors from the ROU-USAMS 1965 Datum to the ROU 1995 Datum was 260° — a mean scalar of 2 m in Latitude and –37 m in Longitude. The Brazilian geodesists Piña and Costa (Universidade Federal do Paraná) published the transformation parameters from the ROU-USAMS 1965 Datum to the ROU 1995 Datum (Yacaré to WGS84) with both four-parameter and with seven-parameter models. Providing both sets of transformation parameters resolves any uncertainty regarding the sense of the rotations in the seven-parameter model by using the four-parameter set as blunder control. The four parameters are as follows: $\Delta X = 154$ m ±5 m, $\Delta Y = +162$ m ±7 m, $\Delta Z = +46$ m ±5 m, and the scale in ppm = 2.1365 ±1.5 ppm. The corresponding seven parameters are as follows: $\Delta X = 124$ m ±14 m, $\Delta Y = +184$ m ±11 m, $\Delta Z = +45$ m ± 12 m, the scale in ppm = -2.1365 ±1.5 ppm, R_x = -0.4384" ±0.001", R_y = +0.5446" ±0.001", and R_z = -0.9706" ±0.001". Piña and Costa state that the average error ellipse accuracy of the classical stations on the ROU 98 Datum is better than 50 centimeters. In contrast, the TR8358.2 transformation parameters published by NIMA without accuracy estimators are ΔX= 155 m, ΔY = +171 m, and ΔZ = +37 m. Thanks go also for their kind assistance to Leonardo Ferrando of Montevideo and also to Rubén Rodríguez of Buenos Aires.

Cliff Mugnier teaches Surveying, Geodesy, and Photogrammetry at Louisiana State University. He is the Chief of Geodesy at LSU's Center for GeoInformatics (Dept. of Civil and Environmental Engineering), and his geodetic research is mainly in the subsidence of Louisiana and in Grids and Datums of the world. He is a Board-certified Photogrammetrist and Mapping Scientist (GIS/LIS), and he has extensive experience in the practice of Forensic Photogrammetry.