Questionnaire
Summary of the main activities of a research institute of the Slovak Academy of Sciences

Period: January 1, 2012 - December 31, 2015

1. Basic information on the institute:

1.1. Legal name and address- Institute of Measurement Science, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava 4, Slovakia

1.2. URL of the institute web site- http://www.um.sav.sk

1.3. Executive body of the institute and its composition

Directoriat	Name	Age	Years in the position
Director	Tyšler Milan	64	10
Deputy director	Witkovský Viktor	52	10
Scientific secretary	Maňka Ján	54	10

1.4. Head of the Scientific Board- Assoc. Prof. RNDr. Viktor Witkovský, CSc.

1.5. Basic information on the research personnel

1.5.1. Number of employees with university degrees (PhD students included) engaged in research projects, their full time equivalent work capacity (FTE) in 2012, 2013, 2014, 2015, and average number of employees in the assessment period

	2012		2013		2014		2015		total		
	number	FTE	number	FTE	number	FTE	number	FTE	number	averaged number per year	averaged FTE
Number of employees with university degrees	46,0	31,090	46,0	30,500	42,0	29,560	41,0	28,610	**175,0**	**43,8**	**29,940**
Number of PhD students	5,0	4,350	4,0	3,050	4,0	3,350	6,0	4,700	**19,0**	**4,8**	**3,863**
Total number	51,0	35,440	50,0	33,550	46,0	32,910	47,0	33,310	**194,0**	**48,5**	**33,803**

1.5.2. Institute units/departments and their FTE employees with university degrees engaged in research and development

Research staff	2012		2013		2014		2015		average	
	No.	FTE	No.	FTE	No.	FTE	No.	FTE	No.	FTE
Institute in whole	46,0	31,090	46,0	30,500	42,0	29,560	41,0	28,610	**43,8**	**29,940**
Department of Optoelectronic Measuring Methods	8,0	5,900	8,0	6,100	7,0	5,370	7,0	4,790	**7,5**	**5,540**
Department of Magnetometry	9,0	6,020	9,0	6,100	8,0	5,790	7,0	5,500	**8,3**	**5,853**
Department of Theoretical Methods	14,0	9,190	13,0	7,980	10,0	6,330	10,0	6,790	**11,8**	**7,573**
Department of Imaging Methods	9,0	5,680	10,0	6,100	10,0	7,600	11,0	7,390	**10,0**	**6,693**
Department of Biomeasurements	6,0	4,300	6,0	4,220	7,0	4,470	6,0	4,140	**6,3**	**4,283**

1.6. Basic information on the funding of the institute
Institutional salary budget and others salary budget

Salary budget	2012	2013	2014	2015	average
Institutional Salary budget *[thousands of EUR]*	582,029	583,280	566,656	584,059	**579,006**
Other Salary budget *[thousands of EUR]*	72,616	113,899	168,420	149,905	**126,210**

1.7. Mission Statement of the Institute as presented in the Foundation Charter

1. The Institute is specialized to basic research in measurement science and mathematical methods for processing of measured data. It is concentrated to development of new methods for measurement, modelling and computer processing of selected physical quantities, properties of materials and biological objects. The scope of the research falls within technology, natural and biomedical sciences and is oriented mainly to mathematical sciences, electrical engineering, automation and control systems (in particular to measurement techniques, metrology, and optoelectronics), mechanical engineering (with focus on bionics and biomechanics, biomedical engineering), material engineering, and biotechnology for health services.
2. The Institute is oriented to research and design of measuring methods and systems dedicated to non-standard measurement problems in research, industry and economical and social sphere. It develops and implements unique measuring systems as the result of the scientific research carried out in the Institute.
3. The Institute offers advisory and other expert services related to the main activities of the organisation.
4. The Institute performs postgraduate education governed by current legislative regulations.
5. The Institute publishes results of its scientific activities in periodical and non-periodical publications. The publishing of periodical and non-periodical publications is governed by resolutions of the Presidium of the Slovak Academy of Sciences.

1.8. Summary of R&D activity pursued by the institute during the assessment period in both national and international contexts *(recommended 5 pages, max. 10 pages)*

In compliance with the Mission Statement, as presented in the Foundation Charter of the Institute, research activities of the Institute of Measurement Science SAS encompasses the following areas of basic and applied research:

- Measurement theory, mathematical and statistical methods for processing of measured data;
- Principles and systems for measurement of selected physical quantities;
- Measuring methods and systems for biomedicine, mathematical and computer modelling of biological structures and processes, methods for biosignal processing;
- Design of methods and measuring systems for non-standard problems of measurement in science and industry, technologies for non-destructive or noninvasive material testing and diagnostics.

The research activities of the Institute are organized within 5 scientific departments:

- Department of Optoelectronic Measuring Methods;
- Department of Magnetometry;
- Department of Theoretical Methods;
- Department of Imaging Methods;
- Department of Biomeasurements.

In following paragraphs, the main research activities of the Institute's research departments during the assessment period are summarized and their role and positions in national and international scientific cooperation is outlined.

Research in the **Department of Optoelectronic Measuring Methods** in the assessed period was targeted to the development of X-ray microtomographic measuring methods, infrared thermography and optical measuring methods. Research activities were covered by scientific project VEGA 2/0126/13 „New advanced methods of measurement and non-destructive testing of materials: X-ray microtomography and active infrared thermography", project APVV-14-0719 „Physical non-destructive methods for complex testing and analysis of cultural heritage artefacts", international EU project COST TD 1201 „Colour and Space in Cultural Heritage (COSCH)" and cooperation project with industrial sphere to develop and implement measurement of inclination of reactor vessels for the 3rd and 4th block of the nuclear power plant in Mochovce, Slovakia.

In the field of **X-ray microtomography,** analysis of limiting possibilities of the measurement method, particularly in terms of achieving the best resolution and uncertainty, was performed; the results of which have been and in the future also will be used to optimize CT measurement methodologies.

The impact of the spectral composition of X-rays on the formation of beam-hardening effect in computed tomography and the possibility of influencing the X-ray spectrum by filtration of the outgoing radiation by means of different metallic filters was analyzed. The influence of the ratio between generation of braking and characteristic radiation by selection of metallic targets (tungsten, molybdenum, copper) was also sized up.

To the most important achievements of the department in the field of material research, engineering, mineralogy, geology, microelectronics, biology, archaeology and cultural heritage protection belongs the design of new methodologies for measurement and non-destructive testing using X-ray microtomography.

For the use in the **field of material research** a microtomographic methodology for non-destructive visualization of the internal structure of superconductors was designed and optimized, which allows non-destructive measurement of the effective cross section along a superconducting wire.

In the field of geology and mineralogy a methodology of microtomographic characterization of minerals and rocks was proposed, with emphasis on distinguishing different phases of minerals, visualization of microstructure, inclusions, voids and cracks. The method was used for example to evaluate the quality of marble samples exposed to stress test of salt crystallization and frost test.

For the application in the **field of biological research** the micro CT methodologies were designed for imaging and comparisons of small bony structures that were used in the comparative anatomical analysis of the type Pseudopus apodus with representatives of the genus Anguinae. An important benefit of this new methodology using microtomography is considerable increase of the complexity of compared structures throughout their substance, quantitative analysis of selected dimensional structures with small achievable measurement uncertainty.

Scientific results achieved in the department were published in internationally recognized journals.

The research in the **Department of Magnetometry** was focused at the following main areas:

- Development of SQUID magnetometric methods for magnetic nanoparticles and nanoliquids;
- Synthesis of nanomaterials based on Vanadium;
- Research of superconducting model of the magnetic admixtures in diamagnetic matrix;
- Research of magnetic properties of ferroliquids.

In the field of **SQUID magnetometric methods for magnetic nanoparticles and nanoliquids**, two SQUID magnetometric methods and methodology for quantification of the content of magnetic nanoparticles transported by magnetic liquids into the tissue of the laboratory animals and into the human normal and cancer cell lines have been designed. The first method utilizes one-channel 2nd order SQUID gradiometer, driven by a low-frequency AC magnetic field and Fe_3O_4 nanoparticles. The estimated sensitivity of measurements of the concentration of nanoparticles in the biological tissues and colloid solutions is 3-5 $\mu g_{Fe3O4}/cm^3_{H2O}$. The second method has been developed for determination of the content of uptaken magnetite nanoparticles by human cell lines. The method is based on the use of the SQUID susceptometer MPMS XL 7AC and comparison of the magnetic properties of the cells exposed to magnetic nanoparticles with the magnetic properties of the used nanoparticle suspension. Composite nanoparticles of Fe_3O_4@OS.BSA (OS – Sodium Oleate; BSA - Bovine Serum Albumin), 10/70 nm, were applied into the human cell cultures (hepatal cells Hep 62, lung cancer cells A 549, bone cancer cells U2OS and skin cells HaCaT). The obtained Fe contents were compared and correlated with Fe contents determined by standard atomic absorption spectroscopy.

In the field of **synthesis of nanomaterials based on Vanadium**, a new procedure of preparation of 25-60 nm V_2O_3 nanocrystals in the salt matrix of Na_2SO_4 using the mechanochemical-thermal reduction between V_2O_5 and Na_2SO_3 was developed. The magnetic characteristics of V_2O_3 nanocrystals show the paramagnetic to antiferromagnetic state transition at the temperature of 144 K.

Study of superconducting model of the magnetic admixtures in diamagnetic matrix. Samples of high-Tc Eu-123 superconductor doped by Ru were synthetized by the solid phase reaction and the effect of doping has been studied. The superconductor is a model of an ideal diamagnetic matrix and the doping by the Ru leads to creation of $Ba_3EuRu_2O_9$ phase containing the magnetic Ru_2O_9 dimers. The obtained results imply possible new way to study the interaction between diamagnetic and magnetic media using the superconductors and temperature as keys for turning of their diamagnetic properties.

In cooperation with our partner research institutions, *Polymer Institute of SAS* and the *Institute of Electrical Engineering of SAS,* the Department contributed to the **research of magnetic properties of ferroliquids.** Superparamagnetic suspensions of Fe_3O_4, Ni and

NiFe nanoparticles were prepared. The magnetic properties of aqua suspensions of biocompatible composite nanoparticles of the core/shell type were studied. They were prepared by precipitation of the iron oxide from $FeCl_3.6H_2O$ and $FeCl_2.4H_2O$ (or $FeCl_3.6H_2O$ and $FeSO_4.7H_2O$) into dH_2O by adding NH_4OH and citric acid. Correlations between selected magnetic and technological parameters were found. We have measured and analyzed the magnetic properties of suspensions of Fe_3O_4, Ni and NiFe nanoparticles prepared by so called green technology using ionic liquids. Magnetic suspensions of Ni and NiFe nanoparticles have been prepared by vacuum sputtering from metal targets into ionic liquids BMIM-PF6 and BMIM-NTf2. We have obtained original results on the temperature dependence of molar magnetic susceptibility of used ionic liquids.

The research in the **Department of Theoretical Methods** was oriented into the area of applied mathematics and focused on basic research and advanced applications in the field of measurement science and metrology. In particular, the research was primarily oriented to

- mathematical statistics,
- nonlinear dynamic systems and mathematical modelling,
- scientific computing and applied informatics.

The emphasis was placed into the research of modelling and evaluation of measurement processes, including proper design of experiments, development of mathematical and statistical models, methods and algorithms for evaluation and proper interpretation of experimental data in different areas of technical and biomedical research.

During the assessed period, the Department had **intensive scientific cooperation** with research partners in Slovakia (e.g. Faculty of Mathematics, Physics and Informatics, Comenius University and Mathematical Institute of the SAS in Bratislava) and abroad (Faculty of Mathematics and Physics, Charles University in Prague, Institute of Computer Science, Academy of Sciences of the Czech Republic, Faculty of Natural Sciences, Palacky University in Olomouc and Faculty of Natural Sciences, Masaryk University in Brno, Czechia, Breath Research Institute, Austrian Academy of Sciences, Austria, Louisiana State University, New Orleans, USA, Physikalisch-Technische Bundesanstalt (PTB) Braunschweig, and TU Munich, Germany, University of Oxford, UK, and University of California, Los Angeles). In cooperation with our partners we have organized 7th international conference on probability and mathematical statistics focused on mathematical statistics and its applications - PROBASTAT 2015. The Department's members have been well established in international scientific organizations and served as editors of numerous domestic and international scientific journals. Expertise and acknowledged professional competence of the department's research staff allowed participation and effective contribution to several advanced applications in different interdisciplinary areas of technical and biomedical research. In cooperation with our international partners we have been incorporated in participation and/or preparation of several bilateral and multilateral projects.

In the area of **mathematical statistics for measurement science and metrology**, the basic research was focused on development of the theory, methods and algorithms for univariate calibration of sensors and transducers, as well as for determination and evaluation of the associated measurement uncertainties and their comparison with the currently adopted standards. We have contributed to the development of statistical methods for proper evaluation of interlaboratory comparisons, by designing new methods for determination of the comparison reference value and/or the key comparison reference value, i.e. the estimate of the parameter of a common mean of the quantity measured in different laboratories, typically in high-level metrological institutes, e.g. in the National Metrology Institutes (NMIs). As a main representative result of this part of research we consider the published monograph 'Evaluation of the Gauge Calibration: Statistical Methods for Uncertainty Analysis in Metrology'. New original results have been achieved in the development of the theory of nonparametric methods, linear mixed effects models,

statistical tolerance intervals, methods and algorithms for deriving the exact probability distribution by numerical inversion of its characteristic functions. Significant results have been achieved by application of new developed advanced methods applied in metrology and measurement (e.g., determination of measurement uncertainty of the phase in high precision measurements using the quadrature homodyne interferometer, in co-operation with PTB Germany), and in processing of electrophysiological signals (e.g. comparison of coherence and phase synchronization on sleep electroencephalogram, in co-operation with the Institute of Computer Science in Prague and/or detection of the EEG oscillations involved in the sensorimotor transformation of pain, in co-operation with the TU Munich and the University of Oxford).

In the area of **nonlinear dynamical systems**, the research was focused on (1) time series causality analysis in reconstructed state spaces, (2) problems of complexity evaluation, and (3) applications to EEG measurements. The original results include the recognition that for optimal state space reconstruction the time delay and embedding dimension are critical. Moreover, if several time series of the system are observed, the choice of the one for the reconstruction could also be important. In properly reconstructed state spaces, we used correlation dimension and other causality methods to study unidirectional coupling and synchronization of interconnected dynamical systems. We have developed methods that can be used to estimate their active degrees of freedom, detect full synchronization and reveal the direction of coupling. Applications concern sleep electroencephalograms (EEG) of patients after ischemic stroke and healthy subjects, brain signals during relaxation and audio-visual stimulation. When it comes to the complexity measures, our results were consistent with the rising hypothesis about complexity decrease of the EEG after various types of brain damage. Moreover, we found that the EEG complexity is age-dependent – it increases up to the age of about 60 years and then the complexity stagnates or slightly decreases.

The research of **bio-inspired networks of artificial intelligence** based on deep learning architecture was focused on the further development of the model of Hierarchical Temporal Memory (HTM) enabling its application to the area of computer vision. We proposed a novel method of temporal pooling of image data that makes possible a faster and more reliable training of the HTM networks in the tasks of image classification. We elaborated novel measures of importance using classification complexity characterization. As the initial architecture of the HTM was oriented exclusively to gray-level images, we explored suitability of various color features and eventually extended the HTM functionality by several types of such complex features. An extremely challenging problem for the HTM network was the classification of objects located in clutter color scenes. We proposed a novel concept consisting in a combination of a special computational model of visual attention, generating image saliency maps, with three parallel HTM networks, which separately process color, texture, and shape information. Our benchmark experiments (comparison with cascade detectors and template matching algorithms) showed comparable results in obtained recall values, while the HTM outperformed the other methods in achieved accuracy. The research results justified our concept and showed its potential for further advancement. All mentioned results were included in two PhD theses which were successfully defended in 2014-15.

The research in the area of **biomedical applications** was oriented onto two major topics: (1) we investigated the effects of sleep disturbances on day-time neurocognitive performance of patients with stroke. We addressed a challenging question how a typical, good quality structure of sleep should look like in patients with stroke and how their sleep profiles differ from healthy population. With this aim we applied and evaluated completely new approach of characterizing the sleep process using a novel probabilistic sleep model (PSM). In addition, we developed novel functional data clustering methodology for clustering posterior probability curves of the PSM which characterize activation of a set of sleep microstates during the night. In a series of tests on stroke patients and healthy subjects we have shown that the model contains significantly more objective information about external measures of the sleep quality than the traditional sleep staging. Collaboration with Professor Eran Zaidel from the Department of Psychology, University of

California, Los Angeles, was focused on sleep and day-time cognitive status monitoring of patients after stroke. The modified Lateralized Network Attention Test (LANT) developed by Prof. Zaidel and his colleagues was implemented in our project. The test was included into a battery of cognitive tests carried out by stroke patients at the I. Neurology Clinic, Comenius University Faculty of Medicine. (2) we developed novel hardware and software platform for robot-assisted training for neurorehabilitation. We used advanced tools and methods of applied statistics for the design and development of an intelligent system allowing the users to go through the process of self-controlled training of impaired motor pathways. We combined the brain-computer interface (BCI) technology with a robotic arm system into a compact system that can be used as a robot-assisted neurorehabilitation tool. The BCI directly uses the signal of the brain electrical activity (electroencephalogram or EEG) to allow users to operate the environment without any muscular activation. By applying the new atomic decomposition of the scalp EEG signal we addressed several critical issues associated with using BCI in neurorehabilitation, namely, issues ranging from signal acquisition and selection of the proper BCI paradigm to the evaluation of the affective state, cognitive load and system acceptability of the users. Early in 2015 we started testing the system on two patients with motor impairments caused by stroke, as well as on healthy volunteers.

Basic research in the **Department of Imaging Methods** was aimed at imaging of biological and physical objects using nuclear magnetic resonance (NMR) at low magnetic fields of 0.1 and 0.2 Tesla and in high magnetic fields of 3.0, 4.7 and 7.0 Tesla in the framework of international co-operation. The main goals of the research were:

- new imaging methods,
- special sensors,
- imaging of human articular cartilage,
- instrumentation for polarized helium lung imaging,
- imaging of macro- and microstructures for biomedical and material research,
- imaging using magnetic nano-particles,
- development of a diagnostic tool for quantitative MRI imaging of biogenic iron in clinical practice.

Main aspects and results of the scientific research in the Department have been covered and achieved within the following research projects:

Diagnostics of human articular cartilage using MRI - scientific co-operation with the MR Centre of Excellence with the Department of Radiology, Medical University of Vienna, Austria oriented to (1) diagnostics of human articular cartilage using MRI, (2) imaging of micro- and nanostructures based on magnetic resonance for biomedical and material research, (3) mutual exchanges of scientists and PhD students enabling them to perform imaging experiments on MRI instruments in the partner laboratories.

Development of a diagnostic tool for quantitative MRI imaging of biogenic iron in clinical practice – research project of the Slovak Research and Development Agency based on the assumption that a precursor for Alzheimer's disease, Parkinson's disease, and Huntington's disease is a magnetite formation of ferritin, which changes the structure due to disrupted iron homeostasis. Moreover, the excess concentrations of ferritin in tissue can lead to so called iron-overloaded complications, which include diabetes, cirrhosis, and heart disease. For successful diagnostics and therapy, it is necessary to have a diagnostic tool for early detection of pathological processes related to disrupted iron homeostasis. However, at present, such diagnostic tool does not exist. In neurodegenerative disorders, the diagnostics is restricted just to monitoring of neurological symptoms and the only reliable proof of disorder is autopsy. For diagnostics of ferritin there are two methods available in clinical practice: biopsy and samples from the blood serum. The ability of MRI to detect body iron has been already proposed, however the most important problem - body iron quantification in vivo, has not been solved yet. Within the project a diagnostic tool for the non-invasive quantification of the biogenic iron

with the help of MRI techniques will be created. This could be useful in clinical practice for early detection of pathological processes connected with the disrupted iron homeostasis.

Imaging and mapping of organic and synthetic materials and objects using magnetic resonance imaging methods - project of the VEGA Scientific Grant Agency focused on basic research of selected imaging techniques based on NMR and measurement and mapping of specific physical quantities of organic and synthetic materials and objects. Tasks of the project include (1) theoretical and experimental study of measurement and mapping techniques of specific physical qualities of organic and synthetic materials and objects, (2) detection of iron homeostasis in organism and magnetic qualities of ferric complexes, (3) monitoring of the ripening of the cartilage of human limbs in the period following the cartilage transplantation. Algorithms for processing of the relaxation times of the Achilles tendon., (4) Imaging of the phosphocreatine re-synthesis after burden, using the MRI and MRSI, (5) study of spectral features of vibrations in MR scanner, development of algorithms for its suppression, Theoretical models of the movement dynamics of spherical drops of aerosol made of magnetic nanoparticles of lungs alveoli.

Building of a top laboratory aimed at NMR research – project of a state program of research and development (Complex solution of support and effective utilization of science and research infrastructure). The aim of the project was to build the Centre for NMR Based Material Imaging in the Institute of Measurement Science as a part of the National Centre of NMR – the Centre of excellence. Some of the main goals of the specialized center as a part of the NC of NMR during solving the task and after its finishing were (1) education of experts for NMR based measuring systems, technical as well as postdoctoral-study-based scientific, (2) function of an initialization center for a new products and technologies support, (3) support of other research and development projects solving (own projects, local and international projects, technical services for other projects, (4) support of activities of other research centers and projects (centers of excellence).

European Network for Hyperpolarization Physics and Methodology in NMR and MRI - European COST project oriented to stimulating and accelerating collaborations and joint research efforts between European groups into hyperpolarization physics and methodology with the goal to develop robust strategies for sensitivity enhancement in NMR and MRI. Coordinated short-term scientific missions (STSMs) made it possible to fully exploit the potential of unique scientific instrumentation which already exists in a number of European groups. Summer schools and workshops provided education and training for the early stage researchers that are entering the interdisciplinary research field. The scientific program was organized into 5 different working groups that focused on key issues related to the topic of the Action. The scientific program of this Action was supported by a wide range of research groups thus generating a high added value for the European research landscape.

The research in the **Department of Biomeasurements** is in the long-term oriented to new measurement technologies and methods for diagnostic and therapeutic interpretation of selected biosignals. Within the assessed period, the activities of the Department were focused on the measurement, analysis and modelling of the cardiac electrical field in humans, particularly on 3 topics:

- realistic modeling of the heart activation to explain variations of the generated cardiac electrical field during normal activity and in selected pathologies,
- research of methods for non-invasive assessment of local cardiac pathologies based on models of the cardiac electric generator and solution of the inverse problem of electrocardiology; analysis of conditions that influence the results of the proposed inverse methods or limit their applicability,
- development of advanced technologies for biomedical measuring systems oriented to multichannel measurement of the cardiac electrical field.

The research was covered by two grants from the APVV agency (APVV-0153-10 “Measuring, communication and information systems for monitoring of the cardiovascular risk in hypertension patients”, APVV-14-0875 “Noninvasive localization of ectopic arrhythmias of heart ventricles using ECG mapping and its use for causal therapy”), two VEGA grants (VEGA 2/0210/10, “Methods and systems for multichannel measurement and evaluation of bioelectric signals of heart and brain”, VEGA 2/0131/13 “Methods and systems for measurement, displalying and evaluation of the cardiac electrical field at hypertension hypertrophy“) and grant from the EU structural funds “University research park Biomedicine, Bratislava”. These projects included also cooperation with National institute of cardiovascular diseases in Bratislava (NICD).

The international cooperation included three international bilateral projects – two with Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, Warsaw, Poland (“Model based analysis and diagnostic interpretation of cardiac electric field measured by high-resolution ECG” and “High Resolution Multiple-lead ECG measurement for model based interpretation of cardiac electrical field”) and one with Panonia University in Veszprém, Hungary (“Measurement and Information Processing for Diagnostic Imaging of Cardiac and Brain Electrical Fields”) and direct cooperations with Faculty of Biomedical Engineering, Czech Technical University in Prague, Czechia, Halifax University in Canada and Institute of Computational Science, Università della Svizzera Italiana, Lugano, Switzerland. The cooperation with newly established CEI – Consortium for ECG-Imaging started in 2015. CEI is the international group of researchers interested in the concepts of noninvasive ECG imaging and cooperating by sharing the measured data and comparing the obtained results. Members of the Department were also active as members and officers of the IEEE Engineering in Medicine and Biology Society and International Measurement Confederation IMEKO.

Within the first topic, the previously developed **cellular automaton model of the heart activation was extended** to simulate different velocities of activation. Using this model, in cooperation with the partner in Hungary, action potential changes were modelled that led to changes of so called “nondipolarity index” in surface ECG maps observed in patients with ectopic ventricular activation. The same model was used in cooperation with the Polish partner to explain some T-Wave Alternans (TWA) by alternated global and local changes of the repolarization phase of action potentials. More advanced **heart activation model using eikonal equations and parallel computing was developed** within a doctoral study in cooperation with the partner in Lugano that allows fast heart activation modelling including anisotropy of the cardiac tissue. Finally, **reaction-diffusion models were implemented** using the Courtemanche-Ramirez–Nattel or FitzHugh-Nagumo equations to simulate atrial and ventricular activation on the cellular level and to study the influence of changed tissue parameters on the activation spread.

Within the second topic two methods for non-invasive localization of cardiac pathologies have been developed using multichannel surface ECG measurements, models of the torso geometry and simplified single or multiple dipole models of the cardiac electric generator.

The first method uses the difference between surface ECG maps with and without manifestation of the pathology **to localize one or two ischemic lesions**. The method has been developed and tested on data (with CT torso models) obtained from the partner in Canada and on real patient data (with approximate torso model without CT) measured in cooperation with partners in Poland. Several approaches using one or two dipoles or a group of dipoles to represent larger ischemic lesions were proposed and evaluated. Good agreement of the results with SPECT examinations was achieved.

The second developed method is intended for **noninvasive pre-operational localization of the focus of ectopic ventricular activity**. The method evaluates initial phase of the ectopic beat and looks for an equivalent dipole generator representing the focal pathological activity. The method has been developed and optimized in cooperation with partners in Czechia. Several patients were measured in Prague and in Kiev, Ukraine. Obtained results showed accuracy promising possible clinical usage of the method.

Currently, a national project for its clinical implementation is running in cooperation with NICD in Bratislava.

Extensive testing of the proposed inverse method on simulated as well as on real patient data was performed in cooperation with the partners. The accuracy of electrode positions, different levels of torso model approximation (with or without CT), selection of evaluated time interval in ECG, noise in ECG data etc. were tested. The results led to the optimization of the proposed methods.

Within the third topic the technology for ECG measurement was further developed and methods for ECG processing, CT usage for torso modelling, and computations for the proposed inverse methods were implemented. Partial parallelization of signal processing and model computations was included. High resolution 128-channel **ECG mapping device ProCardio 8 with active electrodes was completed** and devices were supplied to the partners for measurements on patients in Czechia, Ukraine and Slovakia.

2. Partial indicators of main activities:

2.1. Research output

2.1.1. Principal types of research output of the institute: basic research/applied research, international/regional (ratios in percentage)

- ratio of the basic research / applied research: 70 / 30
- ratio of the international / regional research: 90 / 10

2.1.2 List of selected publications documenting the most important results of basic research. The total number of publications listed for the assessment period should not exceed the average number of employees with university degrees engaged in research projects. The principal research outputs (max. 5, including Digital Object Identifier - DOI) should be underlined

[1] ANDRIS, Peter – FROLLO, Ivan. Measurement of magnetic field with background using a low field NMR scanner. In *Measurement Science and Technology*, 2012, vol. 23, no. 6, art. no. 065006. ISSN 0957-0233. (1.494-IF2011). DOI: 10.1088/0957-0233/23/6/065006.

[2] BILLIK, Peter – ČAPLOVIČOVÁ, M. Mechanochemical synthesis of oxide nanopowders. In *Advances in Nanotechnology: Volume 8*. Editor Z. Bartul, J. Trenor. – Hauppauge NY, USA: Nova Science Publishers, 2012. ISBN 978-1-61324-062-5, p. 111-164.

[3] FROLLO, Ivan – ANDRIS, Peter - GOGOLA, Daniel - PŘIBIL, Jiří - VALKOVIČ, Ladislav – SZOMOLÁNYI, Pavol. Magnetic field variations near weak magnetic materials studied by magnetic resonance imaging techniques. In *IEEE Transactions on Magnetics*, 2012, vol. 48, no. 8, p. 2334-2339. ISSN 0018-9464. (1.363-IF2011). DOI: 10.1109/TMAG.2012.2191298.

[4] JURÁŠ, Vladimír - ZBÝŇ, Š. - PRESSL, Ch. – VALKOVIČ, Ladislav - SZOMOLÁNYI, Pavol - FROLLO, Ivan – TRATTNIG, S. Regional variations of T2* in healthy and pathologic achilles tendon in vivo at 7 Tesla: Preliminary results. In *Magnetic Resonance in Medicine*, 2012, vol. 68, p. 1607-1613. ISSN 0740-3194. (2.964-IF2011). DOI: 10.1002/mrm.24136.

[5] KÖNING, R. - KAROVIČ, Karol - WIMMER, G. - WITKOVSKÝ, Viktor. Estimating the standard uncertainty contribution of the straight-line fit algorithm used to determine the position and the width of a graduation line. In *Metrologia,* 2012, vol. 49, no. 3, p. 169-179. ISSN 0026-1394. (1.750-IF2011). DOI: 10.1088/0026-1394/49/3/169.

[6] LENKOVÁ, Jana – ŠVEHLÍKOVÁ, Jana – TYŠLER, Milan. Individualized model of torso surface for the inverse problem of electrocardiology. In *Journal of*

Electrocardiology, 2012, vol. 45, no. 3, p. 231-236. ISSN 0022-0736. (1.141-IF2011). DOI: 10.1016/j.jelectrocard.2012.01.006.

[7] MEZEIOVÁ, Kristína – PALUŠ, M. Comparison of coherence and phase synchronization of the human sleep electroencephalogram. In *Clinical Neurophysiology*, 2012, vol. 123, no. 9, p. 1821-1830. ISSN 1388-2457. (3.406-IF2011). DOI: 10.1016/j.clinph.2012.01.016

[8] ŠVEHLÍKOVÁ, Jana – LENKOVÁ, Jana – TURZOVÁ, Marie – TYŠLER, Milan – KANIA, M. – MANIEWSKI, R. Influence of individual torso geometry on inverse solution to 2 dipoles. In *Journal of Electrocardiology*, 2012, vol. 45, no. 1, p. 7-12. ISSN 0022-0736. (1.141-IF2011). DOI: 10.1016/j.jelectrocard.2011.07.012.

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[12] JURÁŠ, Vladimír – APPRICH, S. – SZOMOLÁNYI, Pavol – BIERI, O. – DELIGIANNI, X. – TRATTNIG, S. Bi-exponential T2* analysis of healthy and diseased Achilles tendons: An in vivo preliminary magnetic resonance study and correlation with clinical score. In *European Radiology*, 2013, vol. 23, no. 10, p. 2814-2822. ISSN 0938-7994. (3.548-IF2012). DOI: 10.1007/s00330-013-2897-8.

[13] MOLCAN, L. - TEPLAN, Michal - VESELA, A. - ZEMAN, M. The long-term effects of phase advance shifts of photoperiod on cardiovascular parameters as measured by radiotelemetry in rats. In *Physiological Measurement*, 2013, vol. 34, no. 12, p. 1623-1632. ISSN 0967-3334. (1.496-IF2012). DOI: 10.1088/0967-3334/34/12/1623.

[14] ROSIPAL, Roman – LEWANDOWSKI, A. – DORFFNER, G. In search of objective components for sleep quality indexing in normal sleep. In *Biological Psychology*, 2013, vol. 94, no. 1, p. 210-220. ISSN 0301-0511. (3.399-IF2012). DOI: 10.1016/j.biopsycho.2013.05.014.

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[17] DVUREČENSKIJ, Andrej – BILLIK, Peter – CIGÁŇ, Alexander – BYSTRICKÝ, Roman – MAŇKA, Ján - ŠKRÁTEK, Martin – MAJEROVÁ, Melinda. Magnetic properties of V_2O_3 nanooxide prepared mechanochemically with and without salt matrix. In *Acta Physica Polonica A*, 2014, vol. 126, no. 1, p. 398-399. ISSN 0587-4246. (0.604-IF2013). DOI: 10.12693/APhysPolA.126.398.

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[24] ŠTRBÁK, Oliver – KRAFČÍK, Andrej - TEPLAN, Michal - GOGOLA, Daniel – KOPČANSKÝ, P. – FROLLO, Ivan. Biogenic magnetite nanoparticle ensemble use in MRI diagnostics. In *Acta Physica Polonica A*, 2014, vol. 126, no. 1, p. 388-389. ISSN 0587-4246. (0.604-IF2013). DOI: 10.12693/APhysPolA.126.388.

[25] VALKOVIČ, Ladislav – GAJDOŠÍK, M. – TRAUSSNIGG, S. – WOLF, P. – CHMELÍK, M. – KIENBACHER, Ch. – BOGNER, W. – KREBS, M. – TRAUNER, M. – TRATTNIG, S. – KRŠŠÁK, M. Application of localized 31P MRS saturation transfer at 7 T for measurement of ATP metabolism in the liver: Reproducibility and initial clinical application in patients with non-alcoholic fatty liver disease. In *European Radiology*, 2014, Vol. 24, no. 7, p. 1602-1609. ISSN 0938-7994. (4.338-IF2013). DOI: 10.1007/s00330-014-3141-x.

[26] ANDRIS, Peter – DERMEK, Tomáš – FROLLO, Ivan. Simplified matching and tuning experimental receive coils for low-field NMR measurements. In *Measurement*, 2015, vol. 64, p. 29-33. ISSN 0263-2241. (1.484-IF2014). DOI: 10.1016/j.measurement.2014.12.035.

[27] DURMEKOVÁ, T. - RUŽIČKA, P. - HAIN, Miroslav – ČAPLOVIČOVÁ, M. Changes in marble quality after sodium sulphate crystallization and long-lasting freeze-thaw testing. In *Engineering Geology for Society and Territory - Volume 5: Urban Geology, Sustainable Planning and Landscape Exploitation*. Editors G. Lollino, A. Manconi, F. Guzzetti, M. Culshaw, P. Bobrowsky, F. Luino. – Springer, 2015. ISBN 978-3-319-09047-4, p. 237-241. DOI: 10.1007/978-3-319-09048-1_46.

[28] DVUREČENSKIJ, Andrej – CIGÁŇ, Alexander – BYSTRICKÝ, Roman – ŠKRÁTEK, Martin – BILLIK, Peter – MAJEROVÁ, Melinda – MAŇKA, Ján. Magnetic studies of $EuBa_2Cu_{3-x}Ru_xO_{7-\delta}$ compounds. In *Acta Physica Polonica A*, 2015, vol. 127, no. 2, p. 300-302. ISSN 0587-4246. (0.530-IF2014). DOI: 10.12693/APhysPolA.127.300.

[29] GOGOLA, Daniel – ŠTRBÁK, Oliver - KRAFČÍK, Andrej - ŠKRÁTEK, Martin – FROLLO, Ivan. Magnetic resonance imaging of the static magnetic field distortion caused by magnetic nanoparticles: Simulation and experimental verification. In *Journal of Magnetism and Magnetic Materials*, 2015, vol. 380, p. 261-265. ISSN 0304-8853. (1.970-IF2014). DOI: 10.1016/j.jmmm.2014.10.038.

[30] JURÁŠ, Vladimír - WINHOFER, Y. - SZOMOLÁNYI, Pavol - VOSSHENRICH, J. - HAGER, B. - WOLF, P. - WEBER, M. - LUGER, A. - TRATTNIG, S. Multiparametric MR imaging depicts glycosaminoglycan change in the Achilles tendon during ciprofloxacin administration in healthy men: Initial observation. In

Radiology, 2015, vol. 275, no. 3, p. 763-771. ISSN 0033-8419. (6.867-IF2014). DOI: 10.1148/radiol.15140484.

[31] KÖNING, R. - WIMMER, G. - WITKOVSKÝ, Viktor. The statistical uncertainty of the Heydemann correction: A practical limit of optical quadrature homodyne interferometry. In *Measurement Science and Technology*, 2015, vol. 26, no. 8, p. 084004. ISSN 0957-0233. (1.433-IF2014). DOI: 10.1088/0957-0233/26/8/084004.

[32] KRAFČÍK, Andrej – BABINEC, P. – FROLLO, Ivan. Computational analysis of magnetic field induced deposition of magnetic particles in lung alveolus in comparison to deposition produced with viscous drag and gravitational force. In *Journal of Magnetism and Magnetic Materials*, 2015, vol. 380, p. 46-53. ISSN 0304-8853. (1.970-IF2014). DOI: 10.1016/j.jmmm.2014.10.018.

[33] ŠTRBÁK, Oliver - MASÁROVÁ, Marta – GOGOLA, Daniel - SZOMOLÁNYI, Pavol – FROLLO, Ivan. Influence of saline and glucose molecules to contrast properties of clinically used MRI contrast agents. In *Measurement*, 2015, vol. 69, p. 109-114. ISSN 0263-2241. (1.484-IF2014). DOI: 10.1016/j.measurement. 2015. 03.036.

[34] ŠVEHLÍKOVÁ, Jana – TEPLAN, Michal – TYŠLER, Milan. Noninvasive identification of two lesions with local repolarization changes using two dipoles in inverse solution simulation study. In *Computers in Biology and Medicine*, 2015, vol. 57, p. 96-102. ISSN 0010-4825. (1.240-IF2014). DOI: 10.1016/ j.compbiomed.2014.11.020

[35] WITKOVSKÝ, Viktor - WIMMER, G. - DUBY, T. Logarithmic Lambert W × F random variables for the family of chi-squared distributions and their applications. In *Statistics & Probability Letters*, 2015, vol. 96, p. 223-231. ISSN 0167-7152. (0.595-IF2014). DOI: 10.1016/j.spl.2014.09.028.

2.1.3 List of monographs/books published abroad

none

2.1.4. List of monographs/books published in Slovakia

[1] WIMMER, G. - PALENČÁR, R. - WITKOVSKÝ, Viktor - ĎURIŠ, S. *Vyhodnotenie kalibrácie meradiel : Štatistické metódy pre analýzu neistôt v metrológii*. */Evaluation of Calibration the Measuring Instruments : Statistical Methods for the Analysis of Uncertainties in Metrology./* – Bratislava : Nakladateľstvo STU, 2015. ISBN 978-80-227-4374-7.

2.1.5. List of other scientific outputs specifically important for the institute, max. 10 items

Unique measuring systems and technologies for the research infrastructure of the Institute, for research partners and for applications.

[1] **RoboArm - a compact robot-assisted neurorehabilitation tool.** The RoboArm system combines the brain-computer interface (BCI) technology with a robotic system. The hardware was designed and constructed following the clinical expertise for motor rehabilitation training. The BCI directly uses the signal of the brain electrical activity (electroencephalogram or EEG) and allows users to operate the system without any muscular activation. We developed and coded a unique algorithmic procedures sensitive to patients' individual neurophysiological characteristics and allowing automatic adaptation to the day-to-day patients' mental and cognitive variability.
Related project: APVV- 0668-12 „Brain-computer interface with adaptive robotic arm for rehabilitation".

[2] **Nutator - laboratory scale nutating ball mill**. In order to enhance the performance, deliver energy efficiency and significantly reduce high operational costs typically associated with comminution circuits, a high-intensity ball mill based on unusual mechanical principle - nutating mode has been developed and was implemented in our material research. The inner volume of the Nutator reactor is 0.3 dm^3. In contrast with the commercial nutating ball mills, the nutating angle is in the range of 0–20 deg and the speed of rotation up to 1400 rpm, both can be adjusted independently. Mechanochemical synthesis of TiO_2 has been demonstrated by using this prototype.
Related project: APVV-0528-11 „Physical and electrochemical behavior of mechanochemically prepared nanooxides".

[3] **Automated measuring system for monitoring of tilt of reactor vessels in nuclear power plant Mochovce (3-th and 4-th block).** Research, development and realisation of complex measuring systems for automated monitoring of tilt of reactor vessels for the 3-th and 4-th block in nuclear power plant Mochovce. Realisation of this project will significantly increase the safety of operation of the nuclear power plant in Mochovce.
Related project: Research contract with AE Mochovce

[4] **ProCardio 8 - High resolution 128-channel ECG mapping device.** Development and realization of prototypes of a mobile PC-based and battery powered measuring and ECG processing system with active or passive electrodes. The system enables long term recording and processing of multichannel ECG and computation of body surface potential maps as the input for cardiac diagnostics based on inverse solutions (ECG imaging). The built systems are used in the Institute as well as by the clinical research partners (Faculty of Biomedical Engineering, Czech Technical University in Prague, Czechia, National institute of cardiovascular diseases in Bratislava, Slovakia)
Related project: APVV-0513-10 „„Measuring, communication and information systems for monitoring the cardiovascular risk in patients with hypertension."

2.1.6. List of patents, patent applications, and other intellectual property rights registered abroad, incl. revenues

[1] KAWATE, E. – HAIN, Miroslav. *Optical Characteristic Measurement Device*.
Publication number: WO 2012/121323 A1
Publication date: September 13, 2012
Applicant: National Institute of Advanced Industrial Science and Technology, Tokyo, Japan

[2] KAWATE, E. – HAIN, Miroslav. *Optical Characteristic Measuring Apparatus*.
Publication number: US 8 982 345 B2
Publication date: March 17, 2015
Applicant: National Institute of Advanced Industrial Science and Technology, Tokyo, Japan

[3] Country: Czech Republic
Authors: Vít CAITHAML, Karel HÁNA, Pavel SMRČKA, Jan KAŠPAR, Jan MUŽÍK, Milan TYŠLER, Radek FIALA
Title: Equipment for support of patients with sclerosis multiplex disease.
Industrial design submission PUV 2013-28677 on 29.10.2013
Industrial design 26256, granted 16.12.2013
Applicant: Faculty of BMI, CTU in Prague, Kladno

[4] Country: Czech Republic
Autors: Martin VÍTĚZNÍK, Karel HÁNA, Pavel SMRČKA, Jan KAŠPAR, Jan MUŽÍK, Milan TYŠLER, Radek FIALA, Lukáš NESTÁVAL, Adam WOLF

Industrial design 26328, grantd 09.01.2014
Industrial design submission PUV 2013-28675 on 29.10.2013
Title: System for measurement and long time monitoring of blood pressure.
Submitted by: Faculty of BMI, CTU in Prague, Kladno

[5] Country: Czech Republic
Autors: Radim Kliment, Karel Hána, Pavel Smrčka, Jan Kašpar, Jan Mužík, Milan Tyšler, Radek Fiala
Title: System for encrypted communication with mobile telemetric units in real time.
Industrial design 26483, granted 17.02.2014
Industrial design submission PUV 2013-28678 on 29.10.2013
Submitted by: Faculty of BMI, CTU in Prague, Kladno

2.1.7. List of patents, patent applications, and other intellectual property rights registered in Slovakia, incl. revenues

[1] ONDRIŠ, Ľubomír – BUZÁSI, Ján – RUSINA, Viktor – ONDREJKOVIČ, Peter – TRUTZ, Marián. *The optoelectronic hydrolevelling sensor using refracted light beam /Optoelektronický hydronivelačný snímač s lomeným svetelným zväzkom/.*
Publication number: SK 287 855 B6
Publication date: January 4, 2012
Applicant: Institute of Measurement Science, Slovak Academy of Sciences, Bratislava, Slovakia

[2] RUSINA, Viktor - ONDRIŠ, Ľubomír - ONDREJKOVIČ, Peter – TRUTZ, Marián. *The gas pressure measuring method and connecting for its realisation /Spôsob merania tlaku plynov a zapojenie na jeho realizáciu/.*
Publication number: SK 287 861 B6
Publication date: January 4, 2012
Applicant: Institute of Measurement Science, Slovak Academy of Sciences, Bratislava, Slovakia

2.1.8. Table of research outputs (as in annual reports).

Papers from international collaborations in large-scale scientific projects (Dwarf team, ALICE Collaboration, ATLAS collaboration, CD Collaboration, H1 Collaboration, HADES Collaboration, and STAR Collaboration) have to be listed separately.

Scientific publications	2012			2013			2014			2015			total			
	number	No. / FTE	No. / salary budget	number	No. / FTE	No. / salary budget	number	No. / FTE	No. / salary budget	number	No. / FTE	No. / salary budget	number	averaged number per year	av. No. / FTE	av. No. / salary budget
Scientific monographs and monographic studies in journals and proceedings published abroad *(AAA, ABA)*	0.0	0.000	0.000	1.0	0.030	0.002	0.0	0.000	0.000	0.0	0.000	0.000	**1.0**	**0.3**	**0.007**	**0.000**
Scientific monographs and monographic studies in journals and proceedings published in Slovakia *(AAB, ABB)*	0.0	0.000	0.000	0.0	0.000	0.000	0.0	0.000	0.000	1.0	0.030	0.002	**1.0**	**0.3**	**0.007**	**0.000**
Chapters in scientific monographs published abroad *(ABC)*	3.0	0.085	0.005	0.0	0.000	0.000	0.0	0.000	0.000	2.0	0.060	0.003	**5.0**	**1.3**	**0.037**	**0.002**
Chapters in scientific monographs published in Slovakia *(ABD)*	0.0	0.000	0.000	0.0	0.000	0.000	0.0	0.000	0.000	0.0	0.000	0.000	**0.0**	**0.0**	**0.000**	**0.000**
Scientific papers published in journals registered in Current Contents Connect *(ADCA, ADCB, ADDA, ADDB)*	25.0	0.705	0.043	16.0	0.477	0.027	27.0	0.820	0.048	26.0	0.781	0.045	**94.0**	**23.5**	**0.695**	**0.041**
Scientific papers published in journals registered in Web of Science Core Collection and SCOPUS *(ADMA, ADMB, ADNA, ADNB)*	11.0	0.310	0.019	10.0	0.298	0.017	10.0	0.304	0.018	3.0	0.090	0.005	**34.0**	**8.5**	**0.251**	**0.015**
Scientific papers published in other foreign journals (not listed above) *(ADEA, ADEB)*	10.0	0.282	0.017	3.0	0.089	0.005	3.0	0.091	0.005	4.0	0.120	0.007	**20.0**	**5.0**	**0.148**	**0.009**
Scientific papers published in other domestic journals (not listed above) *(ADFA, ADFB)*	2.0	0.056	0.003	3.0	0.089	0.005	3.0	0.091	0.005	0.0	0.000	0.000	**8.0**	**2.0**	**0.059**	**0.003**
Scientific papers published in foreign peer-reviewed proceedings *(AEC, AECA)*	14.0	0.395	0.024	13.0	0.387	0.022	9.0	0.273	0.016	0.0	0.000	0.000	**36.0**	**9.0**	**0.266**	**0.016**
Scientific papers published in domestic peer-reviewed proceedings *(AED, AEDA)*	1.0	0.028	0.002	28.0	0.835	0.048	11.0	0.334	0.019	0.0	0.000	0.000	**40.0**	**10.0**	**0.296**	**0.017**
Published papers (full text) from foreign and international scientific conferences *(AFA, AFC, AFBA, AFDA)*	2.0	0.056	0.003	0.0	0.000	0.000	1.0	0.030	0.002	7.0	0.210	0.012	**10.0**	**2.5**	**0.074**	**0.004**
Published papers (full text) from domestic scientific conferences *(AFB, AFD, AFBB, AFDB)*	0.0	0.000	0.000	3.0	0.089	0.005	3.0	0.091	0.005	22.0	0.660	0.038	**28.0**	**7.0**	**0.207**	**0.012**

- **Supplementary information and/or comments on the scientific outputs of the institute.**

  The detailed list of the Institute's research outputs (publications) prepared by the Central Library of SAS is presented in the Appendix.

  When comparing with the previous assessment period the publication activities in CC journals increased due to internal measures significantly from 14.8 to 22.3 per year (by 50%) while the research staff decreased from 34 to 30 (FTE), giving the increase from 0.42 to 0.70 CC publications / FTE, i.e. increase to 165%.

  For publications published during the assessed period in impacted journals, the average impact factors (IF in the Journal Citation Reports by Thomson Reuters at the time of particular publication) were: 2.116 for publications in 2012, 2.785 for publications in 2013, 2.013 for publications in 2014 and 2.583 for publications in 2015. The total average IF for publications published in 2012-2015 was 2.345.

  The methodology of recording and categorization of the research outputs and activities have been changed during the assessment period. In the years 2012-2014, the publications in the peer-reviewed proceedings have been recorded under categories AEC and AED, i.e. as the scientific publications in international / national scientific proceedings (including the proceedings from conferences). Since 2015, following the new SAS directive about registration and categorization of the research outputs and citations, the publications in the peer-reviewed proceedings are recorded under the categories AFC, AFD, AFA, AFB, i.e. as (published and invited) contributions to international / national scientific conferences.

2.2. Responses to the research outputs (citations, etc.)

2.2.1. Table with citations per annum.

Citations of papers from international collaborations in large-scale scientific projects (Dwarf team, ALICE Collaboration, ATLAS collaboration, CD Collaboration, H1 Collaboration, HADES Collaboration, and STAR Collaboration) have to be listed separately.

Citations, reviews	2011		2012		2013		2014		total		
	number	No. / FTE	number	No. / FTE	number	No. / FTE	number	No. / FTE	number	averaged number per year	av. No. / FTE
Citations in Web of Science Core Collection (1.1, 2.1)	282.0	7.957	320.0	9.538	391.0	11.881	424.0	12.729	**1417.0**	**354.3**	**10.480**
Citations in SCOPUS (1.2, 2.2) if not listed above	78.0	2.201	79.0	2.355	113.0	3.434	87.0	2.612	**357.0**	**89.3**	**2.640**
Citations in other citation indexes and databases (not listed above) (3.2,4.2,9,10)	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	**0.0**	**0.0**	**0.000**
Other citations (not listed above) (3, 4, 3.1, 4.1)	9.0	0.254	6.0	0.179	10.0	0.304	24.0	0.721	**49.0**	**12.3**	**0.362**
Reviews (5,6)	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	**0.0**	**0.0**	**0.000**

2.2.2. List of 10 most-cited publications, with number of citations, in the assessment period (2011 – 2014).

[1] ROSIPAL, Roman - TREJO, L. J. Kernel partial least squares regression in RKHS. In Journal of Machine Learning Research, 2001, vol. 2, p. 97-123. ISSN 1532-4435. 143 citations in WOS + 60 citations in SCOPUS.

[2] TEPLAN, Michal. Fundamentals of EEG measurement. In Measurement Science Review, 2002, vol. 2, p. 1-11. (2001 - Current Contents). ISSN 1335-8871. 89 citations in WOS + 87 citations in SCOPUS.

[3] DOMAYER, S. - WELSCH, G.H. - DOROTKA, R. - MAMISCH, T.C. - MARLOVITS, S. - SZOMOLÁNYI, Pavol - TRATTNIG, S. MRI monitoring of cartilage repair in the knee: A review. In Seminars in Musculoskeletal Radiology, 2008, vol. 12, no. 4, p. 302-317. (0.966 - IF2007). (2008 - Current Contents). ISSN 1089-7860. 28 citations in WOS + 3 citations in SCOPUS.

[4] ROSIPAL, Roman. Kernel partial least squares for nonlinear regression and discrimination. In Neural Network World: International Journal on Non-Standard Computing and Artificial Intelligence, 2003, vol. 13, no. 3, p. 291-300. ISSN 1210-0552. 23 citations in WOS + 8 citations in SCOPUS.

[5] ŠUŠMÁKOVÁ, Kristína - KRAKOVSKÁ, Anna. Discrimination ability of individual measures used in sleep stages classification. In Artificial Intelligence in Medicine, 2008, vol. 44, p. 261-277. (1.825 - IF2007). (2008 - Current Contents). ISSN 0933-3657. 20 citations in WOS + 11 citations in SCOPUS + 5 other citations.

[6] TRATTNIG, S. - MARLOVITS, S. - GEBETSROITHER, S. - SZOMOLÁNYI, Pavol - WELSCH, G.H. - SALOMONOWITZ, E. - WANATABE, A. - DEIMLING, M. - MAMISCH, T.C. Three-dimensional delayed Gadolinium enhanced MRI of cartilage (dGEMRIC) for in vivo evaluation of reparative cartilage after matrix-associated autologous chondrocyte transplantation at 3.0 T - preliminary results. In Journal of Magnetic Resonance Imaging, 2007, vol. 26, no. 4, p. 974-982. (2.637 - IF2006). (2007 - Current Contents). ISSN 1053-1807. 27 citations in WOS + 1 citation in SCOPUS.

[7] BALÁŽ, P. - ACHIMOVIČOVÁ, M. - BALÁŽ, M. - BILLIK, Peter - CHERKEZOVA-ZHELEVA, Z. - CRAIDO, J.M. - DELOGU, F. - DUTKOVÁ, E. - GAFFET, E. - GOTOR, F.J. - KUMAR, R. - MITOV, I. - ROJAC, T. - SENNA, M. - STRELETSKII, A. - WIECZOREK-CIUROWA, K. Hallmarks of mechanochemistry: From nanoparticles to technology. In Chemical Society Reviews, 2013, vol. 42, p. 7571-7637. (24.892 - IF2012). (2013 - Current Contents). ISSN 0306-0012. 27 citations in WOS.

[8] ŠUŠMÁKOVÁ, Kristína. Human sleep and sleep EEG. In Measurement Science Review, 2004, vol. 4, p. 59-74. ISSN 1335-8871. 16 citations in WOS + 11 citations in SCOPUS.

[9] NÖEBAUER-HUHMANN, I.M. - SZOMOLÁNYI, Pavol - JURÁŠ, Vladimír - KRAFF, O. - LADD, M. E. - TRATTNIG, S. Gadolinium-based magnetic resonance contrast agents at 7 tesla: In vitro T1 relaxivities in human blood plasma. In Investigative Radiology, 2010, vol. 45, no. 9, p. 554-558. (4.850 - IF2009). (2010 - Current Contents). ISSN 0020-9996. 21 citations in WOS + 2 citations in SCOPUS.

[10] SCHWARZ, K. - PIZZINI, A. - ARENDACKÁ, Barbora - ZERLAUTH, K. - FILIPIAK, W. - SCHMID, A. - DZIEN, A. - NEUNER, S. - LECHLEITNER, M. - SCHOLL-BÜRGI, S. - MIEKISCH, W. - SCHUBERT, J. - UNTERKOFLER, K. - WITKOVSKÝ, Viktor - GASTL, G. - AMANN, A. Breath acetone - aspects of normal physiology related to age and gender as determined in a PTR-MS study. In Journal of Breath Research, 2009, vol. 3, p. 027003. (2009 - IOP). ISSN 1752-7155. 21 citations in WOS + 2 citations in SCOPUS.

2.2.3. List of most-cited authors from the Institute (at most 10 % of the research employees with university degree engaged in research projects) and their number of citations in the assessment period (2011– 2014).

- SZOMOLÁNYI Pavol 352 WOS + 42 SCOPUS = **394** (WOS+SCOPUS)
- ROSIPAL Roman 199 WOS + 84 SCOPUS = **283** (WOS+SCOPUS)
- TEPLAN Michal 114 WOS + 106 SCOPUS + 4 = **220** (WOS+SCOPUS)
- JURÁŠ Vladimír 131 WOS + 3 SCOPUS = **134** (WOS+SCOPUS)
- WITKOVSKÝ Viktor 113 WOS + 17 SCOPUS + 7 = **130** (WOS+SCOPUS)

- **Supplementary information and/or comments on responses to the scientific output of the institute.**

  The detailed list of responses to the scientific output (citations) of the Institute is presented in the Appendix, prepared by the Central Library of SAS.

  Due to improved publication activity in scientific journals the response to the scientific output of the Institute significantly increased during the assessment period. The number of Web of Science Core Collection citations increased from 207 in 2011 to 435 in 2015. The one-year average of citations increased from 152 in the previous assessment period to to 354 in this period. Similarly, the one-year average of citations in SCOPUS (not listed in WOS) increased from 39 to 98.

2.3. Research status of the institute in international and national contexts

- **International/European position of the institute**

2.3.1. List of the most important research activities demonstrating the international relevance of the research performed by the institute, incl. major projects (details of projects should be supplied under Indicator 2.4). Max. 10 items.

[1] **Optical measurement methods for nanoelectronics**

Long-standing scientific cooperation with the Japanese partner is focused on the development of optical measuring methods applicable in research and electronic industries in the field of nanoelectronics. A new method of measurement the scattering of optical radiation incident on a surface of the test material was jointly elaborated. The measurement is carried out using the specialized optics, digital CCD camera and computer with the developed measuring software. The method was experimentally verified and the experimental apparatus Scatterometer was developed for the fast measurement of distribution function of the reflected light. The results were published and the equipment was protected by a patent on a worldwide basis.

Related projects: bilateral cooperation (covered by Memorandum of Understanding between partner institutions) with Nanoelectronics Research Institute, National Institute of Advanced Industrial Science and Technology, Tsukuba, Japan

[2] **X-ray microtomographic methods for analyzing, testing and documentation of valuable historical artefacts of cultural heritage**

Investigators from the Institute are involved in the case study "Roman silver coins". They have developed and applied specific X-ray microtomographic methods for analyzing, testing and documentation of valuable historical artefacts of cultural heritage. Scientific scope of the research covers the area of multispectral and hyperspectral imaging, X-ray computed tomography, scanning of 3D objects using structured light, laser scanning, terahertz imaging and other optical - physical methods. Institute of Measurement Science SAS within the case study “Roman silver coins” conducted microtomographic measurement of 3D shape and internal structure of silver coins from the times of ancient Rome. Microtomographic measurements have revealed hidden cracks and traces of internal corrosion, which are an important factor in determining the authenticity of historical coins.

Related projects: VEGA 2/0126/13, EU COST project: Colour and Space in Cultural Heritage
http://www.cost.eu/COST_Actions/mpns/TD1201, http://www.cosch.info/

[3] **Magnetometric measurement of low concentrations of coated iron oxide nanoparticles**

The coated magnetic nanoparticles are prospective drug carriers at targeted therapy. In this application it is important to know the distribution (concentration) of nanoparticles in organs or parts of body. Our study has been aimed at investigation of various parameters influencing the minimum detectable level at magnetometric measurements of low concentrations of nanoparticles in suspension model samples using the specially adapted own SQUID gradiometric system and QD MPMS XL 7AC SQUID system by Quantum Design. We have investigated and analyzed the influence of medium, sample size, and its position with respect to the sensor. Results of the study are applicable in measurement of nanoparticle concentration in organs of small laboratory animals, where the limiting factor for minimum detectable concentration of nanoparticles are, besides other things, the small dimensions of organs of these animals.
Related projects: VEGA 2/0152/13, VEGA 2/0143/13, bilateral scientific project with the Department of Inorganic and Physical Chemistry University of Ghent, Belgium.

[4] **Superconducting model of magnetic admixtures in diamagnetic matrix**

Magnetic nanoliquids and nanoparticles are prospective materials for industrial and biomedical applications, e.g. wastewater treatment by separation of toxic heavy metal ions, MRI diagnostics, and targeted drugs transport or cancer treatment by hyperthermia. In the field of development of these materials it is necessary to know their magnetic properties which are important for their functionality. The last is especially important for nanoparticles of small dimensions or composite nanoparticles consisting of core and several coating layers which are bearers of their multifunctional properties. Regarding the magnetic properties it is necessary to solve the influence of the core, its surface layer and individual coating layers on the resulting nanoparticles properties and in magnetic nanoliquids also the mutual influence of the liquid medium, which is mostly diamagnetic, and solid magnetic nanoparticles. We have studied the effect of doping of Eu-123 high-superconductor by ruthenium. Superconductor is a model of ideal diamagnetic matrix and the Ru doping leads to forming of $Ba_3EuRu_2O_9$ phase containing the magnetic Ru_2O_9 dimers. The obtained results signpost a new possible way to study the mutual influence of diamagnetic and magnetic media using the superconductors and temperature as a key for turning off their diamagnetic properties.
Related projects: APVV-0125-11, ASFEU projects 26240220073 (Centre of Competence for New Materials, Advanced Technologies and Power Engineering), 26240120019 (CENTE II), scientific cooperation with the Department of Inorganic and Physical Chemistry University of Ghent, Belgium. Bilateral project: Research and applications on HTc superconductors.

[5] **Determination of the measurement uncertainty of the phase measurements by the quadrature homodyne interferometer**

Optical interferometers are significantly used in dimensional metrology and its applications. The quadrature homodyne interferometers allows to perform very precise measurements (with sub-nanometer precision). In collaboration with the PTB in Braunschweig (Physikalisch-Technische Bundesanstalt, Braunschweig, Germany) original methods and algorithms have been developed that allow simultaneous estimation of the model parameters and the related statistical uncertainties, including the uncertainties of the estimated phases and/or displacements, respectively.

Related projects: APVV-0096-10, VEGA 1/0038/12, VEGA 1/0043/13, bilateral cooperation with PTB Braunschweig, Germany.

[6] **Comparison of coherence and phase synchronization on sleep electroencephalogram**

Synchronization measures applied to the electroencephalogram (EEG) reflect the level of coordination between different parts of the cerebral cortex. Investigation of these phenomena has been done mostly by the means of coherence. The concept of phase synchronization allows to separate the effect of the amplitude and phase of the signals. We have compared the methods to estimate the synchronization of the signals. We have also examined the kinds of synchronization occurring during sleep - depending on the strength of the couplings between signals we detect uncorrelated state, the state of phase synchronization or full synchronization. Further, we have calculated the coherence, the mean phase synchronization and Pearson's correlation coefficient of analytic amplitudes in the spectral ranges used in the analysis of EEG. These measures were calculated for 6-channel whole-night EEG recordings from 25 healthy subjects. Evaluation of the measures was made with respect to three aspects - a state of consciousness (waking, sleep with rapid eye movement (REM) and without rapid eye movement (nonREM)), spectrum band and various positions of the electrodes on the head. The results show that the coherence and phase synchronization provide the same statistical differences between sleep stages of human EEG. Regarding the type of EEG synchronization, the high-frequency gamma-band synchronization depends on the state of consciousness, while synchronization in other spectral ranges depends primarily on the positions of the electrodes on the head. The connection between the EEG signals were mainly characterized by a phase synchronization, for most strongly linked parts of the head, full synchronization was present. Full synchronization, which is characterized by high correlation of amplitudes and phases, occurred between the homologous parts of the hemispheres. Weakest synchronization of EEG during sleep was observed between fronto-occipital electrode positions. Considering gamma band, phase synchronization during vigilance and non-REM sleep turns into complete synchronization in REM sleep stages.

Related projects: VEGA 2/0019/10, bilateral projects in co-operation with the Institute of Computer Science of the Czech Academy of Sciences, Prague, Czech Republic: "Modern methods for evaluation of electrophysiological signals" and "Synchronization and causality in complex systems".

[7] **Measurement of muscle metabolism using phosphorus spectroscopy on ultra-high fields**

A new non-invasive method was developed and tested in muscle tissue for the measurement of creatine-kinase reaction rate based on phosphorus magnetization transfer. The feasibility of this type of experiment was tested at 7 Tesla tomograph MRI, with the conclusion that it can be performed 2.7 to 3.4 times faster compared to the same protocol at 3 Tesla. Further research was dedicated to measure muscle metabolism at rest and during physical exercise. Our findings show that magnetization transfer can be used as an alternative method for oxidative metabolism evaluation in stroke and uncooperative patients. In addition, a new two-dimensional MR method based on spectroscopic imaging of chemical shift was developed and tested *in vivo*. Using newly developed pulses for excitation, a reduction of chemical shift artifacts in MR data can be achieved in range of 1.5-7.7 times. This reduction was experimentally tested in phantoms and this newly developed method was shown feasible for measurements of liver (volunteers) in clinically acceptable measurement time. The reproducibility of the results was tested on ultra-high field MR system of 7 Tesla.

Related projects: VEGA 2/0013/14, ŠPVV no. 2003SP200280203, cooperation with MR Center, Highfield MR, Department of Radiology, Medical University of Vienna, Austria.

[8] **Research of static magnetic field deformation due to the presence of magnetic nanoparticles using imaging methods based on magnetic resonance principles**

Magnetic nanoparticles are widely used as a contrast agent in magnetic resonance imaging (MRI). Nanoparticles as contrast agents possess a magnetic moment which generates local inhomogeneities in the static magnetic field of the MR scanner. The goal of this study was to investigate the influence of the arrangement of magnetic nanoparticles on the final image contrast during MRI. The magnetic field distortions of the near surroundings of the groups of magnetic nanoparticles Fe_3O_4, which are regarded as small magnetic dipoles were analyzed. The influence of saline and glucose molecules to contrast properties of clinically used MRI contrast agents were investigated. Because in general, circular samples were investigated as objects for imaging based on magnetic resonance, detailed mathematical models were developed. Resultant simulations were experimentally verified. The computer-aided analysis of magnetic nanoparticles deposition caused by magnetic field was carried out. The methods find applications in research of physiologic and pathologic changes of metabolism in biological objects and could be used mainly in the clinical practice.
Related projects: VEGA 2/0013/14, APVV-0513-10, cooperation under EU COST project: European Network for Hyperpolarization Physics and Methodology in NMR and MRI. COST Action TD1103.

[9] **Model-based interpretation of accidental changes in QRST integral maps and repolarization heterogeneity in patients with arrhythmias.**

In cooperation with the Hungarian partners and Institute of normal and pathological physiology SAS possible reasons for accidental changes of heart repolarization indicated by nondipolariry index (NDI) - specific parameter of body surface potential maps (BSPMs) - were studied by simulations on our ventricular model. The changes observed in measured BSPMs in patients with arrhythmias were simulated in ventricular heart model by alterations of starting points of ventricular activation as well as by shortening of action potential (AP) duration or decreasing of activation propagation velocity in selected areas of ventricles. Equivalent electrical generator derived from the heart model was used for computing BSPMs on torso model by boundary element method. Based on computer simulations the observed NDI changes can be a result of ectopic activity in the apex epicardium arising simultaneously with normal heart depolarization. The increased dispersion of repolarization in the left ventricle was simulated by changes in AP duration on the endocardium and epicardium (the difference between AP duration on endocardium and epicardium is called transmural gradient) and by slowing of activation propagation. It was shown that the NDI parameter is a sensitive indicator of repolarization changes and can provide valuable information for therapy of patients with arrhythmia.
Related projects: VEGA 1/0131/13, Measurement and information processing for diagnostic imaging of cardiac and brain electrical fields. Bilateral project with CRIP Research Institute for Material Science and Technical Physics, Hungarian Academy of Sciences, Budapest and cooperation with Panonia University in Veszprém, Hungary,

[10] **Noninvasive localization of premature ventricular activity in the heart**

Noninvasive identification of local cardiac pathologies is a long term research topic of the Dept. of Biomeasurements. Recently the research was oriented on the possibility of pre-operational localization of the focus of ectopic activity in the ventricles. The proposed method uses multichannel ECG and torso model obtained from CT for the solution of the inverse problem of electrocardiology and

finding the pathological electrical generator (in the form of a single dipole or a group of dipoles). Computer simulations showed that with quality ECG and individual CT-based torso model a localization error of 0.7 ± 0.7 cm can be achieved. The method was optimized and experimentally tested in cooperation with the Czech partner and applied in 10 patients in Prague and another 2 patients in Kiev, Ukraine. The focus positions obtained by the inverse method were in clinically acceptable agreement with the sites obtained during the invasive intracardial mapping what makes the method a promising tool for future clinical applications.
Related projects: VEGA 1/0131/13, APVV-14-0875, Bilateral cooperation with Faculty of Biomedical Engineering, Czech Technical University in Prague, Kladno, Czechia.

2.3.2. List of international conferences (co)organised by the Institute

[1] Optical Workshop, Smolenice, Slovak Republic, March 13- 15, 2013.
[2] Measurement 2013: 9th international conference on measurement, Smolenice, Slovak Republic, May 27- 30, 2013.
[3] The 1st IEEE EMBS Summer School on Emerging Technologies and Applications in Telemedicine, Smolenice, Slovak Republic, August 26- 31, 2013.
[4] The 41st International Congress on Electrocardiology, Bratislava, Slovak Republic, June 4 - 7, 2014.
[5] Measurement 2015 - 10th international conference on measurement, Smolenice, Slovak Republic, May 25- 28, 2015.
[6] PROBASTAT 2015 - The 7th International Conference on Probability and Mathematical Statistics, Smolenice, Slovak Republic, June 29- July 3, 2015.
[7] The 2nd IEEE EMBS Summer School on Emerging Applications and Technologies in Telemedicine, Smolenice, Slovak Republic, August 16- 22, 2015.

2.3.3. List of edited proceedings from international scientific conferences.

[1] *PROBASTAT '11: Proceedings of the Sixth International Conference on Probability and Mathematical Statistics*. Editors: J. Volaufová, V. Witkovský. Bratislava: Mathematical Institute, SAS, 2012. Vol. 51, 202 p. ISSN 1210-3195.
[2] *MEASUREMENT 2013: 9th International Conference on Measurement*. Editors: J. Maňka, M. Tyšler, V. Witkovský, I. Frollo. Bratislava: Institute of Measurement Science, SAS, 2013. xv, 365 p. ISBN 978-80-969-672-5-4.
[3] *ELECTROCARDIOLOGY 2014: Proceedings of the 41th International Congress on Electrocardiology*. Editors: M. Tyšler, J. Švehlíková, L. Bacharová, K. Kozlíková. Bratislava: Institute of Measurement Science, SAS, 2014. 264 p. ISBN 978-80-969-672-7-8.
[4] *MEASUREMENT 2015: 10th International Conference on Measurement*. Editors: J. Maňka, M. Tyšler, V. Witkovský, I. Frollo. Bratislava: Institute of Measurement Science, SAS, 2015. xiii, 326 p. ISBN 978-80-969672-9-2.
[5] *PROBASTAT 2015: The Seventh International Conference on Mathematical Statistics. Abstracts*. Editors: V. Witkovský, J. Somorčík. Bratislava: Institute of Measurement Science, SAS, 2015. 58 p.

2.3.4. List of journals edited/published by the institute:

2.3.4.1. WOS (IF of journals in each year of the assessment period)

Measurement Science Review. Berlin, Germany: Walter de Gruyter GmbH, ISSN 1335-8871. http://www.degruyter.com/view/j/msr.

- IF2012 - 1.233
- IF2013 - 1.162
- IF2014 - 0.989
- IF2015 - 0.969

2.3.4.2. SCOPUS

Measurement Science Review. Berlin, Germany: Walter de Gruyter GmbH, ISSN 1335-8871. http://www.degruyter.com/view/j/msr.

2.3.4.3. other databases

Measurement Science Review. Berlin, Germany: Walter de Gruyter GmbH, ISSN 1335-8871. http://www.degruyter.com/view/j/msr.

- Astrophysics Data System (ADS)
- Baidu Scholar
- Cabell's Directory
- Celdes
- CNKI Scholar (China National Knowledge Infrastructure)
- CNPIEC
- DOAJ (Directory of Open Access Journals)
- EBSCO (relevant databases)
- EBSCO Discovery Service
- Elsevier - EMBASE
- Genamics JournalSeek
- Google Scholar
- Inspec
- J-Gate
- JournalTOCs
- Meta (formerly Sciencescape)
- Naviga (Softweco)
- Primo Central (ExLibris)
- ProQuest (relevant databases)
- ReadCube
- ResearchGate
- SCImago (SJR)
- Summon (Serials Solutions/ProQuest)
- TDOne (TDNet)
- TEMA Technik und Management
- Thomson Reuters - Journal Citation Reports/Science Edition
- Ulrich's Periodicals Directory/ulrichsweb
- WorldCat (OCLC)

2.3.4.4. not included in databases

none

- **National position of the institute**

2.3.5. List of selected projects of national importance

[1] *Effects of sleep disturbances on day-time neurocognitive performance in patients with stroke*. Project number: MZ 2012/56-SAV-6. Principal investigator IMS SAS: Roman Rosipal. Project duration: 7/2013-12/2015.

[2] *Supporting of a top laboratory aimed at NMR research*. Project number: 2003SP200280203. Principal investigator IMS SAS: Ivan Frollo. Project duration: 9/2013-12/2016.

Other projects of national importance are presented in Sections 2.3.6. – 2.3.9.

2.3.6. Projects of the Slovak Research and Development Agency (APVV)

[1] *Biodecorated composite magnetic nanoparticles: Preparation, collective properties and aplications*. Project number: APVV-0125-11. Principal investigator IMS SAS: Alexander Cigáň. Project duration: 7/2012- 12/2015.

[2] *Physical and electrochemical behavior of mechanochemically prepared nanooxides*. Project number: APVV- 0528-11. Principal investigator IMS SAS: Peter Billik. Project duration: 7/2012- 12/2015.

[3] *Measuring, communication and information systems for monitoring of the cardiovascular risk in hypertension patients*. Project number: APVV-0513-10. Principal investigator IMS SAS: Milan Tyšler. Project duration: 5/2011-6/2014.

[4] *Statistical methods for uncertainty analysis in metrology*. Project number: APVV-0096-10. Principal investigator IMS SAS: Viktor Witkovský. Project duration: 5/2011-10/2014.

[5] *Braincomputer interface with robot- assisted training for rehabilitation*. Project number: APVV- 0668-12. Principal investigator IMS SAS: Roman Rosipal. Project duration: 10/2013- 9/2016.

[6] *Development of a diagnostic tool for quantitative MRI imaging of biogenic iron in clinical practice*. Project number: APVV-0431-12. Principal investigator IMS SAS: Oliver Štrbák. Project duration: 10/2013-9/2016.

[7] *Physical non-destructive methods for complex testing and analysis of cultural heritage artefacts*. Project number: APVV-14-0719. Principal investigator IMS SAS: Miroslav Hain. Project duration: 7/2015-6/2019.

[8] *Noninvasive localization of ectopic arrhythmias of heart ventricles using ECG mapping and its use for causal therapy*. *P*roject number: APVV-14-0875. Principal investigator IMS SAS: Milan Tyšler. Project duration: 7/2015-6/2018.

2.3.7 Projects of the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education (VEGA)

[1] *Advanced classification and prediction methods in biosignal analysis and biologically inspired computer vision*. Project number: VEGA 2/0019/10. Principal investigator IMS SAS: Ivan Bajla. Project duration: 1/2010-12/2012.

[2] *Progressive methods of measurement and nondestructive testing - active infrared thermography and X-ray*. Project number: VEGA 2/0101/10. Principal investigator IMS SAS: Ján Bartl. Project duration: 3/2010-12/2012.

[3] *The added value of chemistry for the knowledge and development of i) novel autoclaved aerated concrete and ii) macrodefectfree (MDF) materials*. Project number: VEGA 2/0020/11. Principal investigator IMS SAS: Peter Billik. Project duration: 1/2011-12/2013.

[4] *Measuring and imaging methods based on magnetic resonance for material and biomedical research*. Project number: VEGA 2/0090/11. Principal investigator IMS SAS: Ivan Frollo. Project duration: 1/2011-12/2013.

[5] *Application of SQUID magnetometry and magnetic resonance in evaluation of efficiency of the gene therapy using magnetic nanoparticles*. Project number: VEGA 2/0160/10. Principal investigator IMS SAS: Ján Maňka. Project duration: 1/2010-12/2012.

[6] *New methods of mathematical statistics*. Project number: VEGA 2/0038/12. Principal investigator IMS SAS: František Rublík. Project duration 1/2012-12/2014.

[7] *Methods and systems for multichannel measurement and evaluation of bioelectric signals of heart and brain*. Project number: VEGA 2/0210/10. Principal investigator IMS SAS: Milan Tyšler. Project duration: 1/2010-12/2012.

[8] *Research into dynamical methods of biosignal analysis and bio-inspired pattern recognition*. Project number: VEGA 2/0043/13. Principal investigator IMS SAS: Ivan Bajla. Project duration: 1/2013-12/2015.

[9] *Mechanism of uptake and trafficking of magnetic iron oxide nanoparticles into human tumor and normal (diploid) cells*. Project number: VEGA 2/0143/13. Principal investigator IMS SAS: Ján Maňka. Project duration: 1/2013-12/2016.

[10] *New advanced methods of measurement and non-destructive testing of materials: X-ray microtomography and active infrared thermography.* Project number: VEGA 2/0126/13. Principal investigator IMS SAS: Miroslav Hain. Project duration: 1/2013-12/2015.

[11] *Development of SQUID gradiometric and susceptometric methods for iron homeostasis related bio-applications*. Project number: VEGA 2/0152/13. Principal investigator IMS SAS: Ján Maňka. Project duration: 1/2013-12/2016.

[12] *Grounded cognition paradigm, interaction between perception and action in the brain–computer interface.* Project number: VEGA 1/0503/13. Principal investigator IMS SAS: Roman Rosipal. Project duration: 1/2013-12/2015.

[13] *Methods and systems for measurement, displaying and evaluation of the cardiac electrical field at hypertension hypertrophy*. Project number: VEGA 1/0131/13. Principal investigator IMS SAS: Milan Tyšler. Project duration: 1/2013-12/2015.

[14] *Imaging and mapping of organic and synthetic materials and objects using magnetic resonance imaging methods*. Project number: VEGA 2/0013/14. Principal investigator IMS SAS: Ivan Frollo. Project duration: 1/2014-12/2016.

[15] *New acoustical horns in sonochemistry*. Project number: VEGA 2/0092/14. Principal investigator IMS SAS: Klára Hornišová. Project duration: 1/2014-12/2016.

[16] *Discrete and continuous probabilistic models and their applications*. Project number: VEGA 2/0047/15. Principal investigator IMS SAS: Viktor Witkovský. Project duration: 1/2015-12/2017.

2.3.8. Projects of SAS Centres of Excellence

none

2.3.9. National projects supported by EU Structural Funds

[1] *CEKOMAT II - Centre of Excellence for research and development of structural composite materials for engineering, construction and medical applications. P*roject number: ITMS 26240120020. Principal investigator IMS SAS: Miroslav Hain. Project duration: 9/2010-12/2012.

[2] *Center of Competence for new materials, advanced technologies and power engineering.* Project number: ITMS 26240220073. Principal investigator IMS SAS: Ján Maňka. Project duration: 8/2011-11/2014.

[3] *CENTE II - Centre of Excellence for new technologies in electrical engineering.* Project number: ITMS 26240120019. Principal investigator IMS SAS: Ján Maňka. Project duration: 3/2010-9/2012.

[4] *University Research Park for biomedicine.* Project number: ITMS 26240220087. Principal investigator IMS SAS: Milan Tyšler. Project duration: 8/2013-7/2015.

2.3.10. List of journals (published only in the Slovak language) edited/published by the institute:

2.3.10.1. WOS (IF of journals in each year of the assessment period)

none

2.3.10.2. SCOPUS

none

2.3.10.3. Other databases

none

2.3.10.4. Not included in databases

none

- **Position of individual researchers in an international context**

2.3.11. List of invited/keynote presentations at international conferences, as documented by programme or invitation letter

[1] GRENDÁR, Marián - JUDGE, G. Not all empirical divergence minimizing statistical methods are created equal? In *ICNPAA 2012: 9th International Conference on Mathematical Problems in Engineering, Aerospace and Sciences*. Vienna, Austria, July 10-14, 2012.

[2] ŠVEHLÍKOVÁ, Jana – LENKOVÁ, Jana - TYŠLER, Milan. Inverse localization of various sizes of ischemic lesions from variations in body surface potential maps. In *Variability in Biomedical Signals: 128th ICB Seminar*. Warsaw, Poland, November 4-7, 2012.

[3] TYŠLER, Milan. Noninvasive finding of local repolarization changes in the heart using dipole models and simplified torso geometry. In *The 39th International Congress on Electrocardiology*. Beijing, China, August 9-12, 2012.

[4] TYŠLER, Milan – LENKOVÁ, Jana – ŠVEHLÍKOVÁ, Jana – KANIA, M. – MANIEWSKI, R. Noninvasive assessment of ischemic heart regions from variations in body surface potentials using dipole models and simplified torso geometry. In *Variability in Biomedical Signals: 128th ICB Seminar*. Warsaw, Poland, November 4-7, 2012.

[5] WITKOVSKÝ, Viktor. FEM_Trace and its international aspects: Strong inspiration for Slovak students and researchers. In *International Sparkling Science Conference - Young Research*. University of Vienna, Vienna, Austria, September 17, 2012.

[6] JURÁŠ, Vladimír. MSK imaging at 7T. In *Siemens 4th UHF User Meeting 2013*. Vienna, Austria, November 14-16, 2013.

[7] TRATTNIG, S. - ZBÝŇ, Š. - SCHMITT, B. - FRIEDRICH, K. - *JURÁŠ, Vladimír* - SZOMOLÁNYI, Pavol - BOGNER, W. Advanced MR methods at ultra-high field (7 Tesla) for clinical musculoskeletal applications. In *MEASUREMENT 2013: 9th International Conference on Measurement*. Smolenice, Slovakia, May 27-30, 2013.

[8] WITKOVSKÝ, Viktor. On the exact tolerance intervals for univariate normal distribution. In *Computer Data Analysis and Modeling (CDAM 2013): Theoretical and Applied Stochastics. 10th International Conference*. Belarusian State University, Minsk, Belarus, September 10-14, 2013.

[9] JURÁŠ, Vladimír. New methods and clinical applications of the knee MRI at high and ultra-high field. In *Sommer-Symposium für Radiologe*. Rostock, Germany, June 20-22, 2014.

[10] JURÁŠ, Vladimír. Tissue characterisation of cartilage. In *ESMOFIR: First Workshop on Clinical Functional Imaging*. Berlin, Germany, July 3-5, 2014.

[11] ROSIPAL, Roman. Modulation of sensory-motor rhythmic activities for improving BCI training in neurorehabilitation. In *MEi:CogSci Conference*. Krakow, Poland, June 12-14, 2014.

[12] WITKOVSKÝ, Viktor - WIMMER, G. - AMANN, A. Statistical methods for exhaled breath analysis based on linear mixed models. In *BREATH 2014: 8th International Conference on Breath Research & Cancer Diagnosis*. Toruń, Poland, July 6-9, 2014.

[13] FROLLO, Ivan. Magnetic resonance imaging methods in material research. In *MEASUREMENT 2015: 10th International Conference on Measurement*. Smolenice, Slovakia, May 25-28, 2015.

[14] GRENDÁR, Marián. Regresia na dátach z experimentu versus z pozorovaní. (Regression: Data from experiment vs observational study). In In *Workshop „Teorie a praxe statistického zpracování dat“*. Pusté Žibřidovice, Czech Republic, 26.-28.11.2015.

[15] CHVOSTEKOVÁ, Martina. Štatistické intervaly /Statistical intervals/. In *Workshop „Teorie a praxe statistického zpracování dat“*. Pusté Žibřidovice, Czech Republic, 26.-28.11.2015.

[16] ROSIPAL, Roman. Modulation of brain oscillatory rhythms: Conceptual, experimental and algorithmic design. In *Zimní škola kognitivní psychologie 2015*. Malá Skála, Czech Republic, 5.2.2015.

[17] WITKOVSKÝ, Viktor – WIMMER, G. Exact statistical inference by using FFT inversion of the characteristic function. In *ODAM 2015: Olomoucian Days of Applied Mathematics*. Palacký University in Olomouc, Czech Republic, May 20-22, 2015.

2.3.12. List of researchers who served as members of the organising and/or programme committees

- P. Andris - 1 activity
- I. Bajla - 5 activities
- J. Bartl - 1 activity
- K. Bartošová - 1 activity
- E. Cocherová - 3 activities
- Dvurečenskij - 2 activities
- I. Frollo - 2 activities
- D. Gogola - 2 activities
- M. Hain - 2 activities
- M. Chvosteková - 1 activity
- J. Jakubík - 1 activity
- V. Juráš - 2 activities
- J. Maňka - 2 activities
- M. Škrátek - 4 activities
- J. Švehlíková - 2 activities
- M. Teplan - 1 activity
- M. Tyšler - 6 activities
- V. Witkovský - 5 activities

- **Position of individual researchers in a national context**

2.3.13. List of invited/keynote presentations at national conferences, as documented by programme or invitation letter

[1] ROSIPAL, Roman. System of mirror neurons and perceptual modulation of motor cortical oscillations. In *Cognition and Artificial Life 2015*. Trenčianske Teplice, Slovakia, May 27, 2015.

2.3.14. List of researchers who served as members of organising and programme committees of national conferences

none

- **Supplementary information and/or comments documenting the international and national status of the Institute**

During the assessment period the Institute successfully contributed to the international and national scientific community, in particular into the research cooperation in Europe and society at large. This was reflected in increased

number of domestic projects, bilateral and multilateral international projects and scientific cooperation. The long term scientific cooperation with international partners allowed participation in many new proposals of bilateral and multilateral projects. Intensive contacts with international scientific and professional societies remained at high level. The Institute's researchers regularly serve as editors and reviewers of respected international scientific journals and are well established in international scientific organizations as members and officers, namely:

- IEEE Engineering in Medicine and Biology Society (President of CS Section)
- IMEKO International Measurement Confederation
- Central European Academy of Science and Art
- International Society of Electrocardiology (Scientific Secretary)
- IEEE Measurement Society
- IFMBE International Federation of Medical and Biological Engineering
- International Association for Breath Research

International recognition and respect of the scientific community has been achieved by regular organization of international scientific conferences:

- MEASUREMENT 2013, MEASURENT 2015 – 9th and 10th international conference on measurement, Smolenice,
- PROBASTAT 2015 - 7th International Conference on Probability and Statistics, Smolenice,
- ICE 2014 - 41st International Congress on Electrocardiology, Bratislava.

as well as by the journal *Measurement Science Review* published by the Institute in cooperation with the publisher Walter de Gruyter GmbH, Berlin, Germany, ISSN 1335-8871.

At the national level, there has been an extensive scientific and pedagogical cooperation with the most respected universities (Comenius University in Bratislava, Slovak Technical University in Bratislava, Technical University of Košice, and University of Žilina), scientific institutions (Institutes of Slovak Academy of Sciences, Slovak Institute of Metrology), partners from industry (ENEL, Nuclear Power Plant Jaslovské Bohunice, Nuclear Power Plant Mochovce), cultural and healthcare institutions. The number of common laboratories, partnerships in scientific projects and collaborations increased during the assessed period.

Essential is also membership in national scientific societies, namely

- Slovak Society of Biomedical Engineering and Medical Informatics (president)
- Slovak IMEKO national committee (president)
- Slovak Metrological Society
- Slovak Society of Physics

2.4. Tables of project structure, research grants and other funding resources

- **International projects and funding**

2.4.1. Major projects within the European Research Area and other important project – Framework Programmes of the EU, ERA-NET, European Science Foundation, NATO, COST, INTAS, etc.

(here and in items below please specify: type of project, title, grant number, duration, total funding and funding for the institute, responsible person in the institute and his/her status in the project, e.g. coordinator "C", work package leader "W", investigator "I")

	Project title	Typ / Project number	Duration in months	Funding for the Institute (EUR)	Role of the Institute / Responsible person
2012	European network for Hyperpolarization Physics and Methodology in NMR and MRI	TD 1103	52, 7/2011-10/2015	14933	I / Ivan Frollo
	Colour and Space in Cultural Heritage	TDI 1201	48, 11/2012-11/2016	12667	I / Miroslav Hain
2013					
2014	European network for innovative uses of EMFs in biomedical applications	BM 1309	48, 4/2014-4/2018	7000	I / Michal Teplan
	Origins and evolution of lifer on Earth and in the Universe	TD 1308	48, 5/2014-5/2018		I / Oliver Štrbák
2015					

2.4.2. Other international projects, incl. total funding and funding for the institute

none

2.4.3. Other important, international projects and collaborations without direct funding (max. 10 projects)

[1] *Research and applications on HTc superconductors*. Bilateral project in co-operation with the Research Group on Solid State Chemistry and Ceramic Superconductors, Department of Inorganic and Physical Chemistry University of Ghent, Belgium. Principal investigator IMS SAS: Alexander Cigáň. Project duration: Active since 11/1999.

[2] *Measurement and information processing for diagnostic imaging of cardiac and brain electrical fields. B*ilateral project in co-operation with CRIP Research Institute for Material Science and Technical Physics, Hungarian Academy of Sciences, Budapest, Hungary. Principal investigator IMS SAS: Milan Tyšler. Project duration: 01/2010-12/2012.

[3] *Noninvasive measurement and information analysis of bioelectric signals*. Bilateral project in co-operation with the Institute for Problems of Information Transmission, Russian Academy of Sciences, Moscow, Russia. Principal investigator IMS SAS: Milan Tyšler. Project duration: 10/2001-12/2013.

[4] *Modern methods for evaluation of electrophysiological signals*. Bilateral project in co-operation with the Institute of Computer Science of the Czech Academy of Sciences, Prague, Czech Republic. Principal investigator IMS SAS: Viktor Witkovský. Project duration: 01/2012-12/2014.

[5] *High Resolution Multiple-lead ECG measurement for model based interpretation of cardiac electrical field*. Bilateral project in co-operation with the Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, Warszawa, Poland. Principal investigator IMS SAS: Milan Tyšler. Project duration: 01/2013-12/2015.

[6] *Synchronization and causality in complex systems: time series methods*. Bilateral project in co-operation with the Institute of Computer Science of the Czech

Academy of Sciences, Prague, Czech Republic. Principal investigator IMS SAS: Anna Krakovská. Project duration: 01/2015-12/2017.

[7] *Advanced optical methods for nanoelectronics*. Bilateral project in co-operation with the Nanoelektronics Research Institute / Photonics Research Institute, AIST, Tsukuba Japan. Principal investigator IMS SAS: Miroslav Hain. Project duration: 01/2006-12/2016.

[8] *Diagnostics of human articular cartilage using MRI*. Bilateral project in co-operation with the MR Centre of Excellence, Department of Radiology, Medical University of Vienna, Austria. Principal investigator IMS SAS: Ivan Frollo. Project duration: 08/2006-12/2016.

[9] *Synthesis rate of isoprene in the periphery of the human body*. International project in co-operation with the Breath Research Institute, Austrian Academy of Sciences, Dornbirn, Austria. Principal investigator IMS SAS: Viktor Witkovský. Project duration: 01/2013- 12/2014.

[10] *Apparatus for Nuclotron magnetic field control.* International project in co-operation with JINR Dubna, Russia. Principal investigator IMS SAS: Ľubomír Ondriš. Project duration: 01/2010-03/2014.

- **National projects and their funding**

2.4.4. Projects supported by the Slovak Research and Development Agency (APVV)

Role of the Institute e.g. coordinator “C”, investigator “I”.

	Project title	Typ / Project number	Duration in months	Funding for the Institute (EUR)	Role of the Institute / Responsible person
2012	Biodecorated composite magnetic nanoparticles: Preparation, collective properties and aplications	APVV-0125-11	42, 7/2012-12/2015	39997	I / Alexander Cigáň
	Measuring, communication and information systems for monitoring of the cardiovascular risk in hypertension patients	APVV-0513-10	38, 5/2011-6/2014	93969	C / Milan Tyšler
	Statistical methods for uncertainty analysis in metrology	APVV-0096-10	42, 5/2011-10/2014	105902	C / Viktor Witkovský
	Physical and electrochemical behavior of mechanochemically prepared nanooxides	APVV-0528-11	42,7/2012-12/2015	49908	I / Peter Billik
2013	Brain-computer interface with robot-assisted training for rehabilitation	APVV-0668-12	36, 10/2013-9/2016	53148	C / Roman Rosipal
	Development of a diagnostic tool for quantitative MRI imaging of biogenic iron in clinical practice	APVV-0431-12	36, 10/2013-9/2016	115583	C / Oliver Štrbák
2014					
2015	Physical non-destructive methods for complex testing and analysis of cultural heritage artefacts	APVV-14-0719	48 , 7/2015-6/2018	16191	C / Miroslav Hain
	Noninvasive localization of ectopic arrhythmias of heart ventricles using ECG mapping and its use for causal therapy	APVV-14-0875	36, 7/2015-6/2019	27992	C / Milan Tyšler

2.4.5. Projects supported by the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education (VEGA) for each year, and their funding

VEGA	2012	2013	2014	2015
Number	7	9	9	9
Funding in the year (EUR)	72822	73338	72717	71797

- **Summary of funding from external resources**

2.4.6. List of projects supported by EU Structural Funds

[1] *CEKOMAT II - Centre of Excellence for research and development of structural composite materials for engineering, construction and medical applications.* Project number: ITMS 26240120020. Principal investigator IMS SAS: Miroslav Hain. Project duration: 9/2010-12/2012.

[2] *Center of Competence for new materials, advanced technologies and power engineering.* Project number: ITMS 26240220073. Principal investigator IMS SAS: Ján Maňka. Project duration: 8/2011-11/2014.

[3] *CENTE II - Centre of Excellence for new technologies in electrical engineering.* Project number: ITMS 26240120019. Principal investigator IMS SAS: Ján Maňka. Project duration: 3/2010-9/2012.

[4] *University Research Park for biomedicine.* Project number: ITMS 26240220087. Principal investigator IMS SAS: Milan Tyšler. Project duration: 8/2013-7/2015.

2.4.7. Summary of external resources of the EU Structural Funds (ERDF/ESF)

Role of the Institute in the project, e.g. coordinator "C", work package leader "W", investigator "I".

Year	Project title	Project number	Duration in months	Funding for the Institute (EUR)	Role of the Institute
2012	CEKOMAT II - Centre of Excellence for research and development of structural composite materials for engineering, construction and medical applications	ITMS 26240120020	28, 9/2010-12/2012	1592.92	I / Miroslav Hain
	Center of Competence for New Materials, Advanced Technologies and Power Engineering	ITMS 26240220073	40, 8/2011-11/2014	80439	I / Ján Maňka
	CENTE II Centre of excellence for new technologies in electrical engineering	ITMS 26240120019	31, 3/2010-9/2012	1793.87	I / Ján Maňka
2013	University Research Park for Biomedicine	ITMS 26240220087	24, 8/2013-7/2015	157496.13	I / Milan Tyšler
2014					
2015					

External resources	2012	2013	2014	2015	total	average
External resources (milions of EUR)	0,022	0,040	0,075	0,123	**0,260**	**0,065**
External resources transfered to coooperating research institute (milions of EUR)	0,000	0,000	0,000	0,000	**0,000**	**0,000**

- **Supplementary information and/or comments on research projects and funding sources**

  During the assessment period, the Institute has been active in collecting financial support from research grants and other funding resources. Apart from the main state budged contribution distributed by the Presidency of the Slovak Academy of Sciences according to rules adopted by the SAS Assembly, the main proportion

of funding sources comes from domestic research grant projects supported by the Slovak Research and Development Agency (here referred to as APVV), the Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic for the Structural Funds of EU (here referred to as EU Structural Funds), and the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and Slovak Academy of Sciences (referred to as VEGA). Smaller part of the funding sources comes from research and commercial projects with other government organizations and industry partners, as e.g. the Minister of Health of the Slovak Republic, ENEL Nuclear Power Plants Jaslovské Bohunice and Mochovce.

Beyond the bilateral multilateral international research projects (e.g. under EU COST), the Institute have been also active member in international networks and submitted several project proposal in co-operation with its international partners, including the project proposals under the EU Horizon 2020. In particular:

- Horizon 2020, Call: H2020-PHC-2015-two-stage, Topic: PHC-11-2015. Type of action: RIA. Proposal number: 668685-1. Proposal acronym: DYNAMO. Proposal title: *Functional Magnetic Resonance Imaging of Motion for Musculoskeletal Applications*. Principal investigator IMS SAS: Prof. Ing. Ivan Frollo, DrSc. Project evaluation: Criterion Excellence: Mark: 4/5, (Threshold 4/5), Criterion Impact: Mark: 4/5, (Threshold 4/5), Total score: Mark: 8/10, (Threshold 8.5/10). Project was not suggested for financial support.
- Horizont 2020, Call: H2020-MSCA-ITN-2015, Topic: MSCA-ITN-2015-ETN, Action: MSCA-ITN-ETN, Proposal Number: 675233, Proposal Acronym: CRIBIDAT. Proposal title: *Big Data in Crisis Management*. Principal investigator IMS SAS: doc. RNDr. Viktor Witkovský, CSc Project evaluation: 72.4% (Threshold 70%). Project was not suggested for financial support.

2.5. PhD studies and educational activities

2.5.1. List of accredited programmes of doctoral studies, period of validity

- *Measurement Science and Technology* - accredited PhD. programme from 2009 to 2015, and from 2016 to 2019 (new accreditation).
  The Institute is an external educational institution based on cooperation with the Slovak Technical University in Bratislava, Faculty of Electrical Engineering and Information Technology for both, internal and external PhD. study programmes.

2.5.2. Summary table on doctoral studies *(number of internal/external PhD students; number of foreign PhD students, number of students who successfully completed their theses, number of PhD students who quit the programme)*

PhD study	31.12.2012			31.12.2013			31.12.2014			31.12.2015		
Number of potential PhD supervisors	13			15			14			14		
PhD students	number	defended thesis	students quitted	number	defended thesis	students quitted	number	defended thesis	students quitted	number	defended thesis	students quitted
Internal	5,0	1,0	0,0	5,0	2,0	0,0	4,0	0,0	1,0	4,0	0,0	0,0
External	1,0	0,0	0,0	1,0	0,0	0,0	1,0	0,0	0,0	2,0	0,0	0,0
Other supervised by the research employees of the institute	10,0	1,0	0,0	7,0	2,0	0,0	6,0	0,0	2,0	6,0	2,0	0,0

During the doctoral study following study stays of the PhD students took place abroad:

Ing. Peter Kaľavský - February 2013 - May 2013, Edinburgh Parallel Computing Centre, University of Edinburg, United Kingdom

Ing. Peter Kaľavský - January 2015 – March 2016, Center for Computational Medicine in Cardiology, Institute of Computational Science, Università Della Svizzera Italiana, Lugano, Switzerland

After finishing the PhD study following research stays of our post-docs took place abroad:

Mgr. Martina Chvosteková, PhD - February 2013 - December 2014, Faculty of Science, Palacky University in Olomouc, Czech Republic;

- July 2015 - September 2015, Faculty of Science, Palacky University in Olomouc, Czech Republic;

Ing. Ladislav Valkovič, PhD. - September 2013 - September 2015, Dept. of Radiology, Medical University, Vienna, Austria

- October 2015 - (continues), Oxford Centre for Clinical Magnetic Resonance Research, Division of Cardiovascular Medicine, Radcliffe Department of Medicine University of Oxford, United Kingdom

Ing. Daniel Gogola, PhD. - June 2015 - June 2016, Paramed Medical Systems s. r. l., Genova, Italy

2.5.3. Summary table on educational activities

Teaching	2012	2013	2014	2015
Lectures (hours/year)[2]	235	204	101	112
Practicum courses (hours/year)[2]	61	46	36	26
Supervised bachelor theses (in total)	3	3	2	4
Supervised diploma theses (in total)	5	3	6	9
Supervised PhD theses (in total)	15	11	9	11
Members in PhD committees (in total)	7	7	4	4
Members in DrSc. committees (in total)	0	1	0	0
Members in university/faculty councils (in total)	4	4	4	3
Members in habilitation/inauguration committees (in total)	4	3	1	0

2.5.4. List of published university textbooks

none

2.5.5. Number of published academic course books

none

2.5.6. List of joint research laboratories/facilities with universities

[1] Scientific-technical and Pedagogic Laboratory for Engineering Surveys - joint laboratory of Institute of Measurement Science SAS and Department of Theoretical Geodesy, Faculty of Civil Engineering, Slovak University of Technology in Bratislava,

[2] Joint Laboratory for Physical Survey of Object of Art - joint activity of Institute of Measurement Science SAS and Department of Restoration, Academy of Fine Arts and Design in Bratislava,

[3] Faculty of Mechanical Engineering STU and Faculty of Electrical Engineering and Information Technology STU in the framework of Centre of Non-Standard Measurements (with residence at the Institute of Measurement Science),

[4] Faculty of Chemical and Food Technology STU in Bratislava- Department of NMR and mass spectrometry and Department of imaging methods of the Institute of Measurement Science SAS- Building of a top laboratory aimed at NMR research. State program of research and development.

- **Supplementary information and/or comments on doctoral studies and educational activities**

  According the current law, in 2015 the Institute asked for reaccreditation of the doctoral (PhD) study program as an external educational institution of the Slovak Technical University in Bratislava, Faculty of Electrical Engineering and Information Technology for both, internal and external study program in the field

5.2.54 Meracia technika (Measurement Technology). On December 9, 2015 the Accreditation commission recommended accreditation in both forms for the standard period of study.

Garant of the PhD study until November 2015 was Prof. Ing. Jiří Holčík, CSc., since December 2015 the garant of the study is Prof. Ing. Alexander Šatka, PhD.

2.6. Social impact

2.6.1. List of the most important results of applied research projects. *(Max. 10 items)*

[1] **Visualisation of microstructures by X-ray microtomography methods.** The use of X-ray microtomography to visualize microstructures in natural sciences and material research.
Related project: VEGA 2/0101/10 "Progressive methods of measurement and nondestructive testing - active infrared thermography and X-ray microtomography". Several research contracts.

[2] **Measuring system for automated monitoring of tilt of reactor vessels.** Development and realization of complex measuring systems for automated monitoring of tilt of reactor vessels in nuclear power plant Mochovce (3-th and 4-th block).
Related project: Research project with VÚJE, a. s.

[3] **Application of infrared reflectography in non-destructive testing of historical artefacts.** Testing of gothic Altair table pictures from the 15th century. Implementation of infrared reflectography for revealing underdrawings in gothic Altair table pictures. Use of optical methods in nondestructive testing of altar panel paintings of Master Pavol from Levoča. The use of optical methods in nondestructive testing of other historical works.
Related projects: Project: COST (Colour and Space in Cultural Heritage COSCH), research contract with Veronica Gabčová.

[4] **Optoelectronic probes for automotive industry.** Development and production of mechanical parts for special optoelectronic probes for automotive industry. Optoelectronic probes are used for functional testing of complicated casts in automobile production.
Related project: Research contract with Datalan a. s.

Calibration, service and maintenance of the measuring systems in Nuclear Power Plants. Calibration, service and maintenance of the measuring systems developed by Slovak Academy of Sciences in Nuclear power plants Mochovce and Jaslovské Bohunice. Systems for measurement of inclination of reactors at at the Mochovce nuclear power plant units 1and 2 and Jaslovské Bohunice nuclear power plant units 3 and 4.
Related projects: Research contract with Slovenské elektrárne, member of the Enel group.

2.6.2. List of the most important studies commissioned for the decision-making authorities, the government and NGOs, international and foreign institutes

none

2.6.3. List of contracts and research projects with industrial and other commercial partners, incl. revenues

Contracts:

[1] Development and production of mechanical parts for the special optoelectronic measuring probes for automotive industry. Contract with Datalan it works, Inc., Slovak Republic (56340€),

[2] Calibration, service and maintenance of Mochovce nuclear reactors 1 and 2 , and Co-operation with Nuclear Power Station Jaslovske Bohunice (34030,40€),

[3] Calibration, service and maintenance of nuclear reactors 1, 2. Cooperation with Nuclear Power Station Mochovce (42259,50 €),

[4] NMR scanning and testing of fibers for use in surgery - International co-operation with Contipro Biotech, Inc., Czech Republic (2000 €).

Research projects:

[1] Modernization of program equipment, Nuclear reactors 3,4, Co-operation with Nuclear Power Station Jaslovske Bohunice (3095,40 €),

[2] Cooperation with VUJE, development of new systems for monitoring of the tilt of nuclear reactors 3, 4 in Nuclear power plant Mochovce (128660 €).

2.6.4. List of licences sold abroad and in Slovakia, incl. revenues

[1] Country: Slovakia, Czech Republic
Authors: ROSÍK Vladimír, KULIŠOV Andrej, TYŠLER Milan, HÁNA Karel, KNEPPO Peter
Title: Active electrode for recording of bioelectric signals
Industrial design 5598, granted 30.9.2010, prolonged until 26.10.2016
Despite the licence itself was not sold, it was repeatedly used in ProCardio systems manufactured in the Institute and sold to Slovakia and Czech Republic.

2.6.5. List of most important social discourses under the leadership or with significant participation of the institute (max. 10 items)

none

2.6.6. Summary of relevant activities *(max. 300 words)*

In correspondence with the research orientation and the technological background of the Institute, the social impact of its research activities can be seen especially in four main areas, some of them might not be explicitly visible in the lists above:

1. **Unique measuring systems for industry (power engineering, automotive, machinery) to improve productivity, accuracy or safety** – the Institute is developing, installing and maintaining measuring systems for checking the stability of nuclear reactors in all Slovak nuclear power plants, developing and producing special components for optoelectronic measuring and testing systems for car factories and their suppliers, building testing systems for precise machinery.
2. **New technologies and equipment for health care (oncology, cardiology) to help to introduce new diagnostics and therapies or improve the existing** – new MRI methods developed in the Institute in cooperation with Austrian partners were implemented in top high-field MR tomograph in hospital in Vienna, developed neurorehabilitation methods are experimentally used in cooperation with the Comenius University, Bratislava, noninvasice cardiac diagnostics based on ECG imaging is experimentally tested in hospital

Kralovske Vinohrady in Prague and further improved in cooperation with Slovak National Institute of Cardiovascular Diseases in Bratislava.

3. **Methods for nondestructive testing of materials, historical artifacts and objects of the cultural heritage (paintings, buildings, sculptures) to analyze, preserve or confirm their status** – methods based on X-ray microtomography were used for testing homogeneity of superconducting materials, composition of rocks and minerals or structure of palaeonthological fragments, methods based on active infrared thermography and reflectography or ultraviolet fluorescency were repeatedly applied in numerous contract with cultural institutions and individual restorers.
4. **Educational activities for university students, introducing the running research and existing infrastructure** – the Institute was regularly introducing the current research within seminars and lectures, whole day excursions and short visits to students of the Faculty of Electrical Engineering and Informatics and Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Electrotechnical Faculty, University of Zilina and Faculty of Mechnical Engineering, Technical University in Kosice.

Taking into account the positive reactions of mentioned target groups and their interest and requests to continue these activities the management of the Institute is willing to continue in all mentioned directions despite some of these activities cannot be based on clear economic profit.

2.7. Popularisation of Science (outreach activities)

2.7.1. List of the most important popularisation activities, max. 20 items

[1] *Prof. Ing. Ivan Frollo, DrSc.:* Magnetic resonance – movie, in the TV show "Science spectrum", STV2 (TV), 27.02.2012.
[2] *Prof. Ing. Ivan Frollo, DrSc. with T. Liptaj, M. Kaliňák, V. Smieško, R. Szabo:* Top science centers of NMR, STV 1 (TV), 14.11.2012.
[3] *RNDr. Miroslav Hain, PhD. with Mgr. Peter Vršanský, PhD.* - GI SAS: Fluorescent cockroach Lucius, in TV news STV 1 (TV), 23.08.2012.
[4] *Doc. Ing. Milan Tyšler, CSc.:* IMEKO: its international mission, structure and status in SR, Metrological Papers (metrologické listy), 2012, (35)1, (press).
[5] *Doc. Ing. Milan Tyšler, CSc.:* Institute of Measurement Science SAS and research on measurement methods for cardiology, Metrological Papers (metrologické listy), 2012, (35)1, (press).
[6] *Mgr. Michal Teplan, PhD.:* Discussion about topic: brain waves, Morning show of Fun radio (radio), 17.09.2013.
[7] *Mgr. Michal Teplan, PhD.:* Brain waves, TV news of RTVS, (TV), 17.09.2013.
[8] *Doc. Ing. Milan Tyšler, CSc.:* Measurement 2013 Conference, Metrology and Testing 18, 2/2013, p. 40, (press).
[9] *Doc. RNDr. Viktor Witkovský, CSc. with Prof. RNDr. G. Wimmer, DrSc, Prof. Ing. R. Palenčár:* research project APVV-0096-10 Statistical Methods for the Analysis of Uncertainties in Metrology. Metrology and Testing 18 (3-4), 2013, (press), 01.12.2013.
[10] *RNDr. Ing. Ján Bartl, CSc.:* 39. Assembly of Calibration Association SR. Metrology and Testing 18, 3-4/2013, s. 48 Metrology and Testing 18, 3-4/2013, p. 48, (press).
[11] *RNDr. Ing. Ján Bartl, CSc.:* Ing. Igor Brezina 75 years old. Fine mechanics and optics, 58. 7/ 2013, s: Fine mechanics and optics, 58. 7/ 2013, p. 1, (press).
[12] *Prof. Ing. Ivan Frollo, DrSc.:* Bionics all around us. I. Frollo: Measuring and imaging methods based on magnetic resonance for material and biomedical research. www.science.sk (internet), 03.09.2014.
[13] *Prof. Ing. Ivan Frollo, DrSc.:* Interview about magnetic resonance, Radio Regina (radio), 10.10.2014.

[14] *Prof. Ing. Ivan Frollo, DrSc.:* MR methods: How we do not know them, magazine Quark, str. 38. (press), 4.4.2014.

[15] *Prof. Ing. Ivan Frollo, DrSc. with J. Přibil, D. Gogola*- Laser 3D scanner. Display of objects and materials using a laser beam, Researchers' Night 2014 Stará tržnica, Bratislava (excursion), 26.9.2014.

[16] *Mgr. Michal Teplan, PhD.:* European Researchers' Night 2014 2014 – Scientific booth "Neurorehabilitation differently: Mirror therapy " Bratislava, Stará tržnica (excursion), 26.9.2014.

[17] *Mgr. Michal Teplan, PhD.:* European Researchers' Night 2014 2014 – Scientific booth "Neurorehabilitation: robotic BCI training" Stará tržnica, Bratislava (excursion), 25.9.2015.

[18] *Mgr. Michal Teplan, PhD.* contribution in article: "He is visible for all, but only some know him. To identify a person of a different race is an issue!". Magazine Život (Life), 49/2015 (press), 02.12.2015.

[19] *Mgr. Michal Teplan, PhD.:* "From biosignals to acupuncture" magazine interview in Quark, April (press), 01.04.2015.

[20] *Doc. Ing. Milan Tyšler, CSc. with Doc. V. Witkovský, Prof. I. Frollo, Ing. J. Švehlíková, Mgr. M. Teplan, RNDr. M. Hain, Mgr. Škrátek:* Opened door day in IMS SAS, IMS SAS (excursion), 10.11.2015.

2.7.2. Table of outreach activities according to institute annual reports

Outreach activities	2012	2013	2014	2015	total
Articles in press media/internet popularising results of science, in particular those achieved by the Institute	10	9	6	5	30
Appearances in telecommunication media popularising results of science, in particular those achieved by the Institute	3	2	1		6
Public popularisation lectures	7	1	1	2	11

- **Supplementary information and/or comments on popularisation activities, max. 300 words**

The Institute is active in popularisation of science for pupils and secondary school students. In particular, the Institute in co-operation with the Austrian Academy of Sciences (Breath Research Institute, Dornbirn, Austria) and the Mathematical Institute of the Slovak Academy of Sciences, in co-operation with the Journal of Breath Research (published by IOP Science, UK), organized the Austrian-Slovak conference for students of the grammar schools, entitled Sparkling Science: FEM_Pers Conference Bratislava, which has been held at the Institute of Measurement Science on September 19, 2013. The aim of the student conference was to popularize science and its applications, especially for talented students of the grammar schools in Austria and Slovakia. The conference has been attended by 40 students of the following schools: Bundesgymnasium Dornbirn, Gymnasium Adolf Pichler Platz, Innsbruck, Akademisches Gymnasium, Innsbruck, Gymnázium Jura Hronca, and Gymnázium Grösslingová 18, Bratislava.

The popularisation activities of the IMS SAS researchers have been recognized by the award of the Slovak Academy of Sciences:

2015 - Frollo: Award of the Slovak Academy of Sciences for "Scientific-popularization and educational activities".

2.8. Background and management. Human resources and implementation of recommendations from previous assessment

2.8.1. Summary table of personnel

Personnel	2012	2013	2014	2015
All personnel	75,0	74,0	72,0	72,0
Research employees from Tab. Research staff	46,0	46,0	42,0	41,0
FTE from Tab. Research staff	31,090	30,500	29,560	28,610
Average age of research employees with university degree	50,2	49,3	48,2	49,3

2.8.1.1. Professional qualification structure (as of 31.12. 2015) FEMALE

FEMALE	AGE								
Number of	< 30	31 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	> 65
DrSc. / prof.	0	0	0	0	0	0	0	0	0
II.a / Assoc. prof.	0	0	0	0	0	1	0	0	0
Other researchers PhD./CSc.	1	2	2	1	1	2	0	0	0
doc. / Assoc. prof.	0	0	0	0	0	0	0	0	0

2.8.1.2. Professional qualification structure (as of 31.12. 2015) MALE

MALE	AGE								
Number of	< 30	31 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	> 65
DrSc. / prof.	0	0	0	0	0	0	1	0	3
II.a / Assoc. prof.	1	0	2	0	3	3	1	1	3
Other researchers PhD./CSc.	3	2	4	1	2	2	3	2	6
doc. / Assoc. prof.	0	0	1	0	1	1	0	1	1

2.8.2. Postdoctoral and mobility scheme

2.8.2.1. Postdoctoral positions supported by national and international resources

none

2.8.2.2. Postdoctoral positions supported by external funding

none

2.8.2.3. SAS stipends and SASPRO stipends

Research project proposals “Bioinspired representation and modelling of textures for recognition of surface materials and patterns in other signals – BioTex“ under the SAS grant scheme SASPRO, senior researcher position for RNDr. P.Vácha, PhD worker currently at The Institute of Information Theory and Automation (UTIA) Czech Academy of Sciences, project submitted by Prof. I. Bajla as scientist in charge in January 2015 – the project was not proposed for funding.

2.8.2.4. Internal funding - the Slovak Academy of Sciences Supporting Fund of Stefan Schwarz

none

2.8.3. Important research infrastructure *(max. 2 pages)*

Laboratory of MR tomography of the NMR National Center

- **Experimental whole-body tomograph TMR – 96** based on the magnetic resonance principle with resistive magnet 0.1 T with controlling console TECMAG.
- **MR imager ESAOTE – Opera** with permanent magnet 0.178 T.
  (This equipment is placed, used and maintained at IMS SAS as member of the NMR National Centre. However, due to administrative reasons it is a property of the Slovak Technical University).
- **Digital radiological system with energetic separation of detected ions** with an X-ray source with a small focus of 10 μm for scanning and tomography.

Laboratory of X-ray microtomography:

- **Microtomograph Phoenix Nanotom 180** with minimal voxel resolution 500 nm, 180 kV/15 W RTG tube with nanofocusation, detector 2300x2300 pixels, with special software for measurement of porosity, defects and coordinate metrology. Reconstruction computing cluster of 8 PCs.
  (This equipment is placed, used and maintained at IMS SAS, however, due to administrative reasons it is a property of the Institute of Materials and Machine Mechanics of the SAS).

Laboratory of Optical and FTIR Spectroscopy

- **FTIR spectrometer Agilent Cary 680** with sensitivity in infrared spectrum up to 25 μm
- **Optical UV-VIS-NIR spectrometer Horiba–Jobin–Yvon iHR550** sensitive in ultraviolet, visible and near-infrared electromagnetic spectrum.

Laboratory of Optical Measurements

- **Thermographic camera NEC San-ei Thermo Tracer TH7102WX** with noncooled microbolometric matrix detector, space resolution of 320x240 pixels, with measured range of temperatures from -40 to +500°C, noise equivalent temperature resolution 0,08°C at 30°C, sensitivity range 8–14 μm, measurement error ±2% of the range.

Laboratory for Preparation and Measurement of Properties of Materials

- **System for measurement of magnetic properties of materials using SQUID: QD-MPMS-XL-7AC**. Range of applied DC field: +/- 7 T, sensitivity:

10-11Am2 for applied fields (0 T - 0.25 T). Frequency for AC susceptibility: from 10-2 Hz up to 1000 Hz. Temperature range: 2 K – 400 K.

- **One-channel low-Tc RF SQUID system** with equivalent sensitivity of ~20x10-15 T Hz-1/2 in the white noise range. Gradiometer's diameter: 40mm. (own development).
- **Nutator** - laboratory scale nutating high-intensity ball mill based on nutating mode. The inner volume of the Nutator reactor is 0.3 dm^3, the nutating angle range is 0–20 deg, speed of rotation is up to 1400 rpm. (Own development)

Laboratory of Biomeasurements

- **ProCardio 8 -** High resolution 128-channel ECG mapping device. a mobile PC-based and battery powered measuring and ECG processing system with active or passive electrodes. The system enables long term recording and processing of multichannel ECG and computation of body surface potential maps as the input for cardiac diagnostics based on inverse solutions (ECG imaging). (Own development)
- **RoboArm -** a compact robot-assisted neurorehabilitation tool that combines the brain-computer interface (BCI) technology with a robotic rehabilitation system. (Own development)
- **BioLab STI** – PC-based device for measurement of systolic time intervals. (Own development)
- **BioLab ATR** – PC-based device for measurement of the Achilles tendon reflex. (Own development)
- **ProGastro 3** – PC-based device for measurement of the electrical activity of the gastro-intestinal tract. (Own development)

The described infrastructure is crucial and indispensable practically for all research projects running in the Institute. The laboratories and individual systems are accessible within common projects or contracts also to external research and industrial organizations, e.g.:

TMR – 96 and ESAOTE Opera MR tomographs – Department of Radiology, Medical University of Vienna, Austria, Unite de Recherche en Résonance, Université Paris-Sud, France, Université Lyon, France, Faculty of chemical and food technology Slovak University od Technology, Bratislava.

Nanotom 180 X-ray microtomograph – Institute of Materials and Machine Mechanics SAS, Dept. of Ecology and Dept. of Mineralogy and Petrology, Faculty of Natural Sciences, Comenius University, Institute of Electrical Engineering and Earth Science Institute of the SAS, companies Forschner, Mesing.

SQUID QD-MPMS-XL-7AC - Faculty of Chemical and Food Technology, SUT in Bratislava, Alexander Dubcek University of Trencin, Institutes of the SAS: Cancer Research Institute, Institute of Normal and Pathological Physiology.

ProCardio 8 – Faculty of Biomedical Engineering CTU in Prague, Kladno and hospital Kralovske Vinohrady Prague, Czechia, Medical Faculty, Comenius University in Bratislava, National Institute of Cardiovascular Diseases in Bratislava.

RoboArm - Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava.

The whole instrastructure is also freely accessible to educational activitites (seminars, excursions) in cooperation with Faculty of Electrical Engineering and Informatics and Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Electrotechnical Faculty, University of Zilina and Faculty of Mechnical Engineering, Technical University in Kosice.

2.8.4. Description of how the results and suggestions of the previous assessment were taken into account

Specific tasks of the previous assessment, as formulated in the official *Protocol of Evaluation of SAS Scientific Organization*:

1. The Institute has to use its interdisciplinary capability to actualize their research topics in order to succeed in the competition for various research programs.
2. Due to the significantly improved research infrastructure, special care should be given to its effective managing and exploitation.
3. The Institute has to increase the efforts for finding additional sources for the research activities.
4. Give more importance on the publication with higher quality.
5. Improve significantly the activities to transfer knowledge to the industry.
6. The research in the new area of X-ray microtomography due to development of optimal methodologies of measurement and non-destructive testing of objects and materials has a big perspective in many areas (material research, mineralogy, palaeontology, geology, electronics, microelectronics, micromechanics, archaeology and preserving of cultural heritage).

Response:

1. The Institute's interdisciplinary research potential and capabilities helped significantly to strengthen its co-operation with national and international partner institutions, during the assessment period 2012-2015. In 2012, the Institute in cooperation with the Medical University Innsbruck, Austria, submitted a new proposal for international project focused on breath research measurements and analyses in the framework of ERA-NET (ERA-NET on Translational Cancer Research Transcan). In 2012 the Institute submitted also new national project proposals, 2x within the general call of the Slovak Research and Development Agency (APVV) and 5 new project proposals within the grant scheme of the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education (VEGA). In 2013, the Institute participated as a partner in proposal preparation of two new projects supported by the EU Structural Funds. The project "University Research Park for Biomedicine Bratislava" has been approved (under the call of Ministry of Education "Building a university science parks and research centers" - Measure 4.2, call code OPVaV-2012 / 4.2 / 08-RO) and another project proposal has been prepared and submitted: "Research Center for Cloud-Computing for Analysis of Large Data in Biomedicine, Nanotechnology and Material Research "(under the Measure 4.2" Transfer of knowledge and technology from research and development into practice ", OP Research and development, call OPVaV-2013 / 4.2 / 09-RO). In 2014, the Institute participated as a partner in developing proposals for two EU projects within the Horizon 2020 (the "Functional Magnetic Resonance Imaging of Motion for Musculoskeletal Applications (DYNAMO)" call H2020-PHC-2015 and the project "Big Data in Crisis Management (CRIBIDAT) "call H2020-MSCA-ITN-2015). During the years the Institute actively participated in EU Structural Funds projects "University Research Park for Biomedicine Bratislava" and the "Competence Center for New Materials, Advanced Technologies and Energy "(ITMS 26240220073). In 2015, the Institute participated in six new project proposals within the general call of the Slovak Research and Development Agency (APVV) (2x with principal investigator from IMS SAS, 4x as a partner institution). In addition, the Institute participated as partner in 4 EU COST projects (net collaborations).
2. During the assessment period, the Institute has continued in improving its research infrastructure. The research infrastructure was further developed, efficiently managed and effectively exploited for basic and applied research. This infrastructure helped significantly to improve the quality of the Institute's scientific output and to strengthen the project co-operation with national and international partner institutions. In particular, the research in the Department of Optoelectronic

Measuring Methods was intentionally targeted onto the development of X-ray microtomographic measurement methods, infrared thermography and optical measurement methods. Research activities were covered by scientific project VEGA 2/0126/13 „New advanced methods of measurement and non-destructive testing of materials: X-ray microtomography and active infrared thermography“, project APVV-14-0719 „Physical non-destructive methods for complex testing and analysis of cultural heritage artefacts“, international EU project COST TD 1201 „Colour and Space in Cultural Heritage (COSCH)“. In the field of X-ray microtomography, analysis of limiting possibilities of the measurement method, particularly in terms of achieving the best resolution and uncertainty, was performed; the results of which have been and in the future also will be used to optimize CT measurement methodologies. In the Department of Magnetometry the one-channel low-Tc RF SQUID system and the susceptometer QD-MPMS-XL-7AC have been exploited mainly in the research of magnetic properties of the materials using SQUID, in particular magnetometric properties for magnetic nanoparticles and nanoliquids. The Institute's research infrastructure allow development of basic research in the Department of Imaging Methods aimed to imaging of biological and physical objects using nuclear magnetic resonance (NMR) at the low magnetic field of 0.1 Tesla and 0.2 Tesla and in the framework with international co-operation also in high magnetic fields 3.0, 4.7 and 7.0 Tesla. The Institute became an indispensable part of the Centre for NMR Based Material Imaging as a part of the National Centre of NMR – the Centre of excellence. In the field of measurement and analysis of the biosignals the Institute has designed several unique experimental devices for multichannel taking , as e.g. system BioLab ATR, system BioLab STI, device ProGastro 3, ECG – mapper ProCardio 8, which have been efficiently exploited for biomedical research, in co-operation with the partner research and medical institutions.

3. During the assessment period, the Institute has increased the efforts for finding additional sources for the research activities. The Institute received addition (non-institutional) financial sources from the scientific research projects and commercial projects and co-operations (8 projects supported by the Slovak Research and Development Agency, 16 projects supported by the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education, 4 projects supported by the EU Structural Funds, 2 projects of national importance supported by government, 4 EU COST projects, several research and commercial projects with other government organizations and industry partners, as e.g. the Minister of Health of the Slovak Republic, ENEL Group Nuclear Power Plants, Jaslovské Bohunice and Mochovce, Joint Institute for Nuclear Research in Dubna, Russia, etc.). During the assessment period, the Institute participated as the principal investigator and/or the scientific partner in preparation and submitting of several new national and international project proposals, including 1 ERA-NET project and 2 Horizont 2020 project proposals, 11 new project proposals submitted to the Slovak Research and Development Agency, and many VEGA projects supported by the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education.
4. The Institute's publications and the responses to the research outputs have significantly improved during the assessment period 2012-2015 (with respect to the previous assessment period 2007-2011). In particular, the Scientific papers published in journals registered in Current Contents Connect (categories ADCA, ADCB, ADDA, ADDB) increased from 74 (5 years assessment period) to 89 (4 years assessment period), (i.e. in average from 14.8 to 22.3 per year). The average impact factor (IF) of impacted scientific journals where the Institute’s researchers published their research results during the assessment period (i.e. for publications in 2012-2015) was IF=2.345. Similarly, we have observed significantly improved responses to the research outputs during the assessment period. In particular, the one-year average of citations in Web of Science Core Collection

increased from 152 to 354, and the one-year average of citations in SCOPUS (not listed above) increased from 39 to 98.

5. During the assessment period continued the traditionally good cooperation with several industrial partners, clinical and applied research facilities (e.g. ENEL - Nuclear Power Plants Bohunice and Mochovce, Datalan a.s.). The Institute has applied its scientific results and transferred the knowledge to the industry on the basis of cooperation agreements and in the framework of contract research. Under the project "The Competence Center for New Materials, Advanced Technologies and Energy", the Institute has been developed non-destructive testing methods, analysis and characterization of new materials for the energy sector based on X-ray microtomography, focused on precise and nondestructive visualization of internal structures of materials and components for the power industry, as e.g., analysis of cracks and other defects (fatigue) of materials. In cooperation with the Research Institute of Nuclear Power (VÚJE a.s.) in Jaslovské Bohunice we have developed and implemented measurement systems for continuous measurement of inclination of the reactor vessels in the third and fourth units of the Mochovce NPP. During the assessment period the Institute's researchers co-authored several patents and/or patent applications (5 patents registered abroad, 2 patents registered in Slovakia).
6. Research in the field of X-ray microtomography has had a great impact on several scientific goals and co-operations of the Institute. This state-of-the-art method provides possibility to visualize internal structure of materials and objects in non-destructive way, including material's inhomogeneities, cracks, and voids. In the field of material research and electrical engineering a new microtomographic methodology for non-destructive visualisation of internal structure of superconductors was designed and optimized. This allows a non-destructive measurement of the effective cross section of the superconductor along a wire, as e.g. in [1] and [2]. In the field of geology and mineralogy a methodology of microtomographic characterization of minerals and rocks was proposed, with emphasis on distinguishing the different phases of minerals, visualization of microstructure, inclusions, voids and cracks. The method was used for example to evaluate the quality of marble samples exposed to stress test of salt crystallization and frost test, see e.g. [3]. For the application in the field of biological research the microCT methodologies were designed for imaging and comparison of small bony structures, which were used in the comparative anatomical analysis of the type Pseudopus apodus with representatives of the genus Anguinae. An important benefit of this new methodology using microtomography has been a considerable increase in the complexity of comparing structures throughout their substance, quantitative analysis of selected dimensional structures with small achievable measurement uncertainty, see e.g. [4].

   Publications:

   [1] HUŠEK, I. – KOVÁČ, P. – ROSOVÁ, A. – MELIŠEK, T. – PACHLA, W. – HAIN, M. Advanced MgB2 wire made by internal magnesium diffusion process. In Journal of Alloys and Compounds, 2014, vol. 588, p. 366-369.

   [2] KULICH, M. - KOVÁČ, P. - HAIN, M. – ROSOVÁ, A. – DOBROČKA, E. High density and connectivity of a MgB2 filament made using the internal magnesium diffusion technique. In Superconductor Science and Technology, 2016, vol. 29, p. 035004.

   [3] DURMEKOVÁ, T. - RUŽIČKA, P. - HAIN, M. – ČAPLOVIČOVÁ, M. Changes in marble quality after sodium sulphate crystallization and long-lasting freeze-thaw testing. In Engineering Geology for Society and Territory - Volume 5 : Urban Geology, Sustainable Planning and Landscape Exploitation. Springer, 2015. ISBN 978-3-319-09047-4, p. 237-241.

   [4] KLEMBARA, J. – HAIN, M. – DOBIASOVA, K. Comparative anatomy of the lower jaw and dentition of Pseudopus apodus and the interrelationships of

species of subfamily Anguinae (Anguimorpha, Anguidae). In The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology, 2014, vol. 297, no. 3, p. 516-544.

- **Supplementary information and/or comments on management, research infrastructure, and trends in personnel development**

  During the assessment period, the Institute's management in close cooperation with the Scientific Board adopted important policy measures in order to improve the indicators of quality, efficiency and effectiveness of the research work, and to ensure the systematic development of infrastructure and sustainable acquisition of external funding sources. To reach these goals, the Institute:

  - motivated and supported its researchers in activities leading to new collaborations and preparation of new project proposals, at national and international level, in order to receive grants for their funding,
  - was actively involved in cooperation consortia to receive support from the EU Structural Funds in order to improve its research infrastructure (CEKOMAT II - Centre of Excellence for research and development of structural composite materials for engineering, construction and medical applications, Center of Competence for new materials, advanced technologies and power engineering, CENTE II - Centre of Excellence for new technologies in electrical engineering, University Research Park Biomedicine Bratislava),
  - has taken effective measures to improve the quality and efficiency of scientific research by establishing processes for systematic review of scientific results of the departments and the individual researchers, with emphasis on the fulfillment of the accreditation criteria (partial indicators),
  - created conditions and actively support the transfer of knowledge and application of scientific research to social and economic practice. A prominent example in this area is the successful cooperation with the Research Institute of Nuclear Power (VÚJE a.s.) in Jaslovské Bohunice, leading to development of new measurement systems for automatic continuous monitoring of the reactor vessel inclinations of the third and fourth units in Mochovce NPP. These devices greatly help to increase the safety of the nuclear power plants in Slovakia,
  - paid special attention and actively supported the PhD. study in cooperation with the Faculty of Electrical Engineering and Information Technology of the Slovak Technical University in Bratislava, as a basic and indispensable prerequisite for attracting young scientists for measurement science and technology,
  - has taken measures to improve the qualification and age structure of its scientific workers, and created better conditions for admission and employment of young workers and post-docs.

3. ***Research strategy and future development of the institute for the next five years (2016-2020):*** *(Recommended 3 pages, max. 5 pages)*

3.1. Present state of the art in both the national and the international contexts

The role of measurements, mathematical modelling, statistical and computational methods in the field of measurement science and metrology is more than ever up to date and with an important impact on international scientific and industrial cooperation. This problematic is well within the goals of the Slovak strategy for research and development - *Research and Innovation Strategy for Smart Specialization of the Slovak Republic (SK RIS3).*

Current research is focused on developing the models of the measured objects, the theory of measuring systems and on the mathematical and statistical methods for proper evaluation and uncertainty analysis of the measurement results. The new measurement and testing trends in research and industry put the emphasis on increasing the speed of measurement and minimize the uncertainty of measurements.

In most cases, crucial is the requirement on non-destructiveness of the processes of obtaining quantitative and qualitative information about the object. These requirements are particularly manifested in materials research, mechanical engineering and electronics industry with the need for visualization of internal structures, measurement of interior dimensions of 3D objects, materials testing for the presence of internal defects, where conventional methods require mechanical cutting of the object and thus its destruction. Such damage is often unacceptable, especially when it concerns an object of research, which should be preserved in its integrity for its uniqueness or need to take further measurements and tests. To the most progressive measurement methods, meeting the above requirements, belong tomographic and micro- tomographic as well as active infrared thermographic methods.

Advanced high-sensitive magnetometry is, together with other methods, widely utilized for research on new substances and new forms of materials. Magnetic responses of the object under changing temperature and applied electromagnetic fields give useful information which can help to understand also the structural and chemical properties of this object. Magnetometry is a strong tool for exploring and development of nanosuspensions. Application of magnetometry in biology and biomedicine consists not only in measurement of self-generated magnetic field by typical organs, e.g. hearth, brain, muscles, but also in measurement of magnetic moments of various tissues and cell lines, also such that were exposed to magnetic nanoparticles as a potential drug carriers.

A significant part of the current research in measurement science is focused on measurements in biomedicine. Similarly, also in this field the noninvasiveness of the methods is emphasized.

In the field of magnetic resonance imaging, the current research trends are oriented on the accurate NMR imaging and spectroscopic measurements research, based on the usage of the up-to-date equipment available in the top-class world laboratories. The present projects are oriented to diagnostics of human articular cartilage, development of diagnostic tools for quantitative imaging of biogenic iron, imaging and mapping of organic and synthetic materials and imaging with hyperpolarization. The most important research is nowadays oriented to: thin layer organic and inorganic materials testing, measurement of muscle metabolism using phosphorus spectroscopy on ultra-high fields, investigation of muscle and liver energy metabolism using novel phosphorus MR spectroscopy and imaging, evaluation of human extremities, research of static magnetic field deformation due to the presence of magnetic nanoparticles and multiparametric MRI methods for collagen fibers quantification in cartilage and tendons.

Another actual topic connected with biomedical measurements oriented to cardiovascular diseases is the diagnostics and treatment based on combination of CT or MR imaging with information from surface ECG measurements known as ECG imaging that allows

noninvasive assessment of the functional state of the heart using both, structural and electrical properties of the tissues and precise planning and execution of the invasive treatment. In connection with the aging of the population another challenge for measurements in biomedicine is at home patient monitoring and obtaining data relevant for their therapeutic management. These data can be obtained in interaction with the patient but also automatically using a wearable network of senzors (body sensor networks – BSN) and advanced methods for data coding, compression, transmission (mostly wireless, using mobile and internet technologies) and their processing in remote terminals and central telemedicine units. Current research is among others oriented to research and development of nonobstructive sensor and obtaining more informative markers of the patient status from quantities measurable in home environment.

3.2. Research strategy of the institute in the national and the international contexts, objectives and methods

The In the field of **theoretical methods** our main objective is development of the appropriate methods for measurement science and metrology based on mathematical modelling and mathematical statistics. In particular, we shall focus on development of models, methods and algorithms for calibration and determination of measurement uncertainties by deriving the exact and/or approximate probability distributions of measurement results.

In the field of **optoelectronic measuring methods**, the scientific objective for the next period is the development of advanced physical methods of measurement and non-destructive testing: X-ray microtomography and active infrared thermography. The emphasis will be given to the design of new measurement methodologies, theoretical analysis and solution of specific problems resulting from the application of these methods in specific fields of research and in industry. Specific goals for the microtomography are: theoretical analysis of limiting capabilities with regard to resolution and measurement uncertainty, proposal of new methodologies for calibration of microtomography devices for the measurement of micro-dimensions and porosity of materials, analysis and elimination of artefacts in the micro-CT measurement and reconstruction, proposal and implementation of new standards for calibration of the microtomography measurements. Specific goals for the **active infrared thermography** are focused to theoretical analysis and experimental realization of pulse active thermography methods and systems for its application in non-destructive testing and defectoscopy, particularly for testing of modern composite materials. During the next research period we plan to continue applications of microtomographic and active infrared thermographic measurement methods to material research, electronics, biology, geology, and cultural heritage preservation.

In the field of the SQUID magnetometry we plan to show its possibilities to study actual processes in medicine, biology and material research. We shall concentrate on analysis of the properties and magnetic characterization of the nanoparticles and nanoliquids, especially ultra-small superparamagnetic nanoparticles based on iron oxides and on investigation of the influence of these nanoparticles on the human and animal cell cultures and organs.

We suggest a new prospective research topic interesting at least for research departments dealing with magnetometry, optoelectronics and magnetic resonance – the **use of the nitrogen vacancy centres** or colour centres (point defects in the diamond lattice) in development of new measuring methods. Interaction of the light waves with these colour centres, and the result of this interaction – e.g. photoluminescence, absorption, depends on magnetic field, electric field and temperature in the close vicinity of the colour centre/s. Nanoscale dimensions of the colour centres enable a development of new sensors of magnetic and electric fields, temperature, etc. with high space resolution. The colour centres can be utilized also in connection with NMR for imaging with nanometer resolution.

In the field of **dynamical systems** our research will be focused on development of mathematical models of causality and new detection methods. The goal is to reveal

coupling between dynamical systems represented by time series. We are interested in the presence and the direction of coupling and also in distinction of causality and mere correlation. The acquired knowledge and developed computer algorithms will be applied in analyses of experimental time series, in particular, the recordings of human brain electroencephalograms.

In the area of **cognitive neuroscience** and biomedical research based on the probabilistic modelling of the sleep process we will develop mathematical and computing methods for modelling and analysis, with the aim of understanding human performance decrements due to sleep disturbance and sleep loss, and the functional data analysis (FDA) methods for modelling and objective evaluation of the sleep process, monitoring sustained attention, fatigue, sleepiness, or excessive workload. In collaboration with our partners we will continue the research of the brain-computer interface and human-computer interaction protocols. We will continue validating the novel training paradigm based on atomic decomposition of brain signals that we proposed and implemented in our robot-assisted neurorehabilitation studies. Our research will be also oriented towards developing of a new modelling and experimental approaches for efficient monitoring of biological responses to weak low frequency electromagnetic fields (EMF).

Research in the field of the **magnetic resonance imaging** will be based on international co-operation with foreign partners and will be oriented to (1) imaging of properties organic and synthetic materials and objects, imaging of thin weak-magnetic layers, imaging of ferritin in-vivo and in-vitro on various types of tomographs and standardization of MRI protocols on imaging ferritin in laboratory and clinical praxis, (2) imaging methods of cartilage and meniscus and diagnostics of damaged bonding tissues and state of collagen structures, (3) study of superparamagnetic particles for transport of medicaments to the target tissues and possibilities for their targeting with the use of gradient magnetic fields, (4) research of artefacts, testing of spectral vibration and noise due to the activity of the gradient magnetic systems and possibilities for suppression of their influence.

In research in the field of **biomeasurements** we will continue the started activities focused on methods and technology for noninvasive cardiac diagnostic and therapy planning using combined ECG and CT / MR data. The methods will be based on modeling the cardiac electrical field and solution of the inverse problem. To improve accuracy of the solution we plan to implement advanced computation models that can account for the cardiac tissue anisotropy and allow tackling the diagnostic of selected diseases of heart atria. Concerning the measurement technology, in aimed cooperation with academic and business partners we plan to extend our research scope to advanced sensors and their networks for application in telemedicine for home monitoring and remote management of patients with arrhythmias or congestive heart failure.

The research strategy of the Institute is to initiate or join new projects in the above mentioned research areas together with current and possible new research partners from the academic sphere but also with partners from industry – future potential producers or users of the technologies - and partners active in health care or social and cultural environment. In the near few years, besides the projects from the own VEGA Scientific Grant Agency, the possible research schemes include projects supported by the Slovak Research and Development Agency, projects financed from the European structural funds but also European research projects including Horizon 2020, COST or ERC and bilateral international schemes with individual countries or institutions.

Project proposals submited to 7RP or H2020	2012	2013	2014	2015
Institute as coordinator	0	0	0	0
Institute as participant	0	0	2	0

4. Other information relevant for the assessment:

none