

Surveying the Vienna Meridian from Brno to Varaždin

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Abstract. The introduction provides a brief overview of using trigonometric chains for determining meridian arc lengths in Europe, as well as their extension to trigonometric networks in order to produce contemporary accurate maps in France. After Ruđer Bošković had visited Croatian-Hungarian Queen and Roman-German Empress Maria Theresa, she ordered Jesuit Joseph Liesganig to survey the meridian from Brno (Soběšice), over Vienna and Graz to Varaždin by establishing and surveying a trigonometric chain. That distance amounts to 320 km, i.e. the difference between latitude of the starting and finishing points of the chain equaled $2^{\circ} 56' 45.85''$. Two baselines were measured directly between Wiener Neustadt and Neunkirchen of 6410.903 Vienna fathom (12 158.175 m) and between Seyring and Glizendorf in the Moravian field (Moravské pole, Marchfeld) of 6387.862 Vienna fathom (12 114.478 m). Liesganig published previous Vienna Meridian survey results in Philosophical Transactions in London in 1768 and the final results in Latin in *Dimensio Graduum Meridiani Viennensis et Hungarici* in 1770. His results were quickly criticized and subsequently subjected to validation. Trigonometric point Varaždin is the first and oldest trigonometric point in Croatia.

Keywords: meridian arc survey, trigonometric chain, Vienna Meridian, zenith sector, quadrant

1 Introduction

Famous Danish astronomer Tycho Brahe (1546–1601) was the first to establish and survey a trigonometric network in Öresund (nowadays on the border between Denmark and Sweden) between 1578 and 1579, but unfortunately did not calculate it. After that, Dutchman Willebrord Snel van Royen (Snellius) (1580–1626) established and surveyed a trigonometric network in The Netherlands and was the first to calculate it and determined the meridian length and thus Earth's radius. He described that work and published it as *Eratosthenes Batavus* in 1617 (Solarić, Solarić 2009).

Subsequently, trigonometric grids were established in Europe in order to determine Earth's size as accurately as possible. For example, the following trigonometric chains were established along the Paris Meridian in order to determine the meridian arc length and Earth's size: Jean Picard (1620–1682), Cassini I (1625–1712), Cassini II (1677–1756), Cassini III (1714–1784), Cassini IV (1748–1845) and others. However, that trigonometric chain was

later extended by Cassini III and others, so France was covered with a trigonometric network. Thus it was possible to map all details in the entire France and Cassini III published the first map of contemporary France consisting of 18 sheets, 1:870 000, in 1747. In 1790, Cassini III and Cassini IV also published a map of France consisting of 182 sheets, 1:86 400 (Solarić, Solarić 2013a, 2013b).

Meridian arc surveys helped to resolve the dispute on Earth's size. One side was represented by Newton and Huygens, who claimed Earth has the shape of a rotational ellipsoid with flattened poles, while the other side was represented by Cassinis, whose surveys of the Paris Meridian arc made them think Earth has bulging poles. The dispute was resolved by dispatching geodetic scientific expeditions to Peru (1735–1744) and Lapland (1736–1737) in order to survey a meridian arc near the equator and near the polar circle. These surveys proved that Newton and Huygens were right (Solarić, Solarić 2014a, 2014b).

Nevertheless, scientists continued to survey meridian arcs, for example Ruđer Bošković and Ch. Maire surveyed the meridian arc between Rome and Rimini (1750–1752)

Mjerenje duljine luka Bečkog meridijana od Brna do Varaždina

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Sažetak. U uvodu je dan kratki prikaz upotrebe trigonometrijskih lanaca za određivanje duljina lukova meridijana u Europi, ali i njihovo proširivanje na trigonometrijske mreže za izradu suvremenih točnih karata u Francuskoj. Poslije posjeta Ruđera Boškovića hrvatsko-ugarskoj kraljici i rimsko-njemačkoj carici Mariji Tereziji, ona je naložila isusovcu Josephu Liesganigu da izmjeri duljinu luka meridijana od Brna (Soběšica) preko Beča i Graza do Varaždina uspostavom i mjerenjem lanca trokuta. Taj je potez dug oko 320 km, tj. razlika geografskih širina polazne i završne točke toga lanca iznosila je $2^{\circ} 56' 45,85''$. Izravno su izmjerene dvije duljine baza trigonometrijskog lanca i to između Wiener Neustadta i Neunkirchena duga 6410,903 bečkih hvata (12 158,175 m) i između Seyringa i Glizendorfa u Moravskom polju (Moravské pole, Marchfeld) duga 6387,862 bečka hvata (12 114,478 m). Prethodne rezultate mjerenja duljine Bečkog meridijana Liesganig je objavio u *Philosophical Transactions* u Londonu 1768., a poslije i konačne rezultate na latinskom jeziku u djelu *Dimensio Graduum Meridiani Viennensis et Hungarici* 1770. godine. Njegovi su rezultati ubrzo bili kritizirani, a poslije i provjeravani. Trigonometrijska točka Varaždin prva je i najstarija trigonometrijska točka u Hrvatskoj.

Ključne riječi: mjerenje duljine luka meridijana, trigonometrijski lanac, Bečki meridijan, zenitni sektor, kvadranta

1. Uvod

Slavni danski astronom Tycho Brahe (1546–1601) prvi je postavio i izmjerio trigonometrijsku mrežu u Öresundu (danas na granici između Danske i Švedske) između 1578. i 1579. godine, ali je nažalost nije izračunao. Poslije njega je Nizozemac Willebrord Snel van Royen (Snellius) (1580–1626) postavio i izmjerio trigonometrijsku mrežu u Nizozemskoj i prvi je izračunao te uz to odredio duljinu luka meridijana i na taj način radius Zemlje. Taj je rad opisao i objavio pod nazivom *Eratosthenes Batavus* 1617. godine (Solaric, Solaric 2009).

Nakon toga se u Europi počelo postavljati trigonometrijske mreže za što točnije određivanje Zemljinih dimenzija. Tako su u Francuskoj postavljali trigonometrijske lance uzduž Pariškog meridijana za određivanje duljine luka meridijana, odnosno Zemljinih dimenzija: Jean Picard (1620–1682), Cassini I. (1625–1712), Cassini II. (1677–1756), Cassini III. (1714–1784), Cassini IV. (1748–1845) i drugi. Međutim, poslije su taj trigonometrijski lanac proširivali Cassini III. i drugi pa je područje Francuske bilo

prekriveno trigonometrijskom mrežom. Na taj način bilo je omogućeno kartiranje svih detalja čitave Francuske i Cassini III. je izdao prvu suvremenu kartu Francuske u mjerilu 1:870 000 na 18 listova 1747. godine. Poslije su Cassini III. i Cassini IV. izdali i kartu Francuske u mjerilu 1:86 400 na 182 lista (Solaric, Solaric 2013a, 2013b).

Mjerenja duljina luka meridijana pomogla su i da se riješi znanstveni spor o Zemljini obliku. Na jednoj su strani bili Newton i Huygens, koji su na temelju teorijskih razmatranja tvrdili da Zemlja mora imati oblik rotacijskog elipsoida spljoštenog na polovima, a na drugoj Cassiniji koji su iz svojih mjerenja duljine luka Pariškog meridijana tvrdili da je Zemlja na polovima ispupčena. Taj je spor riješen slanjem geodetskih znanstvenih ekspedicija u Peru (1735–1744) i Lapland (1736–1737) na izmjeru duljine luka meridijana u blizini ekvatora i u blizini polarnog kruga. Ta su mjerenja potvrdila da su Newton i Huygens bili u pravu (Solaric, Solaric 2014a, 2014b).

Međutim, znanstvenici su nastavili s mjerenjima duljina luka meridijana, pa je tako i Ruđer Bošković zajedno

(Solarić, Solarić 2016, Lapaine 2016). Comparing their results with previous surveyes by other authors made Bošković think Earth is not shaped like a rotational ellipsoid. Therefore, he wanted to continue surveying meridian arcs in various locations on Earth. Namely, even before surveying the meridian arc between Rome and Rimini, Bošković had thought about surveying meridian arcs in Brazil, Austria, near Torino and in North America.

Bošković was on a diplomatic visit to Vienna from April 1757 to spring of 1758 in order to represent Republic of Lucca (Italy) in the dispute with Grand Duchy of Tuscany and waited for a reception by Croatian-Hungarian Queen and Roman-German Empress Maria Theresa (Čubranić 1961, page 103). He proposed conducting geodetic-astronomic surveys in Austria in order to determine the meridian arc length and produce contemporary accurate maps. Maria Theresa accepted Bošković's proposal so as not to fall behind other leading European countries and in 1760 ordered Jesuit Joseph Liesganig to survey the meridian between Brno (Soběšice) and Varaždin and also to conduct surveys in Hungary and Galicia. Ruđer Bošković and Joseph Liesganig were both Jesuits, knew each other and corresponded to each other (Tolomeo 1991).

2 Joseph Liesganig

Joseph Liesganig (1719–1799) was born in Graz. He was a Jesuit, theologian, astronomer, mathematician and geodesist. He joined the Society of Jesus in 1734 and was educated at the Jesuit College in Vienna. He worked as a mathematics teacher in Graz from 1742 and from 1744 in Linz. After becoming ordained in 1748, he went to Kormarno in 1749 as a German preacher. He was then appointed historian and mathematician in the Society of Jesus. In addition, he worked as a mathematics professor at the University of Vienna from 1752. He was also the chief of the observatory in Vienna from 1756 until the Society of Jesus abolished in 1773.

On proposal by Ruđer Bošković in 1757, when was in Vienna for a long time, Liesganig and Joseph Ramspoeck constructed a zenith sector with radius of 10 Vienna feet (approximately 3 m). Liesganig also constructed and Ramspoeck produced a quadrant with radius of 2.5 Vienna feet which was equipped with measuring screws for increased accuracy in measuring angles. In 1758, Liesganig employed his zenith sector and determined the latitude of the St. Stephen church belfry in Vienna was $48^{\circ} 12' 34.5''$.

Liesganig conducted the astronomic surveys, geodetic survey of the part of the Vienna Meridian arc from Soběšice near Brno to the church tower in Varaždin, and accompanying data processing, from 1758 to 1768



Fig. 1 Memorial plaque in honour of Josef Liesganig located in the building of *Alter Universität* (Old University) in Graz placed in 1931

Slika 1. Spomen ploča podignuta u čast Josefu Liesganigu smještena je u zgradi *Alter Universität* (Staro sveučilište) u Grazu, a postavljena je 1931. godine

(Vykutil 1982, page 421).

Liesganig started surveying the Budapest Meridian arc in Hungary from Szeged to Peterwardein (nowadays Petrovaradin in Serbia) in 1769. There were twenty-six triangles in the trigonometric chain, and trigonometric chain base lengths near Kistelek and Csurog were surveyed directly.

Liesganig was engaged with surveying the trigonometric network in eastern Galicia and Lodomeria (nowadays Vladimir-Volynsky district in Ukraine) from 1772 to 1774. He was also the imperial and royal building inspector in Lemberg (nowadays Lviv) at the same time, as well as a mathematics professor at *Collegium Nobilium* and a province director of the military engineering (Allmer 1987, Dörflinger 2004, Drbal 2014, 2015, Embacher 1962).

A memorial plaque was placed in his honor in the building of *Alte Universität* (Old University), established in 1586 in Graz (Fig. 1). The plaque reads:

In memory of Styrian scientist Josef Liesganig,
* 12. 11. 1719. in Graz, † 4. 3. 1799. in Lemberg
He started his universal career in this location.
His main work were geographic based
survey of meridian degrees
1762 – 1769
County of Styria and city of Graz, 1931.

s Ch. Maireom izmjerio duljinu luka meridijana između Rima i Riminija (1750–1752) (Solarić, Solarić 2016, Lapaine 2016). Usporedba njihovih mjerenja s prethodnima mjerenjima drugih autora ukazivala je Boškoviću da Zemlja neće imati oblik rotacijskog elipsoida. Stoga je želio da se nastavi s mjerenjima duljina lukova meridijana na raznim mjestima na Zemlji. Naime, on je i prije mjerenja duljine luka meridijana od Rima do Riminija pomišljao mjeriti duljinu luka meridijana na geografskim širinama u Brazilu, Austriji, okolici Torina i u Sjevernoj Americi.

U diplomatskom posjetu Beču Bošković je boravio od travnja 1757. do proljeća 1758. obavljajući poslove zastupanja republike Luce (iz Italije) u sporu s velikim vojvodstvom Toscanom i čekao na prijem kod hrvatsko-ugarske kraljice i rimsko-njemačke carice Marije Terezije (Čubranić 1961, str. 103). Mariji Tereziji predložio je da se i u Austriji izvedu geodetsko astronomski mjerenja koja bi omogućila određivanje duljine luka meridijana i izradu suvremenih točnih karata. Carica je prihvatila Boškovićev prijedlog kako njezino carstvo ne bi zaostajalo za drugim vodećim europskim zemljama te je 1760. godine naložila isusovcu Josephu Liesganigu da izmjeri duljinu luka meridijana između Brna (Soběšica) i Varaždina i zatim izvede izmjeru u Ugarskoj i Galiciji. Važno je istaknuti i činjenicu da su se Ruđer Bošković i Joseph Liesganig, obojica isusovci, poznavali i dopisivali (Tolomeo 1991).

2. Joseph Liesganig

Joseph Liesganig (1719–1799) rođen je u Grazu. Bio je isusovac, teolog, astronom, matematičar i geodet. U Družbu Isusovu ušao je 1734. godine i stekao obrazovanje na isusovačkom kolegiju u Beču. Od 1742. radio je kao učitelj matematike u Grazu i od 1744. kao profesor matematike u Linzu. Nakon zaređenja 1748. godine otišao je 1749. godine u Komarno kao njemački propovjednik. Zatim je imenovan povjesničarom i matematičarom u Družbi Isusovoj. Osim toga od 1752. bio je profesor matematike na Sveučilištu u Beču. Načelnik na astronomskoj zvezdarnici u Beču bio je od 1756. pa sve do ukidanja isusovačkog reda 1773. godine, gdje je i započeo svoju znanstvenu djelatnost.

Po prijedlogu Ruđera Boškovića 1757. godine, kad je duže vrijeme boravio u Beču, Liesganig je zajedno s Josephom Ramspoeckom konstruirao zenitni sektor radijusa 10 bečkih stopa (oko 3 m). On je konstruirao i kvadrant, koji je izradio Ramspoeck s radijusom 2,5 bečke stope, a koji je bio opremljen mjernim vijcima za povećanje točnosti očitavanja kutova. Godine 1758. Liesganig je s pomoću svojeg zenitnog sektora odredio da geografska širina tornja crkve sv. Stjepana u Beču iznosi $48^{\circ} 12' 34,5''$.

Astronomska mjerenja, geodetsku izmjeru duljine dijela luka Bečkog meridijana od Soběšica pokraj Brna preko Beča i Graza do crkvenog tornja u Varaždinu, kao i obradu podataka mjerenja, izvodio je od 1758. do 1768. (Vykutil 1982, str. 421).

Godine 1769. Liesganig je započeo izmjeru duljine luka Budimpeštanskog meridijana u Mađarskoj od Szegeda do Peterwardeina (danas Petrovaradina u Srbiji). U trigonometrijskom lancu bilo je dvadeset šest trokuta, a izravno su mjerene duljine baza trigonometrijskog lanca u blizini Kisteleka i Csuróga.

Od 1772. do 1774. Liesganig je bio angažiran u mjerenjima na trigonometrijskoj mreži u istočnoj Galiciji i Lodomeriji (danas oblast Vladimir-Volynsky u Ukrajini). U isto doba bio je na položaju carskog i kraljevskog inspektora zgrada u Lembergu, danas Lavovu, a od 1775. profesor mehanike na *Collegium Nobilium*, kao i pokrajinski ravnatelj vojne inženjerije (Allmer 1987, Dörflinger 2004, Drbal 2014, 2015, Embacher 1962).

Njemu u čast podignuta je spomen ploča u Grazu (sl. 1) u zgradi *Alte Universität* (Staro sveučilište) koji je osnovan 1586. godine. Na njoj piše:

Za sjećanje na štajerskog znanstvenika
Josefa Liesganiga,

* 12. 11. 1719. u Grazu, † 4. 3. 1799. u Lembergu

Na ovom mjestu počeo je svoju univerzalnu karijeru.
Njegovo glavno djelo bilo je geografski utemeljena
gradusna izmjera meridijana

1762 – 1769

Zemlja Štajerska i grad Graz 1931.

3. Duljina Bečkog meridijana od Brna (Soběšica) do Varaždina

Na osnovi iskustva drugih država, posebice u Francuskoj, došlo se do saznanja da se katastarska i topografska izmjera moraju osloniti na trigonometrijsku mrežu. Tako se na zapovijed carice Marije Terezije Austro-Ugarsko Carstvo počinje sustavno pokrivati trigonometrijskom mrežom koju je Joseph Liesganig razvijao u Austriji od 1760. i u Ugarskoj od 1769. godine. Ta je mreža bila nadovezana na francusku trigonometrijsku mrežu Cassinija i pokrivala je područje na današnjem hrvatskom teritoriju sve do Varaždina (Macarol 1977).

Liesganig je odredio duljinu dijela meridijanskog luka kroz Beč od kapele Sv. Križ u mjestu Soběšice (udaljenom 5 km od Brna) u Češkoj (Moravskoj), preko Beča (crkve sv. Stjepana), Graza i četiri točke u Sloveniji, do tornja crkve u Varaždinu izmjerom trigonometrijskog lanca koji je dug oko 320 km (sl. 2). Pri tom je razlika

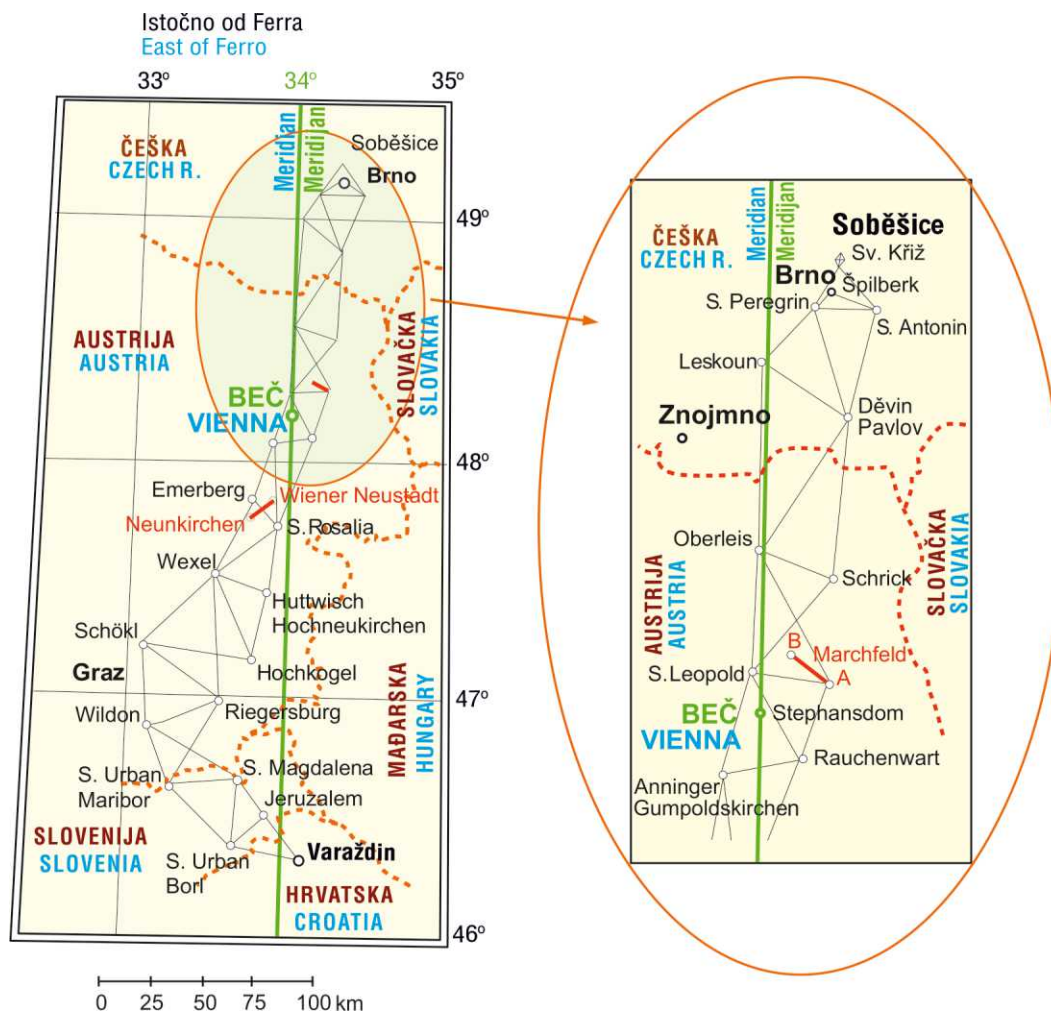


Fig. 2 Liesganig's trigonometric chain from Brno (Soběšice) to Varaždin (left) and a detailed description of the northern part of Liesganig's trigonometric chain from Brno (Soběšice) to Vienna (right) (according to Liesganig 1770)

Slika 2. Liesganigov trigonometrijski lanac od Brna (Soběšica) do Varaždina (lijevo) i detaljniji opis sjevernog dijela Liesganigovog trigonometrijskog lanca od Brna (Soběšica) do Beča (desno) (prema Liesganingu 1770)

(Soběšice) to Varaždin

Based on experiences from other countries, especially France, it was concluded that cadastral and topographic surveys have to rely on a trigonometric network. As ordered by Empress Maria Theresa, Austrian-Hungarian Empire started to become covered with a trigonometric network developed by Joseph Liesganig in Austria from 1760 and in Hungary from 1769. The network was connected to the French trigonometric network established by Cassinis and covered the area of contemporary Croatia up to Varaždin (Macarol 1977).

Liesganig determined the length of the meridian arc through Vienna from the chapel of St. Kříž in Soběšice (5 km from Brno) in Czech Republic (Moravia), over Vienna (church of St. Stephen) and Graz, then four points in Slovenia to the church belfry in Varaždin by surveying

the trigonometric chain (approximately 320 km) (Fig. 2). The difference between latitudes at endpoints equaled $2^{\circ} 56' 45.85''$, and there were 22 triangles in the trigonometric chain. Certain church towers were chosen as trigonometric points and 5 Vienna fathom (about 10 m) high four-sided fir or spruce pyramids were constructed only in some locations.

3.1 Direct Measurement of the Trigonometric Chain Baselines

Liesganig wanted to directly measure baselines of the trigonometric chain at its beginning and end, just like Ruđer Bošković had done with the Rome – Rimini meridian arc. However, Liesganig could not find a suitable terrain on which to set the base at the beginning and end of his trigonometric chain. He found suitable terrain

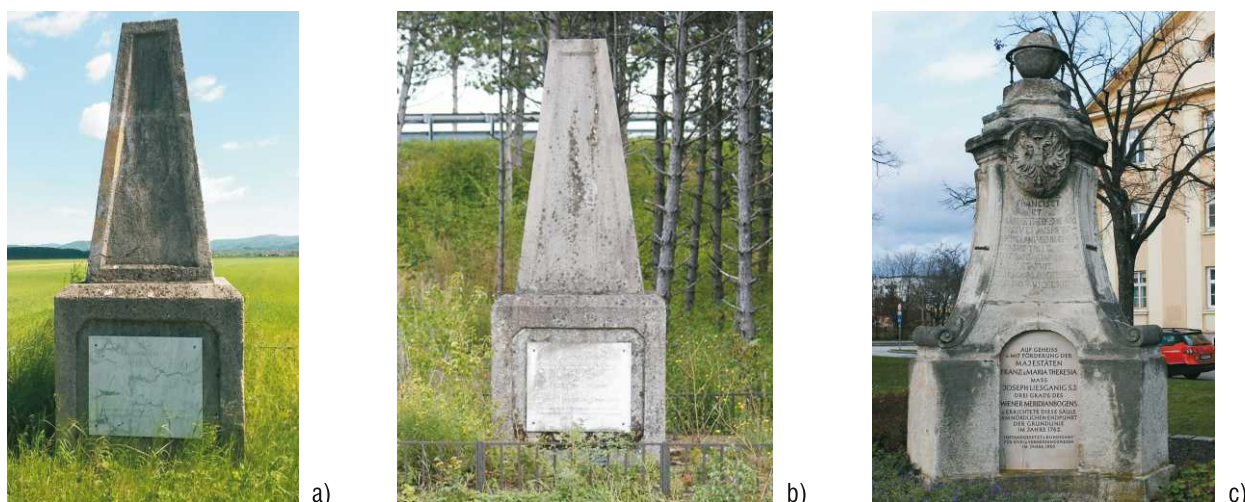


Fig. 3 a) Monument at the southern end point of Liesganig's base in Neunkirchen (Photo Lapaine, 2015), b) monument at the northern end point of Liesganig's base in Wiener Neustadt (Photo Lapaine, 2015) and c) monument to Liesganig in Wiener Neustadt (Photo Lapaine, 2015)

Slika 3. a) Spomenik u blizini najjužnije krajnje točke Liesganigove baze u Neunkirchenu (Foto Lapaine, 2015), b) spomenik u blizini najsjevnije krajnje točke Liesganigove baze u Wiener Neustadtu (Foto Lapaine, 2015) i c) spomenik Liesganigu u Wiener Neustadtu (Foto Lapaine, 2015)

geografskih širina na krajnjim točkama iznosila $2^{\circ} 56' 45,85''$, a u trigonometrijskom lancu nalazila su se 22 trokuta. Kao trigonometrijske točke bili su izabrani pojedini crkveni zvonici, a samo na pojedinim mjestima izgrađivane su drvene četverostrane piramide iz jelovine ili smrekovine, često visoke pet bečkih hvata (oko 10 m).

3.1. Izravna izmjera duljina baza trigonometrijskog lanca

Liesganig je želio izravno izmjeriti duljine baza na početku i na kraju trigonometrijskog lanca, kao što je to činio i Ruđer Bošković pri mjerenju duljine luka meridijana Rim – Rimini. Međutim, Liesganig nije našao povoljan teren za postavljanje baze na početku i na kraju svojeg trigonometrijskog lanca. Povoljne ravne terenske uvjete pronašao je u blizini Wiener Neustadta (Bečkog Novog Mjesta), koji se nalazi oko 50 km južno od Beča. Tu bazu postavio je 1761. godine i izmjerio je njezinu duljinu između Wiener Neustadta i Neunkirchena. Dobio je da je ona duga 6410,903 bečkih hvata¹ (12 158,174 m).

Bazis u Wiener Neustadtu ima tri spomenika, dva u Wiener Neustadtu i jedan u Neunkirchenu (sl. 3a, 3b, 3c). Prijevod s njemačkog jezika na hrvatski jezik na najjužnijoj krajnjoj točki Liesganigove baze u Neunkirchenu (sl. 3a) glasi:

Austrijska državna izmjera, najjužnja krajnja točka, bazis Bečkoga Novog Mjesta, podignuo Vojnogeografski institut 1857., popravio Državni ured za geodeziju 1928. i 1967.

Prijevod s njemačkog jezika na hrvatski jezik na najsjevnijoj krajnjoj točki Liesganigove baze u Wiener Neustadtu (sl. 3b) preveden na hrvatski glasi:

Austrijska državna izmjera, najsjevnija krajnja točka, bazis Bečkoga Novog Mjesta, podignuo Vojnogeografski institut 1857., popravio Državni ured za geodeziju 1928. i 1967.

Treći spomenik podignut je u Wiener Neustadtu (sl. 3c), a otkrio ga je osobno princ Kaunitz. Prijevod teksta sa spomenika s njemačkoga na hrvatski glasi:

Po naredbi i zahtjevu njihovog veličanstva Franza i Marije Terezije Josip Liesganig mjerio je tri stupnja Bečkog meridijanskog luka i podigao je ovaj stup na sjevernoj krajnjoj točki baze 1762. godine. Popravio Bundesamt für Eich- und Vermessungswesen 1930.

Sljedeće godine Liesganig je postavio drugu bazu trigonometrijskog lanca sjeveroistočno u blizini Beča, između Seyringa i Glizendorfa u Moravskom polju (Moravské pole, Marchfeld). Ona je bila duga 6387,862 bečkih hvata (12 114,478 m). Naime, tu je bazu Liesganig želio iskoristiti i za produljenje trigonometrijskog lanca iz Francuske u Austriju, koji prolazi Pariškom paralelom. Na tom je trigonometrijskom lancu u Francuskoj radio Cassini III. (Cassini de Thury) (Embacher 1951).

¹ Jedan bečki hvat dijeli se na šest stopa, a stopa se dijeli na 12 palaca: 1° (bečki hvat) = 1,896484 m, $1'$ (b. stopa) = 0,316081 m, $1''$ (b. palac) = 2,634 cm (Macarol 1977, str. 27).

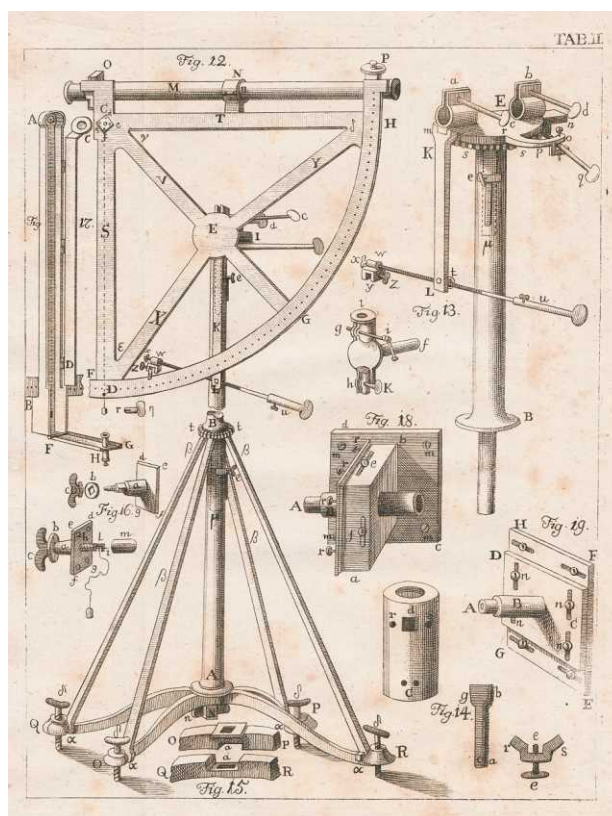
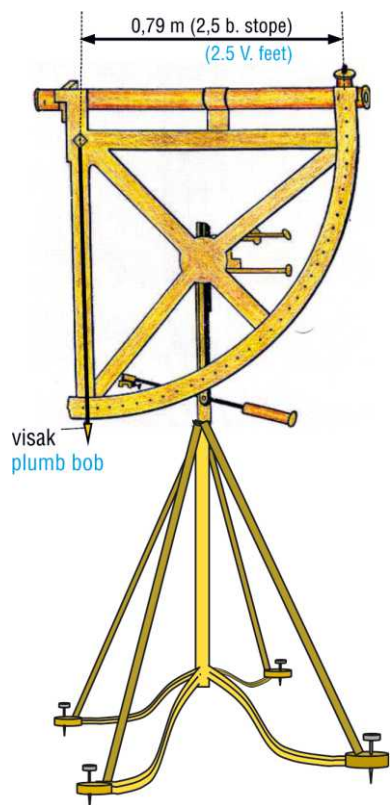


Fig. 4 Liesgang's angle-measuring quadrant, usually placed on a metal stand (according to Liesganiung 1770)
Slika 4. Liesgangov kvadrant za mjerenje kutova koji se postavljao na metalni stativ (prema Liesganiungu 1770)

near Wiener Neustadt, which is approximately 50 km south of Vienna. He set the base on 1761 and measured its length between Wiener Neustadt and Neunkirchen, the result being 6410.903 Vienna fathoms¹ (12 158.174 m).

Wiener Neustädter Grundlinie has three monuments, two in Wiener Neustadt and one in Neunkirchen (Fig. 3a, 3b, 3c). A German transcription on the southernmost endpoint of Liesganig's base in Neunkirchen (Fig. 3a) translates to:

Austrian State Survey, the Southernmost endpoint, Vienna Neustadt baseline, erected by Military and Geographic Institute 1857, Repaired by Bundesvermessungsamt in 1928 and 1967.

A German transcription on the northernmost endpoint of Liesganig's base in Wiener Neustadt (Fig. 3b) translates to:

Austrian State Survey, the Northernmost endpoint, Vienna Neustadt baseline, erected by Military and Geographic Institute 1857, Repaired by Bundesvermessungsamt in 1928 and 1967.

¹ The third monument was constructed in Wiener Neustadt. 1 Vienna fathom is divided into 6 feet, and a foot is divided into 12 inch: 1° (Vienna fathom) = 1.896484 m, 1' (Vienna foot) = 0.316081 m, 1" (Vienna inch) = 2.634 cm (Macarol 1977, page 27).

Neustadt (Fig. 3c) and opened by Chancellor Prince Kaunitz himself. A German transcription on the monument translates to:

By decree and request of His Majesty Francis and Maria Theresa, Josip Liesganig surveyed three degrees of the Vienna meridian arc and erected this pillar on the northernmost point of the base in 1762. Repaired by Bundesamt für Eich- und Vermessungswesen in 1930.

In the following year, Liesganig set a second baseline of the trigonometric chain northeast near Vienna, between Seyring and Glizendorf in the Moravian field (Moravské pole, Marchfeld). It was 6387.862 Vienna fathoms (12 114.478 m) long. Namely, Liesganig also wanted to use that baseline to extend the trigonometric chain from France to Austria which intersects the Paris Parallel. Cassini III (Cassini de Thury) worked on that trigonometric chain in France (Embacher 1951).

In order to directly measure base lengths, Liesganig used 6 Vienna fathoms (about 11.4 m) long wooden rods, which were made out of various types of wood. Led by Liesganig and his associate Joseph Ramspoeck, sixteen workers placed measuring rods horizontally on the ground along a rope in the direction of the base. In doing

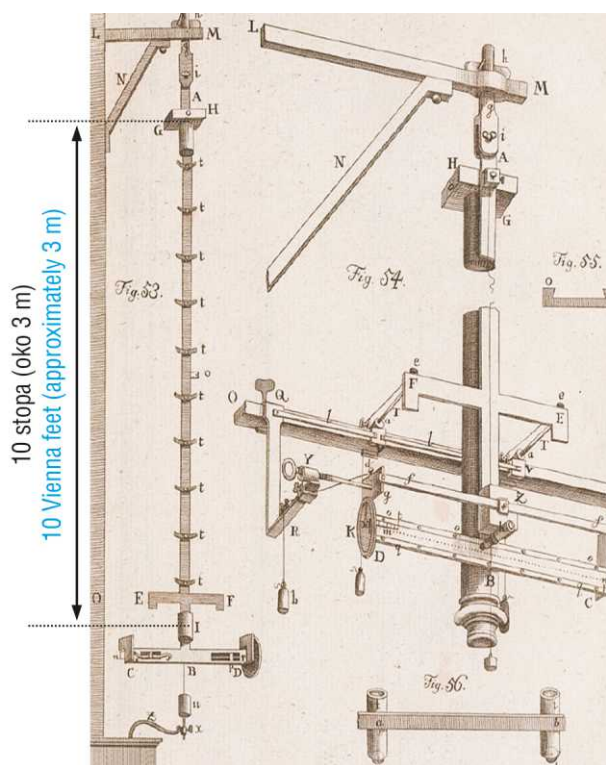


Fig. 5 Liesganig's 10 Vienna feet (approximately 3 m) long zenith telescope (Liesganig 1770)

Slika 5. Liesganigov zenitni teleskop dug 10 bečkih stopa (oko 3 m, Liesganig 1770)

Za izravno mjerenje duljina baza Liesganig je primijenio drvene letve duge šest bečkih hvata (oko 11,4 m) koje su se sastojale od više vrsta drveta. Pod vodstvom Liesganiga i njegovog pomoćnika Josipa Ramspoecka 16 radnika polagalo je mjerne letve na tlo u horizontalni položaj uz unaprijed postavljeno užu u pravcu baze. Pritom su različiti komadi drveta polagani ispod letava za njihovo grubo horizontiranje. Konačno horizontiranje mjernih letava izveo je Liesganig osobno s pomoću libele². Brzina mjerenja duljina iznosila je oko 250 do 300 m u satu. Nakon što je Liesganig izmjerio duljinu baze tri puta, odredio je visinske razlike krajnjih točaka baze. Tako je mogao reducirati duljinu baze u Wiener Neustadt na horizont njezine sjeverne točke. Međutim, poslije je još trebao reducirati duljinu jednog stupnja luka meridijana na razinu mora.

Da bi Liesganig mogao usporediti rezultate svojih mjerenja s francuskim, dobio je iz Pariza od Caniveta kopiju toisea, francuske osnovne jedinice za duljinu izrađenu iz željeza. Tako je mogao utvrditi da 1 toise iznosi 1,02764 bečkog hvata.

² Libelu za horizontiranje izumio je Melchisedec Thévenot 1660. godine (Macarol 1977, str. 126).

3.2. Mjerenje kutova u trokutima trigonometrijskog lanca

Horizontalni i vertikalni kutovi u trokutima trigonometrijskog lanca mjereni su s pomoću kvadranta (sl. 4) dimenzija 0,79 m (2,5 bečke stope), koji je konstruirao sam Liesganig sa svojim mehaničarom Ramspoeckom. Kvadrant je bio opremljen jednim pokretnim i jednim čvrstim durbinom, a stajao je na željeznom stativu. Fino očitavanje kutova izvodilo se s pomoću mikroskopskog vijka. Liesganig se na početku koristio viskom, a kasnije libelom dugom jednu bečku stopu (1,9 m). Kvadrant i mjerni pribor transportirani su između susjednih trigonometrijskih točaka s najvećom pažnjom u dva velika sanduka. Pritom je uvijek sanduk u kojem je bio kvadrant prevožen kolima u kojima se vozio Liesganig te je tako kvadrant bio čitavo vrijeme pod njegovim nadzorom. Prije svakog mjerenja kutova kvadrant je rektificiran na svakom stajalištu, a Liesganig je sam mjerio sve kutove u trigonometrijskoj mreži.

Za ekscentrična stajališta na kojima Liesganig nije mogao postaviti kvadrant na središte trigonometrijske točke, odredio je redukciju s pomoću mjerenja duljine okomica od središta na vizurnu liniju. U tu je svrhu sastavio i vlastite tangentne tablice.

Kutove izmjerene iz stajališta na vizirane točke reducirao je na horizont. Zatim je u trokutima kontroliran zbroj svih triju kutova, a poslije toga su kutovi popravljeni tako da je svakom kutu dodana popravka od $1/3$ nesuglasice (Embacher, P. 1951).

3.3. Računanje duljina stranica u trokutima

Liesganig je, polazeći od duljine baze Wiener-Neustadt reducirane na horizont u njezinoj sjevernoj točki, ali i nereducirane na horizont mora, izračunao s pomoću sinusova poučka duljine stranica svih trokuta u trigonometrijskom lancu. Kako je prethodno kutove reducirao u trokutima na horizont i izjednačio zbroj kutova u trokutima na 180° , to je za kontrolu mogao izračunati preko svih trokuta u lancu i duljinu baze u Moravskom polju. Dobio je da je razlika između izračunane duljine baze u Moravskom polju preko trokuta u lancu i izravno izmjerene duljine te baze iznosila svega jednu bečku stopu (Embacher, P. 1951).

3.4. Astronomska mjerenja

a) Određivanje razlika geografskih širina

Mjerenju razlika geografskih širina mora se posvetiti posebna pozornost jer razlika geografske širine od jedne

so, various pieces of wood were placed below the rods for rough leveling. Liesganig personally carried out final leveling using a level². Lengths were measured at a speed of about 250 to 300 m per hour. After Liesganig had surveyed the base length three times, he determined differences in height between base endpoints. In such a way, he was able to reduce the base length in Wiener Neustadt to the horizon of its northernmost point. Nevertheless, he subsequently had to reduce the length of one meridian arc degree to the sea level.

In order to be able to compare his results with the French results, Liesganig obtained an iron copy of toise (French basic unit of length) from Canivet from Paris. Thus he was able to determine that 1 toise equals 1.02764 Vienna fathoms.

3.2 Measurement of Angles in Triangles of the Trigonometric Chain

Horizontal and vertical angles in triangles of the trigonometric chain were measured using a 0.79 m (2.5 Vienna fathoms) quadrant (Fig. 4), constructed by Liesganig and his mechanic Ramspoeck. The quadrant was equipped with one mobile and one fixed spyglass and was placed on an iron stand. Fine reading of angles was done using a microscopic screw. Liesganig first used a plumbline, and later a 1 Vienna fathom (1.9 m) long level. The quadrant and measuring equipment were carefully transported in two large chests. Liesganig always travelled in the carriage with the chest containing the quadrant and kept an eye on it. Prior to each measurement, the quadrant was rectified in each observation point and Liesganig personally measured all angles in the trigonometric network.

When Liesganig could not place the quadrant in the centre of the trigonometric point he determined the reduction by measuring lengths of normals from the centre to the line of sight. He also composed his own tangent tables for this purpose.

Liesganig reduced to the horizon the angles measured from the observation point to the viewpoints. He then checked whether the sum of angles in triangles was 180° and then adjusted angles so that $1/3$ of the difference was added to each angle (Embacher, P. 1951)

3.3 Calculation of Lengths of Sides in Triangles

Starting with the baseline length of Wiener Neustadt reduced to the horizon in its northernmost point, but not to the sea horizon, Liesganig applied the sine law to

calculate lengths of sides of all triangles in the trigonometric chain. Since he previously reduced angles in triangles to the horizon and adjusted the sum of angles in triangles to 180° , he was able to calculate the baseline length in the Moravian field using all triangles in the chain. The difference between the calculated baseline length in the Moravian field and the directly measured one was only 1 Vienna fathom (Embacher, P. 1951).

3.4 Astronomic Measurements

a) Determination of differences in latitudes

Special attention needs to be paid to the measurement of differences in latitudes because a difference of just one second of angle ($1''$) on Earth equals approximately 30 m. This is why Liesganig and his mechanic Ramspoeck listened to R. Bošković's advice and started constructing a zenith telescope (Fig. 5) in order to determine the difference in latitudes between two locations in 1757. The telescope was about 10 Vienna feet (about 3 m) long. The zenith sector was better than quadrant because one is able to choose stars intersecting the meridian near zenith of both points. In such a way, one avoids errors caused by atmospheric refraction.

Liesganig determined latitude of Vienna from the known latitude of Paris and the surveyed difference between latitudes from simultaneous astronomic measurements in Vienna and Paris. Frenchman Nicolas Louis de Lacaille (1713–1762) conducted measurements in Paris, while Liesganig did the same in Vienna. Thus, Liesganig determined in 1758 that Vienna had the latitude of $48^\circ 12' 34.5''$. Then he determined latitudes of Soběšice, Brno, Graz and Varaždin in the same way.

b) Astronomic determination of the orientation of the trigonometric chain

Liesganig determined the direction of sides in the trigonometric chain in relation to the Vienna Meridian astronomically, by observing positions of the Sun. For example, he measured the origin azimuth between the Jesuit College in Vienna and the dome in Leopoldsberg from repeated observations of positions of the Sun on July 21, 1765. The resulting azimuth equaled $343^\circ 12' 39''$. Then he used that azimuth and angles measured in triangles of the trigonometric chain to calculate bearing angles of other sides in the trigonometric chain. He also calculated the convergence of meridians from rectangular spherical triangles in order to be able to compare the calculated bearing angles with the measured azimuths. Namely, the triangle chain does not comple-

² Level was invented by Melchisedec Thévenot in 1660 (Macarol 1977, page 126).

kutne sekunde (1'') na površini Zemlje iznosi oko 30 m. Zato su Liesganig i njegov mehaničar Ramspoeck, po savjetu R. Boškovića, počeli 1757. godine izrađivati zenitni teleskop (sl. 5) za određivanje razlike geografskih širina između dva mjesta (Liesganig 1765). Teleskop je bio dugačak 10 bečkih stopa (oko 3m). Prednost zenitnog sektora pred kvadrantom sastoji se u tome što se pri astronomskom mjerenju s pomoću zenitnog sektora izaberu zvijezde koje prolaze meridijanom u blizini zenita jedne i druge točke. Na taj se način izbjegavaju pogreške u izmjeri razlika geografskih širina koje su uzrokovane atmosferskom refrakcijom.

Geografsku širinu Beča Liesganig je odredio iz poznate geografske širine Pariza i izmjerene razlike geografskih širina iz simultanih astronomskih mjerenja u Beču i u Parizu. Pri tom je Francuz Nicolas Louis de Lacaille (1713–1762) mjerio u Parizu, a Liesganig u Beču. Tako je 1758. godine dobiveno da Beč ima geografsku širinu $48^{\circ} 12' 34,5''$. Zatim je Liesganig istim načinom odredio i geografske širine Soběšica, Brna, Graza i Varaždina.

b) Određivanje orijentacije trigonometrijskog lanca astronomskim načinom

Smjer stranica u trigonometrijskom lancu u odnosu na Bečki meridijan Liesganig je odredio astronomskim načinom opazajući položaje Sunca. Kvadrantom je izmjerio ishodišni azimut između Jezuitskog kolegija u Beču i kupole u Leopoldsbergu iz ponavljanih opažanja položaja Sunca 21. srpnja 1765. Dobio je da taj azimut iznosi $343^{\circ} 12' 39''$. Zatim je mogao, polazeći od tog azimuta i izmjerenih kutova u trokutima trigonometrijskog lanca, izračunati smjerne kutove ostalih stranica lanca. Da bi izračunane smjerne kutove mogao usporediti s tamo izmjerenim azimutima, izračunao je i konvergenciju meridijana iz pravokutnih sfernih trokuta. Naime, lanac trokuta ne ide točno po Bečkom meridijanu te je i tu korekciju morao uzeti u račun. Kada je usporodio korigirane smjerne kutove s izravno izmjerenim azimutima jedne stranice trokuta u Brnu i druge u Grazu, dobio je razlike od $34''$, odnosno $16''$. Uzrok tim većim razlikama Liesganig je pripisao netočnosti određivanju azimuta s pomoću Sunca (Embacher, P. 1951).

3.5. Računanje udaljenosti svakog stajališta od okomice na Bečki meridijan

Kroz jednostavne projekcije trokutnih stranica na Bečki meridijan Liesganig je izračunao pravokutne koordinate točke ili, kako je to Liesganig nazvao, udaljenost svakog stajališta od okomice i Bečkog meridijana.

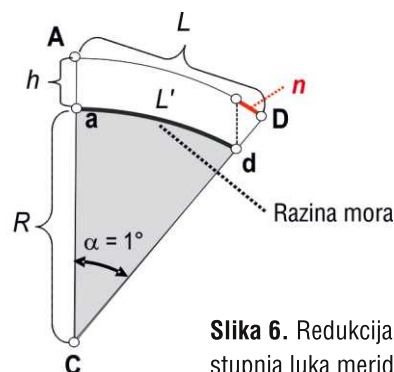
Poslije je reducirao te duljine na toranj crkve sv. Stjepana u Beču.

3.6. Redukcija duljine jednog stupnja luka meridijana na razinu mora

Liesganig je za redukciju duljine jednog stupnja luka meridijana na razinu mora odredio nadmorsku visinu zadnje točke s pomoću barometra. Da bi reducirao duljinu jednog stupnja meridijana na razinu mora, izračunao je da se duljina jednog stupnja luka meridijana, prema slici 6, mora skratiti za 2,3 bečka hvata (4,362 m). Do tog je rezultata došao primjenom formule

$$L - L' = \frac{L \cdot h}{R + h}$$

u kojoj je R polumjer zakrivljenosti određen Eulerovom formulom, izmjerene veličine L duljine jednog stupnja luka meridijana, h nadmorska visina i L' duljina luka meridijana koji odgovara jednom stupnju reducirana na razinu mora.



Slika 6. Redukcija duljine jednog stupnja luka meridijana na razinu mora

4. Trigonometrijska točka Varaždin

Liesganig je postavio posljednju trigonometrijsku točku na Bečkom meridijanskom luku u Varaždinu na zvoniku uz isusovački samostan. U njegovu je sastavu i crkva Uznesenja Blažene Djevice Marije na nebo, koja je završena 1646., a njezin toranj 1676. godine (sl. 7). Danas je ta crkva varaždinska katedrala, a isusovački samostan su nakon ukidanja isusovačkog reda 1773. godine preuzeli pavlini. Samostan zajedno s crkvom, gimnazijom i sjemeništem danas tvori najvredniji kompleks ranobarokne arhitekture u gradu Varaždinu. U njemu je smješten Fakultet organizacije i informatike Sveučilišta u Zagrebu.

Liesganig je u svojem djelu *Dimensio Graduum Meridiani Viennensis et Hungarici* iz 1770. godine naveo da je posljednja trigonometrijska točka u Bečkom meridijanskom luku *turris templi Collegii S.J.* (toranj hrama zajednice S.J.) u Varaždinu. Skraćena S. J. na latinskom znači *Societa Jesu*, tj. Družba Isusova. U *Dimensio Graduum ...* navedeno je

tely coincide with the Vienna Meridian and Liesganig had to account for that correction. When he compared corrected bearing angles with directly measured azimuths of one side of angle in Brno and another in Graz, the differences were 34" (seconds of angle) and 16", respectively. Liesganig attributed these large differences to the lack of accuracy of determining azimuths using Sun (Embacher, P. 1951).

3.5 Calculation of Distances of Each Observation Point from the Normal to the Vienna Meridian

Using simple projections of triangle sides to the Vienna Meridian, Liesganig calculated rectangular point coordinates, which he referred to as the distance of each observation point from the normal and the Vienna meridian. He later reduced those lengths to the tower of the Church of St. Stephen in Vienna.

3.6 Reduction of the Length of one Meridian Arc Degree to Sea Level

In order to reduce the length of one meridian arc degree to sea level, Liesganig determined the elevation of the final point using a barometer. He calculated that the length of one meridian arc degree, according to Fig. 6, has to be shortened by 2.3 Vienna fathoms (4.362 m). He reached this result by applying formula

$$L - L' = \frac{L \cdot h}{R}$$

in which R is the radius of curvature obtained by the Euler's formula, L' length of one meridian arc degree reduced on the sea level, h is elevation, and L calculated values length of one meridian arc degree.

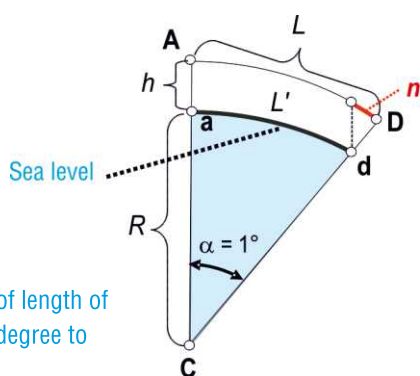


Fig. 6 Reduction of length of one meridian arc degree to sea level

4 Varaždin Trigonometric Point

Liesganig set the final trigonometric point of the Vienna meridian arc by the Jesuit monastery belfry in



Fig. 7 Belfry of the Jesuit Church of Assumption of Virgin Mary into Heaven – nowadays cathedral in Varaždin; end trigonometric point of the Vienna meridian arc (Photo Lapaine, 2015)

Slika 7. Toranj isusovačke crkve Uznesenja Blažene Djevice Marije na nebo, danas varaždinske katedrale, posljednja je trigonometrijska točka Bečkog meridijanskog luka (Foto Lapaine, 2015)

Varaždin. A part of it is the Church of Assumption of Virgin Mary into Heaven, which was completed in 1646, while its tower was finished in 1676 (Fig. 7). Nowadays, the church is Varaždin's cathedral, and the Jesuit monastery was taken over by Paulines after the Jesuit Order was abolished in 1773. The monastery, church, high school and seminary form the most valuable complex of early baroque architecture in Varaždin. Nowadays, it houses the Faculty of Organization and Informatics, University of Zagreb.

In his work *Dimensio Graduum Meridiani Viennensis et Hungarici* from 1770, Liesganig stated that the final trigonometric point in the Vienna meridian is *turris templi Collegii S.J.* (belfry of the temple of the society S.J.) in Varaždin. The abbreviation S.J. in Latin means *Societas Jesu*, i.e. Society of Jesus. According to *Dimensio Graduum ...*, the final point in the Vienna trigonometric chain is the church belfry in Varaždin. Such a description would not suffice nowadays, because the historical centre of Varaždin features 11 church towers, six churches and three monasteries. Since Liesganig was a member of the Society of Jesus, it is completely understandable that he chose *templum Collegii S.J.* in Varaždin to be the final point in the trigonometric chain along the meridian arc



Fig. 8 Trigonometrijska točka St. Urban at Ankenstein (danas stari grad Borl) (lijevo) i Crkva Žalosne Majke Božje u Jeruzalemu blizu Ormoža okružena vinogradima (desno) (Foto Lapaine, 2015)

Slika 8. Trigonometrijska točka Sv. Urban (danas stari grad Borl) (lijevo) i Crkva Žalosne Majke Božje u Jeruzalemu blizu Ormoža okružena vinogradima (desno) (Foto Lapaine, 2015)

samo da je posljednja trigonometrijska točka u Bečkom trigonometrijskom lancu zvonik crkve u Varaždinu. Takav opis danas ne bi bio dovoljan jer u starogradskoj jezgri u Varaždinu ima 11 zvonika, 6 crkava i 3 samostana. Kako je Liesganig bio član Družbe Isusove, potpuno je razumljivo da je izabrao *templum Collegii S.J.* u Varaždinu kao posljednju trigonometrijsku točku u lancu trokuta uzduž meridijanskog luka od Brna (Soběšica) do Varaždina, a u čijem se sastavu nalazi zvonik crkve Uznesenja Blažene Djevice Marije na nebo. Naime, u Varaždinu franjevci imaju crkvu sv. Ivana Krstitelja sa zvonikom visokim 54,4 m, najvišim u Varaždinu, te bi inače za trigonometrijsku točku, po geodetskoj logici, bilo razumljivo izabrati taj najviši toranj.

S tornja u Varaždinu vide se dvije susjedne trigonometrijske točke u Sloveniji: Sv. Urban kod Ankensteina (danas stari grad Borl) i Jeruzalem (sl. 8) u kraju gdje se s posebnom pozornošću uzgaja vinova loza (Lapaine 2012). Preko te dvije trigonometrijske točke Varaždin je bio povezan na čitavi Liesganigov trigonometrijski lanac kojim je on odredio duljinu luka Bečkog meridijana od Soběšica do Varaždina.

5. Objava rezultata izmjere duljine luka Bečkog meridijana i novija istraživanja

Prvi dokument o prethodnim rezultatima izmjere duljine luka Bečkog meridijana Liesganig je objavio 1768. godine u londonskom *Philosophical Transactions* (sl. 9). Pritom je samo ukratko izložio rezultate svojih mjerenja, a u komentaru koji nije potpuno jasan piše da velika razlika u duljinama jednog stupnja luka meridijana na različitim širinama vjerojatno proizlazi pod utjecajem

okolnih brda. Zato treba pogledati ekstremne vrijednosti za duljine jednog stupnja luka meridijana, podcrtane u tablici 1, iz kojih se vidi da najveća razlika iznosi čak 466,3 toisea³ (908,8 m). Naime, prema Newtonovu teorijskom proračunu, razlika duljina za jedan stupanj luka meridijana između susjednih stupnjeva na geografskim širinama između 40° i 50° iznosi svega 13 toisea (Solarić, Solarić 2013b). Zato se Liesganigovo objašnjenje ne bi moglo prihvatiti kao neko posebno opravdanje, pa čak i kad se u račun uzme utjecaj okolnih brda.

Konačne rezultate izmjere Liesganig je napisao i objavio na latinskom jeziku u djelu *Dimensio Graduum Meridiani Viennensis et Hungarici* 1770. godine (sl. 10). Ti se rezultati malo razlikuju od prethodnih Liesganigovih rezultata iz 1767. i u tablici 1. Naglasimo da razlika između duljine jednog stupnja luka meridijana između Beča i Graza te Graza i Varaždina po tim popraavljenim konačnim podacima iznosi 450,5 toisea (878 m). Dakle, to je samo malo smanjenje (poljepšanje) razlike između ekstremnih duljina jednog stupnja meridijana. Tako velika razlika sigurno je mogla ukazivati na neku grubu pogrešku u Liesganigovim mjerenjima.

Rezultati Liesganigovih mjerenja ubrzo su nakon objavljivanja, a i nakon njegove smrti, oštro kritizirani. Tako je geometar i astronom Franz Xaver von Zach, ravnatelj opservatorija u Gothi, optuživao Liesganiga da je obrađivao rezultate mjerenja kako bi bila što bolja suglasnost (Zach 1803, 1804, 1811). Drugim riječima, tvrdio je da je Liesganig uljepšavao svoje rezultate mjerenja. Danas vidimo da je tu bilo i grubih pogrešaka.

³ Prema Bialasu (1982, str. 99), 1 toise = 6 pariških stopa = 1,94905 m, 1 pariška stopa = 0,3248 m.

from Brno (Soběšice) to Varaždin, and the tower of the Church of Assumption of Virgin Mary into Heaven. Namely, there is a Franciscan Church of St. John the Baptist in Varaždin with a 54.4 m high tower (highest in Varaždin), which would be a reasonable choice for a trigonometric point.

Two neighbouring trigonometric points can be seen from the tower in Varaždin: St. Urban at Ankenstein (nowadays old city of Borl) and Jerusalem (Fig. 8) in a land where grapevine is cultivated (Lapaine 2012). Varaždin was connected with these two trigonometric points to Liesganig's entire trigonometric chain, which he used to determine the length of the Vienna meridian from Soběšice to Varaždin.

5 Publishing Results of the Vienna Meridian Arc Survey and More Recent Research

The first document on previous results of surveying the Vienna meridian arc was published by Liesganig in the London Philosophical Transactions in 1768 (Fig. 9). In it, he briefly expounded on the results of his research and he also made an unclear comment about how the large difference in length of one meridian arc degree in various latitudes is probably due to nearby hills. One should therefore look at extreme values for lengths of one meridian arc degree, underlined in Table 1, which shows the largest difference equals as much as 466.3 toises³ (908.8 m). Namely, according to Newton's theoretical calculation, the length difference of one meridian arc degree between neighbouring degrees on latitudes between 40° and 50° equals only 13 toises (Solarić, Solarić 2013b). Therefore, Liesganig's explanation can not be accepted as a special justification.

Liesganig wrote and published the final survey results in Latin in *Dimensio Graduum Meridiani Viennensis et Hungarici* in 1770 (Fig. 10). These results do not differ significantly from Liesganig's previous results from 1767 and in Table 1. Let us emphasize that the corrected difference between one meridian arc degree between Vienna and Graz and Graz and Varaždin equals 450.5 toises (878 m). Therefore, it is just a small reduction (embellishment) of the difference between extreme lengths of one meridian degree. Such a large difference could certainly point out a gross error in Liesganig's surveys.

Results of Liesganig's surveys were harshly criticized soon after publishing and continued soon after his death. For example, director of the observatory in Gotha, surveyor and astronomer Franz Xaver von Zach accused

³ According to Bialas (1982, p. 99), 1 toise = 6 Paris feet = 1.94905 m, 1 Paris foot = 0.3248 m.

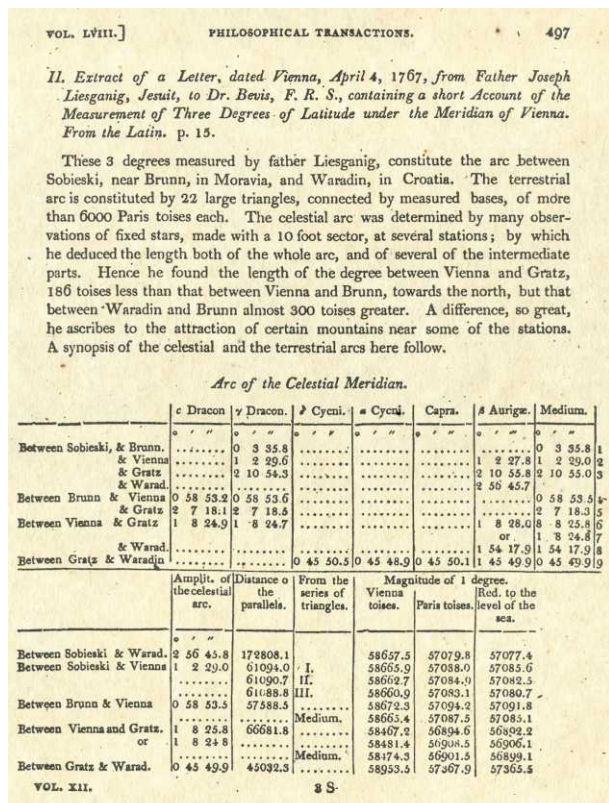


Fig. 9 Philosophical Transactions Vol. LVIII, page 497 from 1768

Slika 9. Philosophical Transactions Vol. LVIII, str. 497 iz 1768. godine

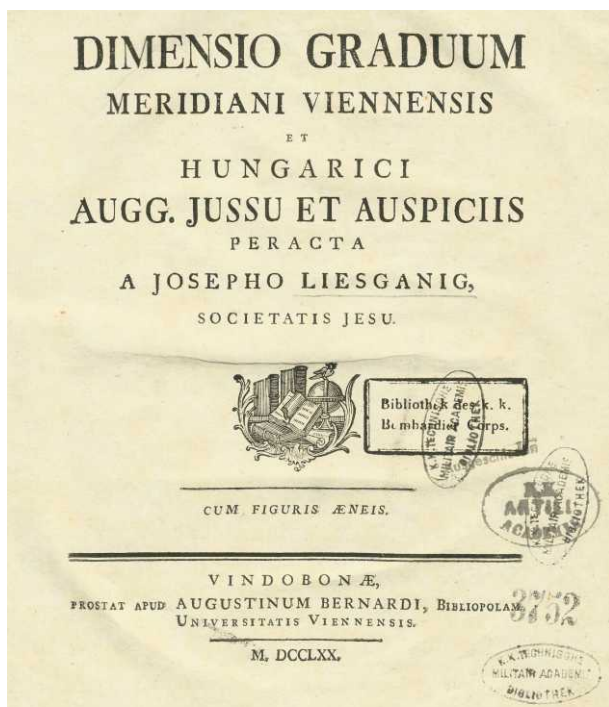


Fig. 10 Cover of Liesganig's *Dimensio Graduum Meridiani Viennensis et Hungarici* published in 1770

Slika 10. Naslovnica Liesganigova djela *Dimensio Graduum Meridiani Viennensis et Hungarici* objavljenog 1770.

Table 1 Review of results of distance measurements of Vienna meridian Sobieschiz-Warasdin (middle taking over from Liesganig (1767) – abbreviation V.fa. (Vienna fathom))**Tablica 1.** Pregled rezultata izmjere duljine luka Bečkog meridijana od Brna (Soběšica) do Varaždina (preuzete sredine od Liesganiga (1767) – skraćenica b. hv. (bečki hvat))

Između mjesta Between locations	Razlika geogr. širina Difference in latitudes	Udalj. između paralela Distance between parallels b.hv. / V.fa	Duljina jednog stupnja luka meridijana Length of one meridian arc degree		Redukcija na razinu mora Reduction on sea level	
			b.hv. / V.fa	toise	toise	m
Soběšice – Beč Sobieschiz – Vienna	1° 02' 29,0''	61 091,2	58 663,2	57 085,3	57 082,9	111 254,6
Brno – Beč Brunn – Vienna	0° 58' 53,7''	57 588,5	58 672,3	57 094,2	57 091,8	111 271,9
Beč – Graz Vienna – Graz	1° 08' 25,3''	66 681,8	58 474,2	56 901,5	56 899,2	110 896,5
Graz – Varaždin Graz – Warasdin	0° 45' 49,9''	45 032,3	58 953,5	57 367,9	57 365,5	111 804,4
Soběšic – Varaždin Sobieschiz – Warasdin	2° 56' 45,8''	172 808,1	58 657,5	57 079,8	57 077,4	111 243,9

Table 2 Angles in the St. Magdalena – Wildon – St. Urban (near Maribor) triangle according to Liesganig and P. Embacher (Embacher, P. 1951)**Tablica 2.** Kutovi u trokutu Sv. Magdalena – Wildon – Sv. Urban (kod Maribora) po Liesganigu i po P. Embacher (Embacher, P. 1951)

Stajalište Station	Kut od Liesganigu Angle by Liesganig	Kut od P. Embacher Angle by P. Embacher
Sv. Magdalena	37° 17' 59''	38° 42' 06,2''
Wildon	46° 59' 00''	42° 33' 43,0''
Sv. Urban	95° 43' 01''	98° 44' 10,8''

Prije 200. obljetnice Liesganigovih mjerenja na Bečkom meridijanu, Paula Embacher iz Beča obranila je doktorsku disertaciju *Die Liesganigische Gradmessung* (Lego 1951). U toj disertaciji ispitala je točnost Liesganigovih mjerenja Bečkog meridijana (Embacher, P. 1951). Savjesno je izvela mjerenja i analizu te pronašla pogrešku u trokutu Wildon – Sv. Urban (kod Maribora) – Sv. Magdalena, što je objasnila zamjenom ciljeva u teškom brdovitom terenu. Dakle, Liesganig je imao pogrešno izmjerene kutove u tom trokutu, kao što se vidi iz tablice br. 2.

Naime, pogreška u trokutu Sv. Magdalena – Wildon – Sv. Urban izazvala je pogrešku u određivanju koordinata četiriju posljednjih točaka: Magdalena, Jeruzalem, Sv. Urban i Varaždin. Osim toga P. Embacher izračunala je i duljine jednostupanjskih dijelova luka Bečkog meridijana (tablica 3).

Iz tablice 3 vidi se da razlika duljine luka od Graza do

Varaždina između Liesganigova rješenja i P. Embacher iznosi 482,05 m. U tablici 4 W. Embacher je dao pregled veličina dijelova luka od jednog stupnja Bečkog meridijana prema Liesganigu i P. Embacher, kao i odgovarajuće duljine dijelova lukova od jednog stupnja na Bečkom meridijanu na Besselovom elipsoidu.

Pod utjecajem studije Paule Embacher ing. Alois Šimek (1883–1967) iz Brna izveo je istraživanje u Moravskoj 1954. godine (Šimek 1963). Naime, iz Liesganigovih dokumenata poznato je da je polazna točka u njegovom mjerenu trigonometrijskom lancu na Bečkom meridijanu bio toranj kapele sv. Križa u selu Soběšica 5 km sjeverno od Brna, na šumovitom brežuljku Ostrá horka. On je na novijim kartama označen kao trigonometrijska točka visine 404 m. Ostali vrhovi trokuta (trigonometrijske točke) bile su kapele sv. Antuna (oko 15 km jugoistočno od Brna) i sv. Peregrina (oko 11 km jugozapadno od Brna). U

Table 3 Differences in lengths of arc sections of one degree of the Vienna Meridian according to Liesganig and P. Embacher (Embacher, P. 1951)

Tablica 3. Razlike u duljinama dijelova lukova jednog stupnja luka Bečkog meridijana po Liesganigu i po P. Embacher (Embacher, P. 1951)

Luk meridijana Arc of meridian	Duljina od Liesniganiga Length according to	Duljina od P. Embacher Length according to P. Embacher	Razlika Difference
Beč – Brno / Vienna – Brno	109 209,02 m	109 209,63 m	+ 0,61m
Beč – Graz / Vienna – Graz	126 463,04 m	126 455,74 m	- 7,30 m
Beč – Varaždin / Vienna – Varaždin	211 843,88 m	211 354,50 m	- 489,38 m
Graz – Varaždin / Graz – Varaždin	85 380,84 m	84 898,70 m	- 482,05 m



Fig. 11 Stone monument in Soběšice – Ostrá Horka under which there is a renovated stabilization stone of the first trigonometric point in the Czech Republic and initial trigonometric points for Liesganig’s survey of a part of the Vienna Meridian arc

Slika 11. Kameni spomenik u Soběšicama – Ostrá Horka pod kojim se nalazi obnovljeni stabilizacijski kamen prve trigonometrijske točke u Češkoj Republici i početne trigonometrijske točke za Liesganigovu izmjeru duljine dijela Bečkog meridijanskog luka



Fig. 12 Pyramid on Ostrá horka hill near Soběšice near the first trigonometric point of the Vienna Meridian

Slika 12. Piramida na brdu Ostrá horka u blizini Soběšica i prve trigonometrijske točke Bečkoga meridijana

Liesganig of processing measurement results in such a way to obtain the best possible concordance (Zach 1803, 1804, 1811). In other words, Liesganig modified his results, and nowadays we see there were gross errors.

Prior to the 200th anniversary of Liesganig's surveys of the Vienna Meridian, graduate engineer Paula Em-

bacher wrote and defended her doctoral dissertation at the University of Vienna. The dissertation was titled Die Liesganigische Gradmessung (Lego 1951) and was about verification of Liesganig's surveys from Vienna and Graz to points in Slovenia and Varaždin (Embacher, P. 1951). She conducted the measurement and analysis consci-

Table 4 Lengths of arc sections of one degree of the Vienna Meridian (Embacher, W. 1962)**Tablica 4.** Duljine dijelova luka jednog stupnja Bečkog meridijana (Embacher, W. 1962)

Meridijanski luk Meridian arc	Razlika geogr. širina Differ. of latit.	Duljina 1° mer. luka Lisg. Length. of Arc 1° Lisg.	Duljina 1° mer.luka Emb. Length. of Arc 1° Emb.	Duljina 1° l.m. (Bessel. elipsoid) Length (Bessel. el.)	Sred. geogr. širina Middle latitude
Beč – Brno Vienna – Brno	0° 58' 53,5''	111 264,25 m	111 265 m	111 191 m	48° 40'
Beč – Graz Vienna – Graz	1° 08' 24,8''	110 910,94 m	110 904 m	111 171 m	47° 40'
Beč – Varaždin Vienna – Varaždin	1° 54' 16,5''	111 227,27 m	110 972 m	111 162 m	47° 10'
Graz – Varaždin Graz – Varaždin	0° 45' 49,9''	111 775,35 m	111 144 m	111 152 m	46° 40'

današnjoj Češkoj bile su još dvije točke Leskoun (kod Moravského Krumlova) i Děvin (kod Pavlovské vrchy). Te su točke bile vezane na točke Oberleis i Schrick u Austriji.

Kapela sv. Križa bila je početna točka u trigonometrijskom lancu, ali je, nažalost, srušena 1786. godine pa je njezin položaj bio neko vrijeme nepoznat. I kapela sv. Antuna srušena je 1814. godine, ali je na zahtjev francuske vlade kao važan spomenik bila obnovljena na svom prvobitnom položaju. Položaj kapele sv. Peregrina ostao je nepromijenjen. Iz Liesganigovih dokumenata poznato je da za točku Špilberg bio izabran jedan dimnjak, ali se nije znalo koji je to dimnjak od mnogih.

Nakon većeg broja geodetskih mjerenja i određenog otkopavanja pronađeno je središte kapelice sv. Križa gdje je bila postavljena prva trigonometrijska točka u Čehoslovačkoj (danas Češkoj). Na to mjesto postavljen je obnovljeni podzemni stabilizacijski kamen u rujnu 1960. godine, a u blizini granitni spomenik dimenzija 40×40×160 cm s dvjema brončanim pločama (sl. 11). Na jednoj od njih piše:

Središte kapele. Prva trigonometrijska točka na teritoriju Čehoslovačke postavljena Liesganigom. Novo označavanje točke provela je Geodetska služba Čehoslovačke Republike 200 godina po njenom uspostavljanju.

Nažalost, metalnih ploča sa spomenika prikazanog na sl. 11 više nema, ukradene su, ali su zamijenjene novima od plastike. U blizini je izgrađena željezna piramida s koje se prostire lijepi pogled na sve strane (sl. 12).

Iz kasnijih radova na trigonometrijskoj mreži stvarno proizlazi da su duljine stranica između trigonometrijskih točaka veće nego je to izračunao Liesganig. Tako

je ing. Alois Šimek iz novijih mjerenja izračunao da je duljina stranice Soběšice – Děvin 42 162,91 m, a prema Liesganigu ta duljina iznosi 41 972,98 m. Dakle, razlika je 189,93 m, što odgovara skoro 100 bečkih hvata, a to stvarno dokazuje da je postojala gruba pogreška u Liesganigovim izračunima (Vykutil 1982, str. 422).

6. Zaključak

Liesganigova mjerenja duljine Bečkog meridijana s pomoću trigonometrijskog lanca bila su prva te vrste u Austrougarskoj, te tako imaju svoje veliko povijesno značenje. Istina, ti rezultati nisu bili primljeni s velikim povjerenjem, ali i pored toga skupljeno znanje u razvijanju trigonometrijskih mreža bilo je vrlo značajno za izradu suvremenih karata i poslije za izradu katastarskih planova u Austrougarskoj.

Za Hrvatsku su Liesganigova mjerenja duljine luka Bečkog meridijana posebno važna jer je pritom u Hrvatskoj po prvi put u povijesti postavljena i izmjerena jedna trigonometrijska točka. Nju bi trebalo i svečano obilježiti spomen pločom tako da se zna da je to bila prva geodetska trigonometrijska točka u Hrvatskoj.

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entiously and found an error in the Wildon – St. Urban (near Maribor) – St. Magdalena triangle, which she explained by change in targets in a difficult mountainous terrain. Table 2 represents Liesganig's erroneous angles in the triangle.

Namely, the error in the St. Magdalena – Wildon – St. Urban (near Maribor) error caused an error in determining coordinates of the final four points: Magdalena, Jeruzalem, St. Urban and Varaždin. In addition, P. Embacher calculated lengths of one-degree parts of the Vienna Meridian which are presented in Table 3.

Table 3 shows that the difference for the arc length from Graz to Varaždin between Liesganig and P. Embacher equals 482.05 m. Table 4 provides an overview of arc sections of one degree of the Vienna Meridian according to Liesganig and P. Embacher, as well as corresponding lengths of arc sections of one degree on the Vienna Meridian and the Bessel Ellipsoid.

Influenced by Paula Embacher's research, engineer Alois Šimek (1883–1967) from Brno conducted a survey in Moravia in 1954 (Šimek 1963). Namely, it was known from Liesganig's documents that the initial point in his trigonometric chain in the Vienna Meridian was tower of the St. Križ chapel in Soběšice, 5 km north of Brno, on the wooded hill of Ostrá horka. It is indicated as a trigonometric point with an altitude of 404 m on recent maps. Other triangle vertices (trigonometric points) included chapels of St. Anthony (approximately 15 km southeast of Brno) and St. Peregrine (approximately 11 km southwest of Brno). Two additional points are located in contemporary Czech Republic, namely Leskoun (by Moravského Krumlov) and Děvin (by Pavlovské vrchy). These points were connected to points Oberleis and Schrick in Austria.

The chapel of St. Križ was the initial point in the trigonometric chain, but it was unfortunately destroyed in 1786, making its location unknown for some time. The chapel of St. Anthony was destroyed in 1814, but the French government considered it a valuable monument and demanded it be restored in the same location. The location of the chapel of St. Peregrine remained unchanged. According to Liesganig's documents, a chimney was chosen for the Špilberg point, but it is unknown which one since there were many chimneys.

After a number of geodetic surveys and some excavations, the centre of the chapel of St. Križ was found, where the initial trigonometric point was set in Czechoslovakia

(nowadays Czech Republic). A renovated subterranean stabilization stone was placed there in September 1960, as well as a granite monument (40×40×160 cm) with two bronze plates (Fig. 11). One of them reads:

Centre of the chapel. First trigonometric point on the territory of Czechoslovakia set by Liesganig. New point designation carried out by Geodetic Service of Czechoslovakia 200 years after it was established.

Unfortunately, metal plates from the monument in Fig. 11 were stolen, but they were replaced by new plastic ones. An iron pyramid was constructed nearby which provides a panoramic view (Fig. 12).

According to more recent work on the trigonometric network, lengths of sides between trigonometric points really are larger than those calculated by Liesganig. For example, engineer Alois Šimek calculated the length of the side Soběšice – Děvin to be 42 162.91 m, which Liesganig determined to be 41 972.98 m. Therefore, the difference is 189.93 m, which corresponds to almost 100 Vienna fathoms, meaning Liesganig's measurements included a gross error (Vykutil 1982, page 422).

6 Conclusion

Liesganig's surveys of the Vienna Meridian using a trigonometric chain were the first of their kind in Austria-Hungary and therefore have a great historical importance. While it is true the results were not accepted with great trust, but the knowledge in developing trigonometric networks was very important for producing contemporary maps and production of cadastral plans in Austria-Hungary.

Liesganig's surveys of the Vienna Meridian are especially important for Croatia because it was the first time a trigonometric point was set and surveyed in Croatia. It should be commemorated with a monument or memorial plaque at least in Varaždin.

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