MINISTRY OF EDUCATION, YOUTH AND SPORTS

Final Report on the Realization of the Large Research, Experimental Development and Innovation Infrastructure (LI) CzechGeo/EPOS

Full name of the LI: CzechGeo/EPOS – Distributed System of Permanent Observatory Measurements and Temporary Monitoring of Geophysical Fields in the Czech Republic – Development and Operation of the National Node of the Pan-European EPOS Project

LI's code: LM2010008

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Another participant/s of the LI:

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Institute of Physics of the Earth, Faculty of Sciences, Masaryk University in Brno (IPE MU)

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A. Overall Assessment of the Realization of the LI

Briefly describe the course of the realization of the LI for the entire financial period, describe and assess the achieved objectives and results of the LI. The extent of 2-5 A4 pages.

Permanent geophysical observatories, local stations and their networks are operated by 7 geoscience institutions in the Czech Republic. Integration in the frame of CzechGeo/EPOS contributed to a better mutual exchange of information and closer cooperation. Financial support of the project enabled upgrade of the infrastructure, extension of the networks and establishment of new networks (seismic network Reykjanet on Iceland). The establishment of CzechGeo coincided with the start of the EPOS Preparatory Phase. The beneficiaries of CzechGeo established the first national consortium, and thank to this act, we were asked to organize the first EPOS regional conference aimed at propagation of EPOS in the countries of Central and Eastern Europe.

Short characteristics of the development of individual components of CzechGeo are given below, including the information on data size, important co-operations, main results and their application.

Czech Regional Seismic Network (CRSN) consists of 19 permanent broad-band observatories. The stations transmit continuously digital data to data centres in IG CAS and IPE. Data are automatically processed by program packets Antelope and SeisComP, archived in data servers, exchanged with international data centres and a group of national data centres. Results of the data evaluation by experienced staff members are regular seismic reports, monthly bulletines, regional catalogues of earthquakes and other seismic events. Registration equipment of most of the stations was modernized. Seismic service was equipped by high-powered servers for data collection and processing. Data from CRSN and other European stations on the data servers are about 2.5 TB (cca 0.4 TB yearly). The data archive is backed-up on the CESNET Data Storage in Pilsen. Data are transmitted to European Integrated Data Archive (EIDA).CRSN got DOI in 2015, which will be used for data citation.

West Bohemian Seismic Network WEBNET consists of 22 stations – 13 broad band and 9 short periodic. Broad band stations are equipped with seismometers Guralp CMG-3ESPC and registration units Centaur Nanometrics. All broad band stations are linked to Internet. Data transmission to the center in IG is automatic (protocol SeedLink) in nearly real-time. 9 short periodic stations are equipped by LE-3D sensors with recording units Gaia. The stations are working in autonomous regime, the data are down-loaded on time per month. All stations are operated with 250 Hz sampling, data volume of all WEBNET stations is 300 GByte/ year. data are processed semi automatically by the program packet Seismon and archived on data servers. Data are used mainly for research and were/are a basis of PhD theses in the Czech Universities and abroad (Universities Potsdam, Freiberg, Leipzig). In case of stronger events, local authorities are regularly informed. Many stations were upgraded thanks to the support provided by CzechGeo/EPOS. Moreover, obsolete seismometers SM-3 on 13 stations were substituted by seismometers Guralp CMG-3ESPC and registration units Centaur Nanometrics in 2013, thanks to the support from central budget of the Academy of Science.

Seismic network REYKJANET was established in 2013, aimed at the study of swarm seismicity in the rift region of peninsula Reykjanes. The network consists of 9 broad band and 6 short periodic stations. All stations are operated with sampling 250 Hz, the data volume is 180 GByte/year. All station are autonomous, equipped by high capacity SHD cards. Stations are power supplied from storage batteries, charged by combination of solar panels and wind turbine. The maintenance and data download is carried out in cooperation with Icelandic GeoSurvey. The data are utilized for research as well as for the purpose of geothermal prospection. The CzechGeo/EPOS support was utilized for purchase of high-capacity batteries, solar panels and wind turbines.

Majority of stations (seismometers and data acquisition systems) of the MOBNET network have been used in passive seismic experiments focused on structural studies of the lithosphere and the upper mantle, namely in the EgerRift, BOHEMA IV, AlpAray-EASI. At present, twenty stations of the MOBNET, deployed on territory of the Czech Republic, form a part of the AlpArray backbone network. The AlpArray project (www.alparray.ethz.ch), called “Probing Alpine geodynamics with the next generation of geophysical experiments and techniques”, is an European initiative for high-resolution seismic imaging of the 3D geometry and physical properties of the lithosphere and the upper mantle in the greater Alpine region with a high-end seismic array and integration of present-day Earth observables to advance our understanding of

orogenesis and its relation to mantle dynamics, plate reorganizations, surficial processes and seismic hazard in the Alps-Apennines-Carpathians-Dinarides orogenic system. 28 institutions of 11 European countries contribute with full-time operation of at least 10 broadband seismic stations to the network, signed the AlpArray Scientific Program Memorandum of Collaboration and form the Core Group for the AlpArray Seismic Network. The AlpArray-EASI was the first implemented complementary Czech-Swiss-Austria-Italian projects of the AlpArray initiative, whose network was running during 2014-2015. The network consisted of 55 broadband seismic stations deployed in a zig-zag pattern on either side of the central longitude line of 13.35°E. The network spanned 540 km of the Bohemain Massif, the Eastern Alps and the Po Plain, from the Erzgebirge Mountains in the Czech-German border to the Adriatic Sea. Twenty stations of the MOBNET (AAE01-AAE20) recorded 585 GB of seismic data during one year of its registration. The initial results on the Earth's structure have been/will be presented at the international meetings EGU2015, EGU2016, ESC2016 etc.

Research Infrastructure (RI) PSLNET is operated in western Greece since 1997 and was equipped by three broadband seismic stations Guralp CMG-3T at the beginning. At the start of the project (2010), RI was already contained of 12 stations with a total of 16 seismographs and was fully operated. The main benefit of the CzechGeo / EPOS (LM2010008) project was to ensure the operation of existing stations and their upgrades. The old recording devices (SAM) from the Guralp were replaced by modern types (CMG-DCM, CMG-EAM) from the same company. This upgrade allowed to connect the instruments to the internet and to send data to the control centre at the University of Patras. Moreover, the seismic stations are under permanent, remote control and a possible technical problems can be resolved quickly. Stations are working in a continuous regime with a sampling frequency of 100Hz. The daily data volume per station is about of 33 megabytes.

Seismic network PSLNET is included into Greece network HUSN (Hellenic Unified Seismic Network) and selected stations provide the data to the international data centre ORFEUS. Based on this cooperation, the Department of geophysics, Charles University in Prague has access to the HUSN data. In the frame of the project could be studied source processes of the significant, moderate, Greece earthquakes and investigated crustal models in the western Greece (Efpalio M5.3, 2010; Van M7.1, 2011, Cephalonia Mw6, 2014). Ten scientific publications in peer-reviewed journals were created, and the computer program ISOLA, allowing calculation of the moment tensor including estimation of uncertainties has been developed. The importance of this program illustrated by several references in Nature Geoscience (2015).
http://www.nature.com/ngeo/journal/v8/n12/abs/ngeo2585.html

Seismological Software Centre (SSC) established and maintained within the CzechGeo project contains more than 100 portable open-source public-domain computer programs together with their hypertext documentation and demo data. SSC cooperates with more than 30 institutions on the development and application of seismological software. Software distributed by means of SSC has over 200 registered users worldwide and an unknown number of non-registered users. Seismological software centre provided over 400000 files with total extent more than 200 GB.

Profound reconstruction and modernization of six stations of the MONET seismological network was carried out. Hermetic steel shafts were built, provided by stable power supply and

equipped by unified high standard instrumentation for signal registration: Quanterra 330S dataloggers and Sercel L4C three-component short-period passive seismometers. GSM routers WR44-EDGE were installed to all stations for on-line data transfer to data centre in Brno. Upgraded stations were registered in the international register of seismic stations under the names ANAC, MUVC, LIPC, LOSC, SUPC a LUKC and data were made accessible to external users.

Comprising 8 stations with low-noise recording and 125-200 Hz sampling rate the current MONET network records 150-300 local natural microearthquakes from a geodynamically anomalous region of Moravia and Silesia and several thousands mining induced events from the Upper Silesia Basin. The MORC, VRAC, KRUC and JAVC stations provide a broadband registration of seismic events form Central Europe and other parts of the world. The number of events identified at these stations and further analysed, exceeds 10 000 per year.

Seismological catalogues built basing on detailed analysis of recorded signals represent basic database for the evaluation of present day seismic activity at the Bohemian Massif - Eastern Alps - Western Carpathians junction region, for seismic hazard assessment and related research. The information gained is used for reporing to state institutions (e.g. State Office for Nuclear Safety, municipal authorities) and private institutions (e.g., nuclear power plant operator ČEZ, a.s.) and it is shared with the international seismological community (e.g., EMSC, ORFEUS, ZAMG).

The Provadia seismic network is installed in the Eastern Bulgaria near the town Provadia. It consists of a broadband seismic station maintained by the Bulgarian Academy of Sciences and a small aperture array operated by the Institute of Rock Structure and Mechanics, Czech Academy of Sciences. The array is designed to monitor frequent small local seismic events not detectable by a single station and hence vastly improve the seismic catalogue. The array also monitors induced events produced by a nearby salt mine.

Within the project the array seismic sensors were upgraded to the broadband Guralp CMG-40T sensors (the same sensor as the main sensor of the station) to ensure maximum compatibility and data quality. The sampling frequency is 250 Hz and data are stored in the international GSE-2 data format.

The GNSS network VESOG consists 8 stations now. The stations are located at buildings of academic or research institutions in the Czech Republic. Initial part of VESOG network – stations GOPE, KUNZ, LYSH, TUBO and VSBO – was erected before start of LI project. The stations GOP6, GOP7 and PRUH was erected during the project duration. The stations perform measurements in permanent regime with sample interval 1 second and the hourly or daily data files are distributed in RINEX format to International GNSS service's data centre (IGS - 3 stations GOPE, GOP6, GOP7), to EUREF Permanent Network (EPN – 3 stations GOPE, KUNZ, TUBO) and to Network of permanent GNSS stations of Czech Republic – CZEPOS (3 stations GOPE, TUBO, VSBO). The data are also available after request (for example from Faculty of Electrical Engineering of Czech Technical University in Prague) and the data are also used in processing and further analysis in the Research Institute of Geodesy, Topography and Cartography, namely for determination of the troposphere delay in GPS meteorology and for determination of the station's position changes. The average size of the zipped date file from one hour is approximately 4 MB. The data files were periodically archived on the media. The data are archived at newly installed storage array last year – for on-line access.

In the cooperation of the Department of geophysics of Faculty of Mathematics and Physics of Charles University, the Research Institute of Geodesy, Topography and Cartography and the Seismological Laboratory of University of Patras (Greece) the PPGNet – network of GNSS stations in Greece – was build. The network consists of 6 stations (KTCH, LEPE, PVOG, RETS, RGNI and VALY). Beside the VALY station at middle-west part of Pelopones peninsula other stations are located at the north from Patras Gulf on the west of Greece. The stations perform measurements in permanent regime with sample interval 1 second or 10 Hz. The hourly files in RINEX format are primary produced. The data are – beside of using for monitoring of geodynamic movements related with earthquake – transferred to National Observatory of Athens and they are available for use in the Corinth Rift Laboratory. Newly, the data from 3 stations are distributed to the METRICA-METRITIKA SISTIMATA AKRIVEIAS A.E.E. company and the data from nearest stations are received reciprocally. Data volume of data with sampling rate 10 Hz is higher – the zipped hourly file has size approximately 40 MB. The data form PPGNet stations are continuously archived at the Geodetic Observatory Pecny. Original archive at CD medias is transferred to newly installed storage array.

The gravimetric laboratory at the Geodetic Observatory Pecny performs daily campaign (2400 basic units - drops) with absolute gravimeter FG5 No. 215 on month basis and continuous observations in 1 second sampling rate with superconducting gravimeter OSG-050. The second absolute gravimeter FG5X No. 251 was put on operation in 2015 but it was send for warranty repair to producer in second part of year. The data in TSF format are distributed to the Global Geodynamic Project (GGP) which was transformed in 2014 to International Gravity and Earth Tides Service (IGETS) and they also processed at the Research Institute of Geodesy, Topography and Cartography. Volume of daily files with the auxiliary sensors records is approximately 7 MB. Data visualization is possible through web interface http://oko.pecny.cz/grav/. The data from superconducting gravimeters in Strasbourg (France) and Wettzell (Germany) are received through international cooperation. These data can be also visualized on the web interface.

Geodynamic Network of the Academy of Sciences (GEONAS) operates eighteen stations in the territory of Czechia. Three of these stations (BISK, POUS, and VACO) are part of the European GNSS network of permanent stations (EPN/EUREF). All stations are equipped with sensitive two-frequency GNSS aerials and Ashtech Z-18, Topcon TPS GB-1000 and Topcon NET-G3 type receivers, which monitor the satellite signals of the US network NAVSTAR and the Russian network GLONASS with recording intervals of 1 and 5 seconds. The stations equipped with Topcon NET-G3 receivers are prepared to monitor the signals of the European position system GALILEO. The satellite signals received are transmitted from all station in real time to the operations centre IRS EPN of the IRSM in Prague. Data flow reaches 1440 MB/day. Measured data are stored and processed within IRSM. Additionally, campaign measurements are performed regularly on four regional networks (Western and Eastern Sudetes, Vysočina and Western Bohemia) on the total of 34 sites.

The network TECNET operates recently 167 stations monitoring fault active displacement. The frequency of recording in Automated stations is between 10 minutes and 1 hour (EU: CZ: Bedřichov Gallery, Šeptouchov Cave, Na Pomezí Cave, 13C Cave; Travná Gallery, Zbrašov Aragonite Caves, Koněprusy Caves, Strašín Cave Germany: tunnel Wattkopf; tunnel Loretto; Swiss: Deep underground rock laboratory Grimsel; Slovenia: cave Postojna; Austria: cave Eisenstein Hohle, cave Emmeberg Hohle, cave Obir Hohle, cave Pottstein Hohle, cave Zede Hohle; Italy: underground space Norcia, Mattinata; Canary Islands: gallery Tijirote on El Hierru;

Slovakia: Čachtická cave; Svalbard: Hornsund 2; Belgium: Rochefort Cave; out of EU: USA: Imler, Anza (CA); Peru: gallery Nana by Lima). Other stations (EU: CZ, Poland, Germany, Slovenia, Italy, Bulgaria, Slovakia, Greece, Canary Islands, Svalbard; out of EU: Peru, Kyrgyzstan, Ethiopia) are operated with a manual reading with frequency 14 to 30 days. The data are centrally processed and archived in the IRSM.

The network of tiltmeters TILTNET consists of 14 vertical static pendulums in 11 localities, mostly in the underground (Praha, Příbram, Ida Gallery, cave No. 13C in Moravian Karst, Karlovy Vary, Lubeník (Slovakia), Beregovo (Ukraine), Sevastopol (Russia), Magdalena jama (Slovenia), Trebiciano abyss (Italy), Garni (Armenia)). The newest stations Garni (Armenia) and Karlovy Vary were put into the operation at the end of 2014. All of data are transmitted on-line to the server in Prague. The data are pre-processed and transmitted to internet for next public use.

The CarbonNet network for monitoring of the amount of natural CO2 degassing in the seismoactive region of Western Bohemia has been modernized and extended by one station in the Bublák mofette. Here a new method for measurement of free gas ascent within a water column by means of pressure gradient measurement is being tested. Similar method is used in the Hartoušov mofette field, where a it is compared with standard flowmeter measurement. At Soos station the gas collection system has been reconstructed in the initial phase of the project. Here an electric resistivity method for gas concentration measurement is being verified. All stations have been supplied by a modern datalogger with a wireless data transfer to a data center. The acquired data amounting to 15 MB annually have been exchanged with institutions in Germany, which are involved in the research of magmatic carbon dioxide degassing.

Geomagnetic observatory Budkov passed through complete reconstruction of AC as well as data (optical cables) networks. Proton and potassium magnetometers were purchased in order to imptove the control over the data quality. Cooperation was started with the Faculty of electrical engineering of the Czech Technical University. Development of communication software enabled to start transmission of 1-second data , instead of former 1-minute data, to the Geomagnetic Information Node of the global high-standard network INTERMAGNET. It is important for analysis and processing of satellite geomagnetic data of SWARM mission. The data are used also for daily forecasts of geomagnetic activity for the Czech TV. daily file of 1-minute data is about 100 kB, of 1-sec data 6 MB. regular measurements on repeat stations are coordinated in the frame of informal consortium MagNetE, that involves more than 20 partners across Europe.

B. LI's Management Structure and Research Team

I. *Describe the management structure and organizational chart of the LI (eventually its changes during the financial period) and its anchorage within the host institution / host institutions. Indicate the composition and possible changes in the external advisory bodies (both scientific and management specialization).*

II. *Describe the LI's plan for human resources development. Indicate the members of LI's research team for the entire financial period (all persons paid from "personnel costs" chapter of the LI), briefly indicate their job description and classification, including their full-time equivalent (lowest, highest and average), employment period and overall financial costs, further differentiate the permanent (core employees) and temporary staff (employees that have signed agreements on work performed outside employment).*

The infrastructure is managed by the Council composed oh representatives of each partners. The Council is chaired by the Principal Investigator (recently also Director of IG). The Council meets now twice a year. Invited are also colleagues responsible for individual networks. Since 2013, representative of Czech geological Survey is also invited.
International Scientific Board was established in the frame of preparation for the new project Its members are Prof. Carla Braitenberg (University of Trieste), Dr. Carine Bruyninx (Royal Observatory of Belgium), Dr. John Clinton (ETH Zürich), RNDr. Jaroslava Plomerová, DrSc. (GFÚ AV ČR), Dr. Alan Thomson (British Geological Survey Edinburgh), Dr. Jørgen Tulstrup (Geological Survey of Denmark).
The project does not cover personal costs of all workers needed for building and operation of the LI. The personal fund had to be completed by institutional money. The project covers about 17 FTE. Agreements to perform a job are closed mostly with local inhabitants for activities connected with the operation of stations. The full list is in Appendix 3.

C. Outcomes of the LI

I. *Indicate the scientific results achieved by the LI's research team on the basis of the LI's use for the entire period. Individual results indicate according to valid methodology of CRDI (Council for Research, Development and Innovation), if possible J type results complete with impact factor according to WoK or Scopus. Among these results specify 20 most important ones.*

II. *Indicate the main scientific results (not more than 20) achieved on the basis of the LI's use (its Czech branch in case of distributed research infrastructures) by its users, if it is possible to attest. Individual results indicate according to valid methodology of CRDI, if possible J type results complete with impact factor according to WoK or Scopus.*

Ad I. Main scientific results achieved by internal workers (20 selected papers are in bold)
Papers in journals with IF

1. Bachura, M. - Fischer, Tomáš (2015). Coda attenuation analysis in the West Bohemia/Vogtland earthquake swarm area. Pure and Applied Geophysics, 172, DOI: 10.1007/s00024-015-1137-3, IF =1.618
2. Benetatos, C., J. Malek, and F. Verga (2012): Moment tensor inversion for two micro-earthquakes occurred inside the Haje gas storage facilities, Czech Republic. Journal of Seismology, doi: 10.1007/s10950-012-9337-0.
3. **Bouchaala, F., Vavryčuk, V., Fischer, T., 2013. Accuracy of the master-event and**

double-difference locations: Synthetic tests and application to seismicity in West Bohemia, Czech Republic, *J. Seismology*, 17, No. 3, 841-859, doi: 10.1007/s10950-013-9357-4. IF=1.388

4. Briestenský M., Košťák B., Stemberk J. (2011): Long-term slope failure monitoring in the Region of the Core High Mountains (the Western Carpathians). – Acta Geodynamica et Geomaterialia, 8, 4. 403 - 412
5. Briestenský M., Rowberry M. D., Stemberk J., Stefanov P., Vozár J., Šebela S., Petro L., Bella P., Gaal L., Ormukov Ch. (2015): Evidence of a plate-wide tectonic pressure pulse provided by extensometric monitoring in the Balkan Mountains (Bulgaria).Geologica Carpathica, 66, 5, 427-438. doi: 10.1515/geoca-2015-0035 IF = 0.761
6. Briestenský M., Stemberk J. (2014): The use of damaged speleothems and in situ fault displacement monitoring to characterise active tectonic structures: an example from Západní Cave, Czech Republic. Acta Carsologica, 43, 129-138. IF = 0.542
7. Briestenský M., Stemberk J., Rowberry M. D. (2014): The use of damaged speleothems and in situ fault displacement monitoring to characterise active tectonic structures: an example from Západní Cave, Czech Republic. Acta Carsologica. IF = 0,542
8. **Briestensky M., Thinova L., Praksova R., Stemberk J., Rowberry M.D. and Knejflova Z. (2014): Radon, carbon dioxide and fault displacement in Central Europe related to the Tohoku earthquake. Radiation Protection Dosimetry, pp. 1–5 doi:10.1093/rpd/ncu090. IF=0.861**
9. Brokesova J., Malek J. (2015): Six-degree-of-freedom near-source seismic motions II: Examples of real seismogram analysis and S-wave velocity retrieval. Journal of Seismology, 19, 2, 511-539, DOI: 10.1007/s10950-015-9480-5. IF = 1.386
10. **Brokešová J., Málek J., and Kolínský, P. 2012, Rotaphone, a mechanical seismic sensor system for field rotation rate measurements and its in-situ calibration, J. Seismol. 16, 603-621 doi: 10.1007/s10950-012-9274-y. IF=1.33**
11. Burda J., Hartvich F., Valenta J., Smítka V., Rybář J. (2013): Climate-induced landslide reactivation at the edge of the Most Basin (Czech republic) – progress towards better landslide prediction. Natural hazards and Earth System Science, 13, 361-374. IF = 1,751
12. **Čermák V., Bodri L., Krešl M., Dědeček P. and Šafanda J. (2015): Eleven years of ground-air temperature tracking over different land cover materials, International Journal of Climatology. (submitted in 2015, in review). IF=3.157**
13. Čermák, V., L.Bodri, J.Šafanda, M.Krešl, P.Dědeček (2014). Ground-air temperature tracking and multi-year cycles in the subsurface temperature time series at geothermal climate-change observatory, Studia geoph. et geod., 58, 406-424. DOI: 10.1007/s11200-013-0356-2. IF=0.752
14. **Čermáková, H., Horálek, J. (2015). The 2011 West Bohemia (Central Europe) earthquake swarm compared with the previous swarms of 2000 and 2008. *J. Seismol.*,19/4,899-913,doi: 10.1007/s10950-015-9502-3. DOI: 10.1007/s10950-015-9502-3, IF=1.388**
15. Dahm, T,. Fischer, T. (2014). Velocity ratio variations in the source region of earthquake swarms in NW Bohemia obtained from arrival time double-differences. Geophysical Journal International, 196, 957-970. IF=2.724
16. Dědeček, P, Rajver, D., Čermák, V., Šafanda, J., Krešl, M. (2013): Six years of ground–air temperature tracking at Malence (Slovenia): thermal diffusivity from subsurface

temperature data. Journal of Geophysics and Engineering. 10, 025012/1-025012/9. IF = 0,721

17. Dědeček, P. - Šafanda, J. - Rajver, D. (2011): Detection and quantification of local anthropogenic and regional climatic transient signals in temperature logs from Czechia and Slovenia. Climatic Change, DOI 10.1007/s10584-011-0373-5, 17-21, 2011. Paper number 684
18. Fischer, T., Bachura, M., 2014. Detection capability of seismic network based on noise analysis and magnitude of completeness, Journal of Seismology 18, 137-150, doi: 10.1007/s10950-013-9407-y. IF=1.388
19. **Fischer, T., Horálek, J., Hrubcová, P., Vavryčuk, V., Bräuer, K., Kämpf, H. (2014). Intra-continental earthquake swarms inWest-Bohemia and Vogtland: A review. Tectonophysics. 1-27. IF=2.866**
20. **Flechsig, Ch., Heinicke, J., Mrlina, J., Kämpf, H., Nickschick, T., Schmidt, A., Bayer, T., Günther, T., Rücker, C., Seidel, E. and Seidl, M. (2015): Integrated geophysical and geological methods to investigate the inner and outer structures of the Quaternary Mýtina maar (W-Bohemia, Czech Republic). – *Int J Earth Sci (Geol Rundsch),* 2087-2105, DOI 10.1007/s00531-014-1136-0. IF = 2.093**
21. Gosar A., Šebela S., Košťák B., Stemberk J. (2011): On the state of the TM 71 extensometer monitoring in Slovenia: seven years of micro-tectonic displacement measurements. – Acta Geodynamica et Geomaterialia, 8, 4
22. **Hartvich F., Valenta J. (2013): Tracing an intra-montane fault: an interdisciplinary approach. Surveys in Geophysics, 34, 317-347. IF = 4,125**
23. Holub K., Kalenda P. and Rušajová J. (2013): Mutual coupling between meteorological parameters and secondary microseisms. TERR ATMOS OCEANIC SCI (TAO), Vol. 24, No. 6, 933-949. IF=0,705
24. Holub, K. - Růžek, B. - and Rušajová, J.: A simple smoothed velocity model of the uppermost Earth's crust derived from joint inversion of Pg and Sg waves. Acta Geophysica, 2011, DOI: 10.2478/s11600-011-0023-3
25. Horálek, J. - Fischer, T.: Intraplate earthquake swarms in West Bohemia/Vogtland (Central Europe). Jökul, Roč. 60 (2011), 67-87
26. J. Janský, V. Plicka and L. Eisner (2013): Feasibility of jointly locating microseismic events with data from surface and downhole receivers. First Break, 31, No: 7, 59-65. IF=0.444
27. Jansky J., Novotny O., Plicka V., Zahradnik J., Sokos E. (2012): Earthquake location from P-arrivals only: problems and some solutions. Stud. Geophys. Geod., 56. Doi:10.1007/s11200-011-9036-2.
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33. **Kämpf, H., Németh, K., Puziewicz, J., Mrlina, J. and Geissler, W.H. (2015): From mantle roots to surface eruptions: Cenozoic and Mesozoic continental basaltic magmatism. – *Int J Earth Sci (Geol Rundsch),* 1909-1912, DOI 10.1007/s00531-015-1252-5. IF = 2.093**
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35. Klimes, L. & Bulant, P. (2016). Prevailing-frequency approximation of the coupling ray theory for S waves. Stud. geophys. geod., 60, in press. IF=0.806
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D. Utilization of the LI

Describe the strategy for the allocation of capacity of the LI. Indicate the utilisation of the LI's capacity (according to the type and scientific field of the LI, describe the percentage utilisation, eventually number of accesses, volume of produced, stored or provided data, including the percentage distribution of users by their affiliation – universities, public research institutions, industry) for the entire period. In case of construction of the LI describe the status of the LI at the end of this period or data from performed tests or limited service providing, etc.

The backbone of the infrastructure consists of permanent observatories that work in non-stop regime. The use of infrastructure is thus 100 per cent. Data are on-line sent to data centres and are free available for non-commercial use. We suppose that the general distribution of users is Universities 40%, Research Institutes 50%, Industry and public authorities 10%. In addition, most observatory data are displayed on the web of the project and on the web of host institutions. The yearly production of seismic data is about 1.7 TB and GNSS data about 1 TB. Other systems do not require such high sampling frequency and the data volumes are lower. Concrete numbers are in part A.

E. Cooperation

I. *Indicate newly established and running cooperation within the Czech Republic and abroad with research institutions, industry and other entities using results of the LI.*

II. *Indicate newly established and running cooperation with other research infrastructures in the field, both Czech and foreign ones, for the entire financial period.*

Cooperation on national and international level is a natural feature of geoscience research. CzechGeo/EPOS offers the user a broad portfolio of data. Their value multiplies in a substantial way, if they are connected with data of other countries. An important group of users are institutions that participate on the operation of stations and networks abroad. Close cooperation was established with the beneficiaries of project EPOS Preparatory Phase and EPOS Implementation Phase. Cooperation with some partners was confirmed also also by common projects listed in part H. list of cooperation is in Appendix 4.

Privilege position among cooperating infrastructures has EPOS. Preparatory phase of this multidisciple infrastruicture was started in November 2010 and coincides with the launch of CcechGeo/EPOS, which is the national node of EPOS. Important is also the cooperation with CESNET, as on-line data transfer is very important for CzecgGeo/EPOS. Several observatory and station were link to internet via CESNET. Other infrastructures in Appendix 4 are mono-disciplinary. Largest groups of cooperating infrastructures are in seismology and GNSS.

F. Users

For the entire period indicate the number of users (eventually number of accesses) of the LI from the Czech Republic and abroad. Indicate the number of conferences and seminars organized by the LI, including the number of participants from the Czech Republic and abroad. Indicate the number of meetings with users and the feedback results thus obtained. Indicate the number of agreements with other institutions (e.g. contracts, memoranda).

The basic service for research community consists in continuous observations of geophysical fields and publication of data via international networks. The number of users cannot be plausibly estimated. For example, number of accesses of portal www.tecnet.cz was 32 685 (40% of new visitors) in 2015, users data of Geomagnetic Observatory Budkov have been download from www.intermagnet.org server by about 80 unique users per year. The software distributed by Seismologic software centre has about 200 registered user worldwide.More than 400 000 files (200 GB) was downloaded. However, most data portals do not have such statistics.

Users of the infrastructure are, of course, all cooperating institutions. Stays of foreign workers on observatories are quite exceptional, sometimes for comparison measurements or training.

Selected users from commerce or public administration:

- Broadband seismic station VRAC is a part of international monitoring system CTBTO - Comprehensive Nuclear-Test-Ban Treaty Organization
- SÚRAO (agency managing repositories of nuclear waste) subscribes to reports on the seismicity of Czech Republic and Central Europe quarterly.
- RWE (gas distribution company) subscribes to annual reports on the seismicity on the territory of Czech Republic, and to alerts of increased earthquake activity.
- ČEZ (power plant operator) is provided by regular reports on seisimicity in the region of the two Czech nuclear power plants.
- The company VODNÍ DÍLA-TBD subscribes to the WEBNET data monitoring the West Bohemia earthquake swarms. We deliver annual reports on seismic activity and alerts in case of increased activity resulting in earthquakes above magnitude 3, the alerts contain data on the ground displacement and ground acceleration amplitude. In 2015, the data from an intense earthquake activity in May 2014 were used for an updated assessment of the earthquake hazard related to the water storage Horka, which is situated just in the epicentre area Nový Kostel.
- Communal offices within the districts Cheb and Sokolov subscribe to the alerts of increased earthquake activity.
- GNSS stations of PPGNet networ are used by greece company METRICA based on the "Memorandum of Understanding" concluded in 2015.
- Severočeská energetická, a.s., Most – monitoring of unstable slopes of the Krušné hory Mts. In the vicinity of the Castle Jezeří just over the mine ČSA. Also the Reserach Institute of

Brown Coal in Most is interested in our data – we start data exchange in 2016.

G. Internationalization

For the entire period indicate the number of international research grants connected to the LI gained by research team, their names, a brief description and financial volume.

EC FP7 SP3 People, AIM – Advanced industrial microseismic monitoring (Grant agreement No. 230669), 2008-12 – Project coordinated by Institute of Geophysics - Support for training and career development of researchers – Industry-Academia partnership – financial support 867 197 €

EC FP7-INFRASTRUCTURES-2010-2014, European Plate Observing System (Grant agreement No. 262229) – Preparatory phase of large European research infrastructure aimed at preparing scientific, technical, legal and financial conditions for the operational phase with special attention paid to e-infrastructure as a basic tool for data integration – 4 500 000 € total, 102 750 € for IG ASCR.

DFG, Maar Mytina - Železná hůrka and active magmatic degassing zone CO2 Milhostov – Hartoušov in western Ohre Rift, 2011 – 2013, 22 000 €.

Polish National Science Centre, project 2789/B/T02/2011/40 „Integration of permanent and epoch GNSS measurements for needs of local and regional investigation on the Czech-Polish network SUDETEN“
National Geographic Society/Waitts Grants Program grant n. W244-12: Mega-landslides: imminent hazard or sleeping giants? Monitoring the landslide hazard related to ongoing volcanic activity around El Hierro, Canary Islands, Spain. (2012-2013)
Using space geodesy to investigate the mechanics of earthquake ruptures, Ident. code 7AMB12GR006, project MOBILITY, MŠMT, 2012 – 2013, 140 000 CZK. Cooperation with geodetic group of Dr. A. Ganase from National Observatory of Athens.

Evaluation of tectonic movements along the faults, project LH12078 (Kontakt II), 2012-2015, cooperation with the University of San Diego, CA, 3 mil. CZK

Scientific Co-operation Agreement GZ 4150/15-23a/92, partner: Central Institute for Meteorology and Geodynamics, Department of Geophysics, Hohe Warte 38, A-1190 Vienna, Austria, 1,2 mil. CZK yearly.

Active tectonics and recent dynamics of micro-displacements along major fault systems of the Eastern Alps registered in caves (SPELEOTECT) – 2013-2016. Main investigator Naturhistorische Museum Wien, monitoring of 3-D movements in selected cave systems in Austria, 5.000 EUR yearly.

ESA project ITT 7076 Assessment Techniques of Tropospheric Effects for Local Augmentation Systems, 2012-2014 – techniques for tropospheric effects introduction in GNSS localisation with augmentation info from surface stations - about 2,2 mil. CZK.

ESA project ITT AO/2-1610/14/NL/CVG DARTMA – Development and Assessment of Regional Tropospheric Model for Augmented GNSS Position and Navigation, 2014-2015 – improvement of GNSS localisation based on augmentation info from surface stations with introduction of

tropospheric effects from regional model - about 2 mil. CZK.

COST Action ES1206 „Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate – „GNSS4SWEC“ (Dr. Michal Kačmárik, Dr. Jonathan Jones)

LASMO (Large Scale Monitoring Project) 2014 – 2018 – monitoring of fault displacement in deep underground rock laboratory Grimsel (Swiss) – cca 0,5 mil. CZK per year (total 2,8 mil. CZK)

„Norwegian Funds“ - project NF-CZ08-OV-1-006-2015 Preparation of a Research Pilot Project on CO2 Geological Storage in the Czech Republic (REPP-CO2). Cooperation with International Research Institute of Stavanger (in 2015 ca 1 mil CZK).

H2020-INFRADEV-1-2015-1, EPOS-IP (Grant agreement No. 676564) – implementation phase of European observatory infrastructure EPOS, 1.10-2015 – 30.9.2019, 18,37 mil EUR, IG ASCR 132 500 EUR, RIGTK 125 000 EUR.

H. Multidisciplinarity

Indicate the number and titles of scientific disciplines that use the LI's services. Append concrete results.

13 scientific disciplines. Numbers in brackets refers to results in the part C.

carstology[7], geodesy [39], geodynamics [4], geology [20], geomagnetism and geoelectricity [104], geomorfology [70], geotechnics[42], geothermics [14], gravimetry [28], meteorology and climatology [13], seismology [1], tectonics [6], volcanology [66].

I. Strategic Management of the Scientific Development of the LI

Indicate the main features of the scientific strategy of the LI used in the past financial period, including plan for update of used technology and plan of possible decommissioning. Indicate experience with this scientific strategy and possible changes' proposals for the future.

The project is aimed at long-term stability in order to get time series as long as possible. Priorities are: continuous upgrade of observatory systems aimed at data quality enhancement, integration of data and continuous maintenance in order to ensure high reliability and 100% time coverage. On-line connecting of stations wherever technically possible and financially bearable belongs to permanent tasks. Cooperation with the infrastructure CESNET is developing successfully.

Upgrade will concentrate on improvement of reliability of measuring equipment, enhancement of their resolution and on improvement of data connection.

Managerial staff is in close contacts with the scientific community in corresponding branches and can thus guarantee that observatories and mobile systems will be on sufficiently high level that is necessary for achievement of scientific goals.

We have submitted proposal to the new call related to the upgrade of the Czech roadmap of large research infrastructures for the period 2016-2022. The consortium was completed by the Czech Geological Survey, because geological and geophysical data in databases managed by CGS are inevitable for complex interpretations. According to the resolution of the government, the LI

will be supported by non-investment in the period 2016-19. The investments could be asked in the frame of Structural funds.

Strategic management of CzechGeo was coordinated with the EPOS PP, which the CzechGeo project team took active part in. EPOS PP was crowned by the preparation of preparatory documents for establishment of European legal body EPOS ERIC. Following-up project EPOS implementation phase was approved in April 2015. IG ASCR and RIGTC participate in this project. Pavel Hejda is coordinator of WP 13 Magnetic observations, Jan Douša coordinates task GNSS Data Disemination in WP10 GNSS Data and Products and Jan Šílený is a leader of IG team in WP14 Antrophogenic Hazard. The project was started on 1 October 2016.

J. The Efficiency of the Use of Funds

Describe the use of the provided grant for the entire period; primarily describe the personnel costs (e.g. number of jobs), overheads and investments. Describe the mechanism of calculation of overhead costs approved by the host institution. Indicate how the allocated funds are used in the context of the overall budget of the LI. Indicate the percentage of the budget of the LI that has been obtained from external international grants, in collaboration with industry or other entities using the LI's services. Describe the procurement mechanism for the investments.

The operation and maintenance of observatories and mobile systems is carried out by about (mostly graduated) technicians (17 - 18 FTE) financed by CzechGeo budget and approx.. identical number of employees paid by institutional or project money of corresponding institute or faculty. Separate components are managed by research workers. They should guarantee that the infrastructure will be developed in accordance with the needs of scientific community and other users. Their personnel costs are not paid from CzechGeo grant.

Beneficiaries do not have an analytical accounting system to fully identify their indirect costs. The overheads of projects are transferred to a common account that is used for covering costs of energy, maintenance, cleaning, cost of administrative staff, etc. The overhead costs are less than 7% of the project budget and do not cover indirect costs related to the project.

The investments were concentrated on improving the quality of instrumental basis, strengthening of computing capacity for storage, processing and accessing data and on high quality internet access for observatories. Investments are listed in the Financial sheets and justified in part A.

Large items in the running costs are electrical energy (power supply of instruments and heating of observatory huts), telecommunications (data transfer from many remote localities), repairs and maintenance of instruments. Travel costs were mostly spent on trips to observatories and stations or for field survey.

The project money was entirely used in benefit of the observatory infrastructure and in accordance with the project targets. The funding had to be completed by additional, mostly institutional sources. Average yearly costs are estimated in the bellow table.

Financing of the observatory infrastructure. Funding by CzechGeo and other public sources (institutional money, grants) in thousands of CZK.

	IG ASCR	IRSM ASCR	IGN ASCR	IPE MU	FMP CU	FS CU	RIGTC	Total
CzechGeo	7 061	7 101	504	1 575	1 175	458	1 575	19 989
other	5 000	5 000	50	2 800	50	100	1 400	14 400

International grants are not used to support operation of the infrastructure, but to support the data utilization. Public procurements are carried out in accordance with the check law.

K. Comparison with the LI's Original Plan of the Realization

Indicate the comparison with the original plan of the realization of the LI stated in the LI's proposal approved by the Government; describe the progress in meeting LI's objectives and the compliance with the timetable of the realization of the LI. Indicate all changes (financial, personnel, etc.) in the realization of the LI and their explanation.

The purpose of the CzechGeo Project is:

- Securing long-term stable operation with emphasis on the high quality of data;
  - The support of the project contributed to the stabilization of the research team, which is now capable to solve flexibly break down of instruments all (fortunately rare) consequences of vandalism. Timely substitution of equipment which is close to the end of its life time increases also the system reliability.
- On-going modernization of existing facilities with the aim of sustaining high technical standards of facilities;
  - Most investments was used for upgrade of existing equipment. The financies are complemented by institutional sources. many networks has been also extended (CRSN, PLSNET, TECNET, TILTNET) and a new network REYKJANET was established.
- Development of methods of processing and distributing data;
  - The development of new methods of data processing and distribution is a consequence of a quick development of ICTs. The most important group in this engaged in processing of GNSS data, including generation of advanced products is direction is the Analytical Centre GOP (Geodetic Observatory Pecny), which (coordinates of stations, exact trajectories of satellites, parameters of the earth rotation) and contributes to the international services IGS and EUREF.
- Support mof joining significant international structures – at present particularly the project from ESFRI Roadmap – EPOS.
  - The involvement in the Preparatory and Implementation Phases of EPOS was described in part I.

L. Socio-economic Impacts of the LI

1. Impact on the Economy

I. *Indicate the number of jobs in the LI for the entire period (researchers / research staff / other).*

II. *Indicate the number and volume of contracts with industry concluded in the framework of public procurement to maintenance and renewal of the LI.*

The support by MEYS was used for salaries of 17 to 18 FTE, 20% researchers, 50% research staff, 30% other. For details see Appendix 3.

Ad II.

Investment costs were used for the purchase of specialized instruments or building of ICTs. (c.f.

the Table of Real; Financial Costs). Domestic companies provided 27 of 76 items (6,1 of 20,6 mio CZK). Other running costs – material, small equipment, services, travel costs (6, 17 mio CZK per year)– are carried out by companies acting on the Czech territory.

2. Impact on the Society

I. *Indicate the number of master and doctorate students using the LI for the entire period.*

II. *Indicate the number of new textbooks, lecture notes and other practical outputs carried out in connection with the LI's operation, number and names of curricula whose students are using the LI.*

I. On average, 10 master or bachelor students and 15 PhD students used the LI yearly. The number of student was increasing.

Study programs:
physics/geophysics – FMP CU
geology – FS CU, IPE MU
physical geodesy and geophysics – Technical University Ostrava

II. Zamarský V., Tylčer, J., Střelec, T., Kaláb, Z., Martinec, P., Paclová, H., Walica, R.: Regeneration of industrial areas. II. díl. Učební text, VŠB – Technická univerzita Ostrava, FAST, 2011, 194 stran. ISBN 978-80-248-2431-4.

3. Impact on Innovation

I. *Indicate the number and names of spin-off companies established on the basis of LI's operation.*

II. *Indicate the number of pilot plants, utility models, demonstrators made in connection with the operation of the LI, number of patents (including their names) registered and recognized in connection with the operation of the LI for the entire period.*

ad I. Spin-offs are not supposed in this infrastructure.
ad II.
Utility model PUV 2010-21974, accepted by the Office of Industrial property: Switch-board and other technicalequipment of GPS observatory.
Prototype of the GNSS station measuring the signals of Galileo system was developed (2012)
Functional sample – GNSS stations measuring navigation signals of QZSS (2013)
Functional sample – GNSS station for measurement of satellite navigation signals from GPS NAVSTAR, GLONASS, Galileo, Beidou and meteorological data (2014)

M. Appendices

1. Mandatory:

1) *Table of the real financial costs of the LI for the entire period*
2) *Table of monitoring indicators of the LI's implementation*

2. Optional:

3) CzechGeo Research team

4) Cooperation with research institutions, industry and other entities using results of the infrastructure chart).

In Prague
Date: 28 January 2016

Signature of investigator: