# Grids & Datums

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# MONGOLIA

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 Mongolia was originally printed in 2003 but contains updates to their coordinate system since then.


Although the region has been inhabited since early times by nomadic peoples, the Mongol tribe made its entrance into history during the 13th century under the leadership of Genghis Khan. The Mongol Empire, with its original capital at Karakorum and later at Beijing, stretched from the Danube River in Eastern Europe to China. In the 14th century, the former empire was broken up and absorbed into China under the Yüan dynasty, originally established in 1279 by Kublai Khan, grandson of Genghis. By 1368, the Ming dynasty supplanted the Yüan, shattering the Mongol unity. The former Outer Mongolia eventually gained its independence from China on 11 July 1921 as the Mongolian People's Republic. The date of the country's present constitution is 12 February 1992, when it was renamed Mongolia. The current capital is Ulaanbaatar, the area of the country is slightly smaller than Alaska, and its borders are with China (4,677 km) and Russia (3,485 km). Mongolia has a continental desert climate with large daily and seasonal temperature ranges; its terrain is comprised of a vast semi-desert and desert plains, grassy steppe, mountains in the west and southwest, and the Gobi Desert in the south central. The lowest point is Hoh Nuur at 518 m, and the highest point is Nayramadlin Orgil (Huyten Orgil) at 4,374 m.

In 1918, the Chinese General Staff compiled a monochrome map series at scales of 1:100,000 and 1:300,000 covering the Mongolia-China border areas. The map sheets are based on original Chinese surveys. Relief is shown by contours and roads are classified by vehicular limitations. In the 1940s, the Survey Department, Ministry of National Defense, compiled a 1:500,000- and 1:1,000,000-scale series covering all of Mongolia. The Kwantung Army Headquarters produced map sheets for military use in 1942-43 for two areas in eastern Mongolia from sheets originally produced by the Japanese in1935 and 1942, from Russian maps dated 1906 and 1933, and from a rough survey made by the Japanese in 1912. Relief is shown by contours of form-line accuracy and hill shading. No grid system was used. Virtually all of the maps produced by the Japanese for Mongolia cover the eastern part. Most were produced by the Japanese General Staff. A 1:100,000-scale monochrome map series published in 1913-14 covers part of Mongolia east of 106º; in the late 1930s a 1:200,000-scale map series was compiled from Russian maps to cover northeastern Mongolia. During the period from 1923 to 1943, a 1:500,000-scale map series was compiled for eastern Mongolia. From this series and from Russian maps, a 1:200,000-scale map series was produced by the Kwantung Army Headquarters mentioned previously. No grid system was used.



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Mapping of Mongolia by the Russians was originally conducted during the 1930s. The Upravleniye Topografov (Military Topographic Administration) was formed in 1932 and compiled a 1:200,000-scale map series of small scattered areas and 1:500,000- and 1:100,000-scale map series for more extensive areas in eastern Mongolia. Relief is shown by form-lines and contours. Geodetic surveys of Mongolia were conducted from 1939 to 1946, and the primary triangulation of the country is comprised of eight northsouth arc chains and three east-west arc chains. I count 27 baselines and 54 LaPlace stations on a diagram published by the government in 1999. Thanks to a letter that year from B. Munkhzul, geodetic engineer for the State Administration of Geodesy and Cartography, the basic classical geodetic network of Mongolia is comprised of secondorder accuracy, with third- and fourth-order points used to densify the network. Including the benchmarks based on the Kronstadt Datum (Kronshtadsky futshtok) *(sic)*, there are 27,500 geodetic monuments in Mongolia. The Russian "System 42" Datum is referenced to the Krassovsky 1940 ellipsoid where $a$ = 6,378,245 meters and $^1/_f$ = 298.3. The origin is at Pulkovo Observatory: $\Phi_o$ = 59° 46′ 18.55″ North, $\Lambda_o$ = 30° 19′ 42.09″ East of Greenwich, and the defining azimuth at the point of origin to Signal A is $\alpha_o$ = 317° 02′ 50.62″. The grid system used in Mongolia for mapping from classical triangulation is the standard Russian Belts such that the False Eastings are equal to 500 km at the central meridians, and the scale factor at the central meridians are equal to unity. The Gauss-Krüger Transverse Mercator uses 6° belts with zones identical to the UTM.



In 1954-55, the U.S. Army Map Service (AMS) compiled sheets for a 1:250,000-scale polychrome map series on the Universal Transverse Mercator Grid. The series covers scattered areas of Mongolia along the Russian and Chinese borders. In 1942-44, AMS copied a few sheets of a Russian 1:1,000,000- scale map series, and from 1949 to 1958 compiled a 1:1,000,000-scale polychrome map series for the remaining three-fourths of the country. Mongolia appears to be the most geodetically advanced country in central Asia. Their national mapping staff was educated in Moscow until 1981 when geodetic and photogrammetric education was offered at the Mongolian Technical University. With the assistance of Swedesurvey, Mongolia has established a new national datum called "MONREF 97." This new datum is based on the International Terrestrial Reference Frame (ITRF 2000) epoch 1997.8. Essentially, this is cartographically identical to the World Geodetic System (WGS 84). The GPS observations were carried out and financed by MONMAP Engineering Services Co., Ltd., Ulaanbaatar, in cooperation with the Ministry of Defense, Mongolia. The processing of the GPS observations, development of transformation formulae, and recommendations for a new grid system were performed by Swedesurvey and financed by the Swedish International Development Agency. The new MONREF 97 system will replace the old Russian "System 42," but the Baltic height system of elevations will not be replaced. MONREF 97 is comprised of 38 points at 34 different locations, and is similar in concept to the High Accuracy and High Precision Reference Networks of each state in the United States. MONREF 97 is based on two national GPS campaigns carried out in the autumn of 1997. Trimble 4000 SSi receivers were used for the observations and "Bernese 4.2" software was used for the adjustment. Because that software package produces results contrary to U.S. military and civilian convention and usage, the standard U.S. rotations will be given herein.

It is fascinating to see that, when Mongolia decided to change things, they even changed their grid system in a most surprising way.

The Russian "System 42" Datum (locally termed "MSK42") used projection parameters identical to those of the Universal Transverse Mercator (UTM) Grid, but with a *different* scale factor at origin. Mongolia has chosen to eschew that old system and has adopted the UTM for their new national grid! (It will be interesting to see if Russia changes to UTM if they are admitted into NATO.) It is gratifying to note that Mongolia recognizes that the UTM Grid may be convenient for national use; individual cities and smaller regions are encouraged to use systems with more sensible scale factors and to use projections better suited for their shapes. Mongolia is covered by UTM zones 46 through 50.

The published datum shift parameters are offered in a variety of different models that are intriguing. The most familiar model to the reader of *PE&RS* is the standard military three-parameter transformation where, for MSK42 to MONREF 97 (WGS84), $\Delta a = -108$, $\Delta f = +0.000000480812$, $\Delta X = +13$ m, $\Delta Y = -139$ m, and $\Delta Z = -74$. Other transformation models include the sevenparameter Bursa-Wolfe where, for MSK42 to WGS84, $\Delta X = -78.042$ m, $\Delta Y = -204.519$ m, $\Delta Z = -77.450$ m, Rx = –1.774", Ry = +3.320", Rz = –1.043", and $\delta = -4.95105766$ ppm. Unfortunately, no test points were provided for these transformation parameters, but the three-parameter model will give a clue. Another datum shift method published by the Mongolian government is the two-dimensional Helmert transformation that works with the Russian Gauss-Krüger Transverse Mercator and the UTM. The parameters are $X_o$ (translation in X), $a$ (X coefficient), $Y_o$ (translation in Y), $b$ (Y coefficient), $\delta$ (scalar), and $\alpha$ (rotation). There is a separate set of parameters published for each UTM zone, and this technique is identical to that used by AMS for the computation of the European Datum 1950.

A fourth technique for performing datum shifts from MSK42 to MONREF 97 is a series of Gauss-Krüger projection parameters to transform directly from MSK42 Latitude and Longitude to MONREF 97 UTM coordinates. A fifth and final technique published by the Mongolian government is a table of differences in Latitude and differences in Longitude (all in meters) that serves as a system for implementing bi-linear interpolation akin to the NADCON technique published by the U.S. National Geodetic Survey. Because there is a paucity of gravity observations in Mongolia, the new datum is not a true three dimensional system. There is great hope to someday have a reliable geoid model for the entire country that will enable GPS leveling techniques to be implemented.

## Update

Zone transformation parameters for UTM zones were recalculated in 2005 and in 2008. A complete airborne gravity survey of Mongolia was carried out in two fall campaigns 2004-2005 by the Danish National Space Center. Absolute gravity was observed in 2006-2007. A Mongolian geoid height model was produced with 16 cm accuracy for the whole country and 2-5 cm accuracy for the city of Ulaanbaatar. Transformation parameters and the geoid height model are accessible from ALAGaC web page for the public (Munkhtsetseg, D., ***Geodetic Network and Geoid Model of Mongolia***, ispr s.org/proceedings/XXXVIII/7-C4/121_GSEM2009).


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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 ($C^4G$).

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**Book Review**
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advice on commercial launch services and costs would likewise be helpful. In the chapter on pushbroom imagers, the author expresses the dwell time as a function of the angle subtended by a resolution element, the subsatellite point velocity, and the altitude, as

$$\tau_p = \frac{\beta}{\left(v/h\right)}$$

In other references it is stated that this dwell time should always be less than one-half this value to avoid unacceptable image smear. He does imply this later in the chapter on Submeter Imaging.

Overall this book is a valuable contribution to the remote sensing literature. No doubt much of the information is available in specialized texts and journals on optics and aerospace engineering, but the author, guided by his unique experience, brings this information together in way that is accessible and interesting to the photogrammetrist, cartographer, or remote sensing analyst.

**Mapping Matters**
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Or,

**Total number of checkpoints required for the project =** 100 (for the 1st 2,500 km$^2$) + 105 (for the remaining 10,449 km$^2$) = 205 checkpoints distributed as follow:

**118 checkpoints within the NVA area**

**87 checkpoints within the VVA area**

> **"For vertical testing of areas >2,500 km2, add five additional vertical checkpoints for each additional 500 km2 area. Each additional set of five vertical checkpoints for 500 km2 would include three checkpoints for NVA and two for VVA"**

Please remember that the new ASPRS standard states, *"The recommended number and distribution of NVA and VVA checkpoints may vary depending on the importance of different land cover categories and client requirements"*. Therefore, you have some flexibility in balancing the number of VVA and VVA checkpoints depending on your project and your client understanding of the issue.



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