ACADEMY OF FINLAND

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RADDESS

Radiation Detectors for Health, Safety and Security (RADDESS)

Academy Programme 2018–2021

Programme memorandum

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1 Background

Radiation Detectors for Health, Safety and Security (RADDESS) is an Academy Programme aimed at developing electromagnetic and particle radiation detection technologies for health, safety and security applications.

RADDESS will be seeking groundbreaking initiatives for the development of new radiation detection technologies that facilitate the measurement of specific properties, parameters or new phenomena in organisms, materials or processes that have a medical, safety, security or industrial context. The programme will also accommodate research into measurement methods based on existing detection technologies, as well as work aimed at significantly improving current measurement methods. *Particle detector* refers here to the detection of particle radiation, which means the focus is restricted to subatomic particles such as alpha, beta and neutron particles. Radiation detectors measure electromagnetic radiation over a wide wavelength or frequency range. Projects addressing the biological and health effects of radiation can also be accommodated in the Academy Programme if they contribute to the development of new methods of radiation detection.

The development of new methods of measurement and alternative imaging methods is an exercise in multidisciplinary basic research that integrates detection technology, materials science, electronics, photonics, physics, mathematics, signal processing, data collection systems, data analysis and system design. The object being measured is often a new challenge that cannot be resolved by using existing tools and equipment. Projects under the Academy Programme will work to create device-driven functional systems that can handle the challenges presented by the objects of measurement. The programme supports the renewal of Finnish science both via the development of new measurement devices and via the identification of new objects of study.

Finland produces international-standard research into particle- or radiation-detection-based measurement methods at RF (radio frequency) and higher frequencies – radio and microwave technology, millimetre wave technology, terahertz range research – as well as in the infrared range, photonics, and in particle and nuclear physics. In addition to ICT applications, radio and microwave radiation detectors are in use in various industrial applications, for instance for the non-invasive measurement of material parameters in the paper and wood product industry. In the millimetre wave range, one important field of research is radar applications, such as the 79 GHz radar used in cars. In the THz range, measurement methods based on radiation detectors have been developed among other things for airport security checks to detect potentially dangerous items hidden under clothing. The THz range also has applicability in pharmacology and can be used in the detection of skin cancer, for instance.

Smart automation, autonomous machines and communication between IoT devices are based on information collected by detectors, which requires more extensive and more accurate real-time monitoring of the environment than before.

RADDESS creates a new kind of multidisciplinary platform for research cooperation. Collaboration between RF and microwave technology and photonics research via the common background of electromagnetic field theory will provide valuable new networking opportunities for research teams that otherwise have limited contact. The integration of different measurement methods will also create interesting new synergies and open up new opportunities. The programme will pave the way for groundbreaking scientific innovations and for start-up businesses especially in the field of terahertz technology and photonics. In photonics, reduced instrumentation costs and hyperspectral technology, for instance, can open up whole new research areas and business opportunities based on measurement techniques. In basic physics research, the development of completely new detectors holds the potential of far-reaching scientific breakthroughs.

Detection technology is a strong growth business in Finland. New companies are being formed, and existing companies are investing in product development. RADDESS will help boost Finnish competitiveness in this sector by strengthening the knowledge and skills base for future needs. There is a particularly strong need for industrial materials testing and monitoring in the process and metal industry as well as in mining and the nuclear industry. Another reason why the Academy Programme has such currency is that the development of new measurement technologies can help address and prevent new security threats such as terrorism. Population ageing and major healthcare reforms are also generating growing demand for diagnostic tools, other new health technology methods and new radiation detectors. The programme will support the growth of Finnish health technology.

2 Objectives

RADDESS will strengthen basic research in radiation detection technologies and facilitate the development of new device-driven and functional radiation detection systems. The programme will deepen dialogue and interaction between basic research and industry. At the same time, it will create mechanisms for the rapid and efficient take-up of new information. The programme supports doctoral training and subsequent research careers in the field, promotes international networking among researchers and advances national multidisciplinary cooperation.

The programme’s main objectives are to

- generate new and innovative scientific knowledge about new radiation detection technologies and their applications especially in the health, safety and security fields
- steer research towards the development of device-driven and functional radiation detection systems in areas of application that are significant for the future
- develop knowledge and expertise in basic research so that physical phenomena can be better understood and used in developing more sensitive and more accurate radiation detectors.

Further objectives are to

- facilitate the creation of new multidisciplinary research teams and national and international collaboration networks
- promote the mobility of researchers and doctoral candidates
- improve the international competitiveness of research and industry
- create societal impact.

All projects should embrace open science in order to promote the renewal of science.

3 Research themes

The programme's main focus is on basic research in radiation detection technologies, with the aim of creating new functional radiation detection systems for health, safety and security applications. It will seek to open up new lines of research and to generate innovations that have application in spectroscopy or imaging, for instance, again with health, safety and security foremost in mind. The breakthrough pursued may consist of a completely new use or application of a detector or a range of different kinds of detectors. *Detector* is used here in a broad sense. The programme comprises both ionising and non-ionising radiation (the complete spectrum of electromagnetic radiation). There are three main research themes:

- alternative imaging methods
- safety and security technology
- fundamental physics of radiation detectors.

3.1 Alternative imaging methods

The future of healthcare imaging applications is personalised. Medicine is increasingly moving towards personalised measurements and the personalised application of measurement results to individual patients. Personal exposure assessments are needed during and after medical procedures. This will require effective methods of radiation detection and exposure assessment and the effective application of knowledge. Access to online measurement data and patient exposure is essential. It is also necessary to determine levels of radiation exposure in relation to each individual patient's physiology. Research is needed in this field to develop appropriate methods of measurement, data collection and computational data processing.

The aim in medical imaging is to optimise patient radiation exposure and image quality by using improved image detectors. Industrial imaging applications have corresponding requirements for optimising image quality and for minimising the exposure of personnel working close to radiation sources. The aim is to convert radiation into a useful image signal as directly as possible, without intermediate stages, making maximum use of the radiation quantums. Finland has globally successful companies in the healthcare device sector. Research and development efforts around detectors will bolster the competitiveness of these companies, produce new competencies and generate new business with international potential.

Improved targeting of radiation therapy is important for preventing the harmful effects of radiation on healthy tissue surrounding the targeted site. Treatments are getting better and recovering patients can look forward to more healthy years than before. It is crucial that every possible step is taken to ensure the safety of treatments using new radiation therapy techniques. This requires measurement methods and detectors that can reliably monitor and measure the dynamic and highly anisotropic radiation fields and ascertain that the treatment is properly targeted. The fast and reliable measurement of 3D dose distributions is also essential. The next phase in development will see magnetic resonance imaging control integrated into radiation therapy devices. Dosage measurement requires ionising radiation detectors that perform reliably in very strong magnetic fields and with MeV energy photons.

In the wavelengths of light visible to the spectrum of non-ionising radiation, hyperspectral imaging opens up potential applications in many areas, including biomedical imaging, the control and security sector, agriculture, the food industry and geoscience. A key advantage of these methods is their non-invasiveness: they can yield more information about the imaged object without any physical contact. Traditional photography-based imaging is also entering a whole new era with the development of new detector solutions and advances in data processing and data storage capacity. Computational imaging has made it possible to record data about the direction and distance of light propagation and so to gain a complete 3D representation of the imaged object. The use of terahertz range waves in medical imaging is a new, evolving area of research. THz waves are used for imaging visible body parts such as the skin and teeth.

3.2 Safety and security technology

In the field of safety and security technology, the focus is to tackle global research challenges in areas of societal importance. The programme's research themes in this field include the detection of ionising radiation, new kinds of spectroscopic methods and the exploitation of the THz range. International terrorism is also a global threat. Sources of radiation and nuclear material may fall into the hands of criminals. It is paramount that this can be effectively prevented, throughout the world. Techniques of radiation source detection and related communication and service systems are important areas of research and development. There is also potential for export industry in this field.

Trade in recycled metals has grown into a global business. Recycled metals can contain unknown or unreported radioactive sources from industry, research or medicine that are a potential health hazard for personnel and the population, or that may render the end product unusable. Research and development efforts are needed in this field to produce more sensitive measurement devices and systems that enable rapid analysis, that can detect radiation sources and ascertain the purity of products.

A new nuclear power plant is nearing completion in Finland and planning for the next one is well underway. The new European radiation protection directive requires that closer attention be paid to natural radioactive materials as well as their safety implications in industries processing these materials. Any radioactive emissions from industry must be minimised. High levels of ground radon concentration in Finland present a national challenge. Research and development around the measurement systems needed for the detection of radioactive materials establishes a solid basis for developing the surveillance of environmental radiation and for the creation of measurement systems based on measurement strategies.

Spectroscopy has gained renewed impetus from new and increasingly accurate detector solutions. Photoacoustic spectroscopy, for instance, allows for the reliable measurement of ever smaller concentrations. Technology based on microelectromechanical systems (MEMS) has radically reduced the size of spectrometers or material radars and paved the way to mass production, helping to reduce prices and so bring them within the reach of consumers. The use of laser or other similar treatments makes it possible to reach hard-to-access measurement objects and to gain more accurate, even real-time measurements. Apart from various plasma-based spectroscopies, another broad and interesting research area is Raman spectroscopy, including surface-enhanced Raman spectroscopy (SERS). There are important safety applications in the areas of food production and analysis, the measurement of intoxicating and harmful substances and in disease diagnosis, for example.

The use of THz waves in industrial and in safety and security applications can bring great advantages compared with using other parts of the electromagnetic spectrum (e.g. determining the authenticity of works of art, testing the purity of foods and medicines, detecting stowaways in heavy goods vehicles, and security checks at airports, schools, conference centres and other public facilities used by large numbers of people). However, much scientific R&D is still needed especially to develop sensitive enough detectors before these and many other new applications that are bound to follow can be successfully commercialised.

3.3 Fundamental physics of radiation detectors

The Academy Programme’s third theme, the fundamental physics of radiation detectors, is focused on developing new measurement methods from the starting point of fundamental physics phenomena. The aim is to demonstrate a prototype on the basis of a new innovation. In the field of photonics, wavelength and light intensity knowledge has expanded to the coherence and polarisation of electromagnetic radiation and light pulse duration, all made possible by more advanced lasers and other light sources. Important advances have also been made through the integration of different types of observations. The key is being able to make observations of significant phenomena that have not been observable before, or to consolidate previously weak observations.

Interest in THz range detectors is above all based on the vibrational energy states of many molecules, which can only change if the molecule absorbs or emits an energy quantum at THz frequency. For the time being, scientific research applications of THz technology have been in the fields of radioastronomy, atmospheric remote sensing and spectroscopy. Components development in the THz spectrum is opening up much wider potential for applications, but there still remain major challenges in detector technology.

Particle radiation and high-energy photon radiation are most typically observed with semiconductor detectors, gas detectors, scintillation counters, calorimeters and shock detectors (Cherenkov radiation, transition radiation). Detector systems have been developed for basic research purposes in particle and nuclear physics, which in turn have led to medical and industrial applications, for example. The latest trend is the integration of different measurement methods in order to obtain a more multidimensional measurement. Examples include imaging calorimeters that combine semiconductor detectors with calorimeters in order to obtain spatial data about particle interactions in material in addition to energy measurements, or gaseous scintillation counters in which infrared light can be detected by virtue of new semiconductor-based light-sensitive components.

4 Programme implementation

The Academy Programme is aimed promoting the renewal of science. It encourages multidisciplinary and interdisciplinary exchange and cooperation. Three Academy research councils have been involved in preparing the programme: Biosciences and Environment, Natural Sciences and Engineering, and Health.

4.1 Funding

RADDESS is an Academy Programme funded and coordinated by the Academy of Finland. The Academy Board has set the programme's funding budget at 10 million euros.

4.2 National cooperation

RADDESS will involve cooperation especially with the Academy Programme *Mineral Resources and Material Substitution* (MISU) and with the Strategic Research Council's (SRC) programme *Security in a Networked World*. The programme will also involve collaboration with Tekes' programme *Bits of Health* (2014–2018). Where possible, the programme will seek to collaborate with foundations.

4.3 International cooperation

The programme selectively aims to establish cooperation with foreign research funding agencies that are committed to supporting leading-edge scientific research in the field and that are recognised and beneficial partners for Finnish research. Another aim, where possible, is to collaborate with corresponding and relevant international programmes and projects as well as with leading foreign research organisations in the field.

4.4 Schedule

Within the programme, funding will be provided to individual projects and consortium projects for a maximum of four years. The funding period starts on 1 January 2018 and ends no later than on 31 December 2021. For more information on the call and review schedules, see Chapter 5 (Application guidelines and review criteria). The programme's kick-off seminar will be arranged in early spring 2018. The Academy will separately announce the funding partners, themes, schedules and application processes of any additional calls to be launched within the programme.

4.5 Steering group and coordination

The programme is run by a steering group composed of members of the Academy's research councils and other expert members. The programme strives to support and promote the development of the selected projects into a coherent and cohesive structure through active cooperation and exchange of information. The programme managers and the project officer are in charge of programme coordination. They work closely with the steering group and the programme's projects to facilitate the attainment of the objectives set for the programme.

The PIs of the projects are required to

- assume responsibility for and report on the scientific progress of the project and on the use of the funds in accordance with the instructions of the programme manager and relevant funding bodies
- see to that the whole research team attends all meetings, seminars and workshops organised by the programme coordination, and facilitate cooperation and exchange of information between the research teams within the programme
- take part in producing reviews, syntheses and information material around the programme, and actively disseminate information about the programme's progress and results on public and scientific forums.

During the course of the programme, the research projects will participate in events arranged together with end-users of research results and in any other activities designed to disseminate information to stakeholders.

4.6 Final evaluation

The implementation and results of the programme will be evaluated upon its completion. The implementation of the evaluation will be planned in detail as the programme progresses, but the evaluation will consider, for instance, the following issues:

- attainment of programme objectives
- programme implementation
- evidence of impacts pursued by the programme
- national and international cooperation.

5 Application guidelines and review criteria

The RADDESS Academy Programme has a two-stage call. At the first stage, applicants submit letters of intent including short plans of intent (see guidelines in the Academy's April 2017 call for applications). The non-negotiable deadline for letters of intent is 26 April 2017 at 16.15 local Finnish time. The steering group will make a proposal to the programme subcommittee appointed by the Academy Board on projects that would best match the programme objectives on the basis of the letters of intent. Genuine cooperation with the business sectors will affect the review of societal impact positively. The projects selected to proceed to the second stage (to submit full applications) will be notified of the programme committee's decision in June 2017.

Applicants requested to submit full applications must prepare a complete research plan and submit it in the Academy's online services by 4 September 2017 at 16.15 local Finnish time. The deadline is non-negotiable. See the guidelines for full applications in the Academy's April 2017 call for applications. The cost estimate must be realistic and justified by type of expenditure in the research plan.

On the basis of the scientific review of the applications and considering the programme's objectives, the steering group will prepare a proposal to the programme subcommittee on the projects to be funded. The subcommittee will make the funding decisions in November 2017. Any additional supplementary calls will be carried out under a separately agreed schedule.

The letters intent will be reviewed by a panel consisting of steering group members and possibly other experts. The full applications will be peer-reviewed by an international expert panel.

The review of applications will be carried out in line with the general review criteria for Academy Programmes (see Guides for reviewers on our website). Besides the general review criteria, focus will also be placed on the objectives specific to the programme, as described in Chapter 2 of this memorandum. This aspect will be considered on the review form under section “Relevance of the project to the Academy Programme”.

6 More information

This programme memorandum is available as a PDF download at www.aka.fi/raddess > EN.

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