Grids & Datums

BY Clifford J. Mugnier, CP, CMS, FASPRS

The Republic of Latvia

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 Latvia was originally printed in 2002 but contains updates to their coordinate system since then.

Between 2500 and 1500 BC, the Finno-Ugric and proto-Baltic tribes settled on Baltic shores. The closest ethnic relatives of the Latvians are the ancient Prussians, the Galinds, the Jatvings, and the Lithuanians. The first settlers in the territory of Latvia were the Livonians or "Libiesi." The Livonians were once concentrated in the northern part of Latvia, but today only about 100 individuals speak their ancient language which nevertheless has contributed to a prominent Latvian dialect. By the 12th century, the natives were split into a number of tribal groups, all practicing nature religions. The Knights of the Sword (Livonian Order) were crusaders that forcibly converted Latvia to Christianity in the 13th century. For centuries, Latvia has been under Swedish, Polish, German, and Russian rule. In 1918, Latvia proclaimed independence from Czarist Russia. By 1940, Latvia was occupied by the Soviet Union and was soon overrun by Nazi Germany. Soviet forces reoccupied the country in 1944-45, and Latvia remained under Soviet rule until 1991 when it was admitted into the United Nations. In May 1994, the Latvian National Independence Movement finished first in Latvia's first post-Soviet local elections; the excommunists fared the worst.

Latvia shares borders with Estonia to the north (343 km), Russia to the east (246 km), Belarus to the southeast (161 km), Lithuania to the south (588 km), and the Baltic Sea and Gulf of Riga to the west comprises a coastline of 498 km. Slightly larger than West Virginia, the country is mostly low coastal plain with the highest point being Gaizinkalns at 312 meters.

Survey activities in Latvia began with Tenner's first-order

network of 1820-32 in Semgallen and Courland, and were published by Czarist Russia in 1843 and 1847. Tenner later supplemented his primary net with lower-order stations. The Tenner chains were originally computed on the Walbeck 1819 ellipsoid where the semi-major axis (a) = 6,376,895 m and $^1/_f$ = 302.7821565; they were later recomputed on the Bessel 1841 ellipsoid. Between 1878 and 1884, Schulgin further increased the density of lower-order stations in the area originally surveyed by Tenner. However, the majority of these latter station monuments did not survive into the 20th century, and they were ignored by the Russians. The Tenner net in the east did not extend further north than the Sestukalns-Gaizinkalns side, and the Struve primary net extended north from this side through Yuryev and over the Gulf of Finland. The Russian Western Frontier surveys were executed mainly by Yemel'yanov and Nikifirov between 1904 and 1912. These chains formed a major part of the modern (early) 20th century network of Eastern Latvia with some of the first-order stations being old Tenner or Struve stations. This Russian sur-

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Deflections of the Vertical in Latvia

Because of the groundbreaking work the University of Latvia's Institute of Geodesy and Geoinformatics published on their research to develop a one-centimeter geoid model and the invention of a relatively inexpensive Digital Zenith Camera (DZC) by Dr. Ansis Zarins, I traveled to Riga a couple summers ago. LSU's Center for GeoInformatics had acquired an absolute gravity meter along with a couple relative gravity meters and various related instruments and vehicles with the same objective for the State of Louisiana. Since their DZC only works at night with clear skies for star shots, days were open for the staff to take me around Riga and environs. A major point of interest for me was the origin of the Yuryev II Datum and the General Latvian Triangulation Net Datum Origin is Riga St. Peter's Church (top of the Riga Church spire).

The Latvian Geodesists then took me inside of the church, and a plaque in the floor of the vestibule, directly under the plumb line of the spire displayed the actual Datum Origin:

By the way, their DZC worked flawlessly, and LSU purchased one for €100K, including training. Our DZC is currently kept busy here in Louisiana observing the deflection of the vertical at all of our GPS CORS sites.

vey covered much of western and central Livonia in 1904-05, and eastern Livonia and Lettgallen were covered with the 1906 and 1912 nets. Lower-order nets to fourth order supplemented the primary chains. These Czarist Russian surveys were computed on the Pulkovo 1904 Datum or the Yuryev II Datum, both of which are referenced to the Bessel 1841 ellipsoid where a = 6,377,397.155 m and $^1/_f$ = 299.1528128.

After Latvia achieved Republic status, the new Latvian Survey Office began to unify these various nets in stages, before commencing with their own survey activities in 1924. The results of this program of unification are published in *Latvijas Valsts Trigonometriskais*. The Pulkovo 1904 Datum points were recomputed into Yuryev II Datum based on 14 available first-order Scharmhorst points, and this was then put into the Senks Soldner Grid. The 1905 Russian net had already been computed on the Yuryev II Datum, and was accepted into the Old Gaizinkalns Soldner Grid where φ_o = 56º 52´ 15.184˝ N and λ_o = 25º 57´ 34.720˝ East of Greenwich. No false origin was used. Similarly, the 1906 and 1912 nets were already on the Yuryev II Datum, and those form the Old Vitoleieki Soldner Grid where φ_o = 56º 40´ 08.64˝ N , λ_o = 27º 15´ 11.79˝ East of Greenwich, and no false origin was used. Tenner's survey had been calculated on the Walbeck 1819 ellipsoid and was now recomputed on the Bessel 1841 ellipsoid and controlled by the Yemel'yanov-Nikifirov survey of the Puci-Sarmes side. This had the effect of introducing a slight swing to the orientation of the Tenner triangulation. The Latvian Kulkigan and Puci systems cover this net. For most of eastern Latvia, the earlier Russian surveys could be used to form the basis of the Latvian triangulation as the station centers could be found. In Courland and Semgallen the original triangulation dated back to 1820 and few of the old stations could be recovered. This necessitated a complete new survey, which was started in 1924 from the Liepaja-Paplaka base and extended in stages to the Puci-Sarmes side and thence to Riga and Jelgava. The origin of this system is the Yuryev II Datum value of Riga St Peter's Church "tower ball" which is the same station as the Tenner first-order point. The Yuryev II Datum azimuth to Jelgava Church was adopted for the orientation of the net. Although the Riga Church and Courland values are the same as Scharnhorst value and the azimuth is identical, the coordinates of Jelgava Church vary slightly by 0.002″ in each axis. This was due to the scales of the Liepaja and Jelgava bases, which were adopted for the Courland System in preference to the less reliable Scharnhorst scale. This became known as the "Provisional Courland System (datum)." The Provisional Courland System was divided into two Cassini-Soldner Grids: The "Riga System" with its origin at Riga St. Peter's Church where $\varphi_o = 56^o\ 56'\ 53.919''$ N and $\lambda_o = 24^o\ 06'\ 31.898''$ East of Greenwich, and the "Vardupe System" with its origin at the Provisional Courland station Vardupe where $\varphi_o = 56^o\ 51'\ 32.961''$N and $\lambda_o = 21^o\ 52'\ 03.462''$East of Greenwich. No false origin was used for either grid. The Provisional Courland System was immediately adjusted and computed before the triangulation of central and east Latvia was completed. This Provisional Courland System was first adjusted within itself and then adjusted to the Latvian part of the Baltic Ring. The lower-order control as far east as 24º 20′ East of Greenwich was adjusted and computed in terms of this system.

The General Latvian Triangulation Net of first-order stations covers practically all of Latvia, including Courland. The lower-order control east of 24º 20′ East of Greenwich was computed in terms of the General Latvian Triangulation Net. Actually, there is a small overlap around 24º 20′ East of Greenwich for which the coordinates of all stations, of all orders, were computed in both the Provisional Courland System and the General Latvian Triangulation Net. The 1924 net was adjusted in stages to fit the following eight bases: Puci-Sarmen Jelgava, Jekabpils-Daborkalns, Garmaniski-Viski, Kangari-Jamilova, Kirbbisi-Akija, Duorno Sielo-Dziedzinka (Polish Base), Arula-Urkaste (Estonian Base), and Liepaja-Paplaka. The chain Puci-Sarmen to Jekabpils-Daborkalns forms the backbone of the modern net from which the adjustment started. The origin of the General Latvian Triangulation Net is Riga St. Peter's Church (top of the Riga Church spire) where $\Phi_o = 56^o\ 56'\ 53.919''$N, $\Lambda_o = 24^o\ 06'\ 31.898''$East of Greenwich, and the reference azimuth to Mitau German Church $\alpha_o = 215^o\ 24'\ 04.38''$. The value for Riga St. Peter's Church approximates the Dorpat II System (datum). The Latvian control was computed in terms of four Cassini-Soldner Grids. The grid names and the coordinates of the respective origins are as follows: Vardupe Cassini-Soldner Grid where $\varphi_o = 56^o\ 51'\ 32.961''$N and $\lambda_o = 21^o\ 52'\ 03.462''$E; the Riga Cassini-Soldner Grid where $\varphi_o = 56^o\ 56'\ 53.919''$N and $\lambda_o = 24^o\ 06'\ 31.898''$E; the Gaizinkalns Cassini-Soldner Grid where $\varphi_o = 56^o\ 52'\ 15.031''$N and $\lambda_o = 25^o\ 57'\ 34.920''$E; and the Vitolnieki Cassini-Soldner Grid where $\varphi_o = 56^o\ 40'\ 08.447''$N and $\lambda_o = 27^o\ 15'\ 12.252''$E. These grid systems cover zones of about 1½º to 2º wide, and overlap slightly. The Vardupe Grid is computed from the geographics of the Provisional Courland System, while the Gaizinkalns and Vitolnieki Grid values correspond to the General Latvian Triangulation Net. The Riga Cassini-Soldner Grid coordinates are computed from both the Provisional Courland System geographics and the General Latvian Triangulation Net. However, care is taken in the Latvian "Trig" Lists to show from which geodetic system the Riga Cassini-Soldner coordinates are computed.

During these inter-war years, the Russians were also actively recomputing their survey information in the Baltic states. Prior to 1932 the Russian horizontal control of the Baltic States was always referenced to Dorpat Observatory at Tartu in Estonia. In 1932 the Russians set up Pulkovo Observatory 1932 as their horizontal datum and origin reference to the Bessel 1841 ellipsoid, and later revised this to Pulkovo 1942, now properly termed "System 42" (datum) referenced to the Krassovsky 1940 ellipsoid.

Thanks to E.A. Early of the U.S. Army Map Service, "In 1942 the German Army undertook the conversion of the Latvian Soldner coordinates to DHG Pulkovo." (Deutches Heeres Gitter – German Army Grid) "The first phase of the conversion embodied the change of projection from Soldner to Gauss-Krüger. The Latvian Geodetic Engineer Mensin set up formulas and tables to convert the four Latvian Soldner systems to the German Gauss-Krüger system. However, upon checking these formulas at the boundaries of the Soldner systems, inadmissible gaps were discovered. Mensin's formulas were then abandoned and new ones were derived following the method given in Jordan-Eggert's *Handbuch der Vermessungskunde*. Since there were no reliable geodetic connections to the Pulkovo system available at that time, the conversion of the Latvian system to the Pulkovo 1932 system could only be approximated. The value of the datum point of the general Latvian triangulation net approximates the Dorpat II system value. The necessary formulas converting Dorpat II system values to the Pulkovo 1932 system were available in the official Russian work of Brigade Engineer O. A. Sergjew, *Making and Editing of Military Maps*, Moscow 1939. In the absence of better data, these formulas were taken as a basis for the conversion to Pulkovo 1932 datum. The German Preliminary DHG Pulkovo 1932 coordinates resulting from this conversion were published in the form of *Ausgabe Koordinatenkartei* by the Kriegs-Karten und Vermessungsamt Riga, in 1943.

In 1943 extensive surveys were executed along the Latvian-Russian border for the final connection of the Latvian triangulation with the Pulkovo system. At the conclusion of these surveys, the Latvian system (already in terms of the preliminary DHG Pulkovo 1932 system) was converted to the Pulkovo 1932 system by a rigidfield adjustment. The Russian Pulkovo 1932 system coordinates used in this adjustment were taken from Russian Catalogs. As a consequence of this adjustment, new conversion constants were computed to convert from the four Latvian Soldner systems to the Final DHG Pulkovo 1932 system. As mentioned previously, the triangulation of Latvia is not completely uniform, since the triangulation in Courland is based on the Provisional Courland System adjustment. Only the first-order stations in Courland are available in terms of the General Latvian Triangulation Net. The lower-order trig in Courland was converted from the Provisional Courland System to the General Latvian Triangulation Net by a graphical adjustment (triangle by triangle) based on the comparison of first-order values. After the lower-order trig in Courland was converted to terms of the General Latvian Triangulation Net, the Final DHG Pulkovo 1932 coordinate for all Latvia were computed. These coordinates were published in 1943 as a second edition *Ausgabe Endwerte Koordinatenkartei* by the Kriegs-Karten und Vermessungsamt, Riga. In the Fall of 1944 the publication of the *Koordinaten-Verzeichnis* (trig books) was begun. The coverage of these books is scanty. Also, it is noted that there are differences of up to a meter, at some stations, between the *Koordinaten-Verzeichnis* values and those from the second edition *Koordnatenkartei*. Is appears that this difference is accounted for by the fact that some of the Latvian traverse points (as included in the second edition *Koordinatenkartei*) were resurveyed by the German Army and consequently were listed in the *Koordinaten-Verzeichnis* books by the German Survey values." To convert from DHG Pulkovo 1932 Datum Grid coordinates to European Datum 1950 coordinates on the UTM Grid, zone 34, use the following: (UTM Northing) = 0.9996056758 * (DHG Northing) + 0.0000176163 * (DHG Easting) + 828.01, and (UTM Easting) = 0.9996056758 * (DHG Easting) + 0.0000176163 * (DHG Northing) + 365.98. The NIMA published values for that general region of Europe from European Datum 1950 to WGS 84 are $\Delta X = -87$m ± 3m, $\Delta Y = -95$m ± 3m, and $\Delta Z = -120$m ± 3m. The NIMA published values for System 42 Datum (in Latvia) to the WGS 84 Datum are $\Delta X = +24$m ± 2m, $\Delta Y = -124$m ± 2m, and $\Delta Z = -82$m ± 2m.

Update

"(The) origin of Latvian Coordinate System LKS-92 definition was based on two GNSS campaigns in 1992 and 2003. There are two continuously operating reference networks in Latvia: LatPos and EUPOS® -Riga. GNSS stations of these networks have fixed coordinate values in LKS-92. At the Institute of Geodesy and Geoinformatics of the University of Latvia both LatPos and EUPOS® -Riga station daily coordinate values are calculated. The coordinate differences between epochs 1989.0 and 2018.5 were obtained for LatPos and EUPOS® -Riga stations, expressed in ITRF14. ITRF reflects the motion of Eurasian plate in global frame of the Earth and ETRF89 system reflects the intraplate motion. Mean yearly coordinate components in ETRF89 were analysed. Comparison of LatPos and EUPOS® -Riga station coordinate components in ETRF89, LKS-92 and ETRF2000 coordinate systems was performed. Future of Latvian coordinate system LKS-92 is discussed." *Baltic J. Modern Computing, Vol. 7 (2019), No. 4, 513-524 https://doi.org/10.22364/bjmc.2019.7.4.05*

"According to the decision of IAG Reference Frame Subcommission for Europe (EUREF) the EVRF2007 solution as the vertical reference has to be deployed in EU countries. The new height system *LAS-2000,5* had been enacted as the European Vertical Reference System's *EVRF2007* realization in Latvia and the new geoid model LV'14 had been introduced by Latvian authority Latvian Geospatial Information Agency. However, the appreciation of the quality of quasi-geoid model LV'14 is rather contradictious among the users in Latvia. The independent estimate and comparison of the two Latvian geoid models developed till now has been performed by the Institute of Geodesy and Geoinformatics. Previous geoid model LV98 which was developed for *Baltic-1977* height system almost 20 years ago is outdated now. Preparatory actions described in order to fulfil the task of comparison the geoids in two different height systems. The equations and transformation parameters are presented in this article for the normal height conversion from *Baltic-1977 height system to the Latvian realization named LAS-2000,5."*

Balodis, J., Morozova, K., Silabriedis, G., Kalinka, M., 2016. Changing the national height system and geoid model in Latvia. *Geodesy and Cartography* 42(1):20-24. DOI: 10.3846/20296991.2016.1168009.

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