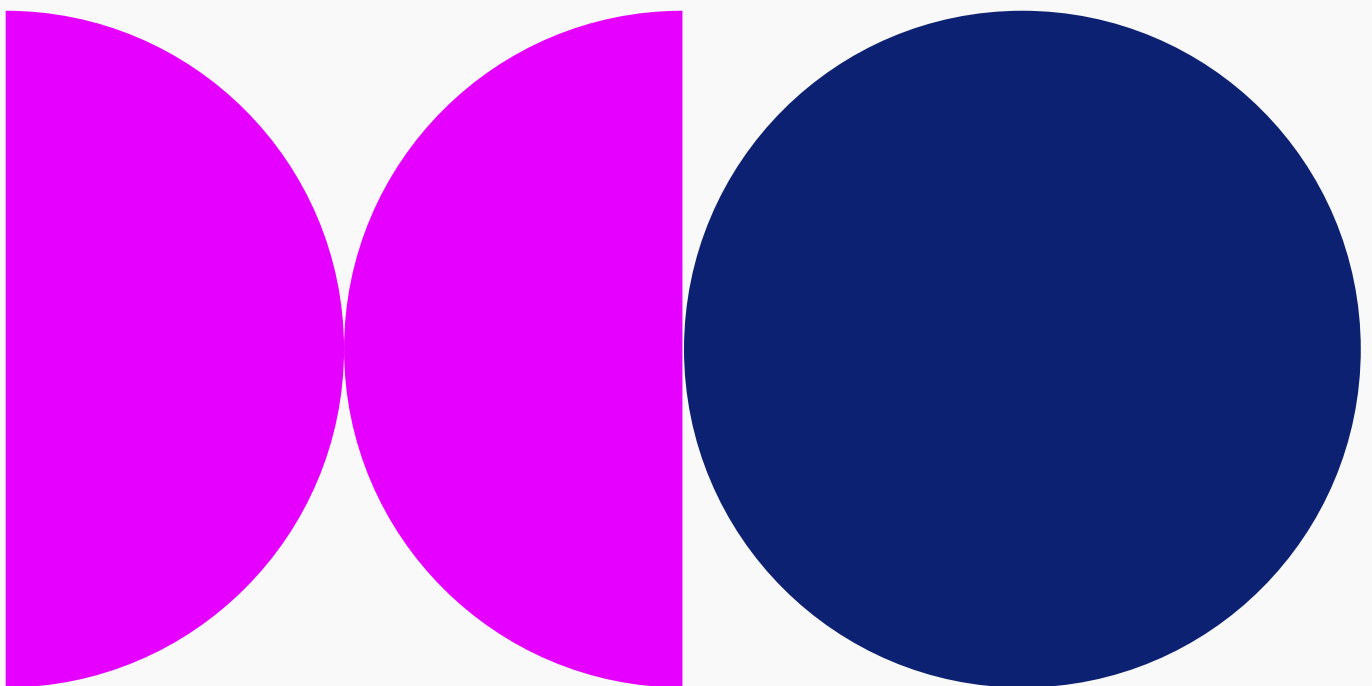


Appendices to research review 2023

Natural and engineering sciences



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1 Research infrastructures

1.1 Inventory of research infrastructures

Many Swedish scientists in the fields of natural and engineering sciences have, for several decades, and to an ever greater extent, been using a variety of research infrastructures. Such infrastructures come in many different forms. Local or regional research infrastructures, often funded by a single university or a group of collaborating universities, serve local and basic needs, so that users get faster and more convenient access to infrastructure to support these needs. National and international research infrastructures (some of which are distributed) are often funded by national agencies or major research foundations. These aim to provide advanced resources that enable research by a number of researchers (or research teams) and projects in specific research fields that in many cases could not have been realised or established by local or smaller constellations of users or research teams. The latter types of infrastructures, a significant number of which are funded (or co-funded) by the Swedish Research Council, serve users in a variety of areas, such as physics and engineering, life science, geophysics, material science, and environmental science. Some infrastructures related to computational resources constitute e-infrastructure.

Examples of national and international research infrastructures of particular importance to natural and engineering sciences in Sweden include (but are not limited to) the following:

- ACTRIS (Aerosols, Clouds and Trace Gases Research Infrastructure) is a distributed European research infrastructure that measures aerosols, clouds and reactive trace gases in the atmosphere – from the surface of the Earth to the stratosphere;
- ALMA (Atacama Large Millimeter Array) is an astronomical interferometer of a multitude of radio telescopes in the Atacama Desert of northern Chile that detects electromagnetic radiation at millimetre and sub-millimetre wavelengths;
- CERN (European Organization for Nuclear Research) is the largest particle physics laboratory for high-energy physics research in the world and includes the Large Hadron Collider (LHC). At this facility, the Swedish Research Council contributes to three experimental (Atlas, Alice and Isolde) and one computations research infrastructure, WLCG (the Worldwide LHC Computing Grid);
- DESIREE (Double ElectroStatic Ion Ring ExpERiment) is a cryogenic ion-beam storage ring for atom, molecule, and chemical physics in which ion-ion interactions in well-defined quantum states can be studied;
- IOPD/ECORD (European Consortium for Ocean Research Drilling of the Integrated Ocean Drilling Program) is a consortium of 14 European countries and Canada that addresses crucial questions in Earth, ocean, environmental and life sciences based on drill cores, borehole imaging, observatory data, and related geophysical imaging obtained from beneath the

ocean floor using specialised ocean-going drilling and research vessels and platforms;

- EISCAT_3D (European Incoherent Scatter Scientific Association) is a radar system for the scientific study of the Earth's atmosphere and ionosphere, including northern lights, plasma physics, and atmospheric physics;
- ELT (Extremely Large Telescope) is an astronomical observatory under construction on top of Cerro Armazones in the Atacama desert of northern Chile, planned to be the world's largest optical/near-infrared extremely large telescope;
- EMBRC (European Marine Biological Resource Centre) is a European 'research infrastructure' that provides researchers and companies with access to marine organisms and the facilities to study them, including experimental facilities and technological platforms;
- EPOS (European Plate Observing System) provides data about the solid ground (or "everything beneath our feet");
- ESO (European Southern Observatory) is an inter-governmental research organisation for ground-based astronomy;
- ESRF (European Synchrotron Radiation Facility) is a joint research synchrotron facility situated in Grenoble, France, at which research in protein crystallography, earth science, palaeontology, materials science, chemistry, and physics is pursued;
- ESS (European Spallation Source) is a multi-disciplinary research facility based on the world's most powerful pulsed neutron source;
- 4MOST (4-metre Multi-Object Spectroscopic Telescope) is the largest telescope in the world dedicated to surveying the sky at near-infrared wavelengths;
- Icebreaker Oden provides a research infrastructure with opportunities for multi-faceted studies of the atmosphere, ocean, cryosphere, marine ecosystems, and also the sediment and geology of ocean floors;
- ICDP (International Continental scientific Drilling Program) is a multinational program to further and fund geosciences in the field of Continental Scientific Drilling (CSD), which, in turn, is a tool in understanding of Earth processes and structure;
- ICOS (Integrated Carbon Observation System) is a distributed European infrastructure that measures and quantifies greenhouse gas uptake and emissions between land/water and atmosphere;
- ILL with Super-Adam is a facility for neutron scattering in France, for research into fields such as materials and life sciences and chemistry. Sweden contributes to a neutron reflectometer, Super-Adam;
- IML (Institut Mittag-Leffler) is an international centre for research and postdoctoral training in mathematical sciences whose mission is to support international top-level research in mathematics, with special attention to the development of mathematical research in Nordic countries;
- InfraVis (National Research Infrastructure for Data Visualization) is a national research infrastructure for visualisation of data;
- ISIS is a pulsed neutron and muon source at the Rutherford Appleton Laboratory in the United Kingdom that enables probing the structure and dynamics of condensed matter on a microscopic scale, ranging from the sub-atomic to the macro-molecular;

- ITER (International Thermonuclear Experimental Reactor) is an international nuclear fusion research and engineering project aimed at creating energy by replicating the fusion processes of the Sun;
- JET (Joint European Torus) is an operational magnetically confined plasma physics instrument, based on a tokamak design, whose purpose is to provide future nuclear fusion grid energy;
- JWST (James Webb Space Telescope) is a high-resolution, high-sensitivity infrared space telescope that will enable investigations across many fields of astronomy and cosmology, for example observation of the first stars, the formation of the first galaxies, and detailed atmospheric characterisation of potentially habitable exoplanets
- Laserlab Sweden is a distributed research infrastructure comprising state-of-the-art laser instrumentation for research in the field of atomic, molecular and optical sciences;
- LHC (Large Hadron Collider) is the world's largest and highest-energy particle collider built by CERN;
- NBIS (National Bioinformatics Infrastructure Sweden) is a distributed national bioinformatics infrastructure, supporting life sciences in Sweden;
- NGI (National Genomics Infrastructure) is a national infrastructure for large-scale DNA sequencing and SNP genotyping;
- NMI (National Microscopy Infrastructure) provides access to instrumentation and competence within advanced microscopy;
- MAX IV is a national laboratory for accelerator physics and research by use of synchrotron light in fields such as materials science, biotechnology, medicine, energy and the environment;
- Myfab is a national Swedish research infrastructure, for research in fields such as materials science, nanoscience, information and communication technology, bio-nanotechnology, life sciences, energy research and micro-nanosystems and for micro and nano-fabrication;
- NordSIM-Vegacenter is a microanalytical facility at the Swedish Museum of Natural History that provides the Swedish geoscience community with state-of-the-art microbeam analytical technology focused on in-situ material analysis at micron scale;
- Onsala Space Laboratory is a Swedish facility with telescopes and measuring instruments for radio astronomy and geodesy;
- PETRA is a German synchrotron light facility at the DESY laboratory outside Hamburg focusing on radiation in the X-ray area, for research in several scientific fields. Sweden funds the Swedish Material Science beamline, SMS, at Petra III;
- Riksriggeren with IODP and ICDP is a drilling rig for scientific surveys of the Earth's crust, where IODP is an international programme for scientific drilling at sea, while ICDP is the land-based equivalent;
- SBDI (Swedish Biodiversity Data Infrastructure) is a portal for biodiversity data comprising information about populations of plants, animals and other life forms;
- SciLifeLab (Science for Life Laboratory) is a national centre for large-scale research in the fields of life sciences, molecular biosciences, computational biology and bioinformatics, with focus on health and environmental research;

- SINQ (Swiss Spallation Neutron Source) is the strongest continuous neutron source in the world. It also has a moderator made of liquid deuterium that enables the production of slow neutrons, which have a lower energy spectrum;
- SITES (Swedish Infrastructure for Ecosystem Science) is a distributed research infrastructure that coordinates a number (presently nine) of Sweden's field stations for land-based climate, environmental and ecosystem research;
- SNIC (Swedish National Infrastructure for Computing), which is to be succeeded by NAIS (National Academic Infrastructure for Supercomputing), is an infrastructure that makes available large-scale high-performance computing resources, storage capacity, and advanced user support and offers national high-performance computing (HPC) resources and data storage for academic research in Sweden;
- SwedNMR (Swedish Nuclear Magnetic Resonance) provides NMR instrumentation and expertise at six Swedish nodes into a national infrastructure, where user support and instrument investments are coordinated at national level within biomolecular NMR, materials NMR and translational NMR;
- TESS (Transiting Exoplanet Survey Satellite) is a space telescope for NASA's Explorer program, designed to search for exoplanets using the transit method in an area significantly (400 times) larger than that covered by the Kepler mission. TESS provides prime targets for further characterisation by the James Webb Space Telescope (JWST);
- VLT (Very Large Telescope) is a telescope facility operated by ESO in the Atacama desert of northern Chile that consists of four individual telescopes working at visible and infrared wavelengths, each with a primary 8.2 m diameter mirror, which can be used together to achieve very high angular resolution; and
- XFEL (X-ray Free Electron Laser Facility) is a European X-ray free electron laser facility that generates intense X-ray flashes for research in a number of fields, including femtochemistry and molecular biology, which can be used to map atomic details of viruses, film chemical reactions, and study processes in the interior of planets;

Examples of research infrastructures that presently are under construction, but that are expected to be of high importance for Swedish scientists in the close future include the following:

- ESS (European Spallation Source) is a multi-disciplinary research facility that will enable scientists to see and understand basic atomic structures and forces at length and time scales unachievable at other neutron sources. It will be useful for research in materials and life sciences, energy and environmental technology, among other fields;
- FAIR (Facility for Antiproton and Ion Research) is an accelerator facility for nuclear, hadron and ion physics; and
- SKA (Square Kilometre Array) is an international radio astronomy project that is being built in Australia and South Africa and will operate across a wide range of frequencies and sizes, which will make it 50 times more sensitive than any other radio instrument.

The wide range of national and international research infrastructures used by Swedish scientists does not only illustrate the great breadth of science being pursued in Sweden, it also emphasises the importance of safeguarding the continuous support and development of national and international research infrastructures.

2 Scientists involved in work on the research review

2.1 Questionnaire to project grant recipients

A questionnaire was sent to 1010 recipients of project grants during the years 2018-2021. The response rate was 46 per cent.

Questions

1. Please define your research area. Select the area that best represents your research from the predefined list.
2. What scientific advances during the last ten years do you regard as most important within your research area, both nationally and internationally?
3. What long-term scientific questions are central to your research area?
4. Looking ten years ahead: what major scientific breakthroughs do you foresee in your research area?
5. What are the main structural challenges within the Swedish research system (university structure, recruitment, funding system, etc.) that your research area is facing?
6. What research infrastructure needs do you anticipate for your research area in the coming decade?

2.2 Reference group and adjunct members

2.2.1 Biology

Reference group

Name	Organisation
Rosa Fernandez	Centre for Genomic Regulation, Barcelona
Per Hammarström	Linköping University
Martin Ott	Stockholm University
Elisabeth Sauer-Eriksson	Umeå University
Åsa Strand	Umeå University
Tobias Uller	Lund University
Dominic Wright	Linköping University

Adjunct members

Name	Organisation
Alexandre Antonelli	Kew Gardens
Erik Lindahl	Stockholm University
Sören Nylin	Stockholm University
Martin Ott	Stockholm University

2.2.2 Chemistry***Reference group***

Name	Organisation
Fredrik Almqvist	Umeå University
Aji Mathew	Stockholm University
Nicole Pamme	Stockholm University
Daniel Topgaard	Lund University
Ola Wendt	Lund University
Per-Olof Åstrand	NTNU Norwegian University of Science and Technology

Adjunct members

Name	Organisation
Martin Malmsten	University of Copenhagen
Ola Wendt	Lund University

2.2.3 Electrical engineering and computer sciences

Reference group

Name	Organisation
Thore Husfeldt	Lund University
Niklas Rorsman	Chalmers University of Technology
Thomas Schön	Uppsala University
Katinka Wolter	Freie Universität Berlin
Karl-Erik Årzén	Lund University

Adjunct members

Name	Organisation
Karl Henrik Johansson	KTH Royal Institute of Technology
Andrei Sabelfeld	Chalmers University of Technology

2.2.4 Geosciences

Reference group

Name	Organisation
Daniel Conley	Lund University
Emma Kritzberg	Lund University
Vivi Vajda	Swedish Museum of Natural History
Pär Weihed	Luleå University of Technology
Qiong Zhang	Stockholm University

Adjunct members

Name	Organisation
Raimund Muscheler	Lund University
Anna Rutgersson	Uppsala University

2.2.5 Mathematics

Reference group

Name	Organisation
Björn Birnir	University of California, Santa Barbara
Tara Brendle	University of Glasgow
Gunilla Kreiss	Uppsala University
Ilya Pavlyukevich	University of Jena

Adjunct members

Name	Organisation
Tobias Ekholm	Uppsala University
Holger Rootzén	Chalmers University of Technology

2.2.6 Mechanical, chemical and biomedical engineering

Reference group

Name	Organisation
Shervin Bagheri	KTH Royal Institute of Technology
Magnus Cinthio	Lund University
Louise Olsson	Chalmers University of Technology
Solveig Melin	Lund University
Ulrika Rova	Lund University
Mohammad Taherzadeh	University of Borås
Karin Wårdell	Linköping University

Adjunct members

Name	Organisation
Francisco Javier Vilaplana Domingo	KTH Royal Institute of Technology
Carolina Wählby	Uppsala University

2.2.7 Physical sciences

Reference group

Name	Organisation
Eleanor Campbell	University of Edinburgh
Vanya Darakchieva	Linköping University
Katia Gallo	KTH Royal Institute of Technology
Fariba Hatami	Humboldt-Universität Berlin
Anders Johansen	Lund University
Susanne Mirbt	Uppsala University
Anders Nilsson	Stockholm University
Christopher Plummer	École Polytechnique Fédérale de Lausanne
Marika Taylor	University of Southampton
Lars Österlund	Uppsala University

Adjunct members

Name	Organisation
Lars Berglund	KTH Royal Institute of Technology
Mattias Marklund	University of Gothenburg
Floriana Lombardi	Chalmers University of Technology
Christian Brylinski	University of Lyon
Ludvig Edman	Umeå University

3 Review panels in natural and engineering sciences

3.1 From 2021 and onwards

Name	Focus areas
NT-A Atmospheric, Aquatic, and Soil Sciences	Biogeochemistry, Climatology, incl. climate modelling; Environmental chemistry; Hydrology; Limnology; Meteorology and atmospheric science; Oceanography; Soil science
NT-B Geology, Geochemistry, and Geophysics	Geochemistry; Geodesy; Geology; Geophysics; Geotechnical engineering; Glaciology; Mineralogy and petrology; Palaeoclimatology, incl. palaeoclimate modelling; Palaeoecology; Palaeoceanography, incl. palaeoceanographic modelling; Palaeogenetics; Palaeontology and palaeobiology; Physical geography; Sedimentology; Tectonics; Quaternary geology, incl. Paleolimnology
NT-C Evolutionary Biology and Genetics	Biological systematics; Comparative biology; Evolutionary biology; Evolutionary ecology; Evolutionary developmental biology; Evolutionary genomics; Phylogenetics; Population genetics
NT-D Ecology and Organism Biology	Behavioural ecology; Biodiversity; Community ecology; Ecophysiology, Ecosystems, Ethology; Marine biology; Microbial ecology; Plant and Zoophysiology; Plant-environment, -microbe-interactions; Toxicology
NT-E Cell Biology, Developmental Biology, and Microbiology	Cell biology; Developmental biology; Epigenetics; Functional genomics; Immunology; Microbiology; Neurobiology and neurochemistry
NT-F Biochemistry, Molecular Biology, and Structural Biology	Biochemistry; Molecular biophysics; Molecular biology; Molecular biotechnology; Structural biology

Name	Focus areas
NT-G Analytical, Physical, and Theoretical Chemistry	Analytical chemistry; Non-targeted and targeted analysis; Physical chemistry; Molecular spectroscopy; Surface and colloid chemistry; Soft Matter; Biophysical chemistry; Theoretical chemistry; Molecular simulations; Quantum chemistry
NT-H Inorganic, Materials, and Organic Chemistry	Inorganic chemistry; Bioinorganic chemistry; Coordination chemistry; Electrochemistry; Solid-state chemistry; Materials chemistry; Green chemistry; Organic chemistry; Medicinal chemistry; Organometallic chemistry; Polymer chemistry
NT-I Materials Science and Engineering	Biomaterials; Ceramics; Composite materials and composite engineering; Corrosion engineering; Manufacturing, surface and joining technology; Materials design; Metallic materials and metallurgy; Polymers and polymer engineering; Thin film materials
NT-J Bioprocess Technology, Chemical Engineering, and Environmental Engineering	Biocatalysis and enzyme technology; Bioenergy; Bio-nanotechnology; Bioprocess technology; Catalysis; Chemical engineering; Environmental technology; Food chemistry; Food technology; Natural resources engineering; Paper, pulp and fibre technology; Pharmaceutical biotechnology; Water engineering
NT-K Applied and Engineering Physics	Semiconductor physics; Electronic devices; Surface physics; Low-temperature physics; Magnetism and spintronics; Superconductivity; Photonics; Optoelectronic technology and instrumentation; Sensor technology; Biophysics; Mesoscopic physics
NT-L Astronomy and Subatomic Physics	Accelerator physics; Astronomy; Astroparticle physics; Astrophysics; Cosmology; Mathematical physics; Nuclear physics; Particle physics; Radiation physics (non-medical aspects)

Name	Focus areas
NT-M Physics of Light and Matter	Atomic physics; Molecular physics; Cluster physics; Condensed matter physics; Soft matter physics, Plasma physics; Space physics, Fusion; Chemical physics; Fundamental optics; Quantum information and quantum optics; Quantum liquids and quantum materials
NT-N Mechanical Engineering	Aerospace engineering; Biomechanics; Energy engineering; Fluid mechanics and acoustics; Mechanics of materials; Nuclear engineering; Rheology; Solid mechanics; Tribology; Vehicle engineering
NT-O Biomedical Engineering	Artificial organs; Biomaterials; Biomechanics; Bio-optics; Biosensor technology; Medical biotechnology; Medical equipment engineering; Medical ergonomics; Medical Image and Signal Processing; Medical informatics; Medical laboratory technology and measurement technology; Medical materials and prosthesis technology; Physiological Measurement Technology and Modelling; Radiation physics (medical aspects); Radiology and image processing; Speech Technology and Technical Audiology
NT-P Systems and Electrical Engineering	Analog and digital electronics; Communication and information theory; Computer vision; Control engineering; Electrical and power engineering; Machine learning; Networked systems; Radio engineering; Robotics; Signal processing
NT-Q Computer Science	Algorithms; Artificial intelligence; Computer systems (computer architecture, embedded systems, computer networks, and operating systems); Human-computer interaction; Information systems; Parallel and distributed computing; Programming languages and systems; Security; Software engineering; Theory of computation
NT-R Computational Mathematics, Data Science, and Statistics	Computational mathematics and numerical analysis; Foundations of data science; Natural language processing; Operations Research; Scientific computing; Statistics

Name	Focus areas
NT-S Mathematics	Algebra; Analysis; Applied mathematics; Discrete mathematics; Geometry; Mathematical logic; Number theory; Probability theory; Topology

3.2 2012-2020

Name	Focus areas
NT-1 Mathematical Sciences	Algebra; Computational mathematics and numerical analysis; Discrete mathematics; Geometry; Mathematical logic; Mathematical analysis; Optimization; Probability theory and statistics; Systems theory; Applied mathematics
NT-2 Computer Science	Computer architecture; Systems engineering; Computer engineering; Interaction Technologies; Human-Computer interaction (Interaction Design); Software engineering; Language technology (Computational linguistics); Information systems; Theoretical computer science
NT-3 Subatomic Physics, Space Physics and Astronomy	Accelerator physics; Astrophysics; Astronomy; Astroparticle physics; Fusion; Cosmology; Mathematical physics; Nuclear physics; Plasma physics; Particle physics; Space physics; Radiation physics (non-medical aspects)
NT-4 Atomic and Molecular Physics, Optics and Condensed Matter Physics	Atomic and molecular physics; Computational physics; Chemical physics; Cluster physics; Condensed matter physics; Quantum information and quantum optics; Quantum liquids and quantum materials; Macromolecular physics; Optics; Statistical physics; Structural and vibrational physics
NT-5 Analytical, Physical and Theoretical Chemistry	Analytical chemistry; Biophysical chemistry; Physical chemistry; Chemometrics; Quantum chemistry; Microfluidics; Molecular simulations; Theoretical chemistry; Surface and colloid chemistry

Name	Focus areas
NT-6 Organic and Inorganic Chemistry	Bioinorganic chemistry; Electrochemistry; Pharmaceutical chemistry; Solid-state chemistry; Cluster chemistry; Nuclear chemistry; Solution chemistry; Materials chemistry (synthesis aspects); Organometallic chemistry; Inorganic chemistry; Organic chemistry; Polymer chemistry
NT-7 Geology and Geophysics	Geodesy; Geophysics; Geology; Geotechnical engineering; Glaciology; Quaternary geology; Mineralogy; Physical geography; Palaeoclimatology; Palaeontology and palaeobiology; Petrology; Tectonics
NT-8 Soil, Air and Water Processes	Geochemistry; Hydrology; Environmental chemistry; Climatology; Soil science; Meteorology and atmospheric science; Oceanography
NT-9 Biochemistry and Structural Biology	Biochemistry; Glycobiology; Nucleic acids biochemistry; Protein chemistry and enzymology; Molecular biophysics; Molecular biotechnology; Structural biology
NT-10 Cell and Molecular Biology	Cell biology; Epigenetics; Functional genomics; Immunology; Molecular biology; Neurobiology and neurochemistry; Proteomics
NT-11 Organism Biology	Bioinformatics; Botany; Genetics; Microbiology; Systems biology; Toxicology; Developmental biology; Zoology
NT-12 Ecology, Systematics and Evolution	Biological systematics; Ecology; Ethology; Evolutionary biology
NT-13 Electronics, Electrical Engineering, Semiconductor Physics and Photonics	Electrical measurement technology and instrumentation; Electrophysics; Electronics; Electrical engineering; Power engineering; Photonics; Semiconductor physics; Radio engineering

Name	Focus areas
NT-14 Signals and Systems	Computer vision; Communication systems; Control engineering; Robotics; Signal processing
NT-15 Applied Physics	Biophysics; Low-temperature physics; Magnetism and spintronics; Mesoscopic physics; Nanoscience and nanotechnology; Sensor technology; Superconductivity; Thin film technology; Surface and colloidal physics
NT-16 Mechanical Engineering	Biomechanics; Energy engineering; Vehicle engineering; Solid mechanics; Mechanics of materials; Rheology; Reactor science; Aerospace engineering; Fluid mechanics and acoustics; Tribology
NT-17 Bioprocess Technology, Chemical Engineering and Environmental Engineering	Bioenergy; Biocatalysis and enzyme technology; Bio- nanotechnology; Bioprocess technology; Catalysis; Chemical engineering; Food chemistry; Food technology; Pharmaceutical biotechnology; Environmental technology; Natural resources engineering; Paper, pulp and fibre technology; Water engineering
NT-18 Materials Science	Manufacturing, surface and joining technology; Ceramics; Composite materials and Composite engineering; Corrosion engineering; Materials design; Materials characterisation; Materials chemistry (not synthesis); Materials structure; Metallic materials and metallurgy; Polymers and polymer engineering; Thin film materials
NT-19 Biomedical Engineering	Artificial organs; Biomaterials; Bio-optics; Biosensor technology; Physiological measurement technology and modelling; Medical equipment engineering; Medical image and signal processing; Medical biotechnology; Medical ergonomics; Medical informatics; Medical laboratory technology and measurement technology; Medical materials and prosthesis technology; Radiology and image processing; Radiation physics (medical aspects); Speech technology and technical audiology



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