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

Period: January 1, 2016 - December 31, 2021

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

https://www.um.sav.sk

https://www.um.sav.sk/en/

1.3. Executive body of the institute and its composition

Directoriat	Name	Year of birth	Years in the position, from - to
Director	Milan TYŠLER	1951	2006 - 2018
Director	Viktor WITKOVSKÝ	1963	2019 - 2022
Deputy director	Viktor WITKOVSKÝ	1963	2006 - 2018
Deputy director	Ján MAŇKA	1961	2019 - 2022
Scientific secretary	Ján MAŇKA	1961	2006 - 2018
Scientific secretary	Milan TYŠLER	1951	2019 - 2022

1.4. Head of the Scientific Board

Ing. Ján Maňka, CSc.

1.4.1. Composition of the International Advisory Board

- **Ing. Pavel JURÁK, Ph.D.** - Institute of Scientific Instruments of the Czech Academy of Sciences, v.v.i., Brno, Czech Republic, jurak@isibrno.cz
- **Dr. Rainer KÖNING** - Department of Dimensional Nanometrology, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany, Rainer.Koening@ptb.de
- **Professor Damian John TYLER** - Department of Physiology, Anatomy & Genetics, University of Oxford, UK, damian.tyler@dpag.ox.ac.uk
- **Professor Isabel VAN DRIESSCHE** - Department of Chemistry, Ghent University, Gent, Belgium, Isabel.VanDriessche@UGent.be
- **Professor Júlia VOLAUFOVÁ, PhD** - Formerly Biostatistics Program, School of Public Health, Louisiana State University Health Sciences Center, USA, jvolau@lsuhsc.edu

1.5. Basic information on the research personnel

1.5.1. Fulltime equivalent work capacity of all employees (FTE all), FTE of employees with university degrees engaged in research projects (FTE researchers)

2016		2017		2018		2019		2020		2021		2016-2021	
FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	average FTE all per year	average FTE researchers per year
52.74	32.75	50.65	30.54	50.75	31.30	48.15	29.72	49.62	31.38	49.57	31.56	**50.25**	**31.21**

1.5.2. If applicable, add also a short information on the merger of the institute in the evaluation period. You can also add rows in the above table corresponding to the founding institutes

Not applicable.

1.6. Basic information on the funding of the institute

1.6.1. Institutional salary budget, other salary budget[1], non-salary budget[2]

Salary budget	2016	2017	2018	2019	2020	2021	average
Institutional salary budget *[millions of EUR]*	0.812	0.883	0.913	1.072	1.150	1.139	**0.995**
Other salary budget *[millions of EUR]*	0.214	0.169	0.181	0.120	0.111	0.178	**0.162**
Total salary budget *[millions of EUR]*	1.025	1.052	1.095	1.192	1.261	1.317	**1.157**
Non-salary budget *[millions of EUR]*	0.236	0.206	0.235	0.287	0.226	0.266	**0.243**

1.7. Mission Statement of the Institute as presented in the Foundation Charter indicating the years when it was adopted and revised

The main purpose and subject of the activities of the organization, valid during the period January 1, 2016 - December 31, 2021, *were established in the Charter of the Institute of Measurement Science of the Slovak Academy of Sciences No. 467/G/12/2008 of July 28, 2008, and updated in the Addendum No. 2 issued by the Decision of the Presidium of the SAS No. 788 of January 10, 2012:*

1. The Institute specialises in basic research in the field of measurement science and mathematical methods of measurement data processing. It focuses on the development of new methods for the measurement, modelling and computer processing of selected physical quantities, properties of materials and biological objects. The research area falls into the field of engineering, natural and biomedical sciences and focuses primarily on mathematical sciences, electrical engineering, automation and control systems (especially measurement technology, metrology and optoelectronics), mechanical engineering (with a focus on bionics and biomechanics, biomedical engineering), materials engineering and biotechnology for healthcare.
2. The Institute focuses on the research and design of measurement methods and systems that address non-standard measurement problems in research, industry, and economic and social fields. It develops and implements unique measurement systems as a result of scientific research conducted at the Institute.

[1] Salary budget originating outside the regular budgetary resources of the organization, e.g. from the project funding.
[2] Includes Goods and Services and PhD fellowships

3. The Institute provides advisory and other expert services related to the main activities of the organisation.
4. The Institute shall conduct doctoral studies in accordance with the generally applicable legal provisions.
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.

On October 5, 2021, Act No. 347/2021 was adopted, which transforms the legal form of SAS organisations into public research institutions as of January 1, 2022. In accordance with the Act on the Academy and the Charter No. 06157/2021 adopted by the Presidium of the SAS on November 15, 2021, the legal form of the Institute of Measurement Science of the Slovak Academy of Sciences changed from 1 January 2022 from a state-subsidised organisation to a public research institution.

The subject of activity of the organisation established in accordance with the Charter of the Institute of Measurement Science of the Slovak Academy of Sciences No. 06157/2021 of November 15, 2021, which entered into force on January 1, 2022:

1. The predominant main activity of the Organisation is research in the fields of science and technology (hereinafter also "fields"), namely in the subset of fields of Mathematical Sciences (010100), in particular in the fields of Applied Mathematics (including for technical sciences) (010102) and Probability and Mathematical Statistics (010108), in the subgroup of Electrical Engineering, Automation and Control Systems (020200), especially in the fields of Measurement Technology (020217) and Metrology (020218), and in the subgroup of Mechanical Engineering (020400), especially in the fields of Physical Engineering (020404) and Biomedical Engineering (020430).
2. Other main activities of the organisation are:
   a) securing and managing the research and development infrastructure in which the Organisation has ownership or other rights; the scope of the research and development infrastructure in which the Organisation acquires rights by changing the legal form of the Organisation into a public research institution on January 1, 2022, determined by the Protocol between the Slovak Academy of Sciences and the Organisation pursuant to § 21aa (11) of the Act on the Academy,
   b) obtaining, processing and disseminating information in the field of science and technology and findings from the Organisation's own research and development in the fields referred to in paragraph 1; publication of the journal Measurement Science Review (ISSN 1335 - 8871),
   c) participation in cooperation with the universities in the implementation of study programmes of the third degree of university study in full-time and external form in Slovak and English, namely the PhD study programme Measurement Technology in the field of Electrical Engineering and the study programme Applied Mathematics in the field of Mathematics,
   d) cooperation in science and technology with universities, other legal entities carrying out research and development and entrepreneurs in the fields referred to in 1.

1.8. Summary of R&D activity pursued by the institute during the evaluation period in both national and international contexts. Describe the scientific importance and societal impact of each important result/discovery. Explain on general level – the information should be understandable for a non-specialist (recommended 5 pages, max. 10 pages for larger institutes with more than 50 average FTE researchers per year as per Table 1.5.1.)

In accordance with the mission set out in the Institute's founding charter, the research activities of the IMS SAS include 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 in 5 scientific departments: 1) Department of optoelectronic measurement methods, 2) Department of magnetometry, 3) Department of theoretical methods, 4) Department of imaging methods, and 5) Department of biomeasurements.

Research at IMS SAS is interdisciplinary and necessarily involves extensive collaboration with leading scientific institutes and other partners at home and abroad. The Institute has established close collaboration with leading academic partners (universities and other academic institutions) and other stakeholders (industry and the health sector) in the development of advanced measurement methods and their applications in engineering, materials science and biomedical and health sciences. The following sections summarise the main research activities of the Institute's research departments during the assessment period and outline their scientific importance and societal impact, as well as their position in national and international scientific cooperation.

The scientific focus in the **Department of Optoelectronic Measurement Methods** was on the development of X-ray microtomographic measuring methods and on the development of optical measuring methods and non-destructive testing in the field of cultural heritage protection and forensic sciences.

X-ray microtomography is a scientific discipline that allows from a series of X-ray shadow images of an object and their subsequent processing, using the inverse Radon transformation, to obtain a three-dimensional image of the object, and thus non-destructively display the interior of objects and materials. This gives it the potential to be beneficial for a wide range of other scientific disciplines and technical applications, such as materials research, palaeontology, geology, biology, medical sciences, mechanical engineering, microelectronics, electrical engineering and other areas of science and industry.

We have investigated the limitations of X-ray microtomography in terms of achieving optimal resolution, minimising measurement uncertainty, suppressing the formation of artefacts in 3D image reconstruction, and generally optimising microtomographic measurement methods. We have explored the possibilities of changing the spectral composition of the generated X-ray radiation by controlling the ratio of decelerating and characteristic radiation through the choice of target material (tungsten, molybdenum), the influence of the spectral composition of the X-ray radiation on the beam hardening effect and the possibilities of influencing the X-ray spectrum by filtering the accelerating voltage of the X-ray tube. The X-ray microCT calibration methods for measuring dimensions in the micrometre range and for measuring the porosity of materials using spherical standards were further developed and improved. Among the most important results achieved are proposals for new methodologies of microCT measurement and non-destructive testing in the field of materials research, engineering, mineralogy, biology, archaeology and cultural heritage protection. In the field of materials research, microtomographic methods for non-destructive imaging of MgB_2-based superconductors (developed at the Institute of Electrical Engineering SAS, Dr. Kováč) were designed and optimised, enabling the imaging of various structural inhomogeneities and the non-destructive measurement of the effective superconductor cross-section along the conductors drawn from the preform. In the field of the use of imaging techniques in biology and palaeontology, methods with optimised measurement conditions have been proposed to achieve an increase in contrast, and methods for the digital processing of image data have been developed. These allow a considerable increase in the complexity of the visibility of structures in their entire volume, supplemented by a quantitative analysis of selected dimensions of structures with achievable low measurement uncertainty.

In the field of applied research, we developed and implemented a measurement system for automatic measurement of reactor vessel inclination for two units of the nuclear power plant

in Mochovce, Slovakia, which was completed in the assessment period 2016-2021. The measurement system at the third unit of the Mochovce nuclear power plant has already been put into operation and contributes to increasing of its operational safety.

The **Department of Magnetometry** is mainly concerned with the study of nanoparticles in ionic liquids and the application of superparamagnetic iron oxide nanoparticles.

Ionic liquids - liquids consisting only of ions - have unique physicochemical properties, such as high thermal and chemical stability, the ability to dissolve various substances and negligible vapour pressure. These properties argue for their use in the development of new technologies for the production of metal nanoparticles or their colloids for industrial and biomedical applications. In cooperation with our partners, we have focused on the preparation and characterisation of colloids of Ni and NiFe nanoparticles by magnetron sputtering directly on the surface of two ionic liquids [BMIM].[PF6] and [BMIM].[Tf2N] at room temperature. The detailed results of the investigation of the magnetic properties of the prepared colloids of Ni and NiFe nanoparticles during their 34-month storage allow a better understanding of the interactions between ionic liquids and nanoparticles and their theoretical modelling. The results obtained point to a new way to produce stable magnetic fluids. Nanoparticles with dimensions of Ni~10 nm and NiFe ~12 nm were stable for more than 2 years without signs of agglomeration and sedimentation. The ionic liquid itself protects the nanoparticles from degradation. The nanoparticles show a superparamagnetic character with a blocking temperature of about 2.5 K. X-ray diffractions show that a nanoscale arrangement of cations and anions is present in ionic liquids alone, at least at room temperature. One of the fundamental questions for the future use of ionic liquids is the interaction of metal nanoparticles with the cations and anions of the respective ionic liquid (e.g., stabilisation of the nanoparticles against agglomeration). Our work is based on thorough magnetic measurements and contributes to the knowledge of these interactions. Our recent results in this field were obtained in collaboration with the Institute of Electrical Engineering SAS, the Center for Energy Research of the Hungarian Academy of Sciences and the Institute of Polymers SAS.

Biogenic iron is found in all biological systems. Recently, ultra-small superparamagnetic iron oxide nanoparticles have also been used in biomedicine as drug carriers that enable targeted dosage by the acting magnetic field. The stability of these nanoparticles depends on the cellular environment (chemical composition, pH, etc.). Their degradation can lead to iron overload, which causes inflammatory processes in the cells, a disturbance of the iron metabolism, oxidative stress and other negative factors. In our research in collaboration with the Institute of Normal and Pathological Physiology of the Center for Experimental Medicine of the SAS, we focused on the determination of the iron content originating from these nanoparticles and on the differentiation of naturally occurring iron in tissues and fluids based on different blocking temperatures. A method has been developed to determine the iron content of rat tissue after administration of a small dose of a dispersion of nanoparticles in saline. We have shown that using SQUID (Superconducting Quantum Interference Device) magnetometry, an extremely small amount of nanoparticulate iron, which cannot be detected by the traditional Pearl histochemical method, can be identified and distinguished from biogenic iron. An important contribution of the result to the field of measurement technique is the development of a methodology and a series of experiments to measure extremely weak magnetic signals from biological samples.

During the assessment period, the **Department of Theoretical Methods** focused on:

Mathematical-statistical models and methods for metrology and biomeasurements. In cooperation with the Slovak Institute of Metrology, Slovak Legal Metrology, Slovak University of Technology and Mathematical Institute SAS we developed theories, methods and algorithms for univariate and multivariate linear and polynomial comparative calibration of sensors and transducers, as well as for the determination and evaluation of the associated measurement uncertainties. In cooperation with our international metrology partners (PTB, NPL, NLE, NIST and VNIIM), who are members of MATHMET - European Metrology Network for Mathematics and Statistics - we compared the results with the currently valid standards. New results were obtained in the theory of non-parametric methods, linear mixed-effects

models, statistical tolerance intervals and exact probability distributions used in the evaluation of measurement uncertainty and derived by numerical inversion of the characteristic functions. In collaboration with the Department of Neurology (Ludwig-Maximilians-University Munich) and the Department of Clinical Neurosciences (University of Oxford) we examined various aspects of pain perception, transcription, intrinsic network activity reflecting the ongoing experience of chronic pain, the efficacy of cognitive strategies for pain relief, based on using mixed-effects statistical models to assess sensorimotor pain transformation.

Causal analysis of measured time series. Identifying causal relationships between processes is one of the fundamental challenges in various scientific fields from economics through climate to neuroscience. Our extensive comparative study (2018) has contributed to the recognition that more complex relationships, such as couplings between nonlinear deterministic systems, require different causal approaches than, for example, the analysis of interconnected autoregressive processes. The methods that work in reconstructed state spaces, which we introduced in 2016-2019, belong to this category. In 2017, we also published a study addressing serious unsolved problems in the detection of delayed causality (in cooperation with the Institute of Informatics of the Czech Academy of Sciences). We also addressed the problems of the so-called arrow of time in the context of the temporal sequence of cause and effect, which is known as the first principle of Granger causality.

Sleep EEG, mirror therapy and brain-computer interface for neurorehabilitation. Part of our research focused on a combination of novel continuous sleep representation, functional data analysis and time synchronisation methods that provided more information about the sleep structure of healthy EEG. This method also allowed us to identify significant differences in sleep patterns between a healthy population and patients after ischaemic stroke. We also showed that mirror box therapy, which is based on visual feedback that mimics the movement of the injured limb, is associated with persistent changes in brain electrical activity, in particular a significant increase in the motor mu rhythm recorded in both hemispheres. This result indicates an improvement in impaired motor skills, leads to changes in brain plasticity and provides an objective neural correlate of the effect of the therapy. The methodology developed allowed us to construct a brain-computer interface that controls the robotic split - a neuro-rehabilitation system in which the patient is asked to imagine the movement of the paretic hand, but without performing the actual movement. The next step was to replace the robotic split with a virtual reality environment to make the rehabilitation more engaging. Both systems were tested on selected patients with motor impairments due to stroke and on healthy volunteers.

Time series analysis of intracranial pressure for monitoring patients with traumatic brain injury. We proposed a novel approach to patient monitoring with multiple global and local features based on the transformation of intracranial pressure into a multidimensional feature vector space. The developed technique can contribute to the detection of the onset of the patients' critical state by extending the standard methods used for emergency protocols.

Biological autoluminescence measurements as a non-invasive tool for monitoring chemical and physical oxidation modulations in yeast cell cultures. Monitoring biological oxidation processes triggered by chemical or physical stimuli is currently extremely important due to environmental exposure to various physicochemical factors. In cooperation with the Institute of Photonics and Electronics of the Czech Academy of Sciences, we have proposed a new approach for monitoring oxidation based on biological autoluminescence, which is used to detect chemical perturbations of yeast due to induced oxidative stress.

The most important research results of the **Department of Imaging Methods**:

New methods of homogeneous signal excitation for quantification of energy metabolism in human skeletal muscle, liver and heart at 7T MRI tomograph. Phosphorus MR spectroscopy (31P-MRS) is a unique technique allowing non-invasive assessment of tissue energy metabolism in vivo. However, due to inherently low signal-to-noise ratio (SNR), it is not commonly used in clinical practice. Ultra-high field MR systems, i.e., 7T, in combination with surface receive arrays provide sufficient SNR, yet they lead to very inhomogeneous excitation, significantly complicating data quantification. Therefore, new methods for

homogeneous signal excitation at 7T were developed and tested. In the first instance, a new excitation pulse was designed that allows uniform excitation even in inhomogeneous field. This new pulse was implemented into a new sequence and applied to quantify cardiac metabolism in healthy volunteers. High reproducibility of results was demonstrated even when using different excitation field intensity. New technology enabling homogeneous excitation field for whole body ^{31}P-MRS at 7T was also developed. Electromagnetic fields simulations were confirmed by in vivo measurements in healthy volunteers, where sufficient SNR was achieved by combining the whole-body excitation with local receive array. This research, in cooperation with the Oxford Centre for Clinical Magnetic Resonance Research (University of Oxford), has high potential in human cardiac metabolism research and may potentially lead to increased quality of life in patients

Mapping the noise and vibration conditions of NMR imagers operating in a weak magnetic field. During scanning in a magnetic resonance (NMR) tomograph, mechanical vibrations occur due to the operation of the gradient system coils, which subsequently generate acoustic noise. This is a source of interference, especially in 3-D imaging - an increase in background noise and a decrease in image sharpness. The imaging method of the human vocal tract was tested, in which the speech signal is also scanned during phonation in an NMR tomograph. Mapping of the distribution of noise intensity and mechanical vibrations in the scanning space of NMR tomographs with weak magnetic field up to 0.2 T (open E-scan OPERA and whole-body TMR96), including the selection of the appropriate position, distance and directional characteristic of acoustic signal sensor and assessment of the metal shielding cage for the reflected acoustic sound wave. The results of the analysis of the spectral properties of vibrations are used to suppress unwanted acoustic signals as well as artefacts in MR images of thin layers and material samples. The knowledge gained will also be used to develop new experimental coils and special test phantoms for mapping the homogeneity, intensity distribution and other properties of weakly magnetic materials.

Magnetic field homogeneity for magnetic resonance imaging equipment, theory, calculation and experiment. Magnetic resonance imaging requires a magnetic field source with maximum homogeneity over the entire volume of the object under investigation. We have proposed methods for the construction of correction (shim) coils, theoretical calculations and the adjustment of the homogeneity of the whole-body tomograph based on three methods for measuring the static magnetic field. The measurements were performed with the following devices: Hall magnetometer, point NMR magnetometer and based on the MR gradient echo imaging method applied on the testing circular tubes. All measurements of the magnetic field are aligned to a point in the centre of the circle and on 12 measurement points around its circumference. A system of linear equations, identification of the objective functions and optimisation of the calculations provide the optimal values of the currents for the correction coils. The results of all three methods were compared and analysed. In terms of applications, the proposed methods are suitable for regular testing and correction of inhomogeneity sources of magnetic fields for MRI equipment. The developed mathematical tool can also be used for other physical objects whose parameters are influenced by external sources, signals or radiation fields.

The scientific focus in the **Department of Biomeasurements** was at these topics:

The sustained mechanical contraction of the heart is initiated by electrical impulses, which can be measured on the torso as the well-known electrocardiographic (ECG) measurement. Standard 12-leads ECG measurement is the essential examination to know about the patient's heart condition. The research of the Department of Biomeasurements is focused on *the study of the electrical field of the heart, multiple-leads ECG measurements and body surface potential mapping (BSPM), modelling and simulation of the cardiac electrical field, and development of necessary equipment.*

The experimental multiple-leads measurements are carried out with the ProCardio8 measuring system. It is a flexible, portable device for high-resolution multi-channel recording of body surface potentials. Both the hardware and the software modules were developed in our Department. The modular software package includes modules for (1) patient data management, (2) ECG recording, (3) ECG processing and analysis, and (4) body surface

potential map calculation and display. During the 2016-2021 evaluation period, a new data acquisition subsystem was integrated into the system to enable long-term multi-channel preview and recording. Subsequently, the device was used in collaboration with the National Institute of Cardiovascular Diseases (NICD) in Bratislava, Faculty of Biomedical Engineering Czech Technical University in Prague, Kladno, and University Hospital Královské Vinohrady in Prague, the Czech Republic for successful measurements in more than 50 patients with different diagnoses.

The large number of electrodes distributed on the entire surface of the chest provides more information that can be used to diagnose various cardiac disorders and evaluate their treatment. To better understand the processes that take place in the heart and are transmitted to the torso, we are developing a ventricular model that allows the simulation of normal and pathological electrical activity of the most important part of the heart. The part of the heartbeat signal that reflects the activation of the ventricles is the so-called QRS complex. The propagation of activation in the model is simulated according to the principle of cellular automata. Possible factors influencing changes of the QRS complex in ECG signals during left ventricular hypertrophy were investigated. The propagation of the activation wavefront was calculated and visualised in a geometric heart model for normal heart function and for pathological cases: the reduced propagation velocity, the left ventricular wall enlargement and a combination of the latter two factors. Higher ECG signals are generally associated with enlargement of the left ventricle. It was shown that the amplitude of the ECG signals is influenced more by the reduced velocity of propagation of activation than by the enlargement of the left ventricular wall. The results obtained in cooperation with International Laser Center in Bratislava suggest that the paradigms for the diagnosis of left ventricular hypertrophy need to be reconsidered. Later, the geometric heart model was updated by a model with realistic geometry obtained from a CT scan of a specific patient. In this model, premature ventricular activity (PVA) was simulated using the known position of the pacing catheter, and the calculated BSPMs on the patient's torso model were compared with the measured BSPMs on that patient. The simulated and measured BSPMs correlated to more than 90% in the first 20 ms of activity, which may be helpful for the preliminary localisation of the origin of the unwanted PVA. During his long-term stay at the Institute of Computational Science in Lugano, our PhD student Peter Kalavsky was involved in developing the method for a computationally fast anisotropic forward model to simulate the activation sequence in cardiac tissue based on eikonal equations. Part of our research in cardiac modelling concerns the use of partial differential equations for the simulation of activation propagation.

The next part of our research focused on using the measured BSPMs to assess local pathological changes in the heart by calculating the inverse problem of electrocardiography. One of these is the aforementioned PVA, which leads to cardiac arrhythmias and dangerously elevated heart rhythm (tachycardia). Such a diagnosis is treated pharmacologically or by a special invasive procedure called radiofrequency ablation (RFA). In RFA, a special catheter is inserted into the right or left ventricle of the heart and the location of the PVA origin is sought by mapping the activation time in the myocardium. The procedure is very time-consuming, so it is helpful to know the preliminary location of the PVA origin in advance. We propose a method to estimate the PVA origin from the measured BSPMs and solve the inverse problem of electrocardiography. In the calculation, a single dipole is assumed to be the equivalent electrical generator of the PVA origin. The method is non-invasive and can significantly shorten the invasive RFA procedure. The method was tested on both simulated data and real patient data. In the simulated data, the localisation error between the real PVA and the inversely estimated PVA origin was less than 2 cm. As mentioned above, we perform the BSPM measurements in collaboration with the NICD in Bratislava. The BSPMs of more than 40 patients with PVA in whom RFA was indicated were measured with the ProCardio8 system. After successful RFA, the position of the applied intervention was compared with the result of the inverse solution. So far, the results for thirteen patients have been evaluated. In eleven of the thirteen cases, the inverse results indicated the correct left or right ventricle. Sometimes during the BSPM measurement, some of the 128 electrodes used are damaged or cannot be used because of another monitoring device on the patient's torso. At the end of the evaluation period, we started to investigate the importance of individual electrodes for the inverse solution and the influence of their omission.

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 (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 should not exceed the number of average FTE researchers per year. The principal research outputs (max. 10% of the total number of selected publications, including Digital Object Identifier – DOI if available) should be underlined. Authors from the evaluated organizations should be underlined.

1. JURÁŠ, Vladimír - ZBÝŇ, Š. - MLYNÁRIK, V. - SZOMOLÁNYI, Pavol - HAGER, B. - BAER, P. - FROLLO, Ivan - TRATTNIG, S. The compositional difference between ankle and knee cartilage demonstrated by T2 mapping at 7 Tesla MR. In *European Journal of Radiology*, 2016, vol. 85, no. 4, p. 771-777. (2015: 2.593 - IF, Q2 - JCR, 1.209 - SJR, Q1 - SJR, 2016 - Current Contents; ADCA). ISSN 0720-048X. DOI: https://doi.org/10.1016/j.ejrad.2016.01.021
2. KRAKOVSKÁ, Anna - HANZELY, Filip. Testing for causality in reconstructed state spaces by an optimized mixed prediction method. In *Physical Review E*, 2016, vol. 94, no. 5, p. 052203. (2015: 2.252 - IF, Q1 - JCR, 1.183 - SJR, Q1 - SJR, 2016 - Current Contents; ADCA). ISSN 2470-0045. DOI: https://doi.org/10.1103/PhysRevE.94.052203
3. VALKOVIČ, Ladislav - CHMELÍK, M. - MEYERSPEER, M. - GAGOSKI, B. - RODGERS, C. - KRŠŠÁK, M. - ANDRONESI, O. - TRATTNIG, S. - BOGNER, W. Dynamic 31P –MRSI using spiral spectroscopic imaging can map mitochondrial capacity in muscles of the human calf during plantar flexion exercise at 7 T. In *NMR in Biomedicine*, 2016, vol. 29, no. 12, p. 1825-1834. (2015: 2.983 - IF, Q1 - JCR, 1.624 - SJR, Q1 - SJR, 2016 - Current Contents; ADCA). ISSN 0952-3480. DOI: https://doi.org/10.1002/nbm.3662
4. MICHAIL, G. - DRESEL, C. - WITKOVSKÝ, Viktor - STANKEWITZ, A. - SCHULZ, E. Neuronal oscillations in various frequency bands differ between pain and touch. In *Frontiers in Human Neuroscience*, 2016, vol. 10, art. no. 182. (2015: 3.634 - IF, Q1 - JCR, 1.964 - SJR, Q1 - SJR, 2016 - WOS, Scopus; ADMA). ISSN 1662-5161. DOI: https://doi.org/10.3389/fnhum.2016.00182
5. COUFAL, D. - JAKUBÍK, Jozef - JAJCAY, N. - HLINKA, J. - KRAKOVSKÁ, Anna - PALUŠ, M. Detection of coupling delay: A problem not yet solved. In *Chaos*, 2017, vol. 27, no. 8, p. 083109. (2016: 2.283 - IF, Q1 - JCR, 0.780 - SJR, Q2 - SJR, 2017 - Current Contents; ADCA). ISSN 1054-1500. DOI: https://doi.org/10.1063/1.4997757
6. SENNA, M. - BILLIK, Peter - YERMAKOV, A.Ye. - ŠKRÁTEK, Martin - MAJEROVÁ, Melinda - ČAPLOVIČOVÁ, M. - MIČUŠÍK, Matej - ČAPLOVIČ, L. - BUJDOŠ, M. - NOSKO, Martin. Synthesis and magnetic properties of CuAlO2 from high-energy ball-milled Cu2O–Al2O3 mixture. In *Journal of Alloys and Compounds*, 2017, vol. 695, p. 2314-2323. (2016: 3.133 - IF, Q1 - JCR, 0.954 - SJR, Q1 - SJR, 2017 - Current Contents; ADCA). ISSN 0925-8388. DOI: https://doi.org/10.1016/j.jallcom.2016.11.097
7. VALKOVIČ, Ladislav - CLARKE, W.T. - PURVIS, L.A.B. - SCHALLER, B. - ROBSON, M.D. - RODGERS, C.T. Adiabatic excitation for 31P MR spectroscopy in the human heart at 7 T: A feasibility study. In *Magnetic Resonance in Medicine*, 2017, vol. 78,

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2.1.3. List of monographs/books published abroad

1. CAPEK, Ignác. Noble Metal Nanoparticles: Preparation, Composite Nanostructures, Biodecoration and Collective Properties. – Springer, 2017. ISBN 978-4-431-56554-3. https://doi.org/10.1007/978-4-431-56556-7_2 (WOS)

2. CAPEK, Ignác. Nanocomposite Structures and Dispersions: Second Edition. – Elsevier, 2019. 458 p. ISBN 978-0-444-63748-2. https://doi.org/10.1016/C2015-0-00616-5 (WOS, SCOPUS)

2.1.4. List of monographs/books published in Slovakia

1. PALENČÁR, R. – WIMMER, G. – PALENČÁR, J. – WITKOVSKÝ, Viktor. Navrhovanie a vyhodnocovanie meraní (Design and Evaluation of Measurements). Reviewers: M. Dovica, D. Janáčová, J. Markovič. – Bratislava: Slovak University of Technology in Bratislava, 2021, 160 p. ISBN 978-80-227-5080-6.

Other books (proceedings) published in Slovakia

1. MEASUREMENT 2017: Proceedings of the 11th International Conference on Measurement. Editors: J. Maňka, M. Tyšler, V. Witkovský, I. Frollo. Bratislava, Slovakia: Institute of Measurement Science, Slovak Academy of Sciences, 2017, 268 p., ISBN 978-80-972629-0-7.

2. MEASUREMENT 2019: Proceedings of the 12th International Conference on Measurement. Editors: J. Maňka, J. Švehlíková, V. Witkovský, I. Frollo. Bratislava, Slovakia: Institute of Measurement Science, Slovak Academy of Sciences, 2019, 340 p., ISBN 978-80-972629-2-1.
3. MEASUREMENT 2021: Proceedings of the 13th International Conference on Measurement. Editors: A. Dvurečenskij, J. Maňka, J. Švehlíková, V. Witkovský. Bratislava: Institute of Measurement Science, Slovak Academy of Sciences, 2021, 258 p., ISBN 978-80-972629-4-5.

2.1.5. List of other scientific outputs specifically important for the institute, max. 10 items for institute with less than 50 average FTE researchers per year, 20 for institutes with 50 – 100 average FTE researchers per year and so on

1. **Statistical and computational methods for measurement and metrology**. We have obtained new theoretical and algorithmic results in the field of exact probability distributions based on methods of numerical inversion of characteristic functions and their applicability in the evaluation of measurement uncertainty. In addition, PolyCal - the Matlab algorithm for comparative calibration - was developed on this basis. The linear function and the polynomial function are the most commonly used calibration functions in comparative calibration. Calibration is a standard tool in the field of measurements and applications to refine our knowledge about the parameters of the calibration function under consideration. This information is further used to refine our knowledge about an unobservable stimulus based on an independent future measurement (measured response) obtained with a calibrated device. The MATLAB algorithm PolyCal is based on the EIV (Errors-In-Variables) modelling approach and the characteristic functions approach. The algorithm is freely available as part of the Characteristic Functions Toolbox (CharFunTool) we developed for MATLAB, https://github.com/witkovsky/CharFunTool. Based on a collaboration with the Slovak Institute of Metrology, the Mathematical Institute SAS and the Slovak University of Technology). Related projects: VEGA 2/0054/18 “New statistical methods for special families of probability distributions and their applications” and APVV-15-0295 “Advanced statistical and computational methods for measurement and metrology”.
2. **Detection of direct and delayed causal effects in time series.** In collaboration with the Institute of Informatics of the Czech Academy of Sciences in Prague, we have focused on the detection of causal relationships between time series. The standard approach is the Granger causality test. In addition, we have analysed methods that estimate conditional mutual information between signals or work with a degree of predictability and mutual mappability in reconstructed state spaces. We have shown that the classical Granger test is only suitable for cases that allow autoregressive modelling. Modern methods are more effective in complicated cases, e.g., connections between complex nonlinear systems or apparent causality due to external influences. However, none of the methods has proven to be generally applicable to determine the lag of a causal effect. For example, for the continuous chaotic systems tested, the mutual information evaluation method dominated, while for discrete systems, the methods in reconstructed spaces were more reliable. However, when the systems studied contain a strong oscillatory component in their dynamics, the results of all methods become ambiguous. We have therefore published a study showing that the detection of delayed causality in general is still an unsolved problem. Related projects: MAD – Bilateral Mobility Project, SAS-AS CR 2015-2018, “Synchronization and causality in complex systems: Synchronization and causality in complex systems: time series methods” and project VEGA 2/0011/16, “Analysis of causal relationships in complex systems with emphasis on biomedical applications”.
3. **Personalised optimisation of cardiac resynchronisation therapy in heart failure based on multiple lead ECG measurement.** The research was focused on time autocorrelation maps (ACM) of instantaneous potential maps as a tool for evaluating changes of the ventricular depolarization dynamics during the cardiac

resynchronisation therapy (CRT). The first ECG measurements were performed on a group of healthy persons and two patients with implanted pacemaker-defibrillator who were CRT. The first patient responded well to the CRT (he was a responder), while the cardiac pumping function of the second patient did not improve with the treatment (he was a non-responder). In all subjects, measurements were performed during spontaneous cardiac activity (without pacemaker). In both patients also measurement in 5 pacing modes were performed: in the standard CRT mode, and in other 4 combinations of cardiac pacing. According to the Mann-Whitney U test, the differences in significance level between a healthy, a treated and a failing heart were 5% for 9 out of 10 parameters derived from the ACM. The results suggest that markers obtained from ACM could be used as another criteria for evaluating the success of the therapy and for optimal setting of the CRT mode. To simplify the multi-lead ECG measurement and further improve its quality, new 132-channel ProCardio 9 measuring system was designed. It uses multiple low noise front-end ECG modules with controlled gain and 24-bit A/D converters and WiFi communication with the control computer. Related project: APVV-19-0531 “Personalized optimisation of cardiac resynchronization therapy in heart failure based on multiple lead ECG measurement”.

4. **Influence of signal preprocessing on inverse localisation of the origin of ventricular pacing.** As part of the collaboration in the Consortium for ECG imaging (www.ecg-imaging.org), we participated in the study of the influence of ECG signal preprocessing methods on the results of inverse solutions. Data were provided by IHU-LYRIC, Bordeaux. ECG signals were recorded during an in vivo experiment while the right ventricle of a porcine heart embedded in a torso tank. 128 signals on the torso and 108 signals on the epicardium were recorded simultaneously. The ECG signals were processed using a combination of 7 high frequency noise removal methods and 4 baseline drift removal methods. The influence of the above methods on the accuracy of localisation of the stimulation origin by the inverse solution using a single dipole was investigated. The greatest influence on the localisation accuracy was the constant shift of the signal (offset) that remained after applying the high and low pass filters. After removing the remaining offset, the localisation error decreased significantly from 5.5 cm to 0.7-1.3 cm. In related publications, the same processed signals have been used as input data for various inverse methods aimed at recovering total ventricular activation from recorded body surface ECG signals. Partners: The Consortium for ECG Imaging – CEI (11 organizations). Related project: VEGA 2/0125/19 „Measurement and modeling of the cardiac electrical field for noninvasive identification and interpretation of structural changes of the ventricular myocardium leading to ventricular arrhythmias“.

5. **Extremely sensitive magnetometry in biomedicine and materials research.** The measurement of magnetic quantities with high sensitivity is applied in various fields of scientific research. In our research, we have focused on the use of nanoparticles in biomedicine and on two topics in the field of materials research in collaboration with other scientific institutions. Ultra-small superparamagnetic iron oxide nanoparticles in a suitable biocompatible package are widely used in biomedicine. The study focused on investigating the deformability of red blood cells from laboratory animals after the application of these nanoparticles. Our contribution was to determine the level of iron in blood derived from nanoparticles in their original form. In another study, we participated in the research of a hybrid inorganic-organic compound. These complex structures, based on the composition of inorganic and organic components at the molecular level, offer the potential for the design of new functional materials. The magnetic properties of the compound [Cu (en) 2 (VO_3) 2] – 3 H_2O were investigated. Measurements of the temperature magnetisation and hysteresis dependence showed that the compound is paramagnetic (1.79 μB) and does not exhibit significant magnetic interactions. In the last study, we investigated the effects of magnetised halloysite (MHNT) on the structure, morphology, chemical composition, and magnetic and mechanical properties of electrospun nanofibres based on blends of polycaprolactone (PCL) and gelatin (gel). It was found that incorporation of 12 wt%

MHNT into PCL/gel nanofibres resulted in the formation of a magnetic biocompatible material with a saturation magnetisation of 0.67 Am^2/kg and a coercivity of 1194 A/m. Related projects: APVV-16-0263, VEGA 2/0157/21, VEGA 1/0141/21, VEGA 2/0164/17. The results were obtained in collaboration with the Center for Experimental Medicine of the Slovak Academy of Sciences, the Institute of Inorganic Chemistry of the Slovak Academy of Sciences and other domestic and foreign university workplaces.

6. **Stress detection during scanning in an MRI scanner by continuous measurement of cardiovascular parameters with an optical photoplethysmographic sensor.** Parallel measurement of cardiovascular parameters with an optical photoplethysmographic (PPG) sensor and commercially available portable blood pressure monitors was performed in different situations of physical and mental stimulation and relaxation. Cardiovascular changes can be detected by Oliva-Roztočil index values, instantaneous heart rate and blood pressure. The proposed measurement procedure was tested in the preliminary trials. Different physiological and psychological stimuli were used to test whether the relaxation and activation phases produce different measurement parameters suitable for further statistical analysis and processing. The recorded PPG signal in analogue form was transferred to the external PC for digitisation and analysis. The main experiment dealt with the analysis of the influence of vibrations and acoustic noise on the changes in the physiological and psychological state (stress factor) of a person who was in an open MRI scanner with a low magnetic induction value. To improve the effectiveness of the measurement, it was necessary to construct a portable PPG sensor with wireless data transmission that can operate in the environment of a weak magnetic field. The results obtained will also be used to analyse, quantify and suppress the stress factor affecting the speech signal recorded during scanning in the MRI scanner for 3D modelling of the human vocal tract. Related projects: VEGA 2/0125/19 "Measurement and modeling of the electric field of the heart for non-invasive identification and interpretation of structural changes in the ventricular myocardium leading to ventricular arrhythmias". COST Action CA16116 "Wearable robotic devices to enhance, support or replace human motor functions". VEGA 2/0003/20 "Magnetic resonance imaging methods for medical diagnostics and materials research".

7. **Method for rapid and complete quantification of myocardial ATP flux using saturation transfer with dual-band quasi-adiabatic pulse.** Adenosine triphosphate (ATP) is an organic compound that provides energy to drive all processes in living cells, such as: Muscle contraction or the propagation of nerve impulses. Phosphorus saturation transfer experiments allow you to quantify ATP metabolism in a non-invasive way. Normally, only the forward flux of ATP synthesis through the creatine kinase reaction is studied in the heart by observing the decrease in phosphocreatine (PCr) after saturation of γ-ATP. Quantification of the opposite reaction, i.e. total ATP utilisation, is currently poorly understood as it requires simultaneous saturation of inorganic phosphate (Pi) and PCr signals. Therefore, a novel quasi-adiabatic radiofrequency pulse for double saturation was developed to enable the determination of total ATP utilisation. The pulses were evaluated in Bloch equation simulations and compared with a conventional hard-cosine saturation sequence. The technique was then applied in perfused rat hearts at 11.7 T. Related projects: APVV-15-0029, VEGA 2/0003/20. Foreign partner: Oxford Centre for Clinical Magnetic Resonance Research, John Radcliffe Hospital, Headington, Oxford, UK, based on a signed scientific collaboration agreement dated 14 October 2021.

8. **Modelling factors influencing changes in the QRS complex in ECG signals in left ventricular cardiac hypertrophy.** Using a computer model of the ventricles, we simulated and visualised the propagation of the activation queue in the ventricles at normal rate, at local slowing of the activation queue, at thickening of the left ventricular wall and at a combination of both factors in hypertrophy. The enlarged ECG signals of the QRS ventricular complex in hypertrophy are generally attributed to the enlargement of the left ventricle. We have shown that slowing of the activation front

has a greater effect on signal amplification than thickening of the left ventricular wall, which causes it to be present for longer in a large area of the myocardium, resulting in an increase in the potentials measured at the chest surface. Slowing the conduction of excitation or thickening the ventricular wall by 50% did not significantly increase the duration of the QRS complex. This was only the case when the propagation of the activation front slowed by 75% in a large part of the myocardium, or in combination with a slowing of excitation propagation when the left ventricular wall was thickened. This situation can occur in a combination of fibrosis and thickening of the myocardial wall of a hypertrophied heart. The results obtained point to the need to change the paradigm of diagnosis of left ventricular hypertrophy. Related projects: VEGA 2/0071/16: "Modeling of cardiac electrical field for the study of manifestation of funtional and structural changes in myocardium in measured ECG signals" and APVV-14-0875: "Noninvasive localization of ectopic arrhythmias of heart ventricles using ECG mapping and its use for causal therapy".

9. **X-ray microtomography methods for 3D imaging in palaeontology.** By using high-resolution X-ray microtomography methods, we have helped evolutionary biology (a team led by Prof. Klembara) to solve a problem more than a hundred years old concerning the origin of amniotes and thus an important stage in the evolution of vertebrates. This stage of evolution is important in that the quadrupeds loosened their ties to the aquatic environment and began to live on land. Two groups of early quadrupeds and precursors of the amniotes - fossil finds of representatives of the diadectomorphs and seymouriamorphs - were analysed using X-ray microCT, namely their inner ear labyrinth. Following the microCT measurements, the obtained 3D data were subjected to mathematical processing and time-consuming data segmentation to distinguish the fossil structures from the sediment. The results were finally subjected to a cladistic analysis, thus providing the palaeobiologists with insights that enabled them to determine a new classification of these groups in the evolutionary cladogram. Related projects: VEGA 1/0228/19, COST CA 17121, COST CA 16101, VEGA 1/0191/21, APVV-14-0719.

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

1. HAIN, Miroslav - BARTL, Ján - KŮR, J.- KŮR, B. Způsob vyhledávání povrchových defektů, zejména ložiskových kroužků, a zařízení pro provádění tohoto způsobu (Method of retrieving surface defects especially that of bearing rings and device for making the same). Date of Patent: August 3, 2016. Patent No.: CZ 306 088.
2. Pavel SMRČKA Ing. Ph.D., Praha, CZ, Karel HÁNA Ing. Ph.D., Říčany u Prahy, CZ, Jan KAŠPAR Ing. Jičín, CZ, Peter KNEPPO Prof. Ing. DrSc. Bratislava, SK, Milan TYŠLER Ing. CSc. Bratislava, SK. Systém pro měření biologických a technických veličin v prostředí silného a proměnlivého elektromagnetického pole. (System for measurement of biological and technical quantities in the environment with strong and variable electromagnetic field). Date of Patent: March 6, 2019. Patent No.: CZ 307 752.

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

None

2.1.8. Narrative on the most important research outputs of the institute – especially focused on their importance for society (3-5 pages)

1. **Optoelectronic systems for automatic measurement of reactor inclination in the Slovakian nuclear power plants Jaslovské Bohunice and Mochovce.** Measuring systems for the automatic measurement of reactor vessel inclination in the Jaslovské Bohunice and Mochovce nuclear power plants are being continuously developed in the Department of Optoelectronic Measurement Methods at IMS SAS and are

currently in operation in these two Slovakian nuclear power plants. The measuring systems are based on the principles of hydronivelisation and pendametry with optoelectronic reading of the measured values. These measuring systems are in continuous operation and are calibrated twice a year by our highly qualified personnel on site, which contributes to increasing the operational safety of these nuclear power plants. Result applicant: Slovenské elektrárne, a.s.

2. **Non-destructive methods for cultural heritage testing.** We have developed a complex methodology with implementation of a range of advanced non-destructive measurement methods and equipment for the analysis and examination of material cultural heritage objects. The examination methods include X-ray microtomography, X-ray microscopy, scanning electron microscopy, energy dispersive X-ray spectrometry, ultraviolet fluorescence, infrared reflectography, FTIR spectroscopy, UV, VIS, NIR spectroscopy and active infrared thermography. We achieved a synergistic effect when information about the artefact obtained with different physical measurement methods and subsequently processed and evaluated together provided qualitatively new, comprehensive information about the historical artefact under investigation. The tests of the methods were carried out in cooperation with the project partners on the panel paintings of the Gothic altar of the Basilica of the Holy Cross in Kežmarok and furthermore applied to a non-destructive physical examination of one of the rarest monuments of our cultural heritage (the altars of churches in Levoča and Spišská Sobota are the work of Master Paul of Levoča). Specifically, twenty Gothic altar panel paintings of the two side altars of the Church of St. George in Spišská Sobota and eight Gothic altar panel paintings on the side altar of the Church of St. Of St. James in Levoča. The result of the use of these physical non-destructive methods with subsequent advanced digital image processing was the detection of the presence and visibility of underdrawings hidden for the human eye, analysis of invisible inscriptions, texts and also the analysis of the so-called secondary interventions in paintings in the past (during their restoration). The obtained results of non-destructive testing are important for art historians and restorers in evaluating the current state of rare artifacts of our cultural heritage, evaluating the construction and authenticity of works and finally in determining the correct procedures for their subsequent restoration. The results of non-destructive testing are extremely important in determining the authenticity of a work and the correct procedures for its restoration. Applicator of the result: The Monuments Board of the Slovak Republic, Chamber of Restorers SR. Related project: APVV-14-0719 “Physical non-destructive methods for complex testing and analysis of cultural heritage artifacts”.

3. **Brain-computer interface with robot-assisted training for rehabilitation.** About 15 million people suffer a stroke each year and about 80% of stroke patients are affected by motor impairments, according to WHO. The major motor impairments include hemiparesis or hemiplegia. About 50% of patients still have motor impairments after months of intensive rehabilitation. As part of our APVV project "Brain-computer interface with adaptive robotic arm for rehabilitation", we have developed and built a brain-computer interface with robotic training for rehabilitation (BCI-RAS). RoboArm is a prototype designed to meet the basic criteria for use in clinical neurorehabilitation. The software part of the system allows the direct acquisition of electrical brain activity (electroencephalographic signal or EEG) from an external EEG measuring device and its subsequent algorithmic processing. The hardware was developed and designed in line with clinical experience in motor rehabilitation training. The BCI directly uses the brain's electrical activity signal (electroencephalogram or EEG) and allows the user to operate the system without any muscle activation. We have developed and coded a unique algorithmic procedure that responds to the individual neurophysiological characteristics of patients and allows automatic adaptation to their daily mental and cognitive variability. The experimental part confirmed the effectiveness of the proposed approach. The video of the BCI-RAS: http://aiolos.um.savba.sk/~roman/rrLab/video/RoboticArm_EN.mp4

4. **Alert function in traumatic brain injury.** When monitoring patients with severe head injuries, the so-called critical value method of intracranial pressure time course (VLT) is used in clinical practise. Exceeding this threshold is considered an alarm situation due to which the medical staff initiates an emergency procedure (protocol) to save the patient's life. However, much more extensive information is hidden in the archived VLT records of many monitored patients. Based on the known VLT curves for surviving and non-surviving patients, we proposed a new approach that uses clustering of intracranial pressure time-series symptoms to monitor the condition of hospitalised patients and retrospectively considers the behaviour of VLT time records of both types of patients. For VLT time series, we designed several global and local flags that form flag vectors in n-dimensional vector space. Using the hierarchical Gaussian mixed n-dimensional model, we proposed a clustering of this space. Based on the a posteriori probability of clusters, three new alert functions were proposed, and we searched for their optimal thresholds by using the receiver operating characteristic (ROC) approach and a new efficiency ratio. Cross-validation showed that the new alert functions are useful additions to the basic VLT method for critical thresholds. The proposed method can help to detect an emerging critical condition of the patient before the VLT exceeds the critical value. (Collaboration with TU Vienna, Prof. Dr. Med. Walter Mauritz and the University of Trnava, Prof. I. Rusnák).
5. **Change of paradigm about increased ECG signals based on modelling of the ventricular activation.** Using our in-house software for simulation of electrical activity of the ventricles we simulated and visualized ventricular activation propagation and computed body surface potential maps under various heart conditions: normal activation, activation when the activation propagation velocity is slowing down in some part of the ventricles and activation for the left ventricular hypertrophy (increasing thickness of the ventricular wall). We showed that the slowing of the activation propagation velocity leads to the similar increasing of the measured ECG signals like in hypertrophy. The results supported a reconsideration of a paradigm about increased ECG signals caused only by left ventricular hypertrophy.
6. **Noninvasive inverse localization of ectopic ventricular activity**. Solving the topics on localization of the premature ventricular activity we computed the results of the so-called inverse problem of electrocardiography from simulated and clinical data. On simulated data we showed, that for localization of premature ventricular activity which starts in a single point/area of the ventricles the geometrical constraint of several forms of the equivalent electrical generator (dipole, epicardial potential or transmembrane potential) can be assumed for the inverse solution. On clinical data we showed that we are able to find the relevant inverse solution using homogeneous torso model. In each patient, the inversely computed position was compared with the position of the catheter during successful ablation procedure. On well defined paced data of one patient (with known exact position of the pacing electrode) we made an optimization of two criterial parameters for the inverse result estimation instead of standardly used one parameter. Such approach improved the localization error by 30%.
7. **Influence of ECG signal preprocessing on the inverse localization of premature ventricular activation.** Within the international cooperation (Consortium for ECG imaging) we contributed to the study of the influence of the measured signals prepocessing on the inverse premature ventricular activation localization. Various types of baseline drift removal and high-frequency filtering were applied on the body surface potentials from animal paced hearts experiments. It was shown that for correct reconstruction of epicardial potentials especially the baseline drift removal is important. The use of different high-frequency filtering methods did not influence the results. It was also shown that for the inverse solution in the form of equivalent single dipole, additional removal of the signal offset at the time of the assumed activation start is important.
8. **Effective cognitive strategies for pain relief.** One of the main goals in pain research is to search for and clarify mechanisms for alleviating suffering. In collaboration with

our partners (Department of Neurology, Ludwig-Maximilians-University Munich, Germany and the Department of Clinical Neurosciences, University of Oxford, UK), an experiment was conducted to investigate the efficacy of cognitive strategies for pain relief. Using 7T fMRI, the effect of three strategies on pain control in healthy subjects was investigated: (a) non-imaginal distraction by counting backwards in steps of seven; (b) imaginal distraction by imagining a safe place; and (c) reinterpretation of pain valence (reappraisal). Based on the results of the statistical analysis of the measured data, we were able to show typical changes in cortical brain activity for the cognitive strategies considered using the algorithms we developed in MATLAB (HPMIXED - The High-Performance Mixed Effects Model Toolbox). A follow-up study found that increased whole brain connectivity underpinned the cognitive strategies for pain relief. An important aspect of our research is the observed variability. We found that each subject has an individual level of brain modulation. We show that a small reduction in brain activity in one subject can change cognition and behaviour as effectively as a large reduction in brain activity in another subject.

9. **Effects of stress on some physiological processes.** A signal analysis was performed to evaluate the stress produced during scanning in a 0.2 Tesla permanent magnet MRI device and a sensitivity analysis of a single receiving coil for NMR experiments. In addition, the physiological effect of vibrations and noise during magnetic resonance imaging was investigated. In collaboration with INPF SAS, the effect of stress on three groups of Wistar rats (WKY, BHR and SHR) was studied. Blood, heart, spleen and liver samples were collected from the above groups of rats and their magnetic properties were analysed using a SQUID magnetometer QD MPMS XL 7 AC. The level of the stress factor was regulated by the number of animals in the defined breeding area. Another point that was investigated was the effect of stress depending on the age of the animals. The results of the stressed groups of animals were compared with those of the control animals. Among the most important results were changes in the mass magnetisation of the liver tissue of normotensive rats compared to the control group in 9-week-old rats at 300 K. The experiments showed that the control group had paramagnetic properties, while the stressed rats had diamagnetic hysteresis curves at an applied field of 32 kA/m.

10. **Cartilage damage determinantion using quantitative magnetic resonance.** Although magnetic resonance imaging is currently considered the most accurate method for examining cartilage damage, morphological imaging is often insufficient to determine the degree of damage and does not detect the early stages of degeneration, which are manifested solely by changes in the internal structure of the cartilage. Quantitative MRI offers methods to analyse the state of collagen (T2 mapping) and proteoglycans (sodium MRI). The result of the solution was a new method for mapping the relaxation constant T2 (based on the so-called steady-state free precision), which allows an acceleration of the measurement (reduction from about 4 minutes to 2 minutes compared to the conventional method), a higher resolution (factor 1.5) and an increase in the number of slices (most obvious at ultra-high fields, where 32 instead of 4 slices can be displayed). This method has been used to detect differences in the collagen matrix in the cartilage of the knee and ankle, which is widely used in clinical practise when examining cartilage. Another modern method for determining proteoglycans is sodium MR, which displays sodium ions instead of protons that are directly proportional to the number of proteoglycans. Since the reduction of proteoglycans in cartilage is the first sign of incipient cartilage degeneration, this method has great potential to become part of screening measurements in clinical practise.

11. **Effect of contrast agents on the relaxation properties of ^{31}P-containing energy metabolites and differences in energy metabolism of skeletal muscle and heart between young and old people.** Phosphorus MR spectroscopy (^{31}P-MRS) is a powerful, non-invasive research tool for quantifying energy metabolism of heart and skeletal muscle in different patient populations. We first quantitatively assessed the effects of contrast agents used in radiology on the relaxation parameters of ^{31}P

metabolites. In addition to Gadolinium-based contrast agents commonly used in MR, we also investigated a low-osmolar iodine-based agent commonly used in CT scans. Our results show that ^{31}P - MRS is not affected by these contrast agents, unlike conventional hydrogen-based MR imaging, allowing accurate measurement even in patients who have previously had an MRI or CT scan. We have also investigated age-related changes in muscle metabolism. Proton (^{1}H) and phosphorus (^{31}P) MRS have been successfully used to study skeletal muscle metabolism at rest and during exercise. In elderly subjects, phosphocreatine (PCr) recovered much more slowly after exercise than in young volunteers, which was closely related to the lower muscle concentration of carnosine in the elderly. MRS has also been used to detect changes in cardiac metabolism in patients with heart failure. ^{31}P MRS showed weaker adenosine triphosphate production and quantified reduced levels of the PCr transport molecule, while carbon (^{13}C) MRS allowed real-time monitoring of glucose metabolism. These techniques make it possible to test metabolic deficiencies in heart failure and therefore have great clinical potential.

2.1.9. Table of research outputs

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	2016			2017			2018			2019			2020			2021			total			
	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. /1 million total salary budget	number	averaged number per year	av. No. / FTE researches	av. No. / one million total salary budget
Scientific monographs and monographic studies in journals and proceedings published abroad *(AAA, ABA)*	0	0.000	0.000	1	0.033	0.950	0	0.000	0.000	1	0.034	0.839	0	0.000	0.000	0	0.000	0.000	**2**	**0.333**	**0.011**	**0.288**
Scientific monographs and monographic studies in journals and proceedings published in Slovakia *(AAB, ABB)*	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	**0**	**0.000**	**0.000**	**0.000**
Chapters in scientific monographs published abroad *(ABC)*	2	0.061	1.951	0	0.000	0.000	**2**	0.064	1.827	2	0.067	1.678	0	0.000	0.000	0	0.000	0.000	**6**	**1.000**	**0.032**	**0.864**
Chapters in scientific monographs published in Slovakia *(ABD)*	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	**0**	**0.000**	**0.000**	**0.000**
Scientific papers published in journals registered in Current Contents Connect *(ADCA, ADCB, ADDA, ADDB)*	21	0.641	20.482	25	0.819	23.759	18	0.575	16.444	19	0.639	15.941	28	0.892	22.206	36	1.141	27.333	**147**	**24.500**	**0.785**	**21.176**
Scientific papers published in journals registered in Web of Science Core Collection and SCOPUS not listed above *(ADMA, ADMB, ADNA, ADNB)*	5	0.153	4.877	34	1.113	32.312	13	0.415	11.877	33	1.110	27.688	13	0.414	10.310	23	0.729	17.463	**121**	**20.167**	**0.646**	**17.430**
Scientific papers published in other foreign journals (not listed above) *(ADEA, ADEB)*	4	0.122	3.901	3	0.098	2.851	3	0.096	2.741	3	0.101	2.517	2	0.064	1.586	0	0.000	0.000	**15**	**2.500**	**0.080**	**2.161**
Scientific papers published in other domestic journals (not listed above) *(ADFA, ADFB)*	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	**0**	**0.000**	**0.000**	**0.000**
Scientific papers published in foreign peer-reviewed proceedings *(AECA)*	0	0.000	0.000	0	0.000	0.000	2	0.064	1.827	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	**2**	**0.333**	**0.011**	**0.288**
Scientific papers published in domestic peer-reviewed proceedings *(AEDA)*	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.032	0.793	0	0.000	0.000	**1**	**0.167**	**0.005**	**0.144**
Published papers (full text) from foreign scientific conferences *(AFA, AFC)*	4	0.122	3.901	4	0.131	3.801	5	0.160	4.568	1	0.034	0.839	2	0.064	1.586	5	0.158	3.796	**21**	**3.500**	**0.112**	**3.025**
Published papers (full text) from domestic scientific conferences *(AFB, AFD)*	4	0.122	3.901	1	0.033	0.950	4	0.128	3.654	6	0.202	5.034	0	0.000	0.000	1	0	1	**16**	**3**	**0**	**2**

2.2. Measures of research outputs (citations, etc.)

2.2.1. Table with citations per annum (without self-citations)

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) are listed separately

Citations, reviews	2015		2016		2017		2018		2019		2020		total		
	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	averaged number per year	av. No. / FTE researchers
Citations in Web of Science Core Collection (1.1, 2.1)	585	17.86	596	19.52	703	22.46	745	25.07	784	24.98	912	28.90	**4,325**	**720.83**	**23.10**
Citations in SCOPUS (1.2, 2.2) if not listed above	64	1.95	65	2.13	72	2.30	101	3.40	139	4.43	181	5.74	**622**	**103.67**	**3.32**
Citations in other citation indexes and databases (not listed above) (3.2,4.2)	0	0.00	0	0.00	0	0.00	2	0.07	3	0.10	0	0.00	**5**	**0.83**	**0.03**
Other citations (not listed above) (3.1, 4.1)	15	0.46	81	2.65	72	2.30	99	3.33	93	2.96	134	4.25	**494**	**82.33**	**2.64**

2.2.2. List of 10 most-cited publications published any time with the address of the institute, with number of citations in the assessment period (2015 – 2020)

1. (ADFB) TEPLAN, Michal. Fundamentals of EEG measurement. In Measurement Science Review, 2002, vol. 2, p. 1-11. ISSN 1335-8871. (**WOS + Scopus citations – 716; other citations - 142**)
2. (ADCA) 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. (2012: 24.892 - IF, Q1 - JCR, 15.022 - SJR, Q1 - SJR). ISSN 0306-0012. https://doi.org/10.1039/c3cs35468g (**WOS + Scopus citations – 411; other citations - 18**)
3. (ADCA) ROSIPAL, Roman - TREJO, L.J. Kernel partial least squares regression in Reproducing Kernel Hilbert Space. In Journal of Machine Learning Research, 2001, vol. 2, p. 97-123. ISSN 1532-4435. (**WOS + Scopus citations – 323; other citations - 22**)
4. (ADCA) KURDIOVÁ, T. - BALÁŽ, M. - VICIAN, M. - PALOVÁ, D. - VLČEK, M. - VALKOVIČ, Ladislav - SRBECKÝ, M. - IMRICH, R. - KYSELOVIČOVÁ, O. - BELAN, V. - JELOK, I. - WOLFRUM, C. - KLIMEŠ, I. - KRŠŠÁK, M. - ZEMKOVÁ, E. - GAŠPERÍKOVÁ, D. - UKROPEC, J. - UKROPCOVÁ, B. Effects of obesity, diabetes and exercise on Fndc5 gene expression and irisin release in human skeletal muscle and adipose tissue: In vivo and in vitro studies. In Journal of Physiology, 2014, vol. 592, no. 5, p. 1091-1107. (2013: 4.544 - IF, Q1 - JCR, 2.717 - SJR). ISSN 0022-3751. https://doi.org/10.1113/jphysiol.2013.264655 (**WOS + Scopus citations – 189; other citations - 32**)
5. (ADCA) MAYERHOEFER, M.E. - SZOMOLÁNYI, Pavol - JIRÁK, D. - MATERKA, A. - TRATTNIG, S. Effects of MRI acquisition parameter variations and protocol heterogeneity on the results of texture analysis and pattern discrimination: An application-oriented study. In Medical Physics, 2009, vol. 36, no. 4, p. 1236-1243. (2008: 3.871 - IF, Q1 - JCR, 0.660 - SJR, Q2 – SJR). ISSN 0094-2405. https://doi.org/10.1118/1.3081408 (**WOS + Scopus citations – 89; other citations - 3**)
6. (ADCA) SCHULZ, E. - MAY, E.S. - POSTORINO, M. - TIEMANN, L. - NICKEL, M.M. - WITKOVSKÝ, Viktor - SCHMIDT, P. - GROSS, J. - PLONER, M. Prefrontal gamma oscillations encode tonic pain in humans. In Cerebral Cortex, 2015, vol. 25, no. 11, p. 4407-4414. (2014: 8.665 - IF, Q1 - JCR, 4.887 - SJR, Q1 - SJR). ISSN 1047-3211. https://doi.org/10.1093/cercor/bhv043 (**WOS + Scopus citations – 75; other citations - 15**)
7. (ADCA) YADAV, S. - HAVLICA, J. - HNATKO, M. - ŠAJGALÍK, P. - CIGÁŇ, Alexander - PALOU, M. - BARTONÍČKOVÁ, E. - BOHÁČ, M. - FRAJKOROVÁ, F. - MASILKO, J. - ZMRZLÝ, M. - KALINA, L. - HAJDÚCHOVÁ, M. - ENEV, V. Magnetic properties of Co1-xZnxFe2O4 spinel ferite nanoparticles synthesized by starch-assisted sol–gel autocombustion method and its ball milling. In Journal of Magnetism and Magnetic Materials, 2015, vol. 378, p. 190-199. (2014: 1.970 - IF, Q2 - JCR, 0.815 - SJR, Q1 - SJR). ISSN 0304-8853. https://doi.org/10.1016/j.jmmm.2014.11.027 (**WOS + Scopus citations – 75; other citations - 3**)
8. (ADEB) TREJO, L.J. - KUBITZ, K. - ROSIPAL, Roman - KOCHAVI, R.L. - MONTGOMERY, L.D. EEG-based estimation and classification of mental fatigue. In Psychology, 2015, vol. 6, no. 5, p. 572-589. ISSN 2152-7180. https://doi.org/10.4236/psych.2015.65055 (**WOS + Scopus citations – 71; other citations - 5**)

9. (ADCA) STADNIK, T.W. - CHASKIS, C. - MICHOTTE, A. - SHABANA, W.M. - VAN ROMPAEY, K. - LUYPAERT, R. - BUDINSKÝ, Ľuboš - JELLÚŠ, Vladimír - OSTEAUX, M. Diffusion-weighted MR imaging of intracerebral masses: comparison with conventional MR imaging and histologic findings. In American Journal of Neuroradiology, 2001, vol. 22, p. 969-976. (2000: 2.126 - IF). ISSN 0195-6108. (**WOS + Scopus citations – 60; other citations - 5**)
10. (ADCA) KRAKOVSKÁ, Anna - MEZEIOVÁ, Kristína. Automatic sleep scoring: A search for an optimal combination of measures. In Artificial Intelligence in Medicine, 2011, vol. 53, no. 1, p. 25-33. (2010: 1.568 - IF, Q2 - JCR, 0.619 - SJR, Q2 - SJR). ISSN 0933-3657. https://doi.org/10.1016/j.artmed.2011.06.004 (**WOS + Scopus citations – 51; other citations - 5**)

2.2.3. List of 10 most-cited publications published any time with the address of the institute, with number of citations obtained until 2020

1. (ADFB) TEPLAN, Michal. Fundamentals of EEG measurement. In Measurement Science Review, 2002, vol. 2, p. 1-11. ISSN 1335-8871. (**WOS + Scopus citations – 956; other citations - 147**)
2. (ADCA) ROSIPAL, Roman - TREJO, L.J. Kernel partial least squares regression in Reproducing Kernel Hilbert Space. In Journal of Machine Learning Research, 2001, vol. 2, p. 97-123. ISSN 1532-4435. (**WOS + Scopus citations – 675; other citations - 23**)
3. (ADCA) 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. (2012: 24.892 - IF, Q1 - JCR, 15.022 - SJR, Q1 - SJR). ISSN 0306-0012. https://doi.org/10.1039/c3cs35468g (**WOS + Scopus citations – 438; other citations - 19**)
4. (ADCA) STADNIK, T.W. - CHASKIS, C. - MICHOTTE, A. - SHABANA, W.M. - VAN ROMPAEY, K. - LUYPAERT, R. - BUDINSKÝ, Ľuboš - JELLÚŠ, Vladimír - OSTEAUX, M. Diffusion-weighted MR imaging of intracerebral masses: comparison with conventional MR imaging and histologic findings. In American Journal of Neuroradiology, 2001, vol. 22, p. 969-976. (2000: 2.126 - IF). ISSN 0195-6108. (**WOS + Scopus citations – 271; other citations - 5**)
5. (ADCA) KURDIOVÁ, T. - BALÁŽ, M. - VICIAN, M. - PALOVÁ, D. - VLČEK, M. - VALKOVIČ, Ladislav - SRBECKÝ, M. - IMRICH, R. - KYSELOVIČOVÁ, O. - BELAN, V. - JELOK, I. - WOLFRUM, C. - KLIMEŠ, I. - KRŠŠÁK, M. - ZEMKOVÁ, E. - GAŠPERÍKOVÁ, D. - UKROPEC, J. - UKROPCOVÁ, B. Effects of obesity, diabetes and exercise on Fndc5 gene expression and irisin release in human skeletal muscle and adipose tissue: In vivo and in vitro studies. In Journal of Physiology, 2014, vol. 592, no. 5, p. 1091-1107. (2013: 4.544 - IF, Q1 - JCR, 2.717 - SJR). ISSN 0022-3751. https://doi.org/10.1113/jphysiol.2013.264655 (**WOS + Scopus citations – 201; other citations - 33**)
6. (ADMB) MATEJ, Samuel - LEWITT, R. M. Practical considerations for 3-D image reconstruction using spherically symmetric volume elements. In IEEE Transactions on Medical Imaging, 1996, vol. 15, p. 68-78. ISSN 0278-0062. https://doi.org/10.1109/42.481442 (**WOS + Scopus citations – 180; other citations - 3**)
7. (ADCA) LI, P. - FARKAŠ, Igor - MACWHINNEY, B. Early lexical development in a self-organizing neural network. In Neural Networks, 2004, vol. 17, p. 1345-1362. ISSN 0893-6080. https://doi.org/10.1016/j.neunet.2004.07.004 (**WOS + Scopus citations – 110; other citations - 3**)

8. (ADCA) MAYERHOEFER, M.E. - SZOMOLÁNYI, Pavol - JIRÁK, D. - MATERKA, A. - TRATTNIG, S. Effects of MRI acquisition parameter variations and protocol heterogeneity on the results of texture analysis and pattern discrimination: An application-oriented study. In Medical Physics, 2009, vol. 36, no. 4, p. 1236-1243. (2008: 3.871 - IF, Q1 - JCR, 0.660 - SJR, Q2 – SJR). ISSN 0094-2405. https://doi.org/10.1118/1.3081408 (**WOS + Scopus citations – 105; other citations – 4**)
9. (ADMB) ROSIPAL, Roman. Kernel partial least squares for nonlinear regression and discrimination. In Neural Network World, 2003, vol. 13, no. 3, p. 291-300. ISSN 1210-0552. (**WOS + Scopus citations – 100; other citations - 2**)
10. (ADCA) 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. (2007: 1.825 - IF, Q1 - JCR, 0.993 - SJR, Q1 - SJR). ISSN 0933-3657. https://doi.org/10.1016/j.artmed.2008.07.005 **(WOS + Scopus citations – 83; other citations - 10**)

2.2.4. List of 10 most-cited publications published during the evaluation period (2016-2021) with the address of the Institute, with number of citations obtained until 2021

1. (ADCA) TRAFIMOW, D.** - AMRHEIN, V.** - ARESHENKOFF, C.N. - BARRERA-CAUSIL, C.J. - BEH, E.J. - BILGIÇ, Y.K. - BONO, R. - BRADLEY, M.T. - BRIGGS, W. - CEPEDA-FREYRE, H.A. - CHAIGNEAU, S.E. - CIOCCA, D.R. - CORREA, J.C. - COUSINEAU, D. - DE BOER, M.R. - DHAR, S.S. - DOLGOV, I. - GÓMEZ-BENITO, J. - GRENDÁR, Marián - GRICE, J.W. - GUERRERO-GIMENEZ, M.E. - GUTIÉRREZ, A. - HUEDO-MEDINA, T.B. - JAFFE, K. - JANYAN, A. - KARIMNEZHAD, A. - KORNER-NIEVERGELT, F. - KOSUGI, K. - LACHMAIR, M. - LEDESMA, R.D. - LIMONGI, R. - LIUZZA, M.T. - LOMBARDO, R. - MARKS, M.J. - MEINLSCHMIDT, G. - NALBORCZYK, L. - NGUYEN, H.T. - OSPINA, R. - PEREZGONZALEZ, J.D. - PFISTER, R. - RAHONA, J.J. - RODRÍGUEZ-MEDINA, D.A. - ROMÃO, X. - RUIZ-FERNÁNDEZ, S. - SUAREZ, I. - TEGETHOFF, M. - TEJO, M. - VAN DE SCHOOT, R. - VANKOV, I.I. - VELASCO-FORERO, S. - WANG, T. - YAMADA, Y. - ZOPPINO, F.C.M. - MARMOLEJO-RAMOS, F.**. Manipulating the alpha level cannot cure significance testing. In Frontiers in Psychology, 2018, vol. 9, art. no. 699. (2017: 2.089 - IF, Q2 - JCR, 1.043 - SJR, Q1 - SJR). ISSN 1664-1078. https://doi.org/10.3389/fpsyg.2018.00699 (**WOS + Scopus citations – 47; other citations - 6**)
2. (ADCA) CAPEK, Ignác. Polymer decorated gold nanoparticles in nanomedicine conjugates. In Advances in colloid and interface science, 2017, vol. 249, p. 386-399. (2016: 7.223 - IF, Q1 - JCR, 2.155 - SJR, Q1 - SJR). ISSN 0001-8686. https://doi.org/10.1016/j.cis.2017.01.007 (**WOS + Scopus citations – 45; other citations - 2**)
3. (AAA) CAPEK, Ignác. Noble Metal Nanoparticles: Preparation, Composite Nanostructures, Biodecoration and Collective Properties. Springer, 2017. xvii, 554 p. ISBN 978-4-431-56554-3. https://doi.org/10.1007/978-4-431-56556-7_2 (**WOS + Scopus citations – 37**)
4. (ADCA) TRATTNIG, S. - BOGNER, W. - GRUBER, S. - SZOMOLÁNYI, Pavol - JURÁŠ, Vladimír - ROBINSON, S. - ZBÝŇ, Š. - HANEDER, S. Clinical applications at ultrahigh field (7T). Where does it make the difference? In NMR in Biomedicine, 2016, vol. 29, no. 9, p. 1316-1334. (2015: 2.983 - IF, Q1 - JCR, 1.624 - SJR, Q1 - SJR). ISSN 0952-3480. https://doi.org/10.1002/nbm.3272 (**WOS + Scopus citations – 35; other citations - 1**)
5. (ADCA) VALKOVIČ, Ladislav - CHMELÍK, M. - KRŠŠÁK, M. In-vivo 31P-MRS of skeletal muscle and liver: A way for non-invasive assessment of their metabolism. In Analytical Biochemistry, 2017, vol. 529, p. 193-215. (2016: 2.334 - IF, Q2 - JCR, 0.719 - SJR, Q2 - SJR). ISSN 0003-2697. https://doi.org/10.1016/j.ab.2017.01.018 (**WOS + Scopus citations – 35; other citations - 1**)

6. (ADCA) ZBÝŇ, Š. - MLYNÁRIK, V. - JURÁŠ, Vladimír - SZOMOLÁNYI, Pavol - TRATTNIG, S. Evaluation of cartilage repair and osteoarthritis with sodium MRI. In NMR in Biomedicine, 2016, vol. 29, no. 2, p. 206-215. (2015: 2.983 - IF, Q1 - JCR, 1.624 - SJR, Q1 - SJR). ISSN 0952-3480. https://doi.org/10.1002/nbm.3280 (**WOS + Scopus citations – 34; other citations - 2**)
7. (ADCA) MINARIKOVA, L. - BOGNER, W. - PINKER, K. - VALKOVIČ, Ladislav - ZARIC, O. - BAGO-HORVATH, Z. - BARTSCH, R. - HELBICH, T. - TRATTNIG, S. - GRUBER, S. Investigating the prediction value of multiparametric magnetic resonance imaging at 3 T in response to neoadjuvant chemotherapy in breast cancer. In European Radiology, 2017, vol. 27, no. 5, p. 1901-1911. (2016: 3.967 - IF, Q1 - JCR, 1.943 - SJR, Q1 - SJR). ISSN 0938-7994. https://doi.org/10.1007/s00330-016-4565-2 (**WOS + Scopus citations – 32; other citations - 2**)
8. (ADMA) CLUITMANS, M.** - BROOKS, D.H. - MACLEOD, R. - DOSSEL, O. - GUILLEM, M.S. - VAN DAM, P.M. - ŠVEHLÍKOVÁ, Jana - HE, B. - SAPP, J. - WANG, L. - BEAR, L.**. Validation and opportunities of electrocardiographic imaging: From technical achievements to clinical applications. In Frontiers in Physiology, 2018, vol. 9, art. no. 1305. (2017: 3.394 - IF, Q1 - JCR, 1.590 - SJR, Q1 - SJR). ISSN 1664-042X. https://doi.org/10.3389/fphys.2018.01305 (**WOS + Scopus citations – 31; other citations - 1**)
9. (ADCA) KRAKOVSKÁ, Anna** - JAKUBÍK, Jozef - CHVOSTEKOVÁ, Martina - COUFAL, D. - JAJCAY, N. - PALUŠ, M. Comparison of six methods for the detection of causality in a bivariate time series. In Physical Review E, 2018, vol. 97, art. no. 042207. (2017: 2.284 - IF, Q1 - JCR, 0.979 - SJR, Q1 – SJR). ISSN 2470-0045. https://doi.org/10.1103/PhysRevE.97.042207 (**WOS + Scopus citations – 28; other citations - 4**)
10. (ADCA) PALUŠ, M.** - KRAKOVSKÁ, Anna - JAKUBÍK, Jozef - CHVOSTEKOVÁ, Martina. Causality, dynamical systems and the arrow of time. In Chaos: An Interdisciplinary Journal of Nonlinear Science, 2018, vol. 28, no. 7, art. no. 075307. (2017: 2.415 - IF, Q1 - JCR, 0.716 - SJR, Q2 - SJR). ISSN 1054-1500. https://doi.org/10.1063/1.5019944 (**WOS + Scopus citations – 23; other citations - 5**)

2.2.5. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations in the assessment period (2015– 2020). The cited papers must bear the address of the institute

1. SZOMOLÁNYI Pavol 805 WOS + SCOPUS citations + 48 OTHER citations
2. TEPLAN Michal 783 WOS + SCOPUS citations + 152 OTHER citations
3. ROSIPAL Roman 551 WOS + SCOPUS citations + 40 OTHER citations

2.2.6. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations obtained until 2020. The cited papers must bear the address of the Institute

1. SZOMOLÁNYI Pavol 1327 WOS + SCOPUS citations + 50 OTHER citations
2. TEPLAN Michal 1082 WOS + SCOPUS citations + 168 OTHER citations
3. ROSIPAL Roman 1065 WOS + SCOPUS citations + 42 OTHER citations

2.2.7. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations obtained until 2021 of their papers published during the evaluation period (2016– 2021). The cited papers must bear the address of the Institute

1. VALKOVIČ Ladislav 262 WOS + SCOPUS citations + 13 OTHER citations
2. SZOMOLÁNYI Pavol 165 WOS + SCOPUS citations + 8 OTHER citations
3. JURÁŠ Vladimír 142 WOS + SCOPUS citations + 7 OTHER citations

- **Supplementary information 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 increased during the assessment period. The number of WOS and SCOPUS citations increased from 649 in 2015 (19,8 per researchers FTE) to 1093 in 2020 (34,6 per researchers FTE). The one-year average of WOS and SCOPUS citations increased from 443,6 in the previous assessment period to to 824,5 in this period.

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

- **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 for institute with less than 50 average FTE researchers per year, max. 20 for institutes with 50 – 100 average FTE researchers per year and so on

1. **Method for rapid and complete quantification of myocardial ATP flux using saturation transfer with dual-band quasi-adiabatic pulse**. Adenosine triphosphate (ATP) is an organic compound that provides energy to drive all processes in living cells, such as: Muscle contraction or the propagation of nerve impulses. Phosphorus saturation transfer experiments allow you to quantify ATP metabolism in a non-invasive way. Normally, only the forward flux of ATP synthesis through the creatine kinase reaction is studied in the heart by observing the decrease in phosphocreatine (PCr) after saturation of γ-ATP. Quantification of the opposite reaction, i.e. total ATP utilisation, is currently poorly understood as it requires simultaneous saturation of inorganic phosphate (Pi) and PCr signals. Therefore, a novel quasi-adiabatic radiofrequency pulse for double saturation was developed to enable the determination of total ATP utilisation. The pulses were evaluated in Bloch equation simulations and compared with a conventional hard-cosine saturation sequence. The technique was then applied in perfused rat hearts at 11.7 T. Related projects: APVV-15-0029, VEGA 2/0003/20. Foreign partner: Oxford Centre for Clinical Magnetic Resonance Research, John Radcliffe Hospital, Headington, Oxford, UK, based on a signed scientific collaboration agreement dated 14 October 2021.
2. **Measurement uncertainty training – MATHMET activity to improve quality, efficiency and dissemination of measurement uncertainty training.** Measurement uncertainty is a key quality parameter to express the reliability of measurements and an understanding of measurement uncertainty is often a precondition for advances in science, industry, health, environment, and society in general. However, there is a documented need for a better understanding of measurement uncertainty and its evaluation in many communities and recently this need was restated pointing to the importance of training on measurement uncertainty. Many metrology institutes, universities, national accreditation bodies, authorities in legal metrology, and others offer training on measurement uncertainty. They do so independently, and there is no community of teachers for exchanging expertise or to focus attention. There is no single contact point in Europe, which coordinates efforts, prioritizes needs, or provides an overview of suitable courses and material.Based on a broad consortium this project will improve the quality, efficiency, and dissemination of measurement uncertainty training. The activity will (1) develop new material for measurement uncertainty training and (2) establish an active community for those involved in measurement uncertainty training. In the EU, the European Metrology Network MATHMET is well-suited to host such an activity. Project website: https://www.euramet.org/european-metrology-networks/mathmet/?L=0.
3. **Multilateral cooperation in consortium for ECG Imaging.** Since 2017 we are actively participating in the informal international community Consortium for ECG

Imaging www.ecg-imaging.org, mainly in the group focused on signal processing (https://www.ecg-imaging.org/workgroups/signal-processing) and model building (https://www.ecg-imaging.org/workgroups/model-building). We prepared several common conference presentations in 2018-2021 (https://cinc.org/cinc-papers-on-line) and two papers in journals. Cooperation with the community also lead in 2020 to successful application for the joint Slovak-Turkish research project (between SAS and TUBITAK) "ClinECGI: Performance Evaluation of Noninvasive Electrocardiographic Imaging for the Localization of Premature Ventricular Contractions from Clinical Data". The project aims to apply and validate several methodologies/approaches to electrocardiographic imaging from experimental clinical data.

4. **Multilateral cooperation within the NATO Science for Peace and Security program on smart wearable system for monitoring of vital parameters.** Since 2021 our Institute is involved in the multilateral NATO project G5825 "Smart Patch for Life Support Systems – SP4LIFE". The project is coordinates by our Institute and partners are from Belgium, North Macedonia, Serbia and Slovakia.The project is focused on research and development of a wearing device (smart patch) able to monitor vital parameters of victims of mass accidents or members of rescue teams.

5. **Exploring cortical coding and understanding of endogenous chronic pain in patients.** In collaboration with the group of Dr Enrico Schulz (Department of Neurology, University Hospital LMU, Ludwig-Maximilians-Universität München, Munich, Germany and Department of Medical Psychology, Ludwig-Maximilians-Universität München, Munich, Germany) we investigated the problem of understanding chronic pain. The pathophysiology of migraine as a complex neurological disorder is not yet fully understood, but the clinical signs of the disease, such as cyclic seizure behaviour and vegetative symptoms, suggest a prominent role of the hypothalamus. Therefore, we focused on studying the course of brain activity in migraine patients during the migraine cycle (STANKEWITZ et al. NeuroImage: Clinical 2021). Using functional magnetic resonance imaging (fMRI) with pseudo-continuous arterial spin labelling (ASL), a longitudinal study was performed to determine the rhythmicity of cerebral perfusion and hypothalamic connectivity during the migraine cycle. We observed cyclical changes in brain perfusion in the limbic circuit (insula and nucleus accumbens), with perfusion being highest during the headache attack. In addition, we found an increase in hypothalamic connectivity to the limbic system in the interictal interval before the attack. These data are strong evidence for the predominant role of the hypothalamus in the development of migraine attacks. Studies and analyses of brain activity have been helpful in identifying cortical processes that are altered in patients with chronic pain (JAHN et al. Scientific Reports 2021). In our new approach, we focused on clarifying how internal functional networks develop in response to the fluctuating intensity of chronic pain. In a longitudinal study of 156 fMRI sessions, 20 patients with chronic low back pain and 20 patients with chronic migraine were asked to continuously assess the intensity of their endogenous pain. The observed diversity in individual cortical outcomes of chronic pain coding furthers the understanding of chronic pain as a complex and multi-layered condition. Our proposed assessment of persistent endogenous pain could be a powerful and promising tool for assessing the coding of a patient's endogenous pain (MAYR et al. Human Brain Mapping 2021). The main task of IMS SAS was the development of the software and the statistical analysis of the data using linear mixed-effects models.

6. **Modern investigation of cartilage damage using quantitative magnetic resonance.** Although magnetic resonance imaging is currently considered the most accurate method for investigating cartilage damage, morphological imaging is often insufficient to determine the degree of damage and does not detect the early stages of degeneration, which are manifested solely by changes in the internal structure of the cartilage. Quantitative MRI offers methods to analyse the state of collagen (T2 mapping) and proteoglycans (sodium MRI). In collaboration with the group of Prof. Dr. Siegfried Trattnig (MR Center, Highfield MR, Department of Radiology, Medical University of Vienna, Austria) we have found a new method for mapping the relaxation

constant T2 (based on the so-called steady-state free precision), which allows an acceleration of the measurement (shortening from about 4 minutes to 2 minutes compared to the conventional method), a higher resolution (factor 1.5) and an increase in the number of layers (which is most obvious for ultra-high fields, 32 slices can be displayed instead of 4 slices). This method has been used to detect differences in the collagen matrix in the cartilage of the knee and ankle, which is widely used in clinical practise when examining cartilage. Another modern method has been used to determine proteoglycans - sodium MR, which displays sodium ions instead of protons, which are directly proportional to the amount of proteoglycans. Since the reduction of proteoglycans in cartilage is the first sign of the onset of cartilage degeneration, this method has great potential to become part of screening measurements in clinical practise.

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

- **Measurement 2017** - 11th International Conference on Measurement, 29 - 31, May 2017, Smolenice Castle, Slovakia.
- **Measurement 2019** - 12th International Conference on Measurement, 27 - 29, May 2019, Smolenice Castle, Slovakia.
- **Measurement 2021** - 13th International Conference on Measurement, 17 - 19, May 2021, held in on-line form, Bratislava and Smolenice Castle, Slovakia.
- **LinStat 2020** - International Conference on Trends and Perspectives in Linear Statistical Inference, held in hybrid form in Będlewo, Poland, from August 30 to September 3, 2021.

2.3.3. List of edited proceedings from international scientific conferences

- **MEASUREMENT 2017**. Proceedings of the 11th International Conference on Measurement. Editors: J. Maňka, M. Tyšler, V. Witkovský, I. Frollo. Bratislava, Slovakia: Institute of Measurement Science, Slovak Academy of Sciences, 2017, ISBN 978-80-972629-0-7.
  https://ieeexplore.ieee.org/xpl/conhome/7973336/proceeding
- **MEASUREMENT 2019**. Proceedings of the 12th International Conference on Measurement. Editors: Ján Maňka, Jana Švehlíková, Viktor Witkovský, Ivan Frollo. Bratislava, Slovakia: Institute of Measurement Science, Slovak Academy of Sciences, 2019, ISBN 978-80-972629-2-1.
  https://ieeexplore.ieee.org/xpl/conhome/8777010/proceeding
- **MEASUREMENT 2021**. Proceedings of the 13th International Conference on Measurement. Editors: Andrej Dvurečenskij, Ján Maňka, Jana Švehlíková, Viktor Witkovský Bratislava, Slovakia: Institute of Measurement Science, SAS, 2021, p. 6-9. ISBN 978-80-972629-4-5.
  https://ieeexplore.ieee.org/xpl/conhome/9446761/proceeding

2.3.4. List of journals edited/published by the institute and information on their indexing in WOS, SCOPUS, other database or no database, incl. impact factor and other metrics of journals in each year of the assessment period

Measurement Science Review (on-line journal, www.sciendo.com/journal/MSR). Since 2001 (Volume 1) published by the Institute of Measurement Science SAS. Since 2008 (Volume 8) published in cooperation with De Gruyter (Poland Sp. z o.o., Sciendo). Journal ISSN 1335-8871. Publication time frame 6 times per year. Journal Subjects: Engineering, Electrical Engineering, Control Engineering, Metrology and Testing. Editor-in-Chief: Ivan Frollo, Institute of Measurement Science, Slovak Academy of Sciences, Slovakia. Executive Editors: Viktor Witkovský, Institute of Measurement Science, Slovak Academy of Sciences, Slovakia, Ida Prokopčáková, Institute of Experimental Psychology, Slovak Academy of Sciences, Slovakia.

Journal Metrics:

- Measurement Science Review, Vol. 16 (2016), IF 1.344 (Q3), SJR 0.472 (Q2).
- Measurement Science Review, Vol. 17 (2017), IF 1.345 (Q3), SJR 0.441 (Q2).

- Measurement Science Review, Vol. 18 (2018), IF 1.122 (Q4), SJR 0.325 (Q2).
- Measurement Science Review, Vol. 19 (2019), IF 0.900 (Q4), SJR 0.326 (Q3).
- Measurement Science Review, Vol. 20 (2020), IF 1.319 (Q4), SJR 0.301 (Q3).
- Measurement Science Review, Vol. 21 (2021), IF 1.980 (Q3), SJR 0.376 (Q3).

Measurement Science Review is covered by the following services:

- Astrophysics Data System (ADS)
- Baidu Scholar
- Cabell's Whitelist
- Case
- CNKI Scholar (China National Knowledge Infrastructure)
- CNPIEC - cnpLINKer
- Dimensions
- DOAJ (Directory of Open Access Journals)
- EBSCO (relevant databases)
- EBSCO Discovery Service
- Embase
- Engineering Village
- Genamics JournalSeek
- GoOA
- Google Scholar
- Inspec
- Japan Science and Technology Agency (JST)
- J-Gate
- Journal Citation Reports/Science Edition
- JournalGuide
- JournalTOCs
- KESLI-NDSL (Korean National Discovery for Science Leaders)
- Meta
- Microsoft Academic
- MyScienceWork
- Naver Academic
- Naviga (Softweco)
- Primo Central (ExLibris)
- ProQuest (relevant databases)
- Publons
- QOAM (Quality Open Access Market)
- ReadCube
- Reaxys
- **SCImago (SJR)**
- **SCOPUS**
- Semantic Scholar
- Sherpa/RoMEO
- Summon (ProQuest)
- TDNet
- TEMA Technik und Management
- Ulrich's Periodicals Directory/ulrichsweb
- WanFang Data
- **Web of Science - Current Contents/Engineering, Computing, and Technology**
- Web of Science - Science Citation Index Expanded

- **National position of the institute**

2.3.5. List of selected activities of national importance

1. **Automatic monitoring system for reactor inclination in the Slovak nuclear power plants.** The measuring systems developed at IMS SAS are in continuous operation and are calibrated twice a year on site by our highly qualified personnel,

which contributes to increasing the operational safety of the Slovak nuclear power plants Jaslovské Bohunice and Mochovce.

2. **Non-destructive methods for inspection and evaluation of rare cultural objects.** Advanced non-destructive measurement methods and equipment developed at IMS SAS were used for a thorough inspection of the panel paintings of the Gothic altar of the Basilica of the Holy Cross in Kežmarok and the altars of the churches in Levoča and Spišská Sobota in the Spiš region in north-eastern Slovakia, which are the work of Master Paul of Levoča (1480-1546), including twenty Gothic altarpieces on the two side altars of the Church of St. George in Spišská Sobota and eight Gothic altarpieces on the side altar of the Church of St. James in Levoča. The results of the non-destructive testing are important for art historians and restorers to assess the current condition of the rare artefacts of our cultural heritage, to evaluate the construction and authenticity of the works, and finally to determine the appropriate procedures for their subsequent restoration.

3. **Forensic applications with X-ray microtomography.** The Department of Optoelectronic Measurement Methods of IMS SAS served as an external expert panel for the National Criminal Agency of the Slovak Republic and provided expert opinions in several criminal cases. In 2020-2021, the dental remains of victims of a violent crime were examined and characterised using high-resolution 3D imaging X-ray microtomography methods. Based on the results of our analysis, the perpetrator of this crime was convicted.

4. **Improvement of diagnostics and treatment of cardiac patients**. During the evaluated period there was a close cooperation with the National Institute for Cardiovascular Diseases (NICD) in Bratislava on improving the cardiologic diagnostic and therapeutic methods using multichannel ECG measurement and modelling of the heart activation. These activities were supported by two applied research projects of the APVV grant agency. The first one was oriented to the development of a method for noninvasive pre-operational localization of the site of premature ventricular contractions. The apriori knowledge of the location can substantially shorten the time of the ablation procedure and decrease the patient and medical staff exposure to the x-rays. The second project aims at finding methods for optimal placing of the pacing electrode in the left ventricle and optimal setting of the pacing timing during the cardiac resynchronization therapy which is a life saving treatment for patients with failing heart.

5. **Scientific conferences in the field of measurement science and mathematical statistics.** The organisation of conferences and workshops is one of the most important activities of the Institute of Measurement Science of the Slovak Academy of Sciences. Among the most important of these conferences in recent years are the international conferences MEASUREMENT and PROBASTAT.

6. **Cooperation with universities. IMS SAS cooperates (in addition to PhD study) with these universities:**

   - Faculty of Electrical Engineering and Informatics, Slovak University of Technology in Bratislava – supervising of bachelor and graduate theses.
   - Faculty of Electrical Engineering and Information Technology, UNIZA Žilina – supervising of bachelor and graduate theses.
   - Faculty of Mathematics, Physics and Informatics and Faculty of Medicine, Comenius University in Bratislava - Memorandum of Cooperation in order to support the implementation of the Data Science study program. The aim is to ensure high quality teaching in this area, to link theory and practice and to ensure excellent readiness of students for the profession.

7. **Cooperation with the Slovak Legal Metrology and the Slovak Institute of Metrology.**

   - Framework agreement with the Slovak Legal Metrology on cooperation. The aim is to create a framework for active cooperation, application of knowledge of

science and research in solving current and conceptual tasks, training of employees, ensuring the connection of theory with practice, as well as cooperation in the implementation of professional activities.
- Cooperation with the Slovak Institute of Metrology in joint research projects – APVV and others.

2.3.6. List of journals (published only in the Slovak language) edited/published by the institute and information on their indexing in WOS, SCOPUS, other database or no database, incl. impact factor and other metrics of journals in each year of the assessment period

None

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

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

- ŠVEHLÍKOVÁ, Jana - TYŠLER, Milan. The noninvasive localization of premature ventricular activity using different equivalent point sources. In Frontiers in Computational Electrocardiology 2016: Electrocardiographic Imaging and Image Integration. Maastricht, The Netherlands, September 29-30, 2016.
- WITKOVSKÝ, Viktor. Selected methods and applications of statistical inference based on numerical inversion of a characteristic function. In ROBUST 2016: 19th Summer School JČ(S)MF. Rejhotice - Loučná nad Desnou, Czech Republic, September 11-16, 2016.
- JURÁŠ, Vladimír. High-field MRI, PET-MRI and new orizon. In EMRI Erasmus Course Musculoskeletal MRI-Joints (finger to toe). Vienna, February 12–16, 2018.
- SZOMOLÁNYI, Pavol. Applied use of imaging in cartilage repair. In ICRS 2018: 14th World Congress. Macau, China, April 4-8, 2018.
- SZOMOLÁNYI, Pavol. From nice pictures to solid data. In First INTERREG - 6th TERMIS Winterschool 2018: Mechanobiology in Musculoskeletal Tissue Regeneration - In Vitro/In Vivo Preclinical Models and Imaging. Radstadt, Austria, January 14-17, 2018.
- WITKOVSKÝ, Viktor. Computational tools and methods for statistical inference based on using the characteristic functions. In 12th International Conference on Computational and Financial Econometrics (CFE 2018) and 11th International Conference of the ERCIM WG on Computational and Methodological Statistics (CMStatistics 2018). University of Pisa, Italy, December 14-16, 2018.
- WITKOVSKÝ, Viktor. Development of tools for numerical inversion of the characteristic functions and the exact distributions of multivariate test statistics. In 12th Workshop on Statistics, Mathematics and Computation (WSMC12): In Honour of Professor Carlos Braumann. Covilhã, Portugal, November 9-10, 2018.
- CHVOSTEKOVÁ, Martina. Testing linear Granger causality - Invited lecture, Workshop on characterization of interactions in nonlinear systems, Institute of Computer Science Czech Academy of Sciences, Prague, Czech Republic, November 6-7, 2019.
- KRAKOVSKÁ, Anna. Causal analysis in reconstructed state spaces – Invited lecture, Workshop on characterization of interactions in nonlinear systems, Institute of Computer Science Czech Academy of Sciences, Prague, Czech Republic, November, 6-7, 2019.
- JURÁŠ, Vladimír. GLCM with T2 Mapping – What is it and how to do it. ICRS Focus Meeting, High Field MR Center, Medical University Vienna, Vienna, Austria, November 21, 2019.
- JURÁŠ, Vladimír. Artificial intelligence in cartilage imaging methods. ICRS Focus Meeting, High Field MR Center, Medical University Vienna, Vienna, Austria, November 21, 2019.

- SZOMOLÁNYI, Pavol. 21.11.2019 T2 Mapping from sequence to postprocessing to clinical trials. ICRS Focus Meeting, High Field MR Center, Medical University Vienna, Vienna, Austria, November 21, 2019.
- SZOMOLÁNYI, Pavol. From nice pictures to solid data. 2nd INTERREG - 7th TERMIS Winterschool 2019 “Musculoskeletal Tissue Regeneration: From Mechanobiology to in Vitro/in Vivo Models and Advanced Imaging", Radstadt Austria, January 16, 2019.

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

2016

Programme committee:

- WITKOVSKÝ Viktor (Measurement 2017),
- TYŠLER Milan 2 x (Measurement 2017, YBERC),
- MAŇKA Ján (Measurement 2017),
- FROLLO Ivan (Measurement 2017),
- BAJLA Ivan (Measurement 2017),
- COCHEROVÁ Elena (Measurement 2017)

2017

Organising committee:

- ANDRIS Peter (Measurement 2017),
- DVUREČENSKIJ Andrej (Measurement 2017),
- GOGOLA Daniel (Measurement 2017),
- HAIN Miroslav (Measurement 2017),
- CHVOSTEKOVÁ Martina (Measurement 2017),
- JURÁŠ Vladimír (Measurement 2017),
- ŠKRÁTEK Martin (Measurement 2017),
- TEPLAN Michal (Measurement 2017)

Programme committee:

- COCHEROVÁ Elena 2 x (Measurement 2017, Trends in biomedical engineering 2017),
- BAJLA Ivan (Measurement 2017),
- FROLLO Ivan (Measurement 2017),
- MAŇKA Ján (Measurement 2017),
- TYŠLER Milan 2x (44th International Congress on Electrocardiology, Trends in biomedical engineering 2017)

Organising and programme committee:

- ŠVEHLÍKOVÁ Jana (Measurement 2017),
- TYŠLER Milan (Measurement 2017),
- WITKOVSKÝ Viktor (Measurement 2017)

2018

Programme committee:

- BAJLA Ivan (International Conference on Computer Vision and Graphics),
- ŠVEHLÍKOVÁ Jana (Measurement 2019),
- TYŠLER Milan 2 x (23rd International Conference on Applied Electronics, Electrical Signals of the Heart: from Myocardial Potentials to ECG),
- WITKOVSKÝ Viktor (MSCSMQ_2018 - Mathematics, Statistics and Computation to Support Measurement Quality)

2019

Organising committee:

- DVUREČENSKIJ Andrej 2 x (Measurement 2019, mODa 12),
- GOGOLA Daniel (Measurement 2019),

- CHVOSTEKOVÁ Martina 2 x (Measurement 2019, mODa12),
- JAKUBÍK Jozef (Measurement 2019),
- KRAFČÍK Andrej (Measurement 2019),
- ROŠŤÁKOVÁ Zuzana (Measurement 2019),
- ŠKRÁTEK Martin (Measurement 2019),
- TEPLAN Michal (Measurement 2019)

Programme committee:

- COCHEROVÁ Elena (Measurement 2019),
- BAJLA Ivan (Measurement 2019),
- FROLLO Ivan (Measurement 2019),
- ŠVEHLÍKOVÁ Jana 2x (Measurement 2019, Computing in Cardiology 2019),
- TYŠLER Milan (Measurement 2019)

Organising and programme committee:

- MAŇKA Ján, (Measurement 2019),
- WITKOVSKÝ Viktor, (Measurement 2019)

2020

Organising committee:

- WITKOVSKÝ Viktor (LinStat2020)

Programme committee:

- PŘIBIL Jiří (7th International Electronic Conference on Sensors and Application),
- TYŠLER Milan (IEEE Engineering in Medicine & Biology Society Int. Student Conference),
- WITKOVSKÝ Viktor (3rd International Colloquium on Intelligent Grid Metrology (SMAGRIMET))

2021

Organising committee:

- DVUREČENSKIJ Andrej (Measurement 2021),
- GOGOLA Daniel (Measurement 2021),
- CHVOSTEKOVÁ Martina (Measurement 2021),
- JAKUBÍK Jozef (Measurement 2021)

Programme committee:

- COCHEROVÁ Elena (Measurement 2021),
- PŘIBILOVÁ Anna (Measurement 2021),
- FROLLO Ivan (Measurement 2021),
- ŠVEHLÍKOVÁ Jana 2x (Measurement 2021, Computing in Cardiology 2021),
- TYŠLER Milan (Measurement 2021)

Organising and programme committee:

- MAŇKA Ján (Measurement 2021),
- WITKOVSKÝ Viktor (Measurement 2021)

2.3.9. List of researchers who received an international scientific award

None

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

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

None

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

Programme committee:

- COCHEROVÁ Elena (Trends in biomedical engineering 2019),
- TYŠLER Milan (Trends in biomedical engineering 2019)

2.3.12. List of researchers who received a national scientific award

2017

- VALKOVIČ Ladislav (1st place: Competition of Young Scientists of the Slovak Academy of Sciences up to 35 years). Evaluator: Slovak Academy of Sciences. Description: New techniques for determining the kinetics of energy metabolism of skeletal muscles and liver using phosphorus magnetic resonance. First Scientific Section of the SAS.
- ROSIPAL Roman (Award of the Presidium of the SAS for a scientific publication with an exceptionally high number of citations in the years 2013 - 2015, which at the same time belongs to the so-called Highly Cited Papers according to the parameters of the database Essential Science Indicators Web of Science). Evaluator: Presidium of the SAS. Description: The award was given to the author of the paper Roman ROSIPAL and L. J. TREJO: Kernel partial least squares regression in reproducing kernel Hilbert space. Journal of Machine Learning Research, Vol. 2, pp. 97-123, 2002. Bratislava. November 9, 2017.
- TEPLAN Michal (Award of the Presidium of the SAS for a scientific publication with an exceptionally high number of citations in the years 2013 - 2015, which at the same time belongs to the so-called Highly Cited Papers according to the parameters of the database Essential Science Indicators Web of Science). Evaluator: Presidium of the SAS. Description: The award was given to the author of the paper M. TEPLAN: Fundamentals of EEG Measurement, Measurement Science Review, vol. 2, no. 2, pp. 1-11, 2002. Bratislava. November 9, 2017.

2018

- BILLIK Peter (Prize of the Slovak Academy of Sciences). Evaluator: Presidium of the SAS. Description: Award for a scientific publication with a high number of citations.
- CAPEK Ignác (Prize for Scientific Literature for the year 2017 in the category of Natural and Technical Sciences). Evaluator: Literary Fund. Description: Prize of the Literary Fund, Section for Scientific and Professional Literature and Computer Programmes: Prize for scientific literature for the year 2017 in the category of natural and technical sciences for the scientific monograph "Noble Metal Nanoparticles, Preparation, Composite Nanostructures, Biodecoration and Collective Properties", Bratislava, September 27, 2018.
- TEPLAN Michal (Award for three-year academic response). Evaluator: Literary Fund. Description: Literary Fund Award, Section for Scientific and Professional Literature and Computer Programmes: Award for Three-Year Scientific Response in the category of Technical Sciences and Earth Sciences as an expression of public recognition for a strong scientific response over the past three years. Bratislava, September 27, 2018.

2019

- CHVOSTEKOVÁ Martina (2nd place: Competition of Young Scientists of the Slovak Academy of Sciences up to 35 years). Evaluator: Slovak Academy of Sciences. Description: 2nd place for the paper "Modified Granger Causality", First Scientific Section of the SAS.
- ROŠŤÁKOVÁ Zuzana (Štefan Schwarz Fund). Evaluator: Slovak Academy of Sciences. Description: Acquisition of the Štefan Schwarz Fund based on the results of the competition for the best doctoral positions.

- ROŠŤÁKOVÁ Zuzana (Honourable mention: Competition of Young Scientists of the Slovak Academy of Sciences up to 35 years). Evaluator: Slovak Academy of Sciences. Description: Honorable mention for the work "Functional data analysis of sleep structure", First Scientific Section of the SAS.
- FROLLO Ivan (Science and Technology Award 2019 for lifetime achievement in science and technology). Evaluator: The Ministry of Education, Science, Research and Sport of the Slovak Republic. Description: Science and Technology Award 2019 in the category of Lifetime Achievement in Science and Technology for exceptional lifetime contribution to the development of the scientific field of Measurement Technology

2020

- FROLLO Ivan (Commemorative medal on the occasion of the 20th anniversary of Biomedical Engineering). Evaluator: Rector of the University of Žilina. Description: Commemorative medal on the occasion of the 20th anniversary of Biomedical Engineering, awarded by the Rector of the University of Žilina, February 2020.

2021

- TYŠLER Milan (Medal of the Slovak Academy of Sciences for the Support of Science). Evaluator: Scientific Advisory Board of the Slovak Academy of Sciences. Description: An award given on the occasion of a significant anniversary expressing gratitude for the contribution to scientific and scientific-organisational work.
- VALKOVIČ Ladislav (Honorable mention: Competition of Young Scientists of the Slovak Academy of Sciences up to 35 years). Evaluator: Slovak Academy of Sciences.
- VALKOVIČ Ladislav (ESET Science Award 2021 in category Exceptional Young Scientist in Slovakia under the age of 35) Evaluator: ESET Foundation. Description: The International Commission, chaired by Nobel Laureate in Physics Kip Thorne, has selected the winners of the ESET Science Award. Ladislav Valkovič became the winner of the category Exceptional Young Scientist in Slovakia under the age of 35.

2.4. Research grants and other funding resources

(List 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". Add information on the projects which are interdisciplinary, and also on the joint projects with several participating SAS institutes)

- **International projects**

2.4.1. List of major projects of Framework Programmes of the EU (which pilar), NATO, COST, etc.

➢

Type of project:	NATO Science for Peace and Security (SPS) Programme
Title:	**Smart patch for life support systems**
Project ID number:	NATO SPS G5825
Duration:	10.3.2021 - 10.3.2024
Responsible person:	Milan TYŠLER (coordinator "C")
Coordinating organisation:	IMS SAS
Partners:	4 - Universitè libre de Bruxelles (ULB) Belgium, Faculty of Computer Sciences and Engineering Sts Cyril and Methodius (FCSE) North Macedonia, Institute for Chemistry Technology and Metallurgy Centre for Microelectronic Technologies (ICTM) Serbia, Faculty of Medicine in Bratislava Comenius University in Bratislava (FM)
Funding:	Total: 490000 €. IMS SAS 2021: 41400 €
Interdisciplinary research:	Yes (biomedical research, material research, informatics, health sciences)
Short annotation:	Development of real-time wearable systems that collect and intelligently analyse information on respiration, heartbeat, SpO2, blood pressure and body temperature. These could help medical personnel take the most appropriate countermeasures in high-stress situations in military and civilian scenarios resulting from terrorist attacks, IEDs or rescue missions. The system will trigger an alarm when a person's health status changes to prevent critical changes from being overlooked. We propose the design and development of a prototype patch-like device and methodology that will allow continuous assessment of vital signs of individuals or victims.

➢

Type of project:	COST Action
Title:	**Colour and space in cultural heritage (COSCH)**
Project ID number:	COST TD1201
Duration:	7.11.2012 / 6.11.2016
Responsible person:	Miroslav HAIN (IMS SAS coordinator / WP leader "W")
Coordinating organisation:	Prof. Frank Boochs, University of Applied Sciences Mainz Lucy Hillebrand Str. 2 55128 Mainz, Germany
Partners:	25 - Belgium: 1, Bosnia and Herzegovina: 1, Cyprus: 0, Czech Republic: 1, Germany: 1, Denmark: 1, Spain: 1, Finland: 0, France: 1, United Kingdom: 1, Greece: 1, Croatia : 1, Hungary: 1, Switzerland: 1, Ireland: 1, Israel: 1, Italy: 1, Malta: 1, Netherlands: 1, Norway: 1, Poland: 1, Portugal: 1, Romania: 1, Serbia: 1 , Slovakia: 1, Slovenia: 1, Sweden: 1
Funding:	IMS SAS 2016: 1890 €
Interdisciplinary research:	Yes (material science, electrical engineering, physics)
Short annotation:	IMS SAS focuses mainly on the field of X-ray computed microtomography, dedicated to non-destructive high-

resolution 3D measurement, visualisation and microstructural analysis of cultural heritage artefacts, as well as the development of optical multi-spectral measurement and imaging techniques, including infrared reflectography, infrared thermography and ultraviolet fluorescence.

➢

Type of project:	COST Action
Title:	**Origins and evolution of life on earth and in the universe**
Project ID number:	COST TD1201
Duration:	15.5.2014 / 31.12.2016
Responsible person:	Oliver ŠTRBÁK (IMS SAS coordinator / WP leader "W")
Coordinating organisation:	Dr. Muriel GARGAUD, Laboratoire dAstrophysique de Bordeaux, 2 rue de lobservatoire 33271 FLOIRAC, FRANCE
Partners:	29 - Austria: 1, Belgium: 1, Czech Republic: 1, Germany: 1, Denmark: 1, Spain: 1, Estonia: 1, Finland: 1, France: 1, United Kingdom: 1, Greece: 1, Croatia: 1 , Hungary: 1, Switzerland: 1, Ireland: 1, Iceland: 1, Israel: 1, Italy: 1, Lithuania: 1, Latvia: 1, Netherlands: 1, Norway: 1, Poland: 1, Portugal: 1, Romania: 1, Serbia: 1, Slovakia: 1, Slovenia: 1, Sweden: 1
Funding:	IMS SAS 2016: 3500 €
Interdisciplinary research:	Yes (biomedicine, astrophysics, physics)
Short annotation:	This action addresses three fundamental questions that fascinate and intrigue scientists and the general public alike, questions that are central to our understanding and appreciation of our place in the universe. Where, when and how did life arise and evolve on Earth. What are the conditions under which life can exist. Does life exist elsewhere in the universe and if so, how can it be detected and identified.

➢

Type of project:	COST Action
Title:	**European network for innovative uses of EMFs in biomedical applications**
Project ID number:	COST BM1309
Duration:	16.4.2014 / 15.4.2018
Responsible person:	Michal TEPLAN (IMS SAS coordinator / WP leader "W")
Coordinating organisation:	Dr Antonio Sarolic, FESB, University of Split, Rudjera Boskovica 32 21000, Split Croatia
Partners:	29 - Austria: 1, Belgium: 1, Bulgaria: 1, Cyprus: 0, Czech Republic: 1, Germany: 1, Spain: 1, Estonia: 1, Finland: 1, France: 1, United Kingdom: 1, Greece: 1 , Croatia: 1, Hungary: 1, Switzerland: 1, Ireland: 1, Israel: 1, Italy: 1, Macedonia: 1, Malta: 1, Netherlands: 1, Norway: 1, Poland: 1, Portugal: 1, Romania : 1, Serbia: 1, Slovakia: 2, Slovenia: 1, Sweden: 1
Funding:	IMS SAS 2016: 3500 €, 2017: 3150 €, 2018: 4329€
Interdisciplinary research:	Yes (biomedicine, astrophysics, physics)
Short annotation:	The action provides a cooperative framework to support research on the beneficial biological effects of non-ionising electromagnetic fields (EMF) and their use in biomedical applications. Research on the biological effects of EMF has traditionally focused on health risks. Stimulated by promising recent studies on beneficial biomedical EMF interactions and applications, this action will focus on the positive effects and target breakthrough results, new discoveries and innovative biomedical technologies.

➢

Type of project:	COST Action
Title:	**MULTI-modal Imaging of FOREnsic SciEnce Evidence (MULTI-FORESEE) - tools for Forensic Science**
Project ID number:	COST CA16101
Duration:	1.8.2018 / 1.3.2021
Responsible person:	Miroslav HAIN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Prof. Simona Francese, Sheffield Hallam University Howard Street, S1 1WB Sheffield, UK
Partners:	28 - Albania: 1, Austria: 1, Belgium: 1, Bosnia and Herzegovina: 1, Czech Republic: 1, Germany: 1, Denmark: 1, Estonia: 1, France: 1, United Kingdom: 1, Greece: 1, Croatia : 1, Switzerland: 1, Israel: 1, Italy: 1, Lithuania: 1, Latvia: 1, Macedonia: 1, Malta: 1, Montenegro: 1, Netherlands: 1, Norway: 1, Poland: 1, Portugal: 1, Romania: 1, Serbia: 1, Slovakia: 1, Turkey: 1
Funding:	IMS SAS 2018: 3147 €, 2019: 5471 €, 2020: 2870 €, 2021: 718 €
Interdisciplinary research:	Yes (conservation, cultural heritage, electrical engineering, material science)
Short annotation:	The main objective is to promote innovative, multi-informative, operationally deployable and commercially exploitable imaging solutions/technology to analyse forensic evidence. Forensic evidence includes, but not limited to, fingermarks, hair, paint, biofluids, digital evidence, fibers, documents and living individuals.

➢

Type of project:	COST Action
Title:	**Understanding and modeling compound climate and weather events**
Project ID number:	COST CA17109
Duration:	14.9.2018 / 13.9.2022
Responsible person:	Martina CHVOSTEKOVÁ (IMS SAS coordinator WP leader)
Coordinating organisation:	Dr. Jakob Zscheischler, University of Bern, Švajčiarsko
Partners:	33 - Austria: 1, Belgium: 1, Bulgaria: 1, Bosnia and Herzegovina: 1, Czech Republic: 1, Germany: 1, Denmark: 1, Spain: 1, Estonia: 1, Finland: 1, France: 1, United Kingdom : 1, Greece: 1, Hungary: 1, Switzerland: 1, Ireland: 1, Iceland: 1, Israel: 1, Italy: 1, Lithuania: 1, Macedonia: 1, Malta: 1, Montenegro: 1, Netherlands: 1, Norway: 1, Poland: 1, Portugal: 1, Romania: 1, Serbia: 1, Slovakia: 1, Slovenia: 1, Sweden: 1, Turkey: 1
Funding:	IMS SAS 2018: 512 €, 2019: 5532 €, 2020: 3440 €, 2021: 2870 €
Interdisciplinary research:	Yes (climatology, physics, statistics)
Short annotation:	Hazards such as floods, wildfires, heatwaves, and droughts are usually the result of a combination of interacting physical processes operating at different spatial and temporal scales. The combination of physical processes that results in an impact is called a compound event. The Action brings together climate scientists, impact modellers, statisticians and stakeholders to better understand, describe and project compound events and to be a major breakthrough in future risk assessments.

➢

Type of project:	COST Action
Title:	**European network for advancing electromagnetic hyperthermic medical technologies**
Project ID number:	COST CA17115
Duration:	4.9.2018 / 3.9.2022
Responsible person:	Michal TEPLAN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Dr Lourdes Farrugia, University of Malta, Malta
Partners:	29 - Austria: 1, Belgium: 1, Bulgaria: 1, Cyprus: 1, Czech Republic: 1, Germany: 1, Denmark: 1, Spain: 1, Finland: 1, France: 1, United Kingdom: 1, Greece: 1 , Croatia: 1, Hungary: 1, Switzerland: 1, Ireland: 1, Israel: 1, Italy: 1, Macedonia: 1, Malta: 1, Netherlands: 1, Norway: 1, Poland: 1, Portugal: 1, Romania : 1, Serbia: 1, Slovakia: 1, Slovenia: 1, Turkey: 1
Funding:	IMS SAS 2018: 4348 €, 2019: 5884 €, 2020: 4100 €, 2021: 2870 €
Interdisciplinary research:	Yes (electrical engineering, biomedicine, physics)
Short annotation:	Electromagnetic (EM) technologies hold great potential for treating diseases, especially cancers, that do not respond to standard therapies. These technologies alter tissue temperature: hyperthermia heats diseased tissue to make it receptive to treatments, and ablation heats tissue until it is destroyed. The Action brings together key players in the field of dielectric spectroscopy, translational research and healthcare professionals in a collaborative network to advance the design, development and commercialisation of EM hyperthermic technologies to reach patients faster and improve treatment outcomes.

➢

Type of project:	COST Action
Title:	**Correlated multimodal imaging in life sciences**
Project ID number:	COST CA17121
Duration:	1.1.2019 / 11.10.2022
Responsible person:	Miroslav HAIN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	BioImaging Austria
Partners:	17 - Austria: 1, Belgium: 1, Czech Republic: 2, Germany: 1, Denmark: 1, Estonia: 1, Finland: 1, France: 1, United Kingdom: 1, Greece: 0, Croatia: 0, Hungary: 0 , Switzerland: 1, Ireland: 0, Israel: 1, Italy: 1, Malta: 0, Netherlands: 0, Norway: 0, Poland: 2, Portugal: 1, Romania: 0, Serbia: 0, Slovenia: 0, Turkey : 1
Funding:	IMS SAS 2019: 5520 €, 2020: 3440 €, 2021: 2870 €
Interdisciplinary research:	Yes (biology, chemistry, physics)
Short annotation:	The network aims to drive much-needed collaboration in the field of correlated multimodal imaging (CMI), promote and disseminate its benefits through flagship pipelines, and pave the way for its technological advancement and application as a versatile tool in biological and preclinical research. CMI combines two or more imaging modalities to gather information about the same specimen. The result is a composite view of the sample with multidimensional information about its macro-, meso- and microscopic structure, dynamics, function and chemical composition.

➢

Type of project:	COST Action
Title:	**Wearable robots for augmentation, assistance or**

	substitution of human motor functions
Project ID number:	COST CA16116
Duration:	15.3.2017 / 14.3.2021
Responsible person:	Anna PŘIBILOVÁ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Dr Jan VENEMAN, Hocoma AG, Industriestrasse 4, Switzerland, Volketswil
Partners:	36 - Austria: 1, Belgium: 1, Bulgaria: 1, Bosnia and Herzegovina: 1, Cyprus: 1, Czech Republic: 1, Germany: 1, Denmark: 1, Spain: 1, Estonia: 1, Finland: 1, France: 1, Great Britain: 1, Greece: 1, Croatia: 1, Hungary: 1, Switzerland: 1, Ireland: 1, Iceland: 1, Israel: 1, Italy: 1, Lithuania: 1, Latvia: 1, Northern Macedonia: 1, Malta: 1, Montenegro: 1, Netherlands: 1, Norway: 1, Poland: 1, Portugal: 1, Romania: 1, Serbia: 1, Slovakia: 1, Slovenia: 1, Sweden: 1, Turkey: 1
Funding:	IMS SAS 2020: 4587 €, 2021: 2153 €
Interdisciplinary research:	Yes (robotics, biomedicine, electrical engineering)
Short annotation:	Wearable Robots (WRs) is an emerging field of personal devices that are integrated with human functions and consist of typical robotic components such as actuators, sensors and control algorithms. This Action focuses on the European integration of the different underlying disciplines in science and technology, as well as stakeholder engagement to improve the WR technology and its societal impact.

➢

Type of project:	COST Action
Title:	**Sudden cardiac arrest prediction and resuscitation network: Improving the quality of care**
Project ID number:	COST CA19137
Duration:	26.10.2020 / 25.10.2024
Responsible person:	Jana ŠVEHLÍKOVÁ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Dr. Hanno L. Tan, Amsterdam Medical Center, The Netherlands
Partners:	16 - Belgium: 1, Germany: 1, Denmark: 1, Spain: 1, France: 1, Greece: 1, Ireland: 1, Italy: 1, Luxembourg: 1, Malta: 1, Netherlands: 1, Norway: 1, Romania: 1, Slovakia: 1, Sweden: 1, Turkey: 1
Funding:	IMS SAS 2020: 0 €, 2021: 4513 €
Interdisciplinary research:	Yes (biomedical engineering, medicine, biology)
Short annotation:	Sudden cardiac arrest (SCA) occurs unexpectedly and is fatal within minutes if untreated. Addressing this problem requires (1) identifying those at risk and developing prevention strategies, (2) providing timely and effective treatment. The main objectives of the action are to promote the development of standards for the collection of clinical data and biological samples and the harmonisation of data analysis. This will support the development of risk prediction models based on inherited, acquired and environmental risks.

- **National projects, incl. international projects with only national funding**

2.4.2. List of ERA-NET projects funded from SAS budget

None

The ERA -NET CHIST ERA IV project **ReHaB - Towards an ecologically valid symbiosis of BCI and head-mounted VR displays: Focus on collaborative post-stroke neurorehabilitation** was approved in 2021. Responsible researcher: Roman ROSIPAL. Coordinating organisation: IMS SAS. Project partners: - D- ITET ETH Zurich, Switzerland, - Electronics and Data Institute, Cyber-physical systems, Latvia, - Ben-Gurion University, Israel, - Sensomedical Labs LTD., Israel, - Technical University of Lodz, Poland. - TUKE, Košice, Slovakia. Solution period: 01.01.2022-31.12.2024. Funding required for IMS SAS: 120000 €.

2.4.3. List of projects of the Slovak Research and Development Agency, APVV

Total sum (EUR) obtained by the organisation from all APVV grants in particular year

Year	Total sum from APVV grants
2016 (6 running projects)	209465 €
2017 (7 running projects)	184156 €
2018 (6 running projects)	177959 €
2019 (6 running projects)	113484 €
2020 (6 running projects)	128151 €
2021 (5 running projects)	168948 €
2016 – 2021 (all 11 projects)	**982163 €**

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Research of comparative imaging methods based on magnetic resonance for diagnostics of neurological and musculoskeletal diseases**
Project ID number:	APVV-15-0029
Duration:	1.7.2016 / 30.6.2019
Responsible person:	Ivan FROLLO (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	1 - Slovak Technical University in Bratislava
Funding:	Total 236707 €. IMS SAS: 2016: 37365 €, 2017: 63004 €, 2018: 63911 €, 2019: 33610 €
Interdisciplinary research:	Yes (biomedical research, health sciences)
Short annotation:	Development of comparative MRI imaging methods using the full range of MRI scanners (0.1, 0.2, 4.7 to 7 Tesla) with particular emphasis on theoretical and experimental investigation of scanning approaches, measurement and mapping of specific physical quantities of organic and synthetic materials, in vivo and in vitro imaging of ferritin at different MR scanners, development of sequences, data processing and investigation of the influence of ferritin on the MR image.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Physical non-destructive methods for complex testing and analysis of cultural heritage artefacts**
Project ID number:	APVV-14-0719
Duration:	1.7.2015 / 30.6.2019
Responsible person:	Miroslav HAIN (coordinator “C”)
Coordinating organisation:	IMS SAS

Partners:	Academy of Fine Arts and Design in Bratislava
Funding:	Total 178000 €. IMS SAS: 2016: 36950 €, 2017: 29044 €, 2018: 27649 €, 2019: 17450 €
Interdisciplinary research:	Yes (conservation, cultural heritage)
Short annotation:	Development and application of advanced non-destructive measurement methods and equipment for the analysis and examination of objects of material cultural heritage. Methods of investigation include X-ray microtomography, X-ray microscopy, scanning electron microscopy, energy dispersive X-ray spectrometry, ultraviolet fluorescence, infrared reflectography, FTIR spectroscopy, UV, VIS, NIR spectroscopy and active infrared thermography. We have achieved a synergistic effect when information about the artefact obtained with different physical measurement methods and subsequently processed and evaluated together provides qualitatively new, comprehensive information about the historical artefact under investigation. Within the project, the tests of the methods were carried out in cooperation with the project partners on the panel paintings of the Gothic altar of the Basilica of the Holy Cross in Kežmarok.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Brain-computer interface with robot- assisted training for rehabilitation**
Project ID number:	APVV-0668-12
Duration:	1.10.2013 / 30.9.2017
Responsible person:	Roman ROSIPAL (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	2 – Faculty of Mathematics, Physics and Informatics and Faculty of Medicine, Comenius University in Bratislava
Funding:	Total: 211492 €. IMS SAS: 2016: 20160 €, 2017: 16110 €
Interdisciplinary research:	Yes (biomedical research, health sciences)
Short annotation:	Design and development of an intelligent system that allows the user to go through the process of self-training damaged motorways. We combine brain-computer interface (BCI) technology with the robotic arm system to create a compact system that can be used as a robot-assisted neurorehabilitation tool. BCI directly uses the brain's electrical activity signal to allow the user to control the environment without any muscle activity. The software part of the system allows the direct acquisition of electrical brain activity from an external EEG measurement device and subsequent algorithmic processing to control the robotic part of the device in real time via a mental movement concept.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Development of a diagnostic tool for quantitative MRI imaging of biogenic iron in clinical practice**
Project ID number:	APVV-0431-12
Duration:	1.10.2013 / 30.9.2016
Responsible person:	Oliver ŠTRBÁK (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	2 – Faculty of Chemical and Food Technology STU in Bratislava, Slovak Medical University in Bratislava
Funding:	Total 237029 €. IMS SAS 2016: 44740 €
Interdisciplinary research:	Yes (biomedical research, health sciences)

Short annotation:	Investigation and development of a new methodology for a diagnostic tool for the non-invasive diagnosis of pathological processes associated with the accumulation of iron in tissues. This is the result of disturbed iron homeostasis and includes in particular neurodegenerative and neuroinflammatory diseases as well as liver and heart diseases.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Noninvasive localization of ectopic arrhythmias of heart ventricles using ECG mapping and its use for causal therapy**
Project ID number:	APVV-14-0875
Duration:	1.7.2015 / 30.6.2018
Responsible person:	Milan TYŠLER (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	1 – The National Institute of Cardiovascular Diseases
Funding:	Total 249967 €. IMS SAS: 2016: 59000 €, 2017: 40494 €, 2018: 23975 €
Interdisciplinary research:	Yes (biomedical research, health sciences)
Short annotation:	The main objective of the project was to design, optimise and verify a measurement method for non-invasive localisation of one or two small areas of abnormal ventricular activation. The method is based on a multi-channel measurement of the surface ECG and a customised 3D model of the patient's chest derived from tomographic imaging. The proposed method appears to be sufficiently accurate and robust for the given objective. The non-invasive localisation of the target area allows better intervention planning, shortening of the intervention time and less stress for the patient.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Advanced statistical and computational methods for measurement and metrology**
Project ID number:	APVV-15-0295
Duration:	1.7.2016 / 30.6.2020
Responsible person:	Viktor WITKOVSKÝ (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	3 – Faculty of Mechanical Engineering STU in Bratislava, Slovak Institute of Metrology, Mathematical Institute SAS
Funding:	Total: 250000 €, IMS SAS - 2016: 11250 €, 2017: 22500 €, 2018: 22500 €, 2019: 22500 €, 2020:11250 €
Interdisciplinary research:	Yes (mathematics, metrology, engineering)
Short annotation:	Development of mathematical and statistical methods and algorithms for the evaluation of measurement results with a focus on the development of models and methods for the multivariate calibration of measuring instruments and methods and algorithms for the determination of measurement uncertainties by deriving the exact or approximate probability distributions of the measurement results.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Research of magnetic forms of iron in development of cardiovascular diseases and behavioural disorders**
Project ID number:	APVV-16-0263
Duration:	1.7.2017 / 30.6.2021

Responsible person:	Ján MAŇKA (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Institute of Normal and Pathological Physiology of the SAS, Iveta BERNÁTOVÁ (project coordinator)
Partners:	2 – Institute of Normal and Pathological Physiology of the SAS, Faculty of Medicine, Comenius University in Bratislava
Funding:	Total: 249000 €. IMS SAS 2017: 3454 €, 2018: 11000 €, 2019: 11000 €, 2020: 11000 €, 2021: 7000 €
Interdisciplinary research:	Yes (biomedical research, health sciences)
Short annotation:	Using an MPMS XL7 SQUID magnetometer, the magnetic properties of tissue, left ventricle (LV), spleen and liver of two types of rats were studied in relation to age (7 and 52 weeks). In collaboration with the partners, we focused on the determination of iron content derived from superparamagnetic iron oxide nanoparticles and on the discrimination of naturally present iron in tissues and fluids based on different blocking temperatures. A method was developed to determine the iron content of rat tissue after administration of a small dose of a dispersion of nanoparticles in saline. We have shown that extremely small amounts of nanoparticulate iron can be identified and distinguished from biogenic iron using SQUID (Superconducting Quantum Interference Device) magnetometry.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Enhancing cognition and motor rehabilitation using mixed reality**
Project ID number:	APVV-16-0202
Duration:	1.7.2017 / 30.6.2021
Responsible person:	Roman ROSIPAL (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava, Igor FARKAŠ (project coordinator)
Partners:	2 – Comenius University in Bratislava - Faculty of Mathematics of Physics and Informatics, Technical University of Košice - Faculty of Electrical Engineering and Informatics
Funding:	Total: 249447 €. IMS SAS 2017: 9550 €, 2018: 28924 €, 2019: 27124 €, 2020: 28324 €, 2021: 13050 €
Interdisciplinary research:	Yes (biomedical research, health sciences)
Short annotation:	The project focused on two objectives in relation to healthy subjects and hemiparetic patients after stroke: We investigated whether cognitive training based on a mixed reality (MR) improves perceptual and cognitive characteristics in healthy subjects, and tested whether experiential training in MR (in combination with a brain-based motor brain-computer interface) improves oscillatory sensorimotor rhythms in patients by measuring subjects' brain EEG activity before and after each training session. We used both clinical tests and questionnaires to identify human factors that could be influenced by the measurement, such as mental fatigue, motivation, irritation, or drowsiness.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Development of innovative methods for primary metrology torque forces by force effects of the conventional standards**
Project ID number:	APVV-18-0066
Duration:	1.7.2019 / 31.12.2022

Responsible person:	Viktor WITKOVSKÝ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Slovak Legal Metrology, Ľuboš KUČERA (project coordinator)
Partners:	3 – Slovak Legal Metrology, Faculty of Mechanical Engineering UNIZA Žilina, Faculty of Mechanical Engineering STU Bratislava, Mathematical Institute of the SAS
Funding:	Total: 247802 €. IMS SAS 2019: 1800 €, 2020: 4459 €, 2021: 4459 €
Interdisciplinary research:	Yes (mathematics, metrology, engineering)
Short annotation:	Research to develop innovative methods for the primary metrology of the moment of force. At present, the Slovak Republic does not have a primary metrology system with a laboratory that would represent the highest level with its technical equipment and metrological quality. The laboratories for the calibration of the moment force in the Slovak Republic are forced to look for sources of metrological continuity abroad. The aim of the project is therefore to lay the foundations for primary metrology of the moment of force. The aim of the project is to use the most modern methods and approaches in the development of a methodology and an automated measurement system for the implementation of primary standardisation of the moment of force.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Development and realisation of the standard of the static magnetic field based on a magnetic resonance**
Project ID number:	APVV-19-0032
Duration:	1.7.2020 / 30.6.2023
Responsible person:	Peter ANDRIS (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	1 – Slovak Legal Metrology
Funding:	Total: 248271 €. 2020: 34260 €, 2021: 60897 €
Interdisciplinary research:	No
Short annotation:	Research and design of NMR measurement methods based on the use of low magnetic field systems (0.05 and 0.2 Tesla) for the development and implementation of a standard static magnetic field on a magnetic resonance imaging scanner. This standard would form the basis for testing and calibrating equipment that measures or generates magnetic fields.

➢

Type of project:	Slovak Research and Development Agency (APVV)
Title:	**Personalized optimisation of cardiac resynchronization therapy in heart failure based on multiple lead ECG measurement**
Project ID number:	APVV-19-0531
Duration:	1.7.2020 / 30.6.2023
Responsible person:	Milan TYŠLER (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	-
Funding:	Total: 249994 €. 2020: 38858 €, 2021: 83542 €
Interdisciplinary research:	Yes (biomedical research, health sciences)
Short annotation:	Cardiac resynchronisation therapy (CRT) is currently the most advanced therapeutic method for treating patients with heart failure. The main goal of the project is to explore methods for personalised optimisation of CRT therapy based on multi-lead surface ECG measurements and verify them using simulated data and data from real patients.

2.4.4. List of projects of the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education, VEGA (for funding specify only total sum obtained from all VEGA grants in particular year)

Total sum (EUR) obtained by the organisation from all VEGA grants in particular year

Year	Total sum from VEGA grants
2016 (8 running projects)	63550 €
2017 (7 running projects)	56208 €
2018 (8 running projects)	56826 €
2019 (9 running projects)	58588 €
2020 (9 running projects)	70535 €
2021 (10 running projects)	67699 €
2016 – 2021 (all 23 projects)	**373406 €**

➢

Title: **Imaging and mapping of organic and synthetic materials and objects using magnetic resonance imaging methods**
Project ID number: VEGA 2/0013/14
Duration: 1.1.2014 / 31.12.2016
Responsible person: Ivan FROLLO (coordinator “C”)
Coordinating organisation: IMS SAS
Interdisciplinary research: No

➢

Title: **Mechanism of uptake and trafficking of magnetic iron oxide nanoparticles into human tumor and normal (diploid) cells**
Project ID number: VEGA 2/0143/13
Duration: 1.1.2013 / 31.12.2016
Responsible person: Ján MAŇKA (IMS SAS coordinator / WP leader “W”)
Coordinating organisation: Cancer Research Institute SAS, Alena Gábelová (project coordinator)
Interdisciplinary research: Yes (biomedical research, health sciences)

➢

Title: **New acoustical horns in sonochemistry**
Project ID number: VEGA 2/0092/14
Duration: 1.1.2014 / 31.12.2016
Responsible person: Klára HORNIŠOVÁ (coordinator “C”)
Coordinating organisation: IMS SAS
Partners: Faculty of Natural Sciences, Comenius University
Interdisciplinary research: No

➢

Title: **Analysis of causal relationships in complex systems with an emphasis on biomedical applications**
Project ID number: VEGA 2/0011/16
Duration: 1.1.2016 / 31.12.2018
Responsible person: Anna KRAKOVSKÁ (coordinator “C”)
Coordinating organisation: IMS SAS
Interdisciplinary research: Yes (mathematics, biomedicine)

➢

Title: **Development of SQUID gradiometric and susceptometric methods for iron homeostasis related**
Project ID number: VEGA 2/0152/13

Duration: 1.1.2013 / 31.12.2016
Responsible person: Ján MAŇKA (coordinator “C”)
Coordinating organisation: IMS SAS
Partners: 1 - Institute of Normal and Pathological Physiology SAS
Interdisciplinary research: Yes (biomedical research, health sciences)

➢

Title: **Modeling of cardiac electrical field for the study of manifestation of funtional and structural changes in myocardium in measured ECG signals**
Project ID number: VEGA 2/0071/16
Duration: 1.1.2016/ 31.12.2018
Responsible person: Jana ŠVEHLÍKOVÁ (coordinator “C”)
Coordinating organisation: IMS SAS
Interdisciplinary research: Yes (biomedical research, health sciences)

➢

Title: **Measurement of biological response to weak low-frequency electromagnetic fields**
Project ID number: VEGA 2/0138/16
Duration: 1.1.2016/ 31.12.2018
Responsible person: Michal TEPLAN (coordinator “C”)
Coordinating organisation: IMS SAS
Interdisciplinary research: Yes (biomedicine, electrical engineering)

➢

Title: **Discrete and continuous probabilistic models and their applications**
Project ID number: VEGA
Duration: 1.1.2015 / 31.12.2017
Responsible person: Viktor WITKOVSKÝ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation: Mathematical Institute SAS, Gejza Wimmer (project coordinator)
Partners: 2 - Mathematical Institute SAS, Faculty of Mathematics, Physics and Informatics Comenius University in Bratislava
Interdisciplinary research: No

➢

Title: **Measuring and imaging methods based on magnetic resonance for material and biomedical research**
Project ID number: VEGA 2/0001/17
Duration: 1.1.2017/ 31.12.2019
Responsible person: Peter ANDRIS (coordinator “C”)
Coordinating organisation: IMS SAS
Interdisciplinary research: No

➢

Type of project: Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education (VEGA)
Title: **Effect of ultrasmall superparamagnetic iron oxide nanoparticles on the cardiovascular system of rats with high blood pressure**
Project ID number: VEGA 2/0160/17
Duration: 1.1.2017/ 31.12.2020
Responsible person: Ján MAŇKA (IMS SAS coordinator / WP leader “W”)
Coordinating organisation: Institute of Normal and Pathological Physiology SAS, Iveta Bernátová (project coordinator)
Partners: 1 - Institute of Normal and Pathological Physiology SAS

Interdisciplinary research: Yes (biomedical research, health sciences)

➢

Title: **Research on possibilities and development of SQUID magnetometry for selected applications in biomedicine and material research**
Project ID number: VEGA 2/0164/17
Duration: 1.1.2017/ 31.12.2020
Responsible person: Ján MAŇKA (coordinator “C”)
Coordinating organisation: IMS SAS
Partners: 1 - Institute of Normal and Pathological Physiology SAS
Interdisciplinary research: No

➢

Title: **Morfology of fossil lizards using micro-computed tomography, their phylogeny, paleobiogeography - migrations and faunal changes during the climatic changes of Cenozoic**
Project ID number: VEGA 1/0209/18
Duration: 1.1.2018/ 31.12.2020
Responsible person: Miroslav HAIN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation: Faculty of Natural Sciences of the Comenius University Bratislava, Andrej Čerňanský (project coordinator)
Partners: 1 - Faculty of Natural Sciences of the Comenius University Bratislava
Interdisciplinary research: Yes (biology, paleontology, climatology)

➢

Title: **New statistical methods for special families of probability distributions and their applications**
Project ID number: VEGA 2/0054/18
Duration: 1.1.2018 / 31.12.2020
Responsible person: Viktor WITKOVSKÝ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation: Mathematical Institute SAS, Gejza Wimmer (project coordinator)
Partners: 2 - Mathematical Institute SAS, Faculty of Mathematics, Physics, and Informatics Comenius University in Bratislava
Interdisciplinary research: No

➢

Title: **Origin of amniotes: identification of key structures of the most-basal amniotes using computed microtomography**
Project ID number: VEGA 1/0228/19
Duration: 1.1.2019/ 31.12.2021
Responsible person: Miroslav HAIN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation: Faculty of Natural Sciences of the Comenius University Bratislava, Jozef Klembara (project coordinator)
Partners: 1 - Faculty of Natural Sciences of the Comenius University Bratislava
Interdisciplinary research: Yes (biology)

➢

Title: **Analysis of multivariate time series and its application to research of functional connectivity in the brain**
Project ID number: VEGA 2/0081/19
Duration: 1.1.2019 / 31.12.2021
Responsible person: Anna KRAKOVSKÁ (coordinator “C”)
Coordinating organisation: IMS SAS

Interdisciplinary research: Yes (mathematics, biomedicine)

➢

Title: **Measurement and modeling of the cardiac electrical field for noninvasive identification and interpretation of structural changes of the ventricular myocardium leading to ventricular arrhythmias**
Project ID number: VEGA 2/0125/19
Duration: 1.1.2019/ 31.12.2021
Responsible person: Jana ŠVEHLÍKOVÁ (coordinator "C")
Coordinating organisation: IMS SAS
Interdisciplinary research: Yes (electrical engineering, health sciences)

➢

Title: **Development of experimental platform and analytical tools for measurement of low frequency electromagnetic field effects on biological systems**
Project ID number: VEGA 2/0157/19
Duration: 1.1.2019/ 31.12.2021
Responsible person: Michal TEPLAN (coordinator "C")
Coordinating organisation: IMS SAS
Interdisciplinary research: No

➢

Title: **Magnetic resonance imaging methods for medical diagnostics and material research**
Project ID number: VEGA 2/0003/20
Duration: 1.1.2020/ 31.12.2022
Responsible person: Peter ANDRIS (coordinator "C")
Coordinating organisation: IMS SAS
Interdisciplinary research: Yes (material research, health sciences)

➢

Title: **Role of nuclear factor NRF2-mediated signalling in iron metabolism regulation during stress**
Project ID number: VEGA 2/0157/21
Duration: 1.1.2021/ 31.12.2024
Responsible person: Martin ŠKRÁTEK (IMS SAS coordinator / WP leader "W")
Coordinating organisation: Centre of Experimental Medicine SAS, Iveta Bernátová (project coordinator)
Partners: 1 - The Centre of Experimental Medicine SAS
Interdisciplinary research: Yes (health sciences)

➢

Title: **Ion exchange strengthened aluminosilicate glass/glass-ceramics with additional functionalities**
Project ID number: VEGA 2/0028/21
Duration: 1.1.2021/ 31.12.2024
Responsible person: Melinda MAJEROVÁ (IMS SAS coordinator / WP leader "W")
Coordinating organisation: Institute of Inorganic Chemistry SAS, Dušan Galusek (project coordinator)
Partners: Institute of Inorganic Chemistry SAS
Interdisciplinary research: Yes (material research)

➢

Title: **CT modeling and morphological analysis of the postcranial region of extinct and current lizards and their relatedness based on new morphological data**

Project ID number:	VEGA 1/0191/21
Duration:	1.1.2021/ 31.12.2023
Responsible person:	Miroslav HAIN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Faculty of Natural Sciences of the Comenius University Bratislava, Andrej Čerňanský (project coordinator)
Partners:	1 - Faculty of Natural Sciences of the Comenius University Bratislava
Interdisciplinary research:	Yes (biology research)

➢

Title:	**Probability distributions and their applications in modelling and testing**
Project ID number:	VEGA 2/0096/21
Duration:	1.1.2021 / 31.12.2023
Responsible person:	Viktor WITKOVSKÝ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Mathematical Institute SAS, Ján Mačutek (project coordinator)
Partners:	1 - Mathematical Institute SAS
Interdisciplinary research:	No

➢

Title:	**SQUID magnetometry of nano- and microparticles, nanocolloids and nanostructures in new applications in the field of biomedicine and materials research associated with the development of new measurement methods and procedures**
Project ID number:	VEGA 2/0141/21
Duration:	1.1.2021/ 31.12.2024
Responsible person:	Ján MAŇKA (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	1 - Centre of Experimental Medicine SAS
Interdisciplinary research:	Yes (material research, health sciences)

2.4.5. List of projects supported by EU Structural Funds

None

2.4.6. List of other projects funded from national resources

➢

Type of project:	JRP - Joint Research Project
Title:	**Performance evaluation evaluation of noninvasive electrocardiographic imaging for the localization of premature ventricular contractions from clinical data (ClinECGI)**
Project ID number:	SAS-TUBITAK/JRP/1144
Duration:	01.02.2021 – 31.1.2024
Responsible person:	Jana ŠVEHLÍKOVÁ (coordinator “C”)
Coordinating organisation:	IMS SAS
Partners:	Middle East Technical University (METU); Electrical and Electronics Eng Dept; Ankara; Turkey
Funding:	IMS SAS 2021: 22917 €
Interdisciplinary research:	Yes (biomedicine, electrical engineering)
Short annotation:	The project focuses on advanced non-invasive methods to localise the origin of an undesired ventricular activity known as extrasystoles. The treatment of these arrhythmias involves an invasive procedure using endocardial mapping to remove such origins through the application of radiofrequency energy.

	The methods proposed in the project aim to shorten this time-consuming invasive procedure by guiding clinicians to the correct regions of the arrhythmia's origin. The project offers both groups the opportunity to share their knowledge and expand their expertise in this field.

➢

Type of project:	Interacademic Agreement
Title:	**Novel integrated approaches for research of biomedical effects of pulsed electric fields**
Project ID number:	SAV-18-11
Duration:	1.1.2018 – 31.12.2021
Responsible person:	Michal TEPLAN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Institute of Photonics and Electronics, Czech Academy of Sciences
Partners:	Institute of Photonics and Electronics, Czech Academy of Sciences
Funding:	Travel costs
Interdisciplinary research:	Yes (biomedicine, electrical engineering)
Short annotation:	The project focuses on the theoretical and experimental characterisation of the effects of pulsed electric fields from the level of subcellular biomolecular structures to the cellular level. Our aim was to develop and apply approaches based on impedance spectroscopy and chemiluminescence detection that allow us to study the main biological effects of pulsed electric fields in real time, non-invasively and label-free.

➢

Type of project:	Interacademic Agreement
Title:	**Synchronization and causality in complex systems: time series methods**
Project ID number:	SAV-AV ČR 15-18
Duration:	1.1.2018 – 31.12.2021
Responsible person:	Anna KRAKOVSKÁ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Institute of Informatics Czech Academy of Sciences
Partners:	Institute of Photonics and Electronics, Czecch Academy of Sciences
Funding:	Travel costs
Interdisciplinary research:	Yes (mathematics, biomedical research, climatology)
Short annotation:	The project focused on two fundamentally different approaches to detecting interactions and the direction of coupling (causality in Granger's sense), which were tested and compared using benchmark data generated by different mathematical models.

➢

Type of project:	Multilateral Project
Title:	**MU training – Measurement uncertainty training – MATHMET project to improve quality, efficiency and dissemination of measurement uncertainty training**
Project ID number:	MATHMET-MUT-2021
Duration:	1.10.2021 – 30.9.2023
Responsible person:	Viktor WITKOVSKÝ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Physikalisch-Technische Bundesanstalt (PTB) Germany
Partners:	16 - Belgium, Bosnia and Herzegovina, Germany, Spain, France, United Kingdom, Switzerland, Ireland, Italy, Poland, Portugal, Slovakia

Funding:	Travel costs
Interdisciplinary research:	Yes (statistics, metrology, measurement science)
Short annotation:	Measurement uncertainty is a key quality parameter to express the reliability of measurements and an understanding of measurement uncertainty is often a precondition for advances in science, industry, health, environment, and society in general. However, there is a documented need for a better understanding of measurement uncertainty and its evaluation in many communities and recently this need was restated pointing to the importance of training on measurement uncertainty. The project activity will develop new material for measurement uncertainty training and establish an active community for those involved in measurement uncertainty training. In the EU, the European Metrology Network MATHMET is well-suited to host such an activity.

➢

Type of project:	Bilateral Project
Title:	**Comparative imaging methods based on magnetic resonance**
Project ID number:	ASC-2020
Duration:	1.3.2017 – 31.12.2020
Responsible person:	Ivan FROLLO (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Medical University of Vienna
Partners:	MR Centre of Excellence - Medical University of Vienna Lazarettgasse 14 A-1090 Wien Austria; Univ.-Prof. Dr. Siegfried Trattnig
Funding:	Travel costs
Interdisciplinary research:	Yes (biomedical research, electrical engineering)
Short annotation:	The project focuses on research into comparative imaging techniques based on magnetic resonance for the diagnosis of neurological and musculoskeletal diseases. Imaging of micro- and nanostructures based on magnetic resonance for biomedical and materials research. Reciprocal visits of scientists and PhD students to enable them to perform imaging experiments on MRI equipment in the partners' laboratories in a reasonable time.

➢

Type of project:	Bilateral Project
Title:	**Preparation and study of the precursor properties for development of nanomaterials based on metal oxides**
Project ID number:	AI5/TT/1170
Duration:	1.3.2017 – 31.12.2020
Responsible person:	Alexander CIGÁŇ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Universiteit Gent - Ghent University
Partners:	Department of Inorganic and Physical Chemistry, Ghent Universiteit Gent- Ghent University, prof. Isabel Van DRIESSCHE
Funding:	Travel costs
Interdisciplinary research:	Yes (material sciences, electrical engineering)
Short annotation:	The project interests include the following main areas: Technology of superconducting HTc oxides based on yttrium, bismuth, thalium and mercury - bulks, tapes and thin films. Investigation of the physical properties of these materials by magnetisation measurements. Joint experiments with the LTc SQUID gradiometric system (IMS SAS) and the LakeShore

	susceptometer (at the Department of Inorganic and Physical Chemistry, Ghent). Publication of the results of the joint scientific activities.

➢

Type of project:	Bilateral Project
Title:	**RTS-02 clock series registrar modules**
Project ID number:	08626319/16201274-74
Duration:	18.2.2016 – 31.12.2017
Responsible person:	Dušan KRUŠINSKÝ (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	Joint Institute for Nuclear Research
Partners:	Joint Institute for Nuclear Research, Dubna, Russia
Funding:	IMS SAS 10975,- EUR
Interdisciplinary research:	No (electrical engineering)
Short annotation:	The aim of the NICA project is to develop and manufacture computer modules for controlling the magnetic field cycle in the NUCLOTRON accelerator and the upcoming collider.

➢

Type of project:	Bilateral Project
Title:	**Advanced optical methods for nanoelectronics**
Project ID number:	AIST-IMS-2006
Duration:	1.1.2006 – 31.12.2016
Responsible person:	Miroslav HAIN (IMS SAS coordinator / WP leader “W”)
Coordinating organisation:	National Institute of Advanced Industrial Science and Technology (AIST) Nanoelectronics Research Institute, Tsukuba, Japan
Partners:	National Institute of Advanced Industrial Science and Technology (AIST) Nanoelectronics Research Institute, Tsukuba, Japan
Funding:	Travel costs
Interdisciplinary research:	No (electrical engineering)
Short annotation:	International cooperation is governed by the Memorandum of Understanding between the Institute of Measurement Science of the Slovak Academy of Sciences and the Nanoelectronics Research Institute AIST in Tsukuba, Japan.

2.4.7. List of projects funded from private funds

None

2.4.8. List of projects funded from other competitive funds

Type of project:	Slovak Academic Information Agency (SAIA)
Title:	The National Scholarship Programme of the Slovak Republic for the Support of Mobility of Students, PhD Students, University Teachers, Researchers and Artists
Project ID number:	Dragos Narcis Trinca
Duration:	1.9.2019 – 28.2.2020
Responsible person:	Miroslav HAIN (coordinator “C”)
Coordinating organisation:	IMS SAS
Funding:	6 months research stipend for Dragos Narcis Trinca (Romania)
Short annotation:	The research stay of D Narcis Trinca at the IMS SAS was focused on research and programming in the area of X-ray tomography. In particular, on hybrid CPU-GPU parallelization of tomographic reconstruction algorithms in Version 1.2 of the IRXCT Windows.

2.5. PhD studies and educational activities

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

The Institute of Measurement Science of the Slovak Academy of Sciences (IMS SAS) was the training institute for PhD study and the seat of the commission for conferring scientific degrees in the study program "*Measurement Technology*" since 1962.

Since 1985 the Institute had the rights to conduct PhD study in "Bionics and Biomechanics". After the new Education act in Slovakia was accepted in 1996, in a new structure of study fields the Institute participated in the study programs "*Measurement Technology*" (in cooperation with *Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava*) and "*Bionics and Biomechanics*" (in cooperation with *Faculty of Mechanical Engineering, Technical University in Košice*). This education was conducted during the validity of the Education act until 2010.

- **Since March 2006** the Institute was accredited as an external educational institution of **Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava** to conduct full-time and external study **in the program 5.2.54 „Measurement Technology",** and **it was reaccredited in 2009 and 2016** for the next period according the Education Act.
- **Since 2020** the Institute is an external educational institution of **Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava** for the study program **"Measurement Technology"** (within the study field "Electrical and Electronics Engineering")
- **Since 2020** the Institute is an external educational institution of **Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava** for the study program "**Applied Mathematics**" (within the study field "Mathematics").

The PhD study conforms to the study rules of the above-mentioned universities and obeys "Internal system for PhD study quality assurance".

The source of funding for all accredited study programs is the Slovak Academy of Sciences.

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

PhD study	2016			2017			2018			2019			2020			2021		
Number of potential PhD supervisors																		
PhD students	number, end of year	defended thesis	students quitted	number, end of year	defended thesis	students quitted	unumber, end of yea	defended thesis	students quitted	number, end of year	defended thesis	students quitted	number, end of year	defended thesis	students quitted	number, end of year	defended thesis	students quitted
Internal total	3	0	1	3	0	1	2	2	0	3	0	0	4	0	1	4	0	1
from which foreign citizens	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	1	0	1
External	1	2	0	1	0	0	1	0	0	1	0	0	1	0	0	2	0	0
Other supervised by the research employees of the institute	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2.5.3. PhD carrier path – Information on the next career steps of the PhD graduates who received their degree from the institute

In 2016, Peter KAĽAVSKÝ and Andrej DVUREČENSKIJ completed their doctoral studies.

- At the end of his studies, **Peter KAĽAVSKÝ** completed a long-term stay at the Institute of computational Science in Lugano, Switzerland. Shortly after defending his

doctoral thesis, he did not continue his research and left the IMS SAS for a company in IT bussines. He currently works as an employee of Boge Elastmetal a. s. Slovakia.

- **Andrej DVUREČENSKIJ** remained at the Institute as a researcher in the Department of Magnetometry after his defence.

In 2018, Jozef JAKUBÍK and Zuzana ROŠŤÁKOVÁ completed their doctoral studies.

- **Jozef JAKUBÍK** then started working at the successful IT company ESET, Europe's leading digital security provider headquartered in Slovakia. He later returned to the Institute and now works as a part-time researcher in the Department of Theoretical Methods.
- After completing her studies, **Zuzana ROŠŤÁKOVÁ** stayed at the Institute and works as a researcher in the Department of Theoretical Methods.

2.5.4. Summary table on educational activities

Teaching	2016	2017	2018	2019	2020	2021
Lectures (hours/year)*	108	4	2	72	0	4
Practicum courses (hours/year)*	21	16	18	70	0	0
Supervised diploma and bachelor thesis (in total)	6	7	7	4	7	7
Members in PhD committees (in total)	5	3	5	2	2	1
Members in DrSc. committees (in total)	0	1	0	0	0	0
Members in university/faculty councils (in total)	3	2	2	1	1	0
Members in habilitation/inauguration committees (in total)	1	2	0	2	3	2

2.5.5. List of published university textbooks

None

2.5.6. Number of published academic course books

None

2.5.7. List of joint research laboratories/facilities with universities

- Joint research laboratory with the Department of Geodesy, Faculty of Civil Engineering STU in Bratislava. Cooperation was focused on the design and development of new measuring instruments for applications in engineering geodesy and on the education of students and young researchers - PhD students in the field of engineering geodesy. (Finished in 2017)
- Joint research laboratory with the Academy of Fine Arts and Design in Bratislava is aimed at physical non-destructive exploration of historical and artistic artifacts.

2.5.8. Supplementary information and/or comments on doctoral studies and educational activities – focused on what changes have occurred since the last evaluation in 2016

As part of the legislative changes in 2020, the Institute has developed **an internal quality assessment system** that defines the conditions under which the Institute may offer a study programme and determines the criteria for the guarantor of the study programme, the supervisors and the members of the programme committees. It also defines the study

programme and the criteria that a successful graduate must meet. These criteria must not be less stringent than those of the cooperating university.

In order to achieve a high quality of the topics and their consistency with the focus of the Institute, the study topics are approved in the scientific council of the Institute.

In order to attract more students, since 2020 all study topics are published not only on the Institute's and SAS's website, but also on the EURAXESS website. At the same time, presentations or videos on individual topics are also published. In addition to Slovak students, these activities have also led to the admission of students from Iran and Vietnam.

However, the Institute has long struggled with the problem of disinterest or low interest among local students in pursuing doctoral studies in Measurement Technology and Applied Mathematics. In the field of technical sciences, jobs in industry or at research institutes abroad are more attractive to capable young people, offering them comparatively much better financial security. We consider it a big problem that a large part of young talents wants to study at foreign universities and work abroad in the long term. The recruitment of Slovak students from abroad as well as other foreign doctoral students is inefficient despite the special programmes for their recruitment. Recruitment of doctoral students from outside the EU is not a sufficient and sustainable substitute. The Institute develops and supports SAS activities to acquire, maintain and improve conditions, especially for domestic young researchers. We create the conditions for active recruitment of doctoral students in order to arouse the interest of suitable domestic engineering graduates (support of temporary activities of high school and university students, active cooperation with universities to conduct bachelor's and master's theses, admission of university graduates for a certain period of time before starting doctoral studies, active involvement of doctoral students in international scientific cooperation), as well as raising the requirements for the level of admitted students from abroad.

Despite these difficulties, the Institute manages to train successful doctoral students and young researchers. In particular, Ladislav Valkovič (1st place in 2017) and Martina Chvosteková (2nd place in 2019) were awarded in the competition for young scientists of the Slovak Academy of Sciences up to the age of 35. In 2021, Ing Beáta Ondrušová (PhD student in the Measurement Technology programme) submitted an application and also successfully received support for the DoktoGrant APP0323 "Two-step inverse solution in electrocardiography using a single dipole model of the cardiac electric generator". Young scientist Mgr Zuzana Rostakova, PhD. was a finalist in the prestigious competition The Falling Walls Lab Slovakia 2021. Ing Ladislav Valkovič, PhD. currently working in the Department of Imaging Methods at IMS SAS and also at the Oxford Centre for Clinical Magnetic Resonance Research at the University of Oxford, was selected by an international committee chaired by Nobel Laureate in Physics Kip Thorne to receive the prestigious ESET Science Award for Exceptional Young Scientist in Slovakia 2021.

2.6. Societal impact

2.6.1. The most important case studies of the research with direct societal impact, max. 4 for institute with up to 50 average FTE researchers per year, 8 for institutes with 50 – 100 average FTE researchers per year and so on. Structure: Summary of the impact; Underpinning research; References to the research; Details of the impact; Sources to corroborate the impact. One page per one case study

1. **Poststroke motor rehabilitation**

Summary of the impact

Hemiparesis or hemiplegia of the upper limbs is one of the most important motor impairments after a stroke. Current rehabilitation methods help only a fraction of stroke victims to recover. Even after months of intensive rehabilitation efforts, only ~50% of patients show no motor impairment. Research should focus on developing novel rehabilitation strategies and protocols, such as mirror therapy (MT) or brain-computer interface (BCI), to improve patients' quality of life after stroke and reduce their dependence on others. Basic and experimental research was conducted in collaboration with two academic partners from Slovakia at IMS SAS to develop and test a range of MT and BCI protocols.

Underpinning research

Based on the knowledge he gained during his tenure at NASA Ames Research Center, Dr Roman ROSIPAL began developing the topic of motor neurorehabilitation based on MT and BCI in 2013 at IMS SAS. These efforts were reflected in the successful acquisition of financial support through two APVV grants and the CHIST-ERA grant in 2021. The support enabled further development of topics ranging from basic knowledge of MT and BCI, to the design of a unique BCI-controlled robotic splint, to the development of advanced virtual reality interfaces for BCI neurorehabilitation. A series of experiments were conducted with stroke patients, leading not only to confirmation of the technical aspects of the approach, but also to the acquisition and publication of new fundamental electrophysiological knowledge (Rosipal et al., Journal of Neurophysiology, 2019).

Although the IMS SAS does not have the resources and background for more extensive clinical research, we were able to confirm the clinical relevance of the approach under the supervision of a qualified physician, Dr Porubcova. This was reflected in the clinical improvement of motor mobility in the patients who participated in the training.

Details of the impact

There is no question that improving motor impairment in post-stroke patients adds significant value to society. This value is not easy to quantify financially, and every small improvement in this direction plays an important role.

The topic of neurorehabilitation provides a foundation for the development of a rich spectrum of scientific problems, from the measurement and processing of electrophysiological signals to the issue of advanced machine learning and AI, to a deeper understanding of the related problems of neurophysiology. This led to the successful defence of several semester projects, six master's theses and two defended PhD theses by students from our cooperating partner universities, namely the Faculty of Mathematics, Physics and Computer Science at Comenius University in Bratislava and the Technical University in Košice. The research resulted in publications, which are summarised at http://aiolos.um.savba.sk/~roman/rrLab/publications.html.

The research is not yet complete. In 2021, we received a new impetus when we were awarded a grant from CHIST-ERA (ReHaB, 2022-2025) to extend neurorehabilitation to a form of collaborative virtual reality that enables interaction between patient and therapist. The IMS SAS is leading the project, which involves six other European partners. For project details see http://aiolos.um.savba.sk/~roman/rrLab/projects.html#ReHaB.

2. Noninvasive localization of a premature ventricular activity

Summary of the impact

Premature ventricular contractions (PVC), also known as extrasystoles, are common in people of productive age. Frequent and untreated PVC can lead to dangerous ventricular tachycardia and fatal ventricular fibrillation. The first step in treatment is pharmacological treatment, but if this does not work, the next approach on how to stop this unwanted electrical activity of the heart is radiofrequency ablation (RFA). This invasive procedure involves inserting a catheter into the estimated ventricle and then searching for the exact location of the focus of the PVC. Once the focus is successfully located, the electrical activity of the estimated region is turned off through the application of radiofrequency energy. The process of localisation and successful ablation is not always easy and can take several hours. Therefore, methods for preliminary non-invasive estimation of the PVC focal position are being investigated to shorten the invasive RFA procedure.

Underpinning research

Non-invasive localisation of PVC is based on the use of multiple-leads ECG measurement and knowledge of the patient-specific heart-torso geometry with placement of the measurement electrodes. The origin of the PVC is calculated assuming that the torso is an electrical homogeneous or inhomogeneous volume conductor and a model of the equivalent electrical generator is present in the form of epicardial potentials, transmembrane potentials or a multiple dipole. It is known that PVC starts in a single region of the ventricle and does not start in multiple regons simultaneously like normal ventricular activity. In our laboratory, we have taken this knowledge to mean that at the onset of ventricular activation, the activated region is so small that it can be represented by a single dipole. Our inverse solution is therefore to search for the best representative position of a single dipole that most resembles the measured body surface potential map on the torso model. The criterion for finding the best results is a relative residual error between the measured map and the map calculated from the inverse estimated dipole. The method was applied to both simulated and clinical data. Given well-defined pacing data for one patient (simulated PVC with known pacing catheter position), we performed an optimisation of two critical parameters for inverse outcome estimation instead of the default one parameter. The second parameter used all measured PVC heartbeats from the 10-minute measurements and evaluated the stability of the direction of the inversely calculated dipoles from the entire distribution of beats. To find the localisation of the paced region, an optimisation of the both parameters was performed. This approach improved the localisation error of the PVC origin from 16 mm to 11 mm for the homogeneous torso model and from 13 mm to 9 mm for the inhomogeneous torso.

Details of the impact

In 2017 - 2020, we collaborated with the National Institute of Cardiovascular Diseases to perform body surface potential (BSPM) measurements in 35 patients with PVC for whom RFA was indicated. Immediately after BSPM, they underwent a CT scan in which the measurement electrodes remained taped to the body. The personalised model of the patient's torso included the position of the heart, ventricular cavities, lung lobes and electrodes' placement. Then the non-invasive localisation of the PVC origin was calculated by using a single dipole as an equivalent electrical generator in the inverse problem solution. The inverse calculated position was later compared with the position of the applied RF energy during a successful RFA procedure. The topic will be further developed later in the framework of the Slovak-Turkish joint project.

Shortening the RFA procedure can provide more treated patients in the same amount of time and increase patient comfort during the procedure, which is performed under local anaesthesia only.

Sources to corroborate the impact

The topic of noninvasive evaluation of the heart condition by electrocardiographic imaging is up to date in international context, what is proved by activities of the Consortium for ECGI (www.ecg-imaging.org) and many other publications as:

1. Jonathan Chrispin, Alexander Mazur, JeffreyWinterfield, Alireza Nazeri, Miguel Valderrabano, Harikrishna Tandri. Non-invasive localization of premature ventricular focus: A prospective multicenter study. Journal of Electrocardiology, Volume 72, May–June 2022, Pages 6-12. https://doi.org/10.1016/j.jelectrocard.2022.02.007.
2. Helder Pereira, Steven Niederer, and Christopher A. Rinaldi. Electrocardiographic imaging for cardiac arrhythmias and resynchronization therapy. Europace (2020) 22, 1447–1462. https://doi.org/10.1093/europace/euaa165.
3. Wilson W.Good, Jake A.Bergquist, Lindsay C.Rupp, KarliGillette, NathanAngel, DerrickChou, GernotPlank, Rob S.MacLeod. Combining endocardial mapping and electrocardiographic imaging (ECGI) for improving PVC localization: A feasibility study. Journal of Electrocardiology Volume 69, Supplement, November–December 2021, Pages 51-54. https://doi.org/10.1016/j.jelectrocard.2021.08.013.
4. Daniel Nguyen, Jean Jeudy, Alejandro Jimenez Restrepo, and Timm-Michael Dickfeld. A Novel Use of Noninvasive Registered Electrocardiographic Imaging Map for Localization of VT and PVC. J Am Coll Cardiol Case Rep. 2021 Apr, 3 (4) 591–593. https://www.jacc.org/doi/abs/10.1016/j.jaccas.2021.01.031.

RELATED PUBLICATIONS

1. ŠVEHLÍKOVÁ, Jana – ZELINKA, Ján – TYŠLER, Milan – TIŇO, P. Multiobjective optimization approach to localization of ectopic beats by single dipole: Case study. In Computing in Cardiology, 2019, vol. 46, art. no. 9005735. (2018: 0.202 – SJR). ISSN 2325-8861. https://doi.org/10.22489/CinC.2019.303.
2. ŠVEHLÍKOVÁ, Jana** – ONDRUŠOVÁ, Beáta – ZELINKA, Ján – TYŠLER, Milan. The influence of the most powerful signals on the pacing site localization by single dipole. In Computing in Cardiology, 2020, vol. 47, art. no. 9344305. (2019: 0.296 – SJR). ISSN 2325-8861. https://doi.org/10.22489/CinC.2020.304.
3. TYŠLER, Milan – ŠVEHLÍKOVÁ, Jana – DEUTSCH, E. – OSMANČÍK, P. – HATALA, R. Noninvasive imaging of the origin of premature ventricular activity. In IFMBE Proceedings, 2019, vol. 68, no. 1, p. 97-101. (2018: 0.150 – SJR). ISSN 1680-0737. https://doi.org/10.1007/978-981-10-9035-6_18.
4. ŠVEHLÍKOVÁ, Jana – ZELINKA, Ján – DOGRUSOZ, Y.S. – GOOD, W. – TYŠLER, Milan – BEAR, L. Impact of signal preprocessing on the inverse localization of the origin of ventricular pacing. In Computing in Cardiology, 2019, vol. 45, 4 p. (2018: 0.202 – SJR). ISSN 2325-8861. https://doi.org/10.22489/CinC.2018.315.
5. ŠVEHLÍKOVÁ, Jana – TEPLAN, Michal – TYŠLER, Milan. Geometrical constraint of sources in noninvasive localization of premature ventricular contractions. In Journal of Electrocardiology, 2018, vol. 51, no. 3, p. 370-377. (2017: 1.421 – IF, Q4 – JCR, 0.710 – SJR, Q2 – SJR, karentované – CCC). (2018 – Current Contents). ISSN 0022-0736. https://doi.org/10.1016/j.jelectrocard.2018.02.013.
6. ŠVEHLÍKOVÁ, Jana – TYŠLER, Milan. Noninvasive localization of premature ventricular activity using different equivalent point sources. In Computing in Cardiology: 43rd Computing in Cardiology Conference, CinC 2016, 2016, 43, 313-316. (2015: 0.193–SJR). ISSN 2325-8861. https://doi.org/10.22489/CinC.2016.091-239

3. Novel technologies for metabolic imaging of the whole human heart

Summary of the impact

Basic research in collaboration with Oxford Centre for Clinical MR Research and radiofrequency (RF) coil building companies into in vivo cardiac metabolism research has led to development of novel technologies for metabolic imaging of the whole human heart. These new torso RF-coils are now being incorporated into high field metabolic imaging MR systems by Tesla Dynamic Coils and several variations are being constructed by other RF-coil building companies, e.g., Rapid Biomedical. This transforming research towards homogeneous excitation of the whole heart allowed development of methodologies for robust cardiac pH assessment, which is essential for calculation of $\triangle G$, i.e., ultimate marker of energetic reserves available to the heart (healthy and diseased).

Underpinning research

After hitting the limits of the common surface transmit RF coils for cardiac metabolic imaging, we have teamed up with researchers from the University of Oxford and several RF coil building companies in order to develop novel transmit coils that would allow homogeneous excitation without the need for extensively long measurement times, e.g., when using adiabatic excitation pulses that require a lot of power. Building on the premise that resonance frequency of phosphate nuclei (^{31}P) at high magnetic fields of 7 Tesla is very similar to hydrogen (^{1}H) resonance frequency of the clinical 3T systems, a torso transmit coil with birdcage design similar to that of 3T system was designed for ^{31}P at 7T. Besides the transmit performance, sufficient signal-to-noise ratio had to be secured by combination with receive array.

The academic outcomes of this research journey were published in five papers. These demonstrate the (1) ability to perform homogeneous excitation of the human heart using adiabatic pulses at the cost of long scan times; (2) the potential to overcome this limitation using novel birdcage transmit RF-coil wit receive array; (3) benefit of homogeneous excitation for robust cardiac pH determination; (4) further rapid method for pH quantification allowing measurements at rest and during increased workload; and (5) determination of the impact of cardiac gating on the measured energetic of the heart. A further outcome, not published yet, was a demonstration of whole heart coverage for metabolic imaging allowing quantification of cardiac energetics from around whole left ventricle for the first time.

Details of the impact

The impact can be split into three main areas:

- Technology companies – Besides the RF-coil building companies we have worked with, several other have seen the potential of this technology for metabolic imaging and started developing their own products that allow homogeneous excitation. Similarly, vendors of MRI systems have been incorporating these into some of their ultra-high field systems as a standard, as metabolic imaging at high fields became CE marked recently.
- Basic researchers – This development opened up new possibilities for exploring mechanisms of cardiac metabolism across the whole myocardium and brought novel biomarkers for exploration.
- Clinical scientists/cardiologists – These new technologies allow more precise characterization of metabolic changes in patients with cardiomyopathies and heart failure. The possibility to measure $\triangle G$ across the whole heart is unprecedented and opens up a battery of novel clinical trial. In particular now, when metabolism targeting drugs for stopping of development of heart failure are on the rise.

Sources to corroborate the impact: https://www.tesladc.nl/3-tesla/body-arrays-bore-coils-and-head-coils-a-brief-look-into-tdc-projects/, https://www.rapidbiomed.de/product/non-proton-torso-coils/.

RELATED PUBLICATIONS

7. VALKOVIČ, Ladislav** – CLARKE, W.T. – SCHMID, A.I. – RAMAN, B. – ELLIS, J. – WATKINS, H. – ROBSON, M.D. – NEUBAUER, S. – RODGERS, C.T. Measuring inorganic phosphate and intracellular pH in the healthy and hypertrophic cardiomyopathy hearts by in vivo 7T 31P-cardiovascular magnetic resonance spectroscopy. In Journal of Cardiovascular Magnetic Resonance, 2019, vol. 21, p. 19. (2018: 5.070 – IF, Q1 – JCR, 2.896 – SJR, Q1 – SJR, karentované – CCC). (2019 – Current Contents). ISSN 1097-6647. https://doi.org/10.1186/s12968-019-0529-4 Type: ADCA.
8. VALKOVIČ, Ladislav – DRAGONU, I. – ALMUJAYYAZ, S. – BATZAKIS, A. – YOUNG, L.A.J. – PURVIS, L.A.B. – CLARKE, W.T. – WICHMANN, T. – LANZ, T. – NEUBAUER, S. – ROBSON, M.D. – KLOMP, D.W.J. – RODGERS, C.T. Using a whole-body 31P birdcage transmit coil and 16-element receive array for human cardiac metabolic imaging at 7T. In PLoS ONE, 2017, vol. 12, no. 10, art. no. e0187153. (2016: 2.806 – IF, Q1 – JCR, 1.236 – SJR, Q1 – SJR). ISSN 1932-6203. https://doi.org/10.1371/journal.pone.0187153. Type: ADMA.
9. VALKOVIČ, Ladislav – CLARKE, W.T. – PURVIS, L.A.B. – SCHALLER, B. – ROBSON, M.D. – RODGERS, C.T. Adiabatic excitation for 31P MR spectroscopy in the human heart at 7 T: A feasibility study. In Magnetic Resonance in Medicine, 2017, vol. 78, no. 5, p. 1667-1673. (2016: 3.924 – IF, Q1 – JCR, 1.945 – SJR, Q1 – SJR, karentované – CCC). (2017 – Current Contents). ISSN 0740-3194. https://doi.org/10.1002/mrm.26576. Type: ADCA.
10. APPS, A. – VALKOVIČ, Ladislav – PETERZAN, M. – LAU, J.Y.C. – HUNDERTMARK, M. – CLARKE, W. – TUNNICLIFFE, E.M. – ELLIS, J. – TYLER, D.J. – NEUBAUER, S. – RIDER, O. – RODGERS, C.T.* – SCHMID, A.I.**. Quantifying the effect of dobutamine stress on myocardial Pi and pH in healthy volunteers: A 31P MRS study at 7T. In Magnetic Resonance in Medicine, 2021, vol. 85, no. 3, p. 1147-1159. (2020: 4.668 – IF, Q1 – JCR, 1.696 – SJR, Q1 – SJR, karentované – CCC). (2021 – Current Contents). ISSN 0740-3194. https://doi.org/10.1002/mrm.28494. Type: ADCA.
11. WAMPL, S. – KÖRNER, T. – VALKOVIČ, Ladislav – TRATTNIG, S. – WOLZT, M. – MEYERSPEER, M. – SCHMID, A.I.**. Investigating the effect of trigger delay on cardiac 31P MRS signals. In Scientific Reports, 2021, vol. 11, art. no. 9268. (2020: 4.380 – IF, Q1 – JCR, 1.240 – SJR, Q1 – SJR, karentované – CCC). (2021 – Current Contents, WOS, SCOPUS). ISSN 2045-2322. https://doi.org/10.1038/s41598-021-87063-8. Typ: ADCA.

2.6.2. List of the most important studies and/or other activities commissioned for the decision-making authorities, the government and NGOs, international and foreign institutes (title, name of institution, contract value, purpose (max 20 words))

None

2.6.3. List of contracts and research projects with industrial and other commercial partners, incl. revenues (study title, name of institution, contract value, country of partner, purpose (max 20 words))

➢

Study title:	**Calibration, service and corrective maintenance of the SAS system**
Name of institution:	Slovenské elektrárne, Mochovce Nuclear Power Plant and Jaslovské Bohunice Nuclear Power Plant
Duration:	1.1.2016 / 31.12.2021
Contract value:	140 557,- EUR (total amount during 2016 - 2021)
Country of partner:	Slovakia
Short annotation:	Scientific, methodological and technical cooperation in measuring the inclination of nuclear reactor facilities

➢

Study title:	**Development and production of mechanical parts of special optoelectronic measuring probes**
Name of institution:	DATALAN a.s.
Duration:	1.1.2016 / 31.12.2021
Contract value:	91 290,- EUR (total amount during 2016 - 2021)
Country of partner:	Slovakia
Short annotation:	Development and production of mechanical parts of special optoelectronic measuring probes for the automotive industry.

➢

Study title:	**Completion of the Mochovce nuclear power plant 3.4**
Name of institution:	VUJE, a. s.
Duration:	1.1.2018 / 31.12.2021
Contract value:	46 804,- EUR (total amount during 2018 - 2021)
Country of partner:	Slovakia
Short annotation:	The aim of the project is to design and implement an electronic measurement system for measuring the inclination of nuclear reactors.

➢

Study title:	**Development and production of parts of scientific apparatuses of primary standards of ionizing radiation and high pressures**
Name of institution:	Slovak Institute of Metrology
Duration:	1.1.2018 / 31.12.2021
Contract value:	7 650 EUR,- EUR (total amount during 2018 - 2021)
Country of partner:	Slovakia
Short annotation:	Support for research, development and construction of primary standards in the Slovak Republic

➢

Study title:	**Micrototographic non-destructive testing of electrical components**
Name of institution:	Forschner CZ
Duration:	1.1.2016 / 31.12.2021
Contract value:	4 100,- EUR (total amount during 2016 - 2021)
Country of partner:	Czech Republic
Short annotation:	The purpose of the contract with the industrial partner Forschner CZ is non-destructive microtomographic testing of various electrical components from the company's production program, especially encapsulated coils for adaptive car chassis.

2.6.4. List of intangible fixed assets (internally registered IP (confidential know-how), patent applications, patents granted, trademarks registered) denoting background IPR

None

2.6.5. List of licences sold abroad and in Slovakia, incl. revenues (background IPR identification, name of institution, contract value, country of partner, purpose (max 20 words))

None

2.6.6. Summary of relevant activities, max. 300 words (describe the pipeline of valorization in terms of Number of disclosure, Number of registered IP internally, number of CCR/LIC contracts and their respective summary values, the support you are receiving in specific points internally at the institute, at SAS, externally – also the limitations and drawbacks.

None

2.7. Popularisation of Science (outreach activities)

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

1. Open door day at IMS SAS Bratislava - European Science and Technology Week program, Doc. Ing. Milan Tyšler, CSc. co-authors prof. Ing. Frollo, DrSc. Ing. Andris, PhD., RNDr. Hain, PhD., RNDr. Ing. Bartl, CSc. Mgr. Škrátek, PhD., Ing. Švehlíková, PhD. Mgr. Teplan, PhD., November 8, 2016. Excursion.
2. Sparkling Science: FEM_Pers Conference Bratislava 2016, Doc. RNDr. Viktor Witkovský, CSc. co-authors Prof. I. Frollo, Dr. J. Maňka, Dr. M. Teplan, September 22, 2016.
3. Fitting conics and quadric surfaces to correlated data. Public lecture held at IMS SAS on Januar 17, 2017, Eva Fišerová from Palacký University Olomouc, Czech Republic.
4. Scientists have discovered a cockroach with a helmet. Radio Slovensko, RNDr. Miroslav Hain, PhD., March 20, 2017. Radio broadcast.
5. Cortical encoding of the subjective experience of pain. Public lecture held at IMS SAS by Dr. Enrico Schulz, Department of Neurology, Ludwig-Maximilians-Universität München, Munich, Germany, June 21, 2018.
6. Anniversary of the establishment of the Institute of Measurement Science of the Slovak Academy of Sciences, Metrology and Testing, RNDr. Ing. Ján Bartl, CSc. January 31, 2018. Print.
7. Researchers' night at Stará tržnica, Bratislava, Doc. Ing. Milan Tyšler, CSc. co-authors Ing. M. Haška, Ing. J. Zelinka, September 28, 2018. Public lecture.
8. Near-exact distributions: Closer to exact distributions than common asymptotic distributions. Public lecture at IMS SAS by Carlos Coelho, Portugal, May 9, 2019.
9. Program RTVS 2 on Science and Technology (VaT). Robotic assistance system by Ing. Mgr. Roman Rosipal, PhD., October 26, 2019. TV broadcast.
10. New technologies in the treatment of the heart. SAVinci cycle of lectures. Westend plazza Bratislava Doc. Ing. Milan Tyšler, CSc. October 30, 2019. Public lecture.
11. Measurement sciences examine the operation of hearts and the safety of nuclear power plants, SAS news 1, Doc. RNDr. Viktor Witkovský, CSc. Print.
12. Tomographic methods and systems based on magnetic resonance, Prof. Ing. Ivan Frollo, DrSc. web IMS SAS, November 10, 2020. Internet.
13. Neurorehabilitation training using a mental concept of movement, Ing. Mgr. Roman Rosipal, PhD., web IMS SAS, November 10, 2020. Internet.
14. Laboratory for measuring the magnetic properties of materials, Mgr. Martin Škrátek, PhD. web IMS SAS, November 10, 2020. Internet
15. Modeling the electric field of the heart - The direct role of electrocardiography Ing. Jana Švehlíková, PhD. co-author Ing. Beáta Ondrušová, web IMS SAS, November 10, 2020. Internet
16. Measurement and analysis of the influence of electromagnetic fields on cells, Mgr. Michal Teplan, PhD., co-authors Hoang Vu Viet, Ivan Bajla, web IMS SAS, November 10, 2020. Internet.

17. The magic of chaos theory, RNDr. Anna Krakovská, CSc. magazine Téma, pages 22,23,24,25,26,27,28, November 26, 2021. Print.
18. Innovators and their non-traditional solutions, Mgr. Zuzana Rošťáková, PhD, https://www.rtvs.sk/clanky/271043, October 12, 2021. Radio broadcast.
19. ESET Science Award 2021 - Ing. Ladislav Valkovič, PhD. - Exceptional Slovak Young Scientists, https://www.rtvs.sk/televizia/archiv/18022/291922, October 16, 2021. TV broadcast.
20. Toxic fat is burned first. When a person loses weight, he exhales all the organs, says an expert in measuring metabolism, Ing. Ladislav Valkovič, PhD. November 21, 2021. Internet.

2.7.2. Table of outreach activities according to institute annual reports

Citations, reviews	2015		2016		2017		2018		2019		2020		total		
	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	averaged number per year	av. No. / FTE researchers
Citations in Web of Science Core Collection (1.1, 2.1)	585	17.86	596	19.52	703	22.46	745	25.07	784	24.98	912	28.90	**4,325**	**720.83**	**23.10**
Citations in SCOPUS (1.2, 2.2) if not listed above	64	1.95	65	2.13	72	2.30	101	3.40	139	4.43	181	5.74	**622**	**103.67**	**3.32**
Citations in other citation indexes and databases (not listed above) (3.2,4.2)	0	0.00	0	0.00	0	0.00	2	0.07	3	0.10	0	0.00	**5**	**0.83**	**0.03**
Other citations (not listed above) (3.1, 4.1)	15	0.46	81	2.65	72	2.30	99	3.33	93	2.96	134	4.25	**494**	**82.33**	**2.64**

2.8. Background and management. Infrastructure and human resources, incl. support and incentives for young researchers

2.8.1. Summary table of personnel

2.8.1.1. Professional qualification structure (as of 31 December 2021)

	Degree/rank				Research position		
	DrSc./DSc	CSc./PhD.	professor	docent/ assoc. prof.	I.	II.a.	II.b.
Male	1	26	4	5	5	17	5
Female	0	9	0	1	0	5	3

I. – director of research with a degree of Doctor of Science / DrSc.

II.a – Senior researcher

II.b – PhD holder/Postdoc

2.8.1.2. Age and gender structure of researchers (as of 31 December 2021)

Age structure of researchers	< 31		31-35		36-40		41-45		46-50		51-55		56-60		61-65		> 65	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Male	3.0	1.3	2.0	0.7	7.0	4.5	3.0	1.4	4.0	1.9	2.0	1.2	3.0	3.0	3.0	3.0	10.0	5.8
Female	3.0	2.2	1.0	0.2	1.0	1.0	1.0	1.0	0.0	0.0	1.0	0.4	3.0	3.0	0.0	0.0	0.0	0.0

A – number

B – FTE

2.8.2. Postdoctoral fellowships (list of positions with holder name, starting date, duration. Add brief information about each fellow's career path before and after receiving PhD degree, etc.)

2.8.2.1. MoRePro and SASPRO fellowships

None

2.8.2.2. Stefan Schwarz fellowships

Zuzana ROŠŤÁKOVÁ (from June 2019 to May 2021)

2.8.2.3. Postdoctoral positions from other resources (specify)

None

2.8.3. Important research infrastructure introduced during the evaluation period with the information about the sources of funding (max. 2 pages)

IMS SAS Research Infrastructure

To ensure its research activities and to solve research projects, the Institute has several laboratories with specialised technologies. Through the Institute's participation in consortia of SAS institutes within the solved projects of the Structural Funds, there are also other joint laboratories in the Institute. An overview of the laboratories is at https://www.um.sav.sk/en/research/research-infrastructure/.

The list of infrastructure introduced during the evaluation period:

1. **MR spectrometer SISCO**. In 2021, in cooperation with the University Hospital Bratislava, the Institute of Measurement Science SAS became the administrator of the SISCO NMR spectrometer. The aim of the cooperation is primarily the solution of joint research projects focused on the use of nuclear magnetic resonance using the SISCO NMR spectrometer. The in vivo NMR laboratory is equipped with the state-of-the-art hardware (4.7 T Agilent/Varian scanner, 400mT/m gradient insert, multiple dedicated RF coils) and protocols capable of performing various types of experiments. The laboratory is equipped with an animal monitoring system of vital functions (SA instruments).
2. **Laboratory for measuring the effects of low-frequency electromagnetic fields**. The laboratory, which is part of the Department of Theoretical Methods, has an original system for measuring the effects of low-frequency electromagnetic fields (EMP) on cellular systems. The incubation part consists of two thermoboxes with PID temperature control designed for a paired experiment. The part for generating EMP with selectable frequency and amplitude consists of an Owon XDS3102 signal generator, a Behringer NX3000D digital amplifier and Helmholz coils. The measurement section consists of an impedance spectroscopy station with a ScioSpec ISX-3v2 impedance analyser, a Kern OCL-2 inverted optical microscope and a Micronit impedance flux microchip. The impedance spectrometer has two measurement channels with ranges of 1 mΩ - 1 GΩ and 10 MHz - 10 MHz. With the

microchip it is possible to obtain the impedance characteristics of individual cells. Funding – VEGA projects.

3. **Microtomographic Laboratory**. In addition to standard service operations, we also had to reconfigure the reconstruction computer cluster after the failure of several PCs in the cluster. Funding – own Institute funds.
4. **SQUID system QD MPMS XL 7 AC – reparation of the serious failure**. Funding – VEGA and APVV projects.
5. **Reconstruction of the main building of the IMS SAS**. In 2017: the 4th floor (about 120 000 EUR). In 2018: the 2nd floor (about 96 000 EUR). All reconstructions were financed of Institute own reserve fund.

2.9. Supplementary information and/or comments on all items 2.1 – 2.8 (max. 2 pages in total for the whole section)

At the end of the 2016-2021 assessment period, the number of full-time equivalent (FTE) researchers at IMS SAS was 31.56. In 2021, these researchers published a total of 58 scientific articles in scientific journals registered in the Current Contents, WOS or SCOPUS databases. Of these, 36 are in peer-reviewed scientific journals registered in the databases CCC (Current Contents Connect), 32 in ADCA, 1 in ADCB and 3 in ADDA, and 22 articles in publications registered in WOS (Web of Science) and SCOPUS, of which 2 are in the ADMA category, 4 in the ADMB category and 16 in the ADNB category, according to the SAS publication classification.

37 of the total 58 scientific articles were published in journals with an average impact factor (IF) at the level of 4.6984, while 20 publications were included in the first quartile Q1 according to JCR (Journal Citation Reports of the Web of Science Group), of which 11 publications were included in the first decile D1. This number of quality publications represents the best result in the 2016-2021 assessment period and is well above the long-term average of IMS SAS. This result was achieved thanks to the Institute's long-term efforts to increase the quality of scientific outputs, as well as intensive project-related and non-project-related national and international cooperation, in line with the recommendations of the evaluation metapanel in 2017. In 2021, we recorded another significant increase in citations of publications in IMS SAS, with the total number of citations reaching 1240 (of which 925 WOS, 181 SCOPUS, 134 other databases).

During the assessment period 2016-2021, the qualification level of researchers was increased. For example, in 2021 alone, 6 staff members were classified in a higher qualification level, especially that of independent researcher (level IIa according to the SAS qualification system).

Since 2000, IMS SAS (in collaboration with SCIENDO / De Gryuter) has been the publisher of the journal Measurement Science Review, which has reached an impact factor of IF2020 of 1.319 in 2021 (while its further increase to IF2022: 1.980 is already known). MSR is a journal that deals with issues of measurement (Measurement Science), with a focus on measurement theory, measurement of physical quantities and measurement in biomedicine. Thematically, it covers the scientific fields of engineering, especially electrical and control engineering, metrology, measurement technology and testing.

IMS SAS regularly organises international scientific conferences MEASUREMENT in the field of measurement theory, measurement of physical quantities and measurement in biomedicine. From 17 to 19 May 2021, the Institute, in collaboration with its partners, have organised the 13th International Conference on Measurement - MEASUREMENT 2021.

IMS SAS researchers were involved in international scientific and professional activities, participated in the evaluation of domestic and foreign scientific projects, scientific qualification works, as well as in the peer review of scientific articles and book publications.

3. Implementation of the recommendations from the previous evaluation period

Recommendations from the last regular assessment of SAS organisations

Based on the decision of the Presidium of SAS No. 1212.C of 9 February 2017, the Institute of Measurement Science of the Slovak Academy of Sciences was included in the category with the characteristics: ***The research is visible at the European level. The organisation has made valuable contributions in this field within Europe (B).***

In its assessment of the organisation, the international evaluation *Meta-Panel* made recommendations for further improvement of the organisation. In addition to the general comments, which apply to all organisations to varying degrees, the following specific recommendations and comments were made:

- The strategic plan and resource allocation were better explained in the interview than is evident from the report provided. Further linking of this plan would allow a better understanding of the objectives of the cooperation with other national and regional resources, for example, in the cooperation with the Slovak Institute of Metrology.
- Cooperation with the Scientific Council of IMS SAS is mentioned with the aim of improving indicators and ensuring the systematic development of infrastructure and the development of external funding sources. It would be good if these objectives were explicit, quantifiable and timetabled.
- The international dimension should be strengthened in all respects (including funding, cooperation, PhD students).
- There are more opportunities for collaboration with external parties (industry, public sector, and academia) through joint PhDs or other new mechanisms.
- The funding of the Institute would benefit from more clarity in describing or naming the different research areas, e.g., biomedicine, structural integrity, etc.
- There is considerable scope for improving research outcomes through income from international projects in line with the organisation's mission.

Organisation’s response to the comments and recommendations of the Meta-Panel and the International Advisory Committee of the Slovak Academy of Sciences (IAC SAS) on the strategic development and further improvement of the SAS oganisations

In an effort to take into account the above recommendations of the Meta-Panel as well as the general suggestions of IAC SAS to set clear strategic goals and procedures for further development, the Institute has adopted a specific and detailed action plan for the development of IMS SAS for the period 2017-2022 and established the International Advisory Board of IMS SAS (IAB IMS SAS), which is composed of high-level international experts and covers the scientific priorities of the Institute.

In line with the recommendations of IAC SAS, the strategic objectives of IMS SAS have been set as an extension of the general concept of contributing to the building of a knowledge-based society, with a focus on other important objectives. Interdisciplinarity, inclusivity and internationalisation are central and strategic concepts of IMS SAS, as is the goal of being a recognised international player and an integrated part of the global system in the field of measurement science.

In accordance with the objectives of the Strategy for Research and Innovation for Smart Specialisation of the Slovak Republic (RIS3), research at the IMS SAS focuses on:

- Mathematical modelling of measurement objects, research into statistical methods for determining measurement uncertainties and minimising them, and their application in research and social practise,
- Methods of non-destructive testing based on optoelectronic, tomographic and microtomographic methods, especially in materials research, mechanical engineering

and electrical engineering, with a focus on 3D visualisation of internal structures, measurement of internal dimensions of 3D objects and identification of internal defects in cases where conventional methods lead to the destruction or damage of measurement objects,

- Advanced and highly sensitive magnetometric methods for exploring the properties of new substances and new materials, leading to an understanding of the structural physical and chemical properties of the measured objects, with the possibility of application in materials research, biology and medicine,
- Measurements in biology and medicine aimed at the use of advanced and multi-channel electrical and magnetic measurements in combination with tomographic methods based on magnetic resonance (using hydrogen, phosphorus or sodium nuclei) for non-invasive and functional diagnostics of the heart and brain, therapy management and controlled drug delivery.

During the assessment period, the Institute's interdisciplinary research potential and capabilities significantly strengthened its collaboration with national and international partner institutions. The Institute expanded its traditional cooperation with the research, business and public sectors, e.g., with the nuclear power plants Slovenské elektrárne, Mochovce and Jaslovské Bohunice and DATALAN. During the assessment period, the Institute actively sought new opportunities for cooperation in the form of joint scientific research agreements with the economic, health and social sectors. Cooperation was strengthened with partner organisations of SAS (e.g. Institute of Electrical Engineering SAS, Institute of Materials and Machine Mechanics SAS, Institute of Normal and Pathological Physiology of the Centre for Experimental Medicine SAS, Mathematical Institute SAS), with universities and colleges (Faculty of Mathematics, Physics and Informatics Comenius University in Bratislava, Faculty of Electrical Engineering and Faculty of Mechanical Engineering of the Slovak University of Technology in Bratislava, University of Zilina and Jozef Safarik University in Kosice), but also with foreign universities, such as, University of Oxford, Ludwig Maximilian University of Munich, Germany, and the University of Montenegro, etc., with other domestic and foreign partners and companies (OAA Computing Ltd, Oxfordshire, United Kingdom, Slovak Institute of Metrology, Slovak Society of Metrology, Slovak Legal Metrology, European Metrology Network - MATHMET, and also with the private sector such as EuroPain Clinics and Advantest).

In the area of research outputs, specific measures have been taken and applied to improve the quality of publications. The updated principles for the evaluation of publications and other outputs from individuals and research teams were applied in line with the action plan and other applicable performance funding principles. In 2021, we succeeded in increasing the quantity and quality of scientific publications as well as citation rates to the highest level in the entire accreditation period 2016-2021.

The Institute has taken significant steps to improve the quality of doctoral studies. As part of the legislative changes in 2020, the Institute has developed an internal quality assessment system that defines the conditions under which the Institute may offer a study programme and determines the criteria for the guarantor of the study programme, the supervisors and the members of the programme committees. It also defines the study programme and the criteria that a successful graduate must meet. These criteria must not be less stringent than those of the cooperating university.

In order to attract more students, since 2020 all study topics are published not only on the Institute's and SAS's website, but also on the EURAXESS website. At the same time, presentations or videos on individual topics are also published. In addition to Slovak students, these activities have also led to the admission of students from Iran and Vietnam.

The Institute has long struggled with the problem of disinterest or low interest among local students in pursuing doctoral studies in Measurement Technology and Applied Mathematics. In the field of technical sciences, jobs in industry or at research institutes abroad are more attractive to capable young people, offering them comparatively much better financial security. We consider it a big problem that a large part of young talents wants to study at

foreign universities and work abroad in the long term. The recruitment of Slovak students from abroad as well as other foreign doctoral students is inefficient despite the special programmes for their recruitment. Recruitment of doctoral students from outside the EU is not a sufficient and sustainable substitute. The Institute develops and supports SAS activities to acquire, maintain and improve conditions for young researchers. We create the conditions for active recruitment of doctoral students in order to arouse the interest of engineering graduates (support of temporary activities of high school and university students, active cooperation with universities to conduct bachelor's and master's theses, admission of university graduates for a certain period of time before starting doctoral studies, active involvement of doctoral students in international scientific cooperation), as well as raising the requirements for the level of admitted students.

The Institute develops and supports activities to obtain, maintain and improve conditions, especially for young researchers. Support was given to part-time work for students, active cooperation with universities in the supervision of bachelor's and master's theses, admission of graduates for a certain period before admission to doctoral studies, and active participation of doctoral students in international scientific cooperation.

During the 2016 - 2021 assessment period, the qualification level of young researchers has increased. In 2021 alone, 6 staff members (postdocs at the beginning of their scientific careers) were admitted to a higher qualification level, in particular to the level of “independent researcher IIa” (according to the SAS qualification system).

The Institute strives for sustainable development and expansion of the research infrastructure. However, due to the unpredictability of possible funding streams, it has not been possible to establish a formal long-term plan for infrastructure development. Information on the possibilities and conditions for using the Institute's research infrastructure is published on the Institute's website. In 2021, a cooperation was agreed with the University Hospital Bratislava for the supervising of the spectrometer SISCO NMR to provide a comprehensive solution and efficient use of the advanced infrastructure. The aim of the cooperation is primarily the solution of joint research projects that focus on the use of nuclear magnetic resonance.

Strengthening cooperation with domestic and foreign partners is an appropriate strategy for obtaining opportunities to use advanced measurement technology. IMS SAS has very good experience in scientific cooperation with major foreign universities and leading scientific institutes in the field of biomedical research.

In 2021, the Institute managed to participate in two important international projects. NATO SPS G5825 project "Smart patch for life support systems" and JRP SAV-TUBITAK project "Performance evaluation of noninvasive electrocardiographic imaging for the localization of premature ventricular contraction from clinical data". In addition, we have succeeded in acquiring and coordinating a new ERA -NET CHIST project ERA IV in 2021: ReHaB - "Towards an ecologically valid symbiosis of BCI and head-mounted VR displays: Focus on collaborative post-stroke neurorehabilitation", which started in early 2022.

4. Research strategy and future development of the institute for the next five years (Recommended 3 pages, max. 5 pages)

Research strategy of the institute in the national and international contexts, objectives, and methods (including the information on when the strategy was adopted)

The role of measurement, mathematical modelling, statistical and computational methods in measurement science and metrology is more important than ever and has significant implications for international scientific and industrial cooperation. This topic fits well with the objectives of the Slovak Strategy for Research and Development - Research and Innovation Strategy for Smart Specialisation of the Slovak Republic (SK RIS3).

The research strategy for the next five years of IMS SAS focuses on measurement science in the national and international context with special attention and great emphasis on specific problems of biomeasurement and applications in biomedicine and healthcare. In this respect, interdisciplinarity, inclusivity and internationalisation are the central and strategic concepts of IMS SAS.

Department of Optoelectronic Measuring Methods

The scientific goal for the next five years in the field of optoelectronic measurement methods is the development of advanced physical measurement methods and non-destructive testing, namely X-ray microtomography (microCT) and physical-optical methods for the complex testing of cultural objects, namely active infrared thermography, infrared reflectography, X-ray radiography and ultraviolet light induced fluorescence. The focus is on the development of new measurement methods, theoretical analysis and the solution of specific problems arising from the application of these methods in specific areas of research, society and industry. It is planned to address and further develop these specific problems in the field of microCT:

- Proposing new methods for calibrating microCT devices for measuring micro dimensions and porosity of materials,
- Analysis and elimination of artefacts in microCT measurement and reconstruction to improve measurement uncertainty in precise measurement tasks in the mechanical engineering industry,
- Proposing and implementing new standards for the calibration of microCT measurements.
- We attach great importance to linking our research results directly to other fields in science, society and industry, e.g. materials research, microelectronics, palaeontology, biology, geology, mechanical and electrical engineering, forensics and cultural heritage preservation.

Department of Magnetometry

Highly sensitive SQUID magnetometry is an important tool for studying many current processes in medicine, biology and materials research, namely those associated with the movement of electric charges or changes in their spatial distribution. In the future, we plan to focus the development of SQUID magnetometry on the study of interactions between ionic liquids (ILs) and bio-objects such as metal proteins, amino acids or nucleic acids, focusing on the effects of ILs on iron-containing proteins; haemoglobin (Hb), myoglobin (Mg), ferritin and transferrin.

The enzymatic and antioxidant functions of haem proteins, Hb and Mg are well known. Hb has the ability to bind many molecules, including various drugs. However, the role of the binding forces is not well understood. The same is true for the process of protein folding and unfolding. ILs have shown great potential in studying these processes and identifying regulatory mechanisms. Their knowledge opens the way for drug development. In the pharmaceutical industry, ILs can help solve the problems of drug solubility, stability and toxicity. ILs have proven their great value as new therapeutic agents. It is predicted that IL based drug delivery will open new horizons for solving poorly water soluble drugs in the future. The development of the pharmaceutical application of ILs requires an understanding of the relationships between structure and application properties in ILs and an understanding of the IL effects on protein structure and function. The previously mentioned comments point to the similarity between the

inherent nano-ordered structures in ILs and proteins and the role of structural binding forces, including electrostatic interactions.

ILs are solvents that can potentially be used to control the properties of nucleic acids. DNA has been reported to be stable in hydrated ILs over long periods of time. Other applications of IL include nucleic acid research, DNA and RNA handling and storage, nucleic acid extraction and detection of mismatched base pairs, and gene therapy.

Research into ILs also brings new interesting applications in other fields:

- Development of measurement methods and equipment for chemical analysis. ILs are used in gas and liquid chromatography, UV, IR, Raman and fluorescence spectroscopy, NMR and mass spectrometry. IL -based microextraction in combination with gas chromatography and mass spectrometry has been proposed for the determination of cancer biomarkers in urea samples.
- An alternative liquid medium for the incorporation of functional DNA molecules in the development of smart DNA-based nanodevices.
- Solvents for environmentally friendly recycling of waste biomass.
- Antimicrobial and cytotoxic agents for drug delivery or synthesis.

Polymerised ILs can be used as polymer electrolytes, polyelectrolyte membranes for fuel cells, quasi-solid electrolytes for solar cells, batteries, electrochemical supercapacitors, organic transistors and storage devices, light-responsive materials, solvent-responsive objects, oxide-responsive gels, carbon dioxide, carbon dioxide adsorbents and antimicrobial materials. SQUID magnetometry uses the changes in temperature and magnetic field to study the internal processes associated with electrical charges. Thus, magnetometry can be an important complementary method to study new substances and new forms of biomaterials and ILs interference effects.

Department of Theoretical Methods

Mathematical methods for measurement and metrology: The aim is to develop mathematical and statistical methods and algorithms for the evaluation of measurement results with a focus on technical and biomedical applications, multivariate calibration of measuring instruments and determination of measurement uncertainties. The focus is on: - Theoretical research on mathematical and statistical models and methods for multivariate calibration; - Development of calibration theory of sensors and transducers, - Development of methods and algorithms for determining the exact or approximate probability distribution of measurement results by combining and inverting the characteristic functions (Characteristic Function Approach - CFA). Special emphasis is placed on stochastic methods for combining information from different independent sources, on modelling dependence and causality in dynamic processes, on exact methods for determining the probability distribution of values that can be reasonably assigned to the measured quantity based on a combination of measurement results and expert knowledge.

EEG research: There is growing evidence that integrated technologies of brain-computer interfaces (BCI) and virtual reality environments (VR) provide a flexible platform for a range of neurorehabilitation therapies, including significant motor recovery after stroke and cognitive-behavioural therapy. When immersed in such an environment, the subject's perceptual level of social interaction is often impaired because the quality of the interface is not optimal and the social aspect of human interaction is missing. In the near future, we aim to develop a user-friendly, wearable, intelligent BCI system with low power consumption and an ecologically valid environment (VR) in which both the patient and the therapist interact via their person-specific avatar representations. The patient voluntarily and autonomously controls his or her activities in the environment and interacts with the therapist via a BCI-driven mental imagery process. On the other hand, the therapist can fully control the environment due to his unrestricted motor and communicative abilities. In this way, the environment VR can be flexibly changed by the therapist so that different scenarios for occupational therapy can be created and selected according to the patient's recovery needs, mental state and instantaneous responses.

Causality research: Processing and analysis of measured data belongs to main issues addressed at our institute. One of the directions we want to focus on is the causality research. At the national and international levels, we have brought together a community of theorists

developing causal methods and neuroscience-oriented experts to record, preprocess and simulate the EEG signal in a joint effort to develop a universally valid causal analysis method that can be provided to researchers for use in a wide range of neuroscience. We are convinced that only now the causality research is reaching a stage that allows for the ambitious addressing of effective connectivity (meaning directed interactions, not structural or correlation-based functional connectivity) in the brain. We will also extend the detection of causality to multivariate cases - dynamic networks with nodes characterized by time series. Such complex networks are common in the real world. Brain activity, determined by multichannel electroencephalographic signals, is a crucial example. Although the main future applications mainly include better understanding of the effective connectivity differences between healthy and schizophrenic brains, and during selected cognitive experiments and motor neurorehabilitation training of post-stroke patients, our long term goal is improved detection of causality that would become a powerful classification tool for generic data sets.

Research about the effects of EMF on living structures: Although interest in the harmful and beneficial biological effects of electromagnetic fields (EMF) continues unabated, a clear explanation of the influence of electromagnetic fields on living structures is still lacking. Our aim is to experimentally investigate the influence of low frequency electromagnetic fields by using the developed experimental platform based on monitoring cell growth by impedance spectroscopy and studying the distribution of inhibition and stimulation effects in the space of frequency and magnetic flux. Advanced image processing methods suitable for TIRF microscopy images will be developed to quantify the direct effects of pulsed electric fields on microtubules and to assess the movement of kinesin molecules. The relevance of this research area lies in the exploration of physical methods with potential contributions to diagnostics and therapy.

Department of Imaging Methods

Magnetic resonance imaging methods in the study of the properties of magnetic nanoparticles for imaging purposes in biomedical diagnostics.The research will focus on experimental and theoretical research in magnetic resonance imaging (MRI) methods. The following topics will be addressed in the research:

- Research of the properties of magnetic nanoparticles in external magnetic fields with a view to establishing a theoretical model and its subsequent experimental verification.
- Analysis of the effects of MRI scanning on the cardiovascular system of the person tested, in order to find appropriate methods for detecting, quantifying and developing measures to minimise them.
- Analysis of metabolic processes to map the rate of energy production in the human heart and muscles and diagnose slowing of energy production in the heart.
- Automated processing of MR images of the human knee to obtain quantitative features and morphological sizes of individual tissues.
- Calibration of gradient fields to ensure undistorted morphology in measured MR images. Mapping of inhomogeneities in magnetic fields with MRI methods.

The aim of the proposed research is to carry out basic experimental and theoretical research in the field of nuclear magnetic resonance (MRI) imaging techniques, focusing on the following:

- Effect of the properties of magnetic nanoparticles on the Brown and Néel rotation process in external magnetic fields; establishment of a theoretical model and its subsequent experimental verification by observing the effects of such particles on the macroscopic quantities (magnetisation and relaxation) of the sample.
- Mapping the physiological and psychological effects of MRI tomography on the subject under study in order to find appropriate measures to minimise them. Analysis and monitoring of human cardiovascular parameters using portable optical sensors operating on the principle of photopletysmography (PPG). Processing and evaluation of PPG signal parameters to detect and quantify stress effects that occur.
- Development of techniques to map metabolic processes to determine the rate of energy production in the human heart and muscles. Diagnosis of the slowing of the heart's energy production in heart disease, at rest and under stress.
- Design of automatic processing of MR images of the human knee, the result of which will be quantitative features and morphological sizes of individual tissues, especially cartilage.

Development and clinical testing of automatic software for segmentation of human knee cartilage. Co-registration of the segmented high resolution 3-dimensional morphological MR images with the quantitative T2 and T2* MR images and the sodium MR images. Application of the proposed image processing pipeline in clinical trials focusing on osteoarthritis patients, especially in post-drug follow-up.

- Verification of correct calibration of gradient fields to ensure undistorted morphology in the measured MR images. Exploration of measurement methods suitable for a static magnetic field and its inhomogeneities, using MRI methods. The experimental part of the research is performed on our own equipment with magnetic induction of 0.1 T, 0.2 T and 4.7 T and with MRI scanners of 3 T and 7 T in cooperating institutions.
- For continuous long-term measurement of PPG signals, experimental prototypes of sensors with real-time wireless data transmission are being developed, which function in the magnetic field environment of MRI devices.

Department of Biomeasurements

Modern biomedical measurements and investigations in the field of cardiovascular research consist of a combination of different measurement and imaging techniques to obtain new information about the condition of the heart. At IMS SAS, we focus on so-called electrocardiographic imaging, which aims to gain non-invasive insights into the local functionality of the heart muscle. This includes ECG measurements with multiple leads on the body surface and a CT scan of the body, which provides information about the position of the heart and other organs that influence the potentials on the body surface. In addition to the measurements, ECGI also uses heart modelling and simulations to describe the problem mathematically. We collaborate with the National Institute of Cardiovascular Diseases in Bratislava, Department of Arrhythmia Arrhythmias and Pacemakers, the leading hospital in Slovakia. We are working on preoperative assessment of localisation of unwanted premature ventricular activity leading to dangerous ventricular tachycardia (increase in heart rhythm). Recently, we have started a research on the evaluation of cardiac resynchronisation therapy in patients with heart failure. The issue of cardiovascular treatment is always topical and leads to an increase in the life expectancy of individuals.

Regarding the measurement of body surface ECG potential, we plan to continue the cooperation with the Institute of Cardiovascular Diseases in Bratislava and try to transfer the new findings into clinical practise. We will also stay in contact with the international Consortium for Electrocardiographic Imaging, where we are actively involved in signal processing and the creation of heart models. We plan to learn the new methods of electrocardiographic imaging based on clinical data within the framework of our mentioned international collaboration and the ongoing bilateral Slovak-Turkish project. For a more comfortable measurement procedure, we have started with a new wireless design and further development of our in-house ProCardio multiple-leads ECG measurement system.

Bratislava, 30 June 2022.

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