GEODETIC HIGHLIGHTS

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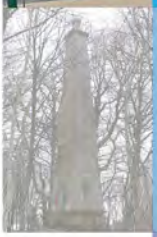
Geodetic points around Črnomelj



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GEODETIC INSTITUTE OF SLOVENIA

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Geodetic points around Črnomelj

Authors: Niko Fabiani, Dr Mihaela Triglav Čekada, Mag Katja Oven, Dr Klemen Medved, Sandi Berk, Rado Škafar, Dr Bojan Stopar

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Dear nature and mountaineering enthusiasts

One of the most important tasks of geodesy in every country is to establish a national coordinate system, which serves as a reference basis for all spatial data. The national coordinate system has always consisted of two parts – horizontal and vertical. In the past, the horizontal coordinate system was represented by so-called trigonometric networks of different orders (accuracy). The vertical coordinate system was – and still is – represented by so-called levelling networks, which are also classified into different orders according to their accuracy. The points of trigonometric networks (trigonometric points) are marked in nature with various marks, ranging from masonry or concrete pillars of varying heights to smaller granite blocks buried in the ground. They are mostly located on the tops of mountains and hills. Points in the levelling networks are called benchmarks. These are marked with brass or iron wall markers embedded in the outer walls of various buildings. The head of the bolt seen on the outer side of the wall can be ball- or barrel-shaped, with a diameter between 2 cm and 5 cm. The points in trigonometric and levelling networks had coordinates (horizontal coordinates and heights) determined in the national coordinate system. Surveyors then used geodetic surveying to connect measurements with geodetic points and to determine the coordinates of any point in the national coordinate system.

The introduction of global navigation satellite systems (GNSS) technology has led to its integration into the field of geodesy. In 2007, we established the first Slovenian national network of permanently operating GNSS stations, called SIGNAL. The SIGNAL network has been designed for different users seeking to determine coordinates in the national coordinate system by utilising GNSS technology. SIGNAL is an acronym representing SI – Slovenia, G – Geodesy, NA – Navigation, L – Location. The GNSS stations in the SIGNAL network consist of GNSS antennas and receivers installed on the roofs of various buildings. As this is a national network of GNSS stations owned by the Republic of Slovenia, the buildings on which the SIGNAL network stations are located are owned by the Republic of Slovenia, and thus are the buildings of municipalities, public institutions and companies.

In 2014, we started establishing a new national geodetic network of the highest order, known as the national combined geodetic network of the Republic of Slovenia, or the zero-order geodetic network. Part of this network is the GNSS network, which is intended for long-term monitoring of the stability of both national coordinate systems, horizontal and vertical. The points of this network are located on publicly owned land. They are represented by concrete pillars set on stable ground and connected to the solid base by foundations. The first six points of the national combined geodetic network were established between 2013 and 2016, with two more in 2023 and 2024. Unlike the trigonometric points of previous trigonometric networks, where geodetic measurements were performed only occasionally, both national GNSS networks are active networks, meaning that measurements are performed continuously on them, 365 days a year, 24 hours a day.

In this booklet, we will present the importance of the SIGNAL GNSS network and provide detailed information about the permanent GNSS station in Črnomelj. At the same time, we will also present other important geodetic points in the vicinity of Črnomelj: the GNSS station of the national combined geodetic network in Prilozje and two first-order trigonometric network points at Trdinov vrh and Debeli vrh. The geodetic points in question are marked in nature with various types of markers, ranging from a GNSS antenna placed with a stainless steel pole on the roof of the fire station building in Črnomelj, to a pillar made of concrete and protected by stainless steel cladding in Prilozje, a very tall masonry tower of the first-order trigonometric point on Trdinov vrh and a unique two-part masonry pillar of the first-order trigonometric point on Debeli vrh.

Even though new GNSS networks have been established, older trigonometric network points are still very important as surveyors occasionally use them for various types of measurements. Therefore, we continue to maintain them in as good a condition as possible. Finally, the various points of the geodetic networks represent a unique and important technical heritage, as well as testify to the fact that Slovenian surveyors are constantly following developments in the field of geodesy, thus ensuring that their work is of as high standards as possible.

Prof Dr Bojan Stopar,
University of Ljubljana, Faculty of Civil and Geodetic Engineering

Surveying points in the Črnomelj area and the SIGNAL network

Where are they located?

Today, the two most important networks in the field of geodesy are the SIGNAL network of permanent GNSS stations and the national combined geodetic network (shortened as the zero-order network). GNSS networks form the basis of the national geoinformation infrastructure and are important for geodesy and many other scientific disciplines as well as the economy. In the city of Črnomelj, a permanent SIGNAL network station is located on the roof of the local fire station building. The national combined geodetic network point in Prilozje is located at the edge of Prilozje airport in Bela Krajina. If you want to go on a short trip in the wider area around the city of Črnomelj, you can also visit the first-order trigonometric points on Trdinov vrh and Debeli vrh.

The SIGNAL network

Global navigation satellite systems (GNSS) have been in use for almost four decades and, in today's technologically advanced world, are used not only for navigation, but also for time measurement, mobile telephony, banking, telecommunications, the internet, maintenance of various databases and much more. Modern geodesy is closely linked to GNSS, as all modern geodetic reference coordinate systems are directly linked to global navigation satellite systems.

In Slovenia, the most important national network of permanent GNSS stations is the SIGNAL network. SIGNAL is an acronym representing SI – Slovenia, G – Geodesy, NA – Navigation, L – Location. Construction of this network began in the year 2000, with the Ljubljana and Maribor permanent stations being built first, which were soon followed by others. By 2007, when the SIGNAL network became operational, 15 permanent GNSS stations were already in operation. Today, the SIGNAL network consists of 30 permanent stations. There are 16 permanent stations evenly distributed across Slovenia: Bodonci, Bovec, Brežice, Celje, Črnomelj, Idrija, Ilirska Bistrica, Koper, Lendava, Ljubljana, Maribor, Nova Gorica, Ptuj, Radovljica, Slovenj Gradec and Trebnje. The network is expanded with 14 permanent stations located in neighbouring countries, near the Slovenian national border: in Austria (permanent stations Villach, Völkermarkt, Deutschlandsberg and Feldbach), in Croatia (permanent stations Poreč, Rijeka, Delnice, Karlovac, Zabok, and Čakovec) in Italy (permanent stations Cervignano del Friuli, Udine and Moggio Udinese) and in Hungary (permanent station Zalaegerszeg). The network is owned by the Surveying and Mapping Authority of the Republic of Slovenia and managed by the GNSS Service Centre, which operates at the Geodetic Institute of Slovenia. The network has a few hundred daily users, who utilise its data and services to perform tasks in the fields of geodesy, construction, agriculture, archaeology, meteorology, land, sea, river and air transport, maintenance of various spatial data bases, etc.

Map of important geodetic points near Črnomelj

GNSS receivers and antennas of permanent stations of the SIGNAL network are installed on the roofs of buildings owned by the Republic of Slovenia or other public institutions. The GNSS antenna has the shape of concentric cylinders protected by a plastic dome with a diameter of 32 to 35 cm and is mounted on a metal pole of varying length connected to the supporting structure of the building. They are installed on buildings belonging to the Surveying and Mapping Authority of the Republic of Slovenia (Brežice, Maribor, and Slovenj Gradec), fire stations (Celje and Črnomelj), post offices (Bodonci), police stations (Bovec), a retirement home (Ilirska Bistrica), a secondary school (Lendava), a meteorological station (Nova Gorica), commercial buildings (Idrija, Ljubljana, and Ptuj) and municipal buildings (Koper, Radovljica, and Trebnje).

The location of a permanent SIGNAL network station must meet numerous conditions, including an open sky and the absence of physical and electromagnetic interferences, so that the GNSS antenna can receive GNSS satellite signals without interruptions. The location must be connected to the electricity and telecommunication networks, among other things. The GNSS antenna is installed on the roof of the building, while inside the building there is a cabinet with a GNSS receiver, power supply, batteries and telecommunications equipment. The receiver continuously sends GNSS measurement data to the GNSS Service Centre, located at the Geodetic Institute of Slovenia, where this data is stored, processed and forwarded to users in the field.

GNSS antenna installed on the roof of the Lendava Bilingual Secondary School building

Layout of devices in the cabinet of the Črnomelj permanent GNSS station

Map of permanent GNSS stations in the SIGNAL network

Users utilise SIGNAL network data to improve the positioning accuracy of their GNSS instruments, which receive data from the GNSS Service Centre. This enables GNSS instruments to determine coordinates in the national coordinate system in real time and with an accuracy of a few centimetres.

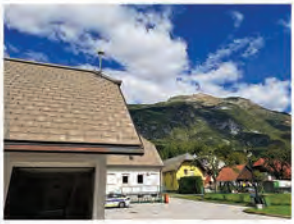
Some SIGNAL network permanent GNSS stations are also included in international GNSS networks designed to maintain a common European coordinate system called ETRS (*European Terrestrial Reference System*) and a global coordinate system called ITRS (*International Terrestrial Reference System*), as well as for other research purposes. Several permanent stations of the SIGNAL network, as well as stations of the national combined geodetic network, are included in the EPN (*EUREF Permanent GNSS Network*) and the EPOS (European Plate Observing System). Data from these stations is continuously sent to several EPN analysis centres across Europe and around the world, which use this data for various scientific and research purposes.

The EPN, or the EUREF network of permanent GNSS stations, is a pan-European network with more than 400 stations. The EUREF[1] community (*see https://www.euref.eu/about-euref*) consists of more than 100 different organisations, from national agencies to universities and research institutions from more than 30 countries, and maintains the European Terrestrial Reference System (ETRS) used by

[1] EUREF is the Reference Frame Sub-Commission for Europe by the International Association of Geodesy – IAG (https://geodesy.science/iag/)

Bodonci

Bovec



Brežice

Celje

Idrija

Ilirska Bistrica

Koper

Ljubljana

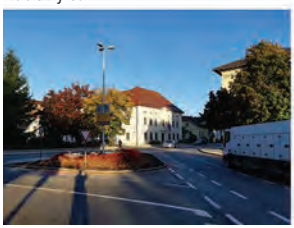
Lendava

Maribor

Nova Gorica

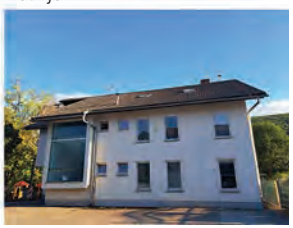
Ptuj

Radovljica



Slovenj Gradec

Trebnje



Fifteen permanent GNSS stations of the SIGNAL network, the Črnomelj station is shown seperately on the following pages

most European countries. It also performs other scientific and research tasks within various working groups. The EPN includes the SIGNAL network station in Ljubljana and the permanent stations of the combined geodetic network in Prilozje, Areh, and Korada (the latter two are presented in other published booklets in the Geodetic Highlights series).

EPOS is the European Plate Observing System intended for research in the fields of seismology, geology, geodesy and many other scientific fields related to Earth exploration. Data from permanent GNSS stations included in the EPOS are used to determine the movements of lithospheric plates in Europe. The EPOS includes the permanent station of the SIGNAL network in Ljubljana and six permanent stations of the combined geodetic network, i.e. Areh, Kog, Koper, Korada, Prilozje and Šentvid pri Stični.

Field measurements with a GNSS instrument

Črnomelj permanent GNSS station of the SIGNAL network

The Črnomelj permanent GNSS station was established in November 2002 as one of the first ones in the SIGNAL network, following immediately after the GNSS stations in Ljubljana and Maribor. The station has the international designation CRNM00SVN. It is located on the building of the Črnomelj Volunteer Fire Department building at Belokranjska cesta 10. The GNSS antenna is mounted on top of the building's tower, with an unobstructed view of the sky. The GNSS antenna, with a protective dome with a diameter of 35 cm, stands on a pole that extends about 1.5 m above the roof.

The cabinet with the GNSS receiver and other equipment was originally installed in the Črnomelj office of the Defence Administration of Novo Mesto, which is located in the same building. In 2010, for reasons of convenience, we moved the cabinet with the equipment to the premises of the office of the Črnomelj Volunteer Fire Brigade, where it is still located today.

The Črnomelj Volunteer Fire Department building, where the GNSS antenna of the Črnomelj permanent GNSS station is located on the top of the tower roof

GNSS technology has advanced significantly over the course of the past 23 years, with the gradual emergence of new global navigation satellite systems. The original American global navigation satellite system, Navstar GPS, has been joined by Russia's GLONASS, Europe's GALILEO, China's BEIDOU and others. As a result, all GNSS receivers, from permanent stations to rovers used by surveyors in the field, use

new GNSS, new frequencies and signals, and new technologies. As a result, the GNSS station in Črnomelj has had to be upgraded several times with new GNSS antennas and receivers since it began operating. While in 2002 the permanent station in Črnomelj received data from eight satellites on two frequencies, today it receives data from 47 GNSS satellites on all frequencies on which GNSS transmit their signals, which increases the accuracy and speed of positioning and the reliability of data and services for users.

Cabinet with devices at the office of the Defence Administration, 2002

Cabinet with devices at the office of the Črnomelj Volunteer Fire Department, 2024

Other interesting stations of the SIGNAL GNSS network

The oldest permanent station of the SIGNAL GNSS network in Ljubljana

The oldest permanent station in the SIGNAL network is the Ljubljana GNSS station, with the international designation GSR100SVN. It was installed in February 2000 and is located on the roof of a commercial building at Litijska cesta 45 in the capital. Over the course of its 25-year operational lifespan, five generations of GNSS receivers and antennas have been replaced on it. It is the only SIGNAL permanent station that is included in the European network of permanent GNSS stations EPN. Every hour its data is sent to several EPN analysis centres, where it is used to obtain various data and products. Despite being located on the roof of a building, it has proven to be very stable and reliable.

Antenna of the Ljubljana permanent GNSS station

Koper tide gauge and permanent GNSS station

In Koper, the SIGNAL network station is located at the tide gauge station of the Slovenian Environmental Agency (ARSO). The tide gauge station is intended for sea level measurements for the purpose of long-term monitoring of sea tides. In addition to sea level and GNSS measurements, various other meteorological measurements are also carried out on it. The long-term determined mean sea level is also a fundamental component of the national height and depth coordinate systems. The tide gauge and permanent GNSS stations in Koper were set up in December 2005. When the combined geodetic network was established, it was also included in this new GNSS network. The GNSS antenna is mounted on a long steel pole located on the roof of the tide gauge station, while the GNSS receiver, power supply and communication equipment are placed in a separate cabinet inside the tide gauge station.

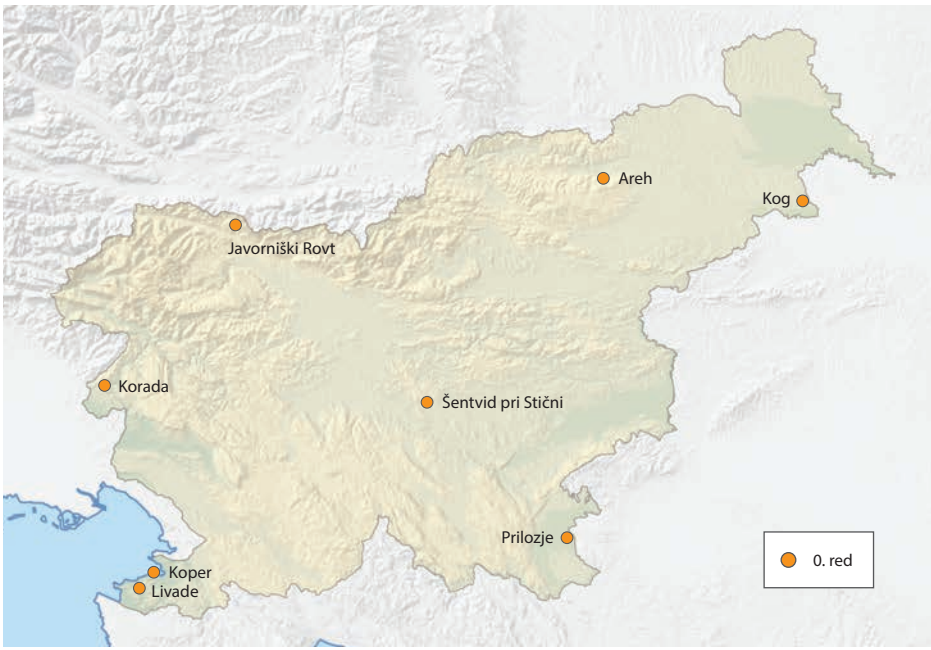
In 2021, the Koper permanent GNSS station (KOPE) collocating with the tide gauge station was replaced by the new SIGNAL network station (KOPR), located in the centre of the old town of Koper. In the zero-order network the Koper permanent GNSS station (KOPE) was also replaced by a new GNSS station in Livade (Izola, on St Donat hill above the village of Baredi) in 2025, as the permanent GNSS station collocating with the tide gauge station had been experiencing stability issues in the previous few years.

GNSS antenna of the SIGNAL network station on the roof of the Koper tide gauge station

Other interesting geodetic points near Črnomelj

The zero-order network point in Prilozje

The geodetic point of the national combined geodetic network or the zero-order network point in Prilozje is located in the area of the Prilozje Sports Airport. Due to the geological conditions at the location and the construction and positional stability requirements for the permanent station, the foundation of the concrete pillar is placed on three 20-metre long concrete piles. The location of the pillar is connected to the electrical and telecommunication infrastructures. The pillar is 2.2 m high and protected by stainless steel cladding, with two GNSS antennas installed on it. The station is equipped with two GNSS receivers, an inclination sensor and several other devices. At the base of the pillar, there are three more marks that enable classic terrestrial geodetic and gravimetric measurements to be carried out. The station is secured with a wire fence, on which a meteorological station is also installed. Outside the fence, there are three additional so-called security marks, which are also placed on concrete pilots and protected with iron covers. The security marks are intended to monitor the local movements of the pillar and other geodetic points in its vicinity. In front of the geodetic pillar, there is an information board informing visitors about the purpose and significance of the Prilozje station and the national combined geodetic network.



Map of the national zero-order network

The Prilozje geodetic point was built in June 2015, and has been operating as part of the zero-order network since 2016. It continuously sends data to the GNSS Service Centre in Ljubljana, where the data is being processed, stored and forwarded. It operates very reliably, and calculations of its coordinates indicate that it is highly stable. The permanent GNSS station of the zero-order network in Prilozje as well as the Ljubljana SIGNAL network station are included in the EUREF Permanent GNSS Network (EPN) and the European Plate Observing System (EPOS).

Drilling to a depth of 20 m for the installation of pilots for the foundation at Prilozje

Concreting the foundation and pillar at Prilozje

Prilozje geodetic point with information board

Interior of the pillar with the equipment cabinet at Prilozje

Security mark at Prilozje (outside the fence)

Three ground marks on the foundation slab of the Prilozje point (inside the fence)

The first-order trigonometric points at Trdinov vrh and Debeli vrh

First-order trigonometric network points in Slovenia

In the wider area around the city of Črnomelj, there are – besides the permanent SIGNAL network station and the Prilozje zero-order network station – two other interesting first-order trigonometric network points: No. 375 – Trdinov vrh (1,178 m) in the Gorjanci and No. 376 – Debeli vrh (865 m), which are both still occasionally used in GNSS surveys. Among the most significant recent surveys were those performed in 2016 as part of the EUREF Slovenia 2016 GNSS campaign. In contrast to the previously mentioned Črnomelj permanent GNSS station and the Prilozje zero-order network station, both accessible by car, to reach the points at Debeli vrh and Trdinov vrh it is more pleasant to walk along the mountain trails. Still, the point at Trdinov vrh can also be reached by car, if preferred.

Trdinov vrh

To reach the border peak of Trdinov vrh (1,178 m), the highest peak of the Gorjanci hills, drive from Novo Mesto through the village of Velike Brusnice and on to the village of Gabrje. At the crossroads, continue straight along the street called Šumeči potok, at the end of which you can leave your car. Then on foot follow the mountain trail signs towards the Gorjanci and further to the mountain hut at Gospodična. From the mountain hut, continue right along the road to the signpost for Trdinov vrh. From there, continue left over the ridge and through the forest. The path crosses the forest road several times until you reach the top of Trdinov vrh.

On Trdinov vrh, about 80 m away from the telecommunications transmitter, there is a 14.27 m high brick pillar of a first-order trigonometric point, which was erected

in 1963. Several similar tall pillars (towers) can be found also elsewhere throughout Slovenia, for example on Rašica, Lokavec, Kamenek, and the Lendavske gorice. A similar pillar once stood on Žigartov vrh in Pohorje, too, and you can learn more about this in another special booklet in the Geodetic Highlights series. The pillar on Trdinov vrh was first renovated in 1978, when a metal ladder, lightning rod and metal fence were added to the top of the pillar. The brick pillar has two reference points, the first is at the top of a small pillar located on top of the whole construction from where geodetic measurements were performed in the past. The second reference point is in an opening at the base of the pillar, right in the middle of it. The lower point is represented by a semicircular carved stone protruding slightly from the concrete floor inside the niche in the pillar. This stone represents the previous marking of this trigonometric point from the year 1934. The additional inscription VGI and the year 1934 were carved on one of its side surfaces. VGI is an abbreviation for the Vojnogeografski Institut (Military Geographic Institute) from Belgrade under the Kingdom of Yugoslavia, which erected this trigonometric point at that time.

Around the brick pillar, at distances of 18 to 27 m, there are four more security marks, represented by concrete squares measuring 20 cm × 20 cm in cross-section, which protrude no more than 20 cm from the ground.

First-order trigonometric pillar at Trdinov vrh from 1963

The lower reference point of the first-order trigonometric point Trdinov vrh today (left) and its appearance when it was erected in 1934 (right)

Three security marks of the first-order trigonometric point Trdinov vrh

Debeli vrh

To reach Debeli vrh (865 m) above Črnomelj, drive to the village of Kanižarica, where you turn right towards Kočevje. Continue to the village of Dobliče and then along the main road past the village of Grič pri Dobličah. At the chapel, turn left and drive to the Lakner restaurant and continue along the macadam road to Miklarje. From there, continue to the Vražji kamen quarry on the left and drive another 1.2 km to the first turn on the left, which leads uphill. After about 4.5 km, take a sharp 180-degree left turn and continue uphill for another 0.7 km, then turn right and continue for about 0.4 km. Park there and continue on foot for about 0.26 km to the top of Debeli vrh.

At Debeli vrh, you will find a special type of first-order trigonometric pillar, which is unique in Slovenia. It is 4.55 m high and consists of a lower base made from ordinary stone, which is 2.5 m high, and an upper part made of masonry, which is covered with concrete and is 2.05 m high. It was erected in 1963 and last renovated in 2018. Around the pillar, at distances of 9 to 33 metres, there are three side security points in the form of metal pins embedded in the rock. This pillar is also listed in the Slovenian Cultural Heritage Register under number EID 1-30603[2].

First-order trigonometric pillar at Debeli vrh

[2] https://geohub.gov.si/ghapp/giskd/?showLayers=MK_EVRD_6832&query=MK_EVRD_6832_0%2CEID%2C1-30603

Promotion of geodetic points as part of our cultural heritage

There are four interesting geodetic points of great importance for geodesy in the vicinity of Črnomelj. Two belong to the latest generation of active GNSS networks, which the surveyors in Slovenia began to establish in the year 2000, while the other two are predecessors of these networks. They are points of the first-order trigonometric network. The first-order trigonometric network was established in Slovenia in the first half of the 19th century. With the development of geodesy, which enabled measurements performed with higher quality, the designations of trigonometric points were also changed over time due to their renovations. The last major renovation of the first-order trigonometric network was carried out in 1963 and 1964, during the time of the former Yugoslavia. Since astronomical measurements were also carried out on this first-order trigonometric network to determine the position and orientation of the trigonometric network on Earth as a planet, it was also called the astrogeodetic network.

All geodetic points presented in this booklet are included in the national geodetic networks that once or still today define the Slovenian national coordinate system. However, these are not the only geodetic points here, as you will find other trigonometric points of lower orders in the vicinity of Črnomelj, marked with smaller granite stones or concrete markers measuring approximately 15 cm × 15 cm in cross-section, levelling points (benchmarks) on the outer walls of buildings, and various types of boundary marks presenting boundaries between individual land plots, cadastral municipalities, etc.

All these geodetic points represent, or will represent in the future, immovable geodetic technical heritage, which is why their promotion is important both for the geodetic profession and for all other users of space and, last but not least, for all residents of Slovenia. Geodetic technical heritage is an asset that we have inherited or are creating, and it represents technical procedures, knowledge and traditions that are worth preserving. It is part of the former professional activities of surveyors and the field of geodesy, which have been and will continue to be witnesses to the development of this discipline and other sciences in our country. The first-order trigonometric point on Debeli vrh is already inscribed in the Slovenian Register of Cultural Heritage.

You can find out more about the establishment and operation of the SIGNAL network in the following paper:

Ritlop, K., Fabiani, N., Oven, K., Pavlovčič Prešeren, P., Sterle, O., Stopar, B., Triglav Čekada, M. (2019): ***Increase of reliability of the SIGNAL and zero-order GNSS networks.*** Geodetski vestnik, vol. 63, no. 4, pp. 514–524, https://www.geodetski-vestnik.com/arhiv/63/4/gv63-4_ritlop.pdf

Scan the QR code to view the digital booklet on the Geodetic points around Črnomelj

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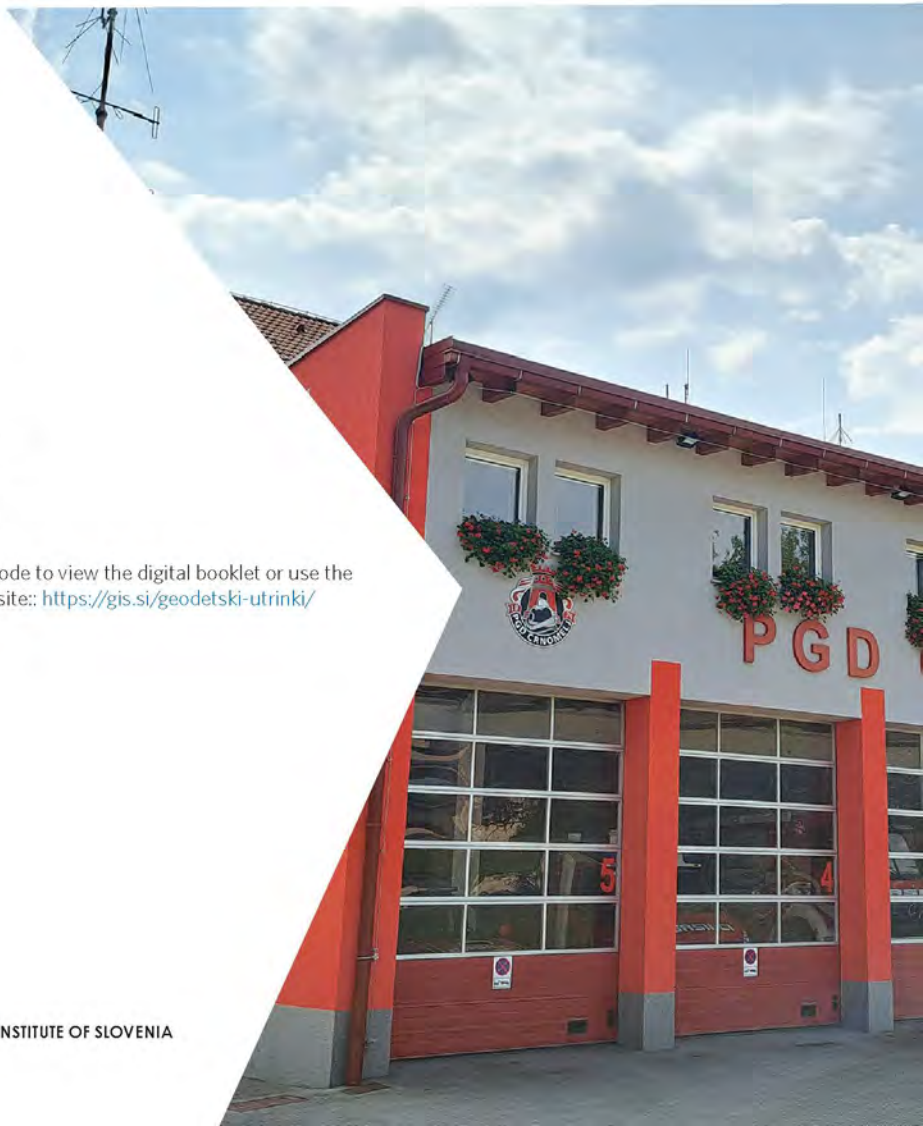

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