

PSNC

Poznan Supercomputing
and Networking Center

Federating Research Infrastructures
and Communities

Information Folder

Living Labs

Networking

Blockchain

Twins

DATA
DIH

Research

Objects,

Digital

Contents

02
Introduction

10
Infrastructure for Data Spaces

24
ICT Research and Development

34
Roadmap for Research Infrastructures

52
Digital Transformation

74
Solutions and Products

76
International Partnerships



About Us

Discover PSNC

Poznan Supercomputing and Networking Center (PSNC) is formally affiliated to the Institute of Bioorganic Chemistry of the Polish Academy of Sciences.

PSNC is an internationally renowned node of the European Research Area that operates a technologically advanced e-Infrastructure and continuously expands its activity as a research and development center in information and communication technologies (ICT). The unrivaled facilities, resources, and services provided by PSNC support research efforts undertaken in a number of domains. Our users may take advantage of PSNC's pillars: the Metropolitan Area Network POZMAN, High Performance Computing Center and the National Research and Educational Network PIONIER, operated and incessantly developed by PSNC.

PSNC actively participates in R&D projects funded primarily through European Framework Programs. Making ICTs and their multiple applications our core focus area, we collaborate with over a thousand global partners. PSNC has been involved in more than 300 projects and coordinated 43 of them. Powered by a state of the art and robust e-infrastructure and the continually broadened competencies of our teams, it is safe to say that we are a reliable solution partner for digital transformation in science, industry and society. Having said that, we are certified in Quality Management (ISO 9001) and in Information Security Management (ISO 27001).



Our Mission Is To Advance Science

The core mission of PSNC is to foster scientific excellence by providing reliable and cutting-edge e-Infrastructure (also referred to as cyberinfrastructure) such as communication networks, data and computing systems, and highly-specialized laboratories. We achieve this goal particularly through extensive R&D activities related to information and communication technologies and their innovative applications. In collaborative project teams we draw from the synergy of science, technology, business, and education to tackle the greatest challenges for our future. It is our highest objective to ensure steady growth of the competencies of our people. They are the pillar for the successful exploration of new technologies and the development of scientific and engineering innovations, and ultimately the winning deployment of our services.

28
years of activity

1.34M^{*}
scientific users

* all users served for 21 MANs

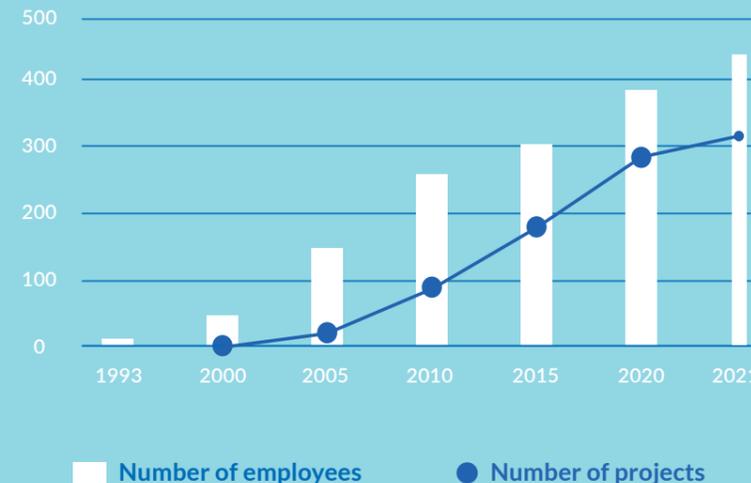
1680^{*}
customers

* since 2016

432
employees

301
projects

PSNC in numbers



Locations



Poznan Supercomputing and Networking Center



The Institute of Bioorganic Chemistry of the Polish Academy of Sciences

The headquarters of the Institute are based in a complex at 12/14 Noskowskiego Street. This is also the location of the PSNC Secondary Data Center and a branch of the Network Operations Center. In fact, we started our activity in this very building in 1993.

The Polish Optical Internet Research Center



The headquarters of PSNC are located in a new complex of the Polish Optical Internet Research Center in Poznan, at 10 Jana Pawła II Street. These premises consists of our Primary Data Center building (total area of almost 4,000 m²) and a laboratory, seminar, and office space in two other buildings (total area of over 10,000 m²). One of the structures also houses a 24/7 Network Operations Center.



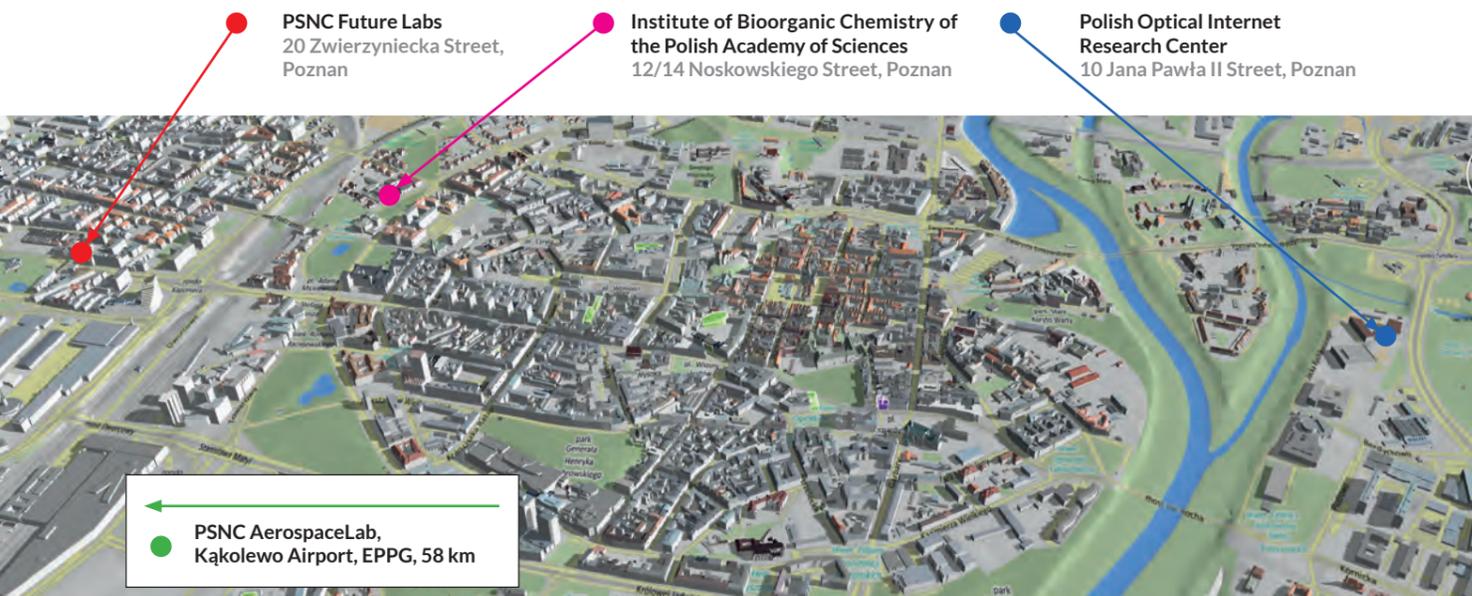
PSNC Future Labs

The PSNC living lab space welcomes citizens and other stakeholders to co-design innovations. This 120-year-old building has been retrofitted with cutting edge facilities for prototyping and experimentation. The Future Labs space hosts interdisciplinary events that inspire collaborations in the areas of Smart City, Healthcare, Industry 4.0, Art & Science, Education, Gaming, and Coworking.



PSNC AerospaceLab, Kąkolewo Airport

Situated in the municipality of Grodzisk Wielkopolski—58 km from the center of Poznan, this site will soon see the construction of the Aerosfera Digital Airport with a view to carrying out research and development work in applications of unmanned aerial vehicles and flight control.



Source: <http://sip.poznan.pl>

Management



Cezary Mazurek,
PhD, Eng.
Director of PSNC



Krzysztof Kurowski,
PhD, Eng.
Technical Director of PSNC



Norbert Meyer,
PhD, Eng.
Director of the Data
Processing Technologies
Division



Artur Binczewski,
MSc, Eng.
Director of the Network
Technologies Division



Robert Pękal,
MSc, Eng.
Director of the Network
Services Division



Tomasz Piontek,
MSc, Eng.
Director of the Applications
Division

Structure

PSNC currently employs over 430 people engaged in as many as 16 technological departments, who are steadily accumulating key competencies essential for the development of IT infrastructure and executing various interdisciplinary R&D endeavors. Our research activities center around Computer Science, Telecommunication, Life Sciences, and Computer Applications in Science and Engineering. Teams composed of young professionals, as well as experienced IT specialists are managed by world renowned executives

—division directors who have been involved in PSNC operations over a number of years. For more than two decades of participation in European programs, we have specialized in providing comprehensive project management services, regardless of the financial instruments. Dedicated administration departments provide continuous supervisory, financial and legal expertise ranging from day-to-day project management to building innovative business models and assisting in startup incubation.



Steering Committee for PSNC Development

The Steering Committee for PSNC Development is an authority which supports the Director of the Institute in strategic activities and directions of PSNC development, in particular,

designing crucial research and infrastructure programs, scientific progress, as well as fostering far-reaching national and international cooperation.



**Prof. Jan Węglarz,
PhD, Eng.**
*Chairman of
the Steering Committee
for PSNC Development*



**Maciej Stroiński,
PhD, Eng.**
*Deputy Chairman of
the Steering Committee
for PSNC Development*



**Cezary Mazurek,
PhD, Eng.**
*Member of
the Steering Committee
for PSNC Development*



**Krzysztof Kurowski,
PhD, Eng.**
*Member of
the Steering Committee
for PSNC Development*

Users Council

**Michał Rychlik, PhD, Eng.
(Chairman)**



Poznan University of Technology

**Prof. Jacek Komasa, PhD
(Vice Chairman)**



Adam Mickiewicz University in Poznan

**Krzysztof Kurowski, PhD, Eng.
(Secretary)**



Poznan Supercomputing
and Networking Center

Anna Philips, PhD



Institute of Bioorganic Chemistry PAS

Adam Glema, PhD, Eng.



Poznan University of Technology

Przemysław Grzeszczak, MSc, Eng.



Poznan University of Economics and Business

**Prof.
Krzysztof Wojciechowski, PhD**



Institute of Molecular Physics PAS

Krzysztof Koszela, PhD



Poznan University of Life Sciences

Prof. Jacek Zieliński, PhD



Poznan University of Physical Education

Barbara Więckowska, PhD



Poznan University of Medical Sciences

Piotr Tomczak, PhD



Adam Mickiewicz University in Poznan

Katarzyna Klessa, PhD



Adam Mickiewicz University in Poznan

Łukasz Łowiński, MSc, Eng.



Lukasiewicz Research Network –
Industrial Institute of Agricultural Engineering

The Users Council is composed of representatives of scientific institutions from Poznan which employ PSNC supercomputing and networking facilities in scientific research. The role of the Council is to identify future trends related to computational methods and deployment in science and engineering, as well as to review computing grant applications submitted by scholars.

Digital Continuum and Twins

The limitations of traditional cloud computing, particularly latency issues associated with accessing cloud computing resources located in data centers, were tackled through developing the concept of edge computing in the early 21st century. This approach involves processing data as close as possible to its point of origin and is most often linked to the Internet of Things (IoT). Edge computing offers considerably reduced requirements for the data transmission network from the place of data generation/creation to the data center, as well as lowered requirements for computing power and infrastructure of the data center itself. Consequently, we can start thinking about the digital or computing continuum, a virtual space integrating all the key players, including different infrastructure operators, cloud, and service providers. That said, in the context of and the

With experimental and federated cloud-based modelling and simulation platforms, PSNC addresses EU-wide and grand global challenges, mainly supporting initial efforts around Destination Earth - Digital Twin of the Earth system in the near future. Thanks to advanced automation and access to remote sensors and new observations that generate real-time data streams, we have been improving multi-scale computational modelling, uncertainty quantification and interactive simulations together with sophisticated visualization for various decision-making processes.

digital continuum, many new challenges are related to non-functional properties, such as power consumption, timing, complexity, security, safety, and sustainability, according to the latest HiPEAC Vision 2021 "The Continuum of Computing." Programming and execution environments will be left with no alternative but to change and offer next-generation languages and tools to orchestrate collaborative distributed and decentralized computing, memory, and data management components. Different workloads will be processed by edge computing, consolidated by federations of systems (FOS) or systems of systems (SOS). A dynamic data-driven decision will push workloads back and forth to the cloud providers or to HPC data centers.



Fig. 1. DestinE Data Lake
Source: <https://digital-strategy.ec.europa.eu/en/library/destination-earth>

	2021	2023
	7.5 PFLOPS	25+ PFLOPS
	120+ PB	400+ PB
	100/400 Gb/s	N x 400 Gb/s
	20 kW	1 MW
	IaaS	Federated IaaS/ PaaS/SaaS

National Research and Education Network PIONIER

Poznan Supercomputing and Networking Center is the operator of the Polish optical research and education network PIONIER. PIONIER acts as an essential element for scientific and innovative endeavors in the research and education community in Poland. It also provides access to state-of-the-art network infrastructure and advanced services, which in turn enable implementation of numerous

national and international projects in such areas as high-performance computing, telemedicine, teleworking and multimedia streaming, and data management. Coupled with the operational excellence of PSNC technical teams ensuring an infrastructure availability of 99.999% per year, it guarantees world-class networking capabilities to Polish scientists and researchers.

PIONIER Optical Backbone

The up-to-the-minute optical backbone is the key enabler of superb research and innovation in Poland, with PSNC as the owner and operator of this infrastructure. The PIONIER optical backbone has been in construction since 2001 has been developing and currently spans through more than 11,000 km of optical fiber lines in Poland and Western Europe. It connects 21 Polish cities with multiple fibers through a number of routes. Major nodes of the PIONIER optical backbone are high performance computing centers. Network connec-

tivity for transfer of research data, as well as specialized network services for advanced applications such as Quantum Key Distribution (QKD) or transfer of ultra-precise time and frequency reaches capacities of 400s Gb/s.

The optical backbone extends national boundaries and has been directly connected to the neighboring NRENs of Czechia, Slovakia, Germany, Ukraine, Lithuania, and Belarus, as well as the Nordic R&E network NORDUNET, CERN, and some other key international partners.

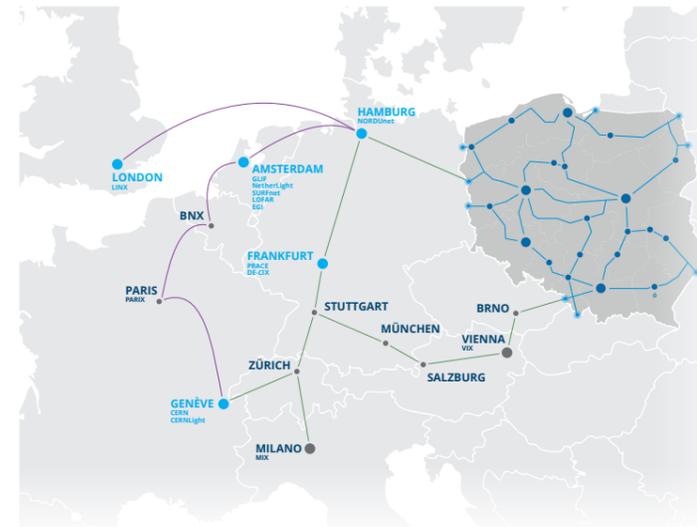


Fig. 2. PIONIER European fiber connections



Fig. 3. PIONIER national optical backbone

PIONIER Consortium

The consortium partners are the Polish Metropolitan Area Networks (MANs) and HPC Centers based around the most exquisite research institutions in the metropolitan hubs of the country. The PIONIER consortium brings together 22 members who share the responsibility of governance, funding, and (most importantly) delivery of state-of-the-art infrastructure and services to research

and education institutions. Partners have adapted the federated model of delivery of services, which allows high penetration of access to intricate and highly engineered infrastructure whilst retaining the subsidiarity of the members. The consortium was established in 2003, based on the previous collaborations on the research and education network dating back to the 1990s.

The strong collaboration of PIONIER consortium partners is key to the success of Poland's NREN. Members of the consortium include:

- Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- Academic Computer Center CYFRONET AGH
- Bialystok University of Technology
- Czestochowa University of Technology
- Gdansk University of Technology
- Institute of Soil Science and Plant Cultivation in Pulawy
- Kazimierz Pulaski University of Technology and Humanities in Radom
- Kielce University of Technology

- Koszalin University of Technology
- Lodz University of Technology
- Maria Curie Skłodowska University in Lublin
- Nicolas Copernicus University in Torun
- Radom University of Technology and Humanities
- Research and Academic Computer Network
- Rzeszow University of Technology
- Silesian University of Technology
- University of Opole
- University of Science and Technology in Bydgoszcz
- University of Warmia and Mazury in Olsztyn
- University of Warsaw
- University of Zielona Gora
- West Pomeranian University of Technology in Szczecin
- Wrocław University of Technology

European Research and Education Network GÉANT

PSNC is an exponent of the Polish NREN in the European NREN association GÉANT. GÉANT operates the European Research and Education network—a high capacity fiber-based infrastructure enabling seamless collaboration between researchers in Europe and beyond. The joint connectivity of PIONIER and GÉANT is fundamental for the co-action of Polish researchers and scientists in the groundbreaking fields of research of astronomy, physics, biology and many more. The GÉANT network enables uninterrupted connectivity to the high-tech instrumentation like CERN, ITER, observatories, and the most

advanced resources for data storage and processing in Europe or indeed the world.

PSNC has strong ties with 40 partner NRENs in the GÉANT association designing services that are important for the community by participating in numerous projects funded by the European Commission. GÉANT partners and PSNC have developed services which are now essential enhancements of scientific processes such as eduroam, eduGAIN, edumeeet, and eduTEAMS. PSNC also has a leading role in the elaboration of perfSONAR and NMaaS (Network Management as a service).

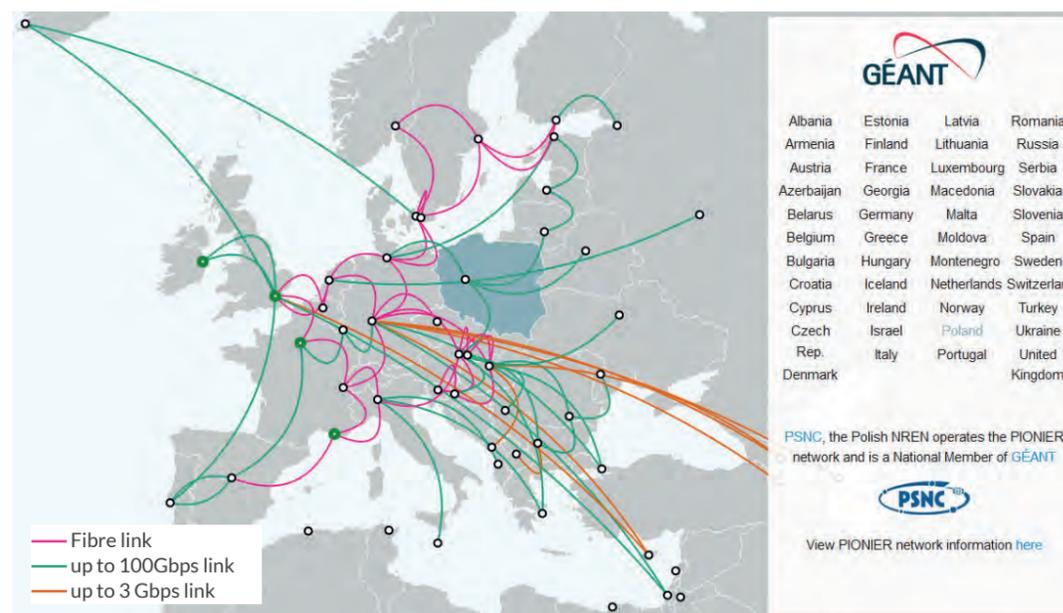


Fig. 4. GÉANT Connectivity Map
Source: <http://map.geant.org/>

POZnan Metropolitan Area Network POZMAN

PSNC is the operator of the Metropolitan Area Network (MAN) which connects the R&E community in the city of Poznan. POZMAN provides extensive services to R&E institutions in Poznan with the primary one being connectivity to national and international research communities through PIONIER and GÉANT, plus access to the Internet, as well as to other advanced options.

The basis of the POZMAN infrastructure is the optical fiber network of more than 300 kilometers which connects 43 R&E facilities in the area. Regional research and education institutions are connected using the optical infrastructure of the PIONIER network. The distributed nature of campuses throughout the city mandates that the POZMAN network provides sufficient services of physical and virtual connectivity to enable their seamless operation. POZMAN features a high capacity MPLS infrastructure for packet services.

Research and education institutions in Poznan have automatic access to a full spectrum of POZMAN and PSNC services once connected to the network:

- Access to networks: PIONIER, GÉANT, GLIF/GNA
- Capability of establishing dedicated links/virtual networks between connected units and institutions

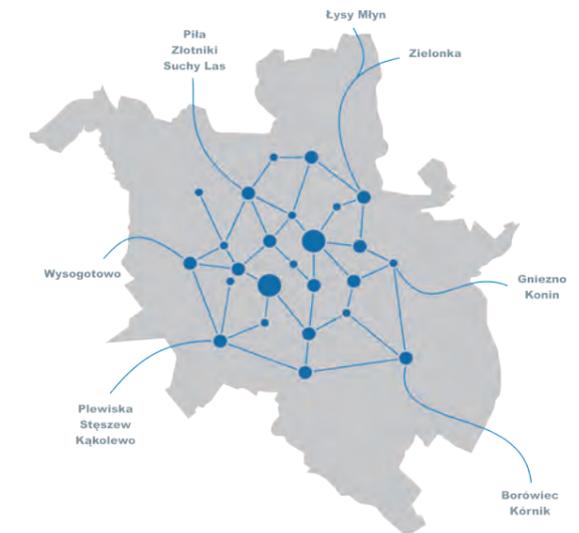


Fig. 5. POZMAN network backbone

- Authentication and authorization services: eduroam, PIONIER.Id
- If required, email support for staff, e.g., with mailing lists
- Hosting for websites or portals
- Electronic certificate services
- Application cloud services
- High volume data archive services
- Multimedia services: access to distribution channels for multimedia content
- Videoconferencing services (eduMEET and others)

PSNC provides round the clock operational support for connectivity and other services through dedicated operations centers, enabling R&E communities to collaborate and engage in the fields of scientific research and creativity.

Computing Services for Science and Industry

PSNC provides two geographically distributed data centers connected with 40 fibers and redundant networking. This redundancy allows us to offer a reliable, potent functionality for critical services under cloud ecosystems, i.e., Infrastructure as a Service (IaaS), Software as a Service (SaaS), and Platform as a Service (PaaS). On top of that, the major data center provides a High Performance Computing (HPC) infrastructure for grand challenges: big applications running in parallel environments.

All major HPC services are provided by two systems: Eagle (since 2016) and Altair (since 2021), which deliver conventional power and a specialized accelerating environment GPGPU for AI and big data analysis.

The remaining cloud services are delivered for specific requirements at universities (dedicated resources, higher availability and critical services), industry and administration entities.



The primary data center – HPC floor

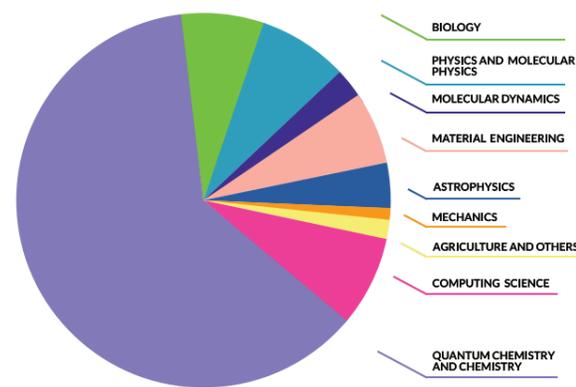


Fig. 6. Scientific disciplines at PSNC

PSNC computing systems have defined 200 grants and 5,000 computing accounts in both HPC and clouds. PSNC resources are used by scientific communities from all over Poland, including universities from Poznan, Torun, Wroclaw, Bydgoszcz, Krakow, Katowice, Warsaw, and Gdansk. We also serve foreign users on the grounds of contracts for the exchange of computing power under Partnership for Advanced Computing in Europe (PRACE), nuclear physics–Worldwide LHC Grid Computing (WLCG), and Low-frequency Array for radio astronomy (LOFAR), as well as a number of international flagship ESFRI projects.

The use of PSNC computing resources in 2021 is anticipated to increase by a factor of 5.



Interconnectivity of HPC



The Altair supercomputer – on TOP500 and Green500 since Nov. 2020

Internet of Things

Connected smart objects have made their way into our everyday lives through multiple domains such as homes with automation solutions, assisted living with sensors, and wearables to monitor personal activities, smart transportation, and environmental monitoring.

Handling, processing, and delivering data from millions of devices around the world is a complex and remarkable feat that hinges on edge computing systems. While edge computing brings computation and data storage closer, fog computing is what takes analytic services to the edge of the network.

Provided data processing services for IoT technology:

- federation of IoT platforms and sensor integration (SymbloTe Core)
- processing and presentation of meteorological data and air quality

To tackle the challenge of optimizing a new class of computing systems in the IoT/Edge/Cloud model we provide our hi-tech IoT lab infrastructure across multiple projects. Drones, cloud and edge-based computing, and storage resources are available to assist the development of innovative applications for agriculture, forestry, smart cities, smart mobility, autonomous flying, and command and control scenarios. In our laboratories we also focus on prototyping and building fully functional elements suitable for testing in “real world scenarios.” Our experienced engineers design and manufacture mechanical (housings, handles, assembly elements), and mechatronic components (mechanical systems using motors, gears, and servos, integrated with the electronics that control them). Throughout the engineering process we utilize various technologies, to name a few: a 3D printer with a large working area (FDM technology), a three-axis CNC milling machine (works on a range of materials, including aluminum), a laser plotter (CO2 laser), and chamber for simulating environmental conditions.

IlluMINEation H2020-SC5-2019-2

The IlluMINEation project will highlight major digitalization aspects in underground mining operations in order to achieve the next level of safety, environmental and economic performance, and to gain and retain a social license to operate. This endeavor will consist in developing a robust multi-level distributed IIoT platform (including cloud computing & distributed cloud management) that connects via wireless communication with the physical mining world, defined by massively installed low-cost all-embracing sensor networks. Advanced analytical algorithms will support the implementation of powerful, sophisticated automated control systems. Mobile user interfaces, dashboards, augmented, and virtual reality as well as digital twins will be employed for data visualization and operational control.



Towards Exascale

In recent years, 13 international projects at PSNC were directly linked to High Performance Computing. Some HPC projects are concerned with the development of Competence Centers in application areas, by which we support competence development of future users of pre-Exascale and Exascale computers in Europe.

EuroCC H2020-JTI-EuroHPC-2019-2

National Competence Centers in the framework of EuroHPC (EuroCC) are to provide a broad service portfolio tailored to the respective national needs of industry, academia, and public administrations. All this to support and significantly enhance the national strengths of High Performance Computing competences as well as High Performance Data Analytics and Artificial Intelligence capabilities.

HiDALGO H2020-INFRAEDI-2018-1

Global decisions with their dependencies cannot rely upon incomplete problem assessments or gut feelings, since impacts cannot be foreseen without an accurate problem representation and its systemic evolution. HiDALGO bridges that shortcoming by enabling highly accurate simulations, data analytics, and data visualization but also by supplying sector-specific expertise on how to integrate various workflows and the corresponding data.

EoCoE-II H2020-INFRAEDI-2018-1

The project applies cutting-edge computational methods to accelerate the transition to the production, storage, and management of clean, decarbonized energy. A large set of diverse computer applications from four energy domains has achieved substantial efficiency gains thanks to its multidisciplinary expertise in applied mathematics and supercomputing. Currently the project channels its efforts into five scientific Exascale challenges in the low-carbon sectors of Energy: Meteorology, Materials, Water, Wind, and Fusion.

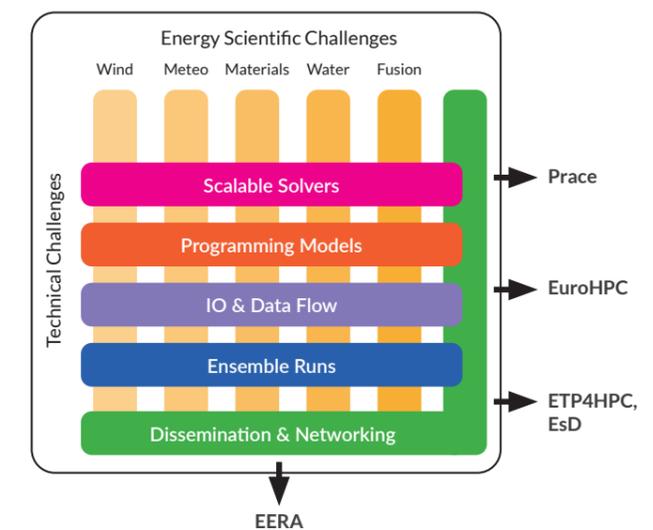


Fig. 7. Technical and scientific challenges EoCoE-II project
Source: <https://www.eocoe.eu/wp-breakdown>

European Open Science Cloud and PSNC

The European Open Science Cloud (EOSC) is a European Commission initiative that aims for a federated infrastructure to provide its users with services promoting Open Science practices. EOSC intends to support three objectives: (1) increase the value of scientific data assets by making them easily available to a larger number of researchers, across disciplines (interdisciplinary) and borders (EU added value), and (2) cut down the costs of scientific data management, while (3) ensuring adequate protection of information/personal data in conformity with applicable EU rules. The EOSC Executive Board

and its Working Groups (2019–2020) have produced 20 reports with recommendations in 6 priority areas for EOSC. They are crucial for the EOSC Strategic Research and Innovation Agenda (SRIA), which offers a transparent roadmap for the period 2021–2027 to bring about the EOSC vision and objectives. PSNC experts have contributed to those reports (e.g., EOSC Interoperability Framework) and started to prepare national-scale networking, storage and computing infrastructures, and corresponding services to be in full compliance with EOSC within the ongoing EOSC implementation phase.

PSNC has been working on 9 EOSC projects in cooperation with more than 220 institutions

Acronym	Role	Title	Dates
 RELIANCE	coordinator	Research lifecycle management for earth science communities and copernicus users in EOSC	2021–2022
EOSC FUTURE	partner	EOSC future	2021–2023
CS3MESH4EOSC	partner	Interactive and agile/responsive sharing mesh of storage, data and applications for EOSC	2020–2022
EOSC-synergy	partner	European Open Science Cloud - Expanding Capacities by building capabilities	2019–2022
SSHOC	subcontractor	Social Sciences & Humanities open cloud	2019–2022
EOSC Enhance	subcontractor	Enhancing the EOSC portal and connecting thematic clouds	2019–2021
EOSC-hub	partner	Integrating and managing services for the European Open Science Cloud	2018–2021
DEEP-HybridDataCloud	partner	Designing and enabling e-infrastructures for high-impact processing in a hybrid data cloud	2017–2020
EOSCpilot	subcontractor	The European Open Science Cloud for Research Pilot Project	2017–2019

The EOSC Association has recently signed a Memorandum of Understanding with the European Commission to progress the EOSC partnership, which will bring together all relevant stakeholders to co-design and deploy a European Research Data Commons where data are findable, accessible, interoperable, and reusable (FAIR), and as open as possible. In 2020, PSNC officially joined the ranks of the EOSC Association and is now working with national partners to build a consistent EOSC ecosystem in Poland. The work plan outlined in the latest Strategic Research and Innovation Agenda (SRIA) of EOSC centers around the first implementation stage of 2021–2022, which aims to develop added value from a federation of infrastructures by providing the core functions of the Minimum Viable EOSC (MVE) that will enable EOSC operations, in particular within EOSC-Core. In a word,

EOSC-Core will offer an infrastructure with basic functionalities, such as persistent identifiers (PIDs) or authentication and authorization infrastructure (AAI) services. Research outputs will have to comply with the FAIR principles, and services will have to be FAIR-enabling. PSNC contributes to EOSC-Core with essential infrastructure services deployed and provided within NREN PIONIER, particularly the Polish Identity Federation PIONIER.Id for federated authentication and authorization. The Digital Object Identifier registration service PIONIER DATA ID supplies a persistent and unambiguous way to access a variety of digital objects and the Federation of Polish Digital Libraries.

PSNC researchers are currently part of various EOSC-related EU projects. One of the leading infrastructure endeavors is EOSC Future, which will provide a fully federated infrastructure and operational EOSC platform (“System of Systems”) with an integrated execution environment consisting of data, professional services, and open research products. Further, PSNC coordinates a domain-specific EU project called RELIANCE. It will deliver a suite of innovative and interconnected services that extend EOSC’s capabilities to support the management of the research lifecycle within Earth Science Communities and Copernicus Users.

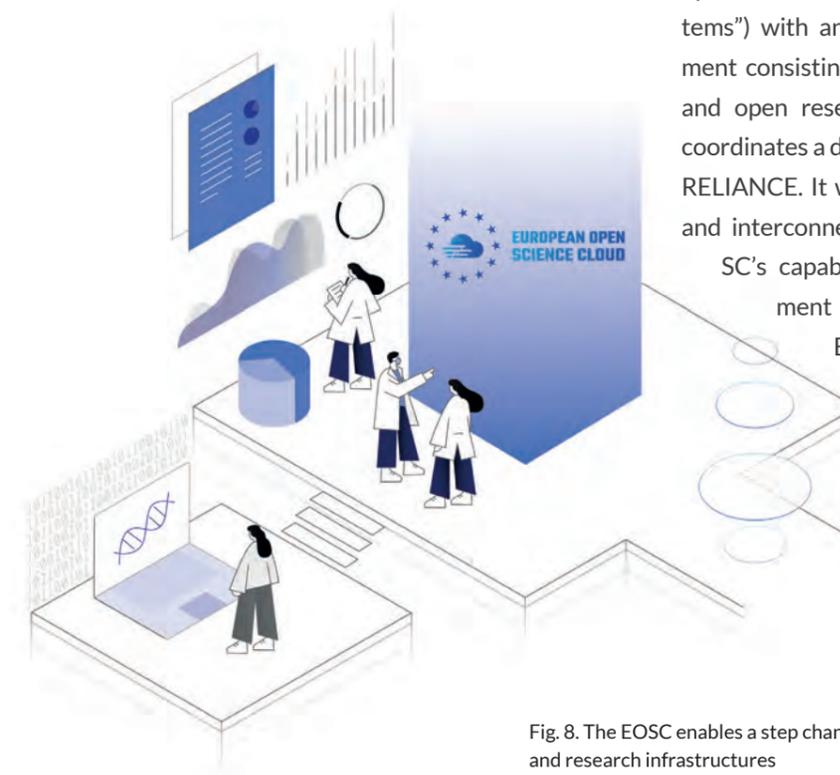


Fig. 8. The EOSC enables a step change across scientific communities and research infrastructures

 Our ambition is to drive all the partners safely through their digital transformation journey. Hereafter, we have highlighted with the special icon all the projects in which we, as a coordinator, are navigating to achieve this destination.

The ultimate goal of PSNC activity is to lead research and development in Information and Communication Technologies (ICT) and their applications, and to provide Polish science with the most cutting-edge digital infrastructure, supporting scientific R&D efforts at the highest level through deployment of solutions developed in our projects.

Quantum Computing and Communication

As the second quantum revolution progresses, we strive to control and modify more and more qubits by means of principles of quantum mechanics such as quantum entanglement, tunneling, superposition, and quantum teleportation. Although there is still room for improvement, e.g., error correction, we are no longer just witnesses but rather active participants in the second quantum revolution. The world's leading economies have already acknowledged the potential of quantum technologies and increased priorities and funding in this field.

In the previous year, the European Commission established a Quantum Flagship strategy and program for the development of quantum technologies. Since 2017, teams from PSNC have been actively involved in various activities related to the development and application of quantum technologies in two key areas: communications and quantum computing. PSNC recognizes the importance of quantum technologies; the global tech race and quantum technologies are considered as a strategic area of PSNC activity.

Quantum communication carries the potential to protect the EU's sensitive data and digital infrastructure in the years ahead. A test quantum communication infrastructure will be set up across several European countries. Launched by the EU-funded **OPENQKD project**, its activities will take place in Austria, Czech Republic, France, Germany, Greece, Italy, Netherlands, Poland, Spain, Switzerland, and the UK. It will boost the security of critical applications in various fields—from telecommunications to electricity supply and healthcare. Bringing together a multidisciplinary team (leading European telecommunication equipment manufacturers, end users, and critical infrastructure providers, network operators, quantum key distribution equipment providers, digital security professionals and scientists) from 13 EU countries, the aim is to bolster Europe's leadership in quantum technologies. PSNC is one of the main OPENQKD testbeds, focusing on a variety of use cases based on its own services in PIONIER and POZMAN networks and integrating the technology with current telecommunication infrastructure.

We have recently launched the first quantum key distribution (QKD) system as an operational and secure network and services connecting two different infrastructures located in our two geographically distributed PSNC data centers in Poznan (~5 km). But that's not the end. PSNC has also launched the first cross-border QKD link between Poland and Czech Republic (~60 km). Currently, we see it as a priority to build the foundations of the pan-European Quantum Communications Infrastructure (QCI).

PSNC has also partnered with international companies all over Central Europe in the **QUAPITAL initiative** to enable unconditionally secure communication owing to quantum technologies and with scalability on a commercial

level. Classical IT has revealed before us what is possible with high-speed communication and by outsourcing difficult problems via cloud computing. Building similar quantum-compatible networks like QUAPITAL will connect quantum experiments between various research facilities all over Central Europe. This, in turn, will tighten scientific collaborations across all fields, bring the community even closer together, and at the same time foster excellence and specialization.

Our expertise in quantum communication has enabled us to coordinate the QKD and quantum communication **activities in GÉANT**. Elaborating on this idea, PSNC helps to establish a common testbed and information exchange between the NRENs in Europe and consequently prepare for the QCI activities and programs. Together with NREN partners, PSNC organizes presentations, tutorials, and demos of QKD technologies.

More than that, we have been experimenting with various quantum simulators and put to the test experimental quantum computing facilities to explore alternative ways of solving challenging problems including scheduling, discrete optimization, and logistic problems. We will also take active steps aimed at linking quantum and classical computing technologies to demonstrate added values of such a hybrid computing infrastructure for new application areas, for instance air traffic management in the **QATM project**. We are planning to study the performance of the available quantum systems and propose near real-time solutions based on algorithmization and solving selected complex issues. We aim to employ quantum technologies to provide streamlined and updated plans and schedules for complex tasks of managing objects located in the airspace. The solutions are also planned to use QKD technologies for internal and external ATM systems communication.

Efficient and Exascale HPC

TEXTAROSSA H2020- JTI-EuroHPC-2019-1

To achieve exceptional performance and high energy efficiency in near-future exascale computing systems, a technology gap needs to be bridged: the efficiency of computation must be enhanced with extreme performance in HW and a new arithmetic, as well as methods and tools for seamless integration of reconfigurable accelerators in heterogeneous HPC multi-node platforms. In the TEXTAROSSA project we are tackling this gap by applying a co-design approach to heterogeneous HPC solutions supported by the integration and extension of IPs, programming models and tools derived from European research projects. In order to drive technology development and assess the impact of the proposed innovations, TEXTAROSSA

reaches for a selected but representative number of HPC, HPDA and AI demonstrators covering challenging domains such as High Energy Physics, Oil & Gas, climate modelling, and others. PSNC leads the analysis and use of these demonstrators with a strong focus on its UrbanAir application for modeling and forecasting of pollutant concentration and dispersion in cities. It is a 3D multiscale model that generates ample synergies within a numerical weather prediction model, running at a larger scale (e.g., mesoscale), with a city-scale geophysical flow solver (EULAG). PSNC will also work on power and thermal monitoring, modeling and management of the new heterogeneous liquid-cooled nodes.

eFLOWS4HPC H2020- JTI-EuroHPC-2019-1

The goal behind the project is to favor dynamic and intelligent workflows for the future Euro-HPC ecosystem. The result will be a European workflow platform that enables the design of complex applications that integrate HPC processes, data analytics, and artificial intelligence, making use of HPC resources in an easy, efficient, and responsible way. To demonstrate the workflow software stack, use cases from three thematic pillars have been selected. Pillar I centers around the construction of DigitalTwins for the prototyping of intricate manufactured objects integrating state-of-the-art adaptive solvers with machine learning and data-mining, contributing to the Industry 4.0 vision. Pillar II develops

pathbreaking adaptive workflows for climate and the study of Tropical Cyclones (TC) in the context of the CMIP6 experiment, including in-situ analytics. Going further, Pillar III explores the modelling of natural catastrophes—in particular, earthquakes and their associated tsunamis shortly after such events are recorded. PSNC will address the key enabling component for a novel HPC access policy: Urgent Computing for Civil Protection. The concept applied to urgent earthquake and tsunami simulations can yield a breakthrough in the way HPC addresses societal challenges, effectively igniting the usage of public supercomputing resources in the field of disaster mitigation.

ASPIDE H2020-FETHPC-2017

Extreme Data is a concept distinguished by the massive amounts of data that must be queried, communicated, and analyzed in (near) real-time by means of a high volume of memory/storage elements and Exascale computing systems. Following the need for streamlining the current concepts and technologies, ASPIDE's activities focus on solutions that enable data-intensive applications to run on future Exascale systems. Practical results include the methodology and software prototypes designed specifically for introducing Exascale applications. The ASPIDE project contributes

with a definition of new programming paradigms, APIs, runtime tools and methodologies for expressing data-intensive tasks, which can open the door to the exploitation of massive parallelism, promoting outstanding performance and efficiency. But that's not all, PSNC has also coordinated the evaluation of project results from all use cases and redounded to enriching the project with its deep learning applications from the domain of time series analysis and image processing. PSNC also participated in the design and integration of the resource and application monitoring solutions.

ADMIRE H2020- JTI-EuroHPC-2019-1

The ever-increasing need to process exceptionally large datasets is among the main drivers for building exascale HPC systems today. That said, the flat storage hierarchies found in classic HPC architectures no longer fulfill the performance requirements of data-processing applications. Uncoordinated file access in combination with limited bandwidth make the centralized backend parallel file system a serious bottleneck. At the same time, the emerging multitier storage hierarchies carry the potential to remove this barrier. The ADMIRE project aims to develop a software-defined framework based upon the

principles of scalable monitoring and control, separated control and data paths, and the orchestration of key system components and applications through embedded control points. PSNC intends to build and optimize the application for processing super-resolution microscopy images that will allow scientists from the Department of Molecular Neurobiology at the Institute of Bioorganic Chemistry PAS to conduct research on brain neurodegenerative disorders. In order to achieve this, PSNC will also make a valuable contribution to the work on monitoring and intelligent control of the computation and I/O access.

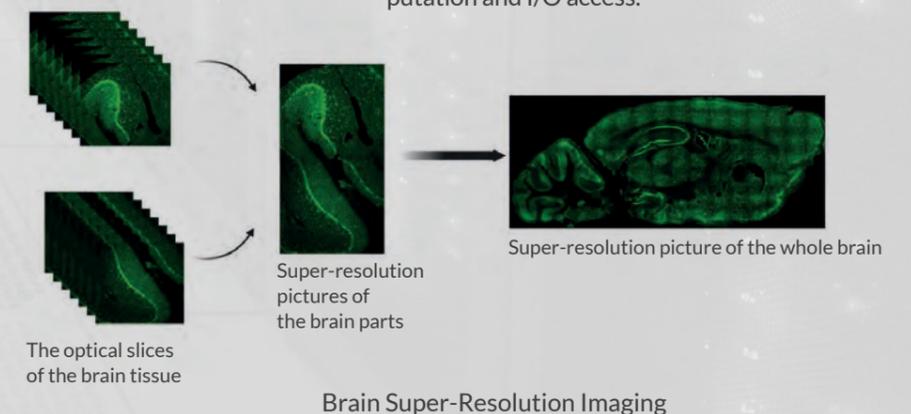


Fig. 9. Brain super-resolution imaging. Credit: IBCH PAS

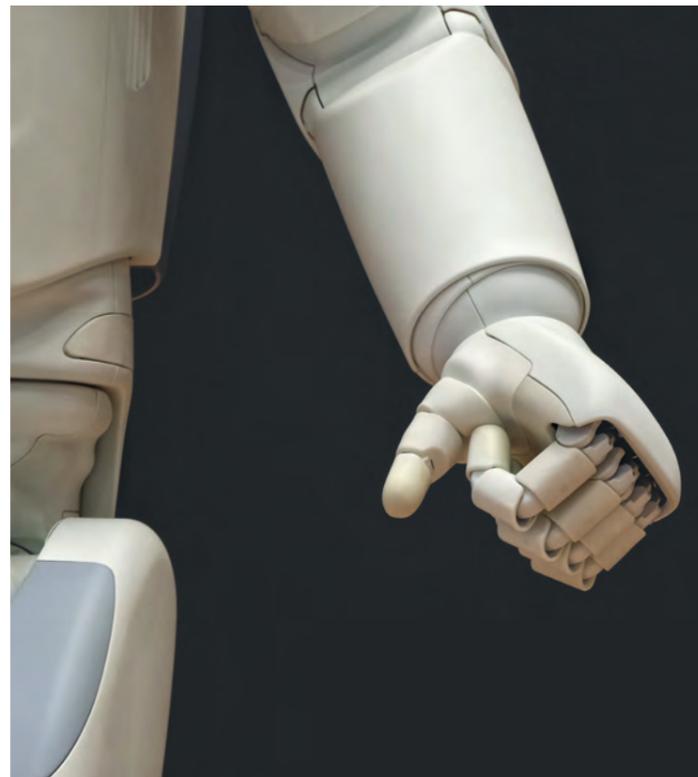
Artificial Intelligence

PSNC is conducting research and development to address various synergetic challenges in AI, Big Data, and HPC. PSNC is a full member of BDVA and the NVIDIA Deep Learning Institute, and promotes Intel's global AI for Youth program to empower young people with AI readiness skills. On top of that, PSNC actively takes part in the European Technology Platform for High Performance Computing (ETP4HPC), EuroHPC and represents Poland in the Partnership for Advanced Computing in Europe (PRACE).

PSNC delivers AI HPC-based services to catalyze the application of machine learning algorithms in real-life decision making involving extremely large data sets (e.g., data generated by next-generation microscopes and new instruments in biological and biomedical sciences and healthcare sectors) and to support industry-driven scenarios, e.g., by seamless integration of distributed IoT technologies and systems with AI-based prediction models to forecast and verify large and extreme events for telco operators, automotive manufacturers, energy suppliers, air navigation agencies, etc.

PSNC has established a Digital Innovation Hub called HPC4Poland to accelerate and scale up new markets and pathbreaking applications of AI, Data, and Robotics at national and regional levels. By working closely with the representatives of SMEs, PSNC assists them in transformation into Industry 4.0. Moreover, PSNC

offers local industry support in building performant ICT ecosystems based on mold-breaking experimental infrastructures and living labs for prototyping and development of new products and services with various industry partners. Together with Poznan University of Technology, PSNC supports the Poznan Center of Competence in AI by focusing on the cost-performance management of learning algorithms and computation resources, extracting knowledge from extensive digital collections and efficient hunt for the ML model parameter space for optimization.



Multiscale Simulations

Sophisticated computer simulations are used to predict the weather and climate change, model refugees, understand materials, develop nuclear fusion, and inform medical decisions. But if we are to use simulations in order to make predictions on the global climate emergency, guide aid to migrants fleeing combat, create new materials, help invent the first fusion reactor, and allow doctors to test medication on a virtual "you" (before the real "you"), then those simulations need to be clocklike. In other words, they must be validated, verified, and their uncertainty quantified, so that they can feed into real-life applications and decisions.



Fig. 10. Predicting contamination transport and dispersion

VECMA H2020-FETHPC-2017

In the Verified Exascale Computing for Multiscale Applications project, we enable and support a set of highly-demanding multiscale and Multiphysics applications to run on current multi-petascale computers and emerging exascale environments with considerable fidelity whose output will be "actionable." All the calculations and simulations in VECMA are certifiable as validated (V), verified (V), and equipped with uncertainty quantification (UQ) by tight error bars such that they may be relied upon for making key decisions in all the domains of concern. There are several tools available in the research area of VVUQ, which provide algorithms for parameter investigations, model calibration, optimization and UQ analysis.

In the VECMA project we put every effort into the Peta scale development and deployment of the QCG-Pilot Job management backend, providing access to heterogeneous and HPC resources and VVUQ-ready urban air pollution simulations. In fact, predicting air quality in urban areas is a challenging topic that requires a trade-off between the accuracy of results and an acceptable time-to-solution. There are numerous models for predicting contamination transport and dispersion, ranging from express, computationally cheap but not necessarily accurate such as simple Gaussian models, to rather meticulous simulations that resolve the difficulty of flows around buildings, but are computationally expensive, e.g., computational fluid dynamics simulations.

Cybersecurity

PSNC brings together groups of over 30 specialists and experts grouped within several, partially intersecting, teams. The operational crew is responsible for configuration, administration and maintenance of the cybersecurity infrastructure. It is supported by a group of ethical (white-hat) hackers, developing their abilities to analyze and bypass protections and hardening services not only by continually analyzing our own, highly expanded and heterogeneous infrastructure, but also thanks to regular cooperation with research institutions, self-government entities, and business. The third research-analytic team is not directly engaged in cyber-protection of PSNC but, as a result of participation in Polish and Europe an R&D cybersecurity projects, it has been able to collect significant knowledge and experience in up-to-date attack techniques and countermeasures based on Big Data and Machine Learning paradigms (and contribute to building such proprietary solutions themselves).

PSNC also provides secure code training and audits for software developers. Both are essential for an overall increase in the quality and security of software solutions as well as growth in the knowledge and mastery of software development teams. PSNC has been leading these endeavors within the GÉANT project for over a decade, resulting with secured high-quality software solutions provided by the project, which at the same time enhance the level of know-how about security and quality coding in the community.

We have also modernized purely commercial cooperation, offering cybersecurity services on the market, e.g., diverse and complex forms of cybersecurity assessments of single systems or whole infrastructures. In this area, PSNC has cooperated with the United Nations (contributing to protect UNFCCC COP Conferences), banks, power plants, and other critical infrastructure operators, public entities, self-government, SMEs and many more. Our successful and long-lasting cooperation with organizations of such varying sizes and characteristics proves the high skills of PSNC in securing access to critical data and systems. PSNC also protects the infrastructure of Polish National Research and Education Network—PIONIER. In 2002, PIONIER CERT acquired the status TF-Listed on the Trusted Introducer list.

Scadvance

RPWP.01.02.00-30-0055/16

The Scadvance system offers fully automated learning process that we have conceptualized and implemented to facilitate system installation and reduce the need for expert knowledge. Moreover, we have brought to life mechanisms that can perform dynamic network architecture mapping, system self-configuration, dynamic server resources optimization and ML hyperparameter optimization along with automated learning. The platform is also able to recalibrate anomaly detection models, hence making it possible to adapt to changes in industrial processes communication. The Scadvance project was carried out in cooperation with our industry partner (ALMA S.A.).

Time and Frequency Distribution

The last decade brought rapid development of fiber optic systems for transfer of time and frequency reference signals. The recent advancement of these technologies, with PSNC's substantial contribution, appeared to be disruptive. The quality of representation of transmitted signals is often several orders of magnitude better than in the current dominant satellite systems. Being able to distribute reference signals with unprecedented precision to recipients even hundreds of kilometers away gave the impetus for faster development of a number of scientific domains, in which the time or frequency parameter is the precondition for further research.

Research on determining the stability limit and optimizing shared distribution (time and frequency as well as data) in telecommunica-

tion networks are in the spectrum of interest of several European projects such as OFTEN, CLONETS-DS and TiFOON (EMPIR), and OTFN (GÉANT), in which PSNC is actively engaged.

TiFOON EMPIR-2018 SIB

The Time and Frequency Over Optical Networks project will advance fiber-based frequency transfer capabilities in Europe towards a universal tool for time and frequency metrology by developing combined time and frequency techniques with enhanced performance, while ensuring compatibility with optical telecommunication networks. On top of that, the project is promoting fiber-optic time and frequency dissemination for applications beyond metrology—for example in geodesy.

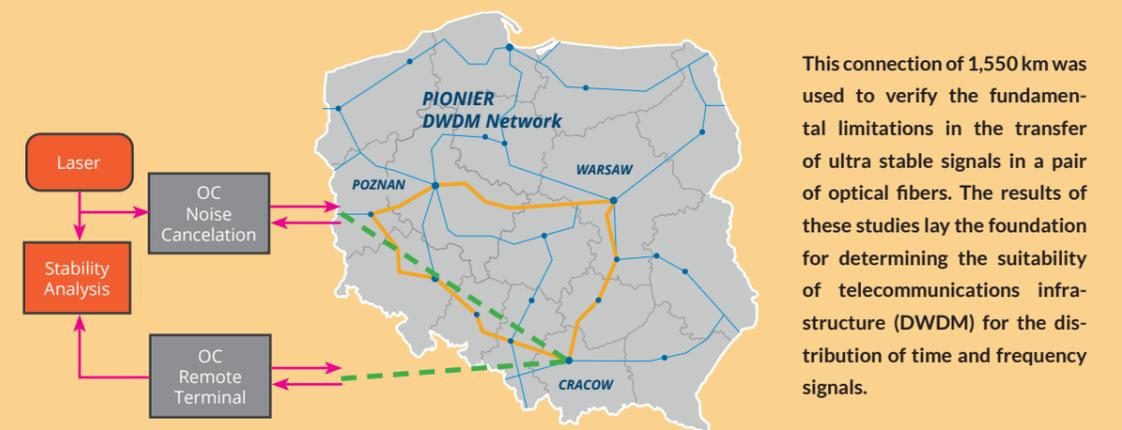


Fig. 11. Diagram of metrological signals transfer in the operational telecommunication network PIONIER.

Source: K. Turza, P. Krehlik, and Ł. Śliwczyński, "Stability Limitations of Optical Frequency Transfer in Telecommunication DWDM Networks," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 67, no. 5, pp. 1066–1073, May 2020, doi: 10.1109/TUFFC.2019.2957176."

Advanced Information Retrieval

Information can be easily created and distributed, resulting in a steadily growing amount of data, an increasing dynamics of spread and diversity of forms following the quest to uncover more engaging and effective means of information presentation. We address these challenges with **Artificial Intelligence-based content processing** and sophisticated **Information Retrieval** techniques.

Automatic Speech Recognition with Deep Neural Networks applied at various speech signal processing stages allows us to obtain high accuracy speech transcripts. Speaker detection and identification provides additional data which complements the transcripts. Audio signal can be further analyzed to detect the presence of specific sounds or sound types. The challenge in audio processing lies in obtaining all of this information with a high accuracy for recordings of spontaneous speech with plenty of background noise, dialogues with sudden changes of speakers, and overlapping sounds.

Image processing is performed to obtain information from still images and video content with AI-based Optical Character Recognition for retrieving text present in images and AI-based object detection and identification techniques. They allow us to perform image analysis in order to secure very distinctive information of interest in a given application.

MediaMonitoring is aimed at developing an automatic, optimal, and powerful method for tracking information resonance in Polish media with sentiment analysis. The service built allows monitoring of information dissemination in media for a given keyword or phrase and determining the history of given pieces of information, which services have re-posted it and how it has affected the dissemination process. Automatic speech recognition has found broad use in audio and audio-visual content in order to obtain its text representation for further analysis.

MediaEstimator is a system for estimating sponsor and product placement effectiveness. Information tracking is performed for all mass media channels—press, TV, Internet, podcasts, and social media. Automatic speech recognition and object detection in images enable retrieval and analysis of information in the form of an audio recording, an image, or a video.

 **EMMA** is an electronic media monitoring and analysis system. Its functionality covers electronic multimedia content acquisition, archiving, processing, tagging, and retrieval. Content processing includes automatic speech recognition providing audio transcripts and image processing to obtain news ticker content from video footage.

CMST

 COMPUTATIONAL METHODS
IN SCIENCE AND TECHNOLOGY
www.cmst.eu

QUARTERLY JOURNAL
Published since 1996



PAN
POLISH ACADEMY OF SCIENCES

PSNC

SUBMISSION OF ARTICLES FOR REVIEW:
editors@cmst.eu



ROADMAP FOR RESEARCH INFRASTRUCTURES

The digital metamorphosis of our societies is enabled by the design, deployment, and operation of steadily progressing, complex digital infrastructures. The Polish Roadmap of Research Infrastructure is a periodically updated list of key research infrastructures announced by the Minister of Science.

The list brings together infrastructures of the highest potential for scientific excellence, consolidating research capacity which are vital for the development of science and industry. The latest update of the list contained 70 infrastructures divided into 6 research areas.

PSNC partners in 11 of these infrastructures in the following sectors: digital research infrastructures (6), biological-medical and agricultural sciences (3), physical sciences and engineering (1), and social sciences and humanities (1).

Presently, PSNC is coordinating five research infrastructure development projects:

PIONIER-LAB, PRACE-LAB, PRACE-LAB2, National Data Storage and DARIAH-PL. We also take an active part in five others. All these infrastructures will be made available for science and industry at the latest by the end of 2023.

The Polish roadmap also includes projects related to Poland's contribution to international projects from the ESFRI roadmap (e.g., ELIXIR, DARIAH). The ESFRI Roadmap contains thoroughly evaluated and carefully selected European science facilities. It combines ESFRI Projects, which are new research infrastructures in progress towards implementation, and ESFRI Landmarks, successfully operationalized Research Infrastructures.

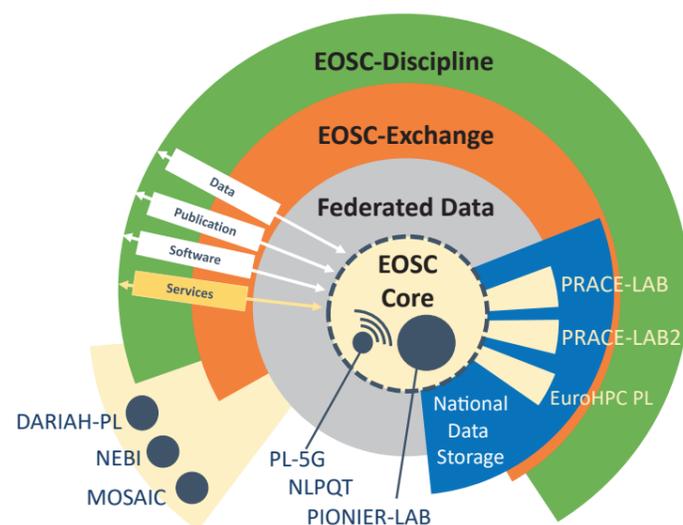


Fig. 12. EOSC and Polish Roadmap of Research Infrastructure projects

The latest update (June 2021) on the ESFRI roadmap includes the SLICES project—a far-reaching scientific infrastructure for computing/communication experimental studies, of which PSNC is a partner. This initiative responds to the demand for research infrastructure of information and telecommunication technologies. Both the rapid spread of Big Data technologies, artificial intelligence, and the first implementations of 5G networks in member countries as well as, consequently, new applications using cutting-edge mechanisms of control and data transmission, fuel a strong demand for digital infrastructure with adapted and appropriately selected tools for testing and developing products designed for the digital society. Poland's contribution to the formation of this infrastructure will be possible thanks to such projects as PIONIER-LAB and PL-5G. PSNC is participating in both EU-funded projects where we co-design SLICES and organize its community: SLICES-DS and SLICES-SC.

Acronym	Role	Title	Dates
PIONIER-LAB	coordinator	PIONIER-LAB—National Platform for Integration of Research Infrastructures for Innovation Ecosystem.	2018–2023
PRACE-LAB	coordinator	Cooperation on Advanced Computing in Europe	2019–2023
PRACE-LAB2	coordinator	Cooperation on Advanced Computing in Europe	2020–2023
DARIAH-PL	coordinator	Digital Research Infrastructure for the Arts and Humanities	2021–2023
KMD	coordinator	National Data Storage—Universal infrastructure for data storage, access and efficient processing of large data volumes in HPC, Big Data and Artificial Intelligence computing models	2021–2023
NLPQT	partner	National Laboratory of Photonics and Quantum Technologies	2018–2023
NEBI	partner	National Center for Advanced Analysis of Biological and Biomedical Imaging	2020–2023
PL-5G	partner	National Laboratory for Advanced 5G Research	2021–2023
EuroHPC PL	partner	National Supercomputing Infrastructure for EuroHPC	2021–2023
MOSAIC	partner	European Center for Bioinformatics and Genomics	2021–2023



PIONIER-LAB

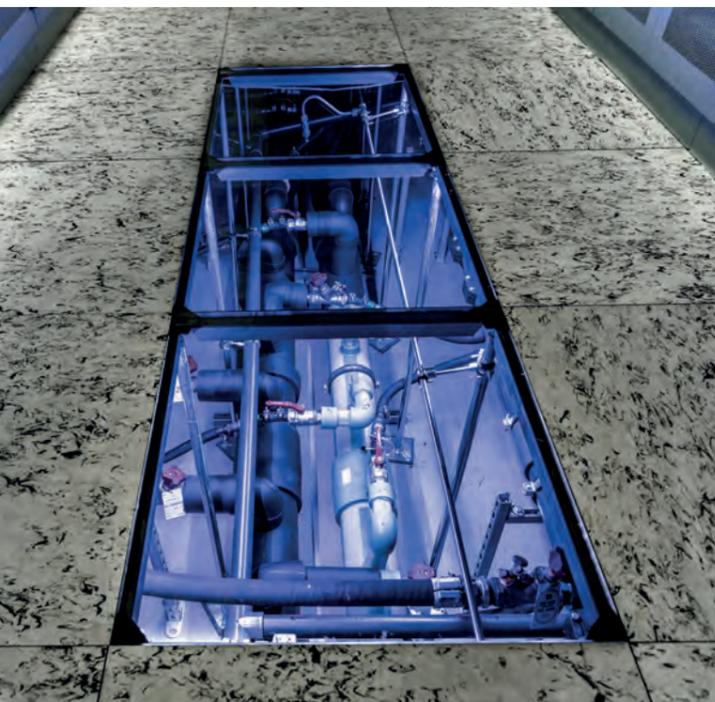
National Platform for Integrating Research Infrastructures with Ecosystems of Innovation

The PIONIER-LAB project is a response of the Polish scientific community to major problems concerning research being undertaken in Poland and the cooperation of Polish industry with science. These concerns were identified as a result of analysis of the current ICT services market, which indicated: i) an insufficient scope of services provided by the existing national research infrastructures; ii) obstructed access to research infrastructures, and iii) a low innovation rate in cooperation between the industrial sector and research and development centers.

The immediate aim of the project is to increase the level of market uptake of research outcomes. At present, it seems necessary to direct the action of scientific entities towards the implementation of R&D works on technological solutions, the need for which has been defined by specific entrepreneurs. The PIONIER-LAB project, through its offer of sophisticated ICT services, will enable close cooperation between the industrial sector and the academic environment in Poland in order to carry out joint research and industrial activities aimed at bringing down barriers related to low effectiveness of transfer of research results to the economy.

The explicit aim of the project will be achieved by designing, building, and making available the PIONIER-LAB research platform for the scientific environment and enterprises. The research platform will constitute an advanced and modern research environment helping to conduct R&D, especially in the increasingly important area of ICT. The PIONIER-LAB platform will constitute an offer of the Polish scientific community towards Polish industry, enabling the integration of science and business in order to enhance the role of research and innovation in the Polish economy.

The cooling infrastructure in the PSNC Data Center



The scope of the project encompasses setting up 8 closely related research laboratories and creating a shared cooperation space for science and industry:

1. Laboratory of innovative network technologies
2. A distributed laboratory of time and frequency
3. Smart Campus as a Smart City Lab
4. Regional Living Innovation Laboratories inspired by ICT
5. Cloud Services Laboratory
6. Multi-Scale Simulation Laboratory
7. Laboratory and e-training Services
8. Laboratory of pre-incubation

The PIONIER-LAB research infrastructure shall be made available on the basis of equal and non-discriminatory access and will be managed by a dedicated access platform that will allow us to control and manage in situ and remote experiments.

<http://pionier-lab.pionier.net.pl/>

PROJECT CONSORTIUM:
PIONIER Consortium members—see page 13
(excluding the Silesian University of Technology)

The Data Center infrastructure in PSNC



Cooperation on Advanced Computing in Europe

The PRACE-LAB project is specifically aimed at strengthening the competitiveness of the scientific community and the Polish economy, especially SMEs.

The project provides production-based advanced computing and data storage services, standing behind the scientific community in Poland and Europe and, at the same time, being capable of offering competitive services for industry in cloud computing/cloud data, and virtual environments, as well as specialized expertise in cybersecurity.

The direct-response goal of the project is to build a widely available HPC infrastructure consisting of high-performance computing servers, specialized processing units and resilient data management systems.



The ALTAIR supercomputer in PSNC

PROJECT CONSORTIUM:

- Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- Academic Computer Center CYFRONET AGH
- Bialystok University of Technology
- Czestochowa University of Technology
- Gdansk University of Technology CI TASK
- Lodz University of Technology
- Kielce University of Technology
- Wroclaw University of Science and Technology—Wroclaw Center for Networking and Supercomputing

The e-infrastructure (cloud/data and HPC), based in 8 geographically distributed sites, is connected to the national academic PIONIER network with the speed of 100–400 Gbps in full-mesh technology and to the European GÉANT network. The integration of this infrastructure with the European EuroHPC and PRACE HPC systems is planned at a later stage and will allow us to take advantage of the national resources under a wider European EuroHPC/PRACE ecosystem.

In April 2021, PSNC released a fully operational Altair system, being the first one within PRACE-LAB. This computer's conventional power is 4 times bigger than the former Eagle (5.9 PFLOPS), and was put on lists of the fastest and most energy-efficient computers in the world: TOP500 and Green500. New PRACE-LAB systems are expected to be found on the upcoming TOP500 list in June this year.

<http://prace-lab.pl/>

Cooperation on Advanced Computing in Europe

The ultimate goal of the PRACE-LAB2 project is to deliver highly-specialized computer architectures for grant challenges supported by AI and big data analysis.

The project's future infrastructure will be dedicated to solving layered problems such as analysis of large data volumes, applications by means of elements of artificial intelligence (AI) and machine learning, as well as quantum computing simulations. The project will influence fields of Polish science and economy, especially innovations, and center around providing high-technology clouds, container solutions and new services such as HPCaaS (HPC as a Service).

The overall purpose is to secure the position of Polish companies on the European and world markets by supporting and encouraging the development of pathbreaking solutions in partnership with the private sector with particular emphasis on SMEs.

These goals will be achieved thanks to fulfilling one of the core challenges of the Europe of Innovation program in the European Research Area (ERA) with postulates of the ESFRI committee regarding the integration of research infrastructure (IB) and ICT infrastructure, as well the Horizon 2020 Framework Program's development guidelines for highest-class new research infrastructures.

PROJECT CONSORTIUM:

- The Institute of Bioorganic Chemistry PAS – Poznan Supercomputing and Networking Center
- The Academic Computer Center CYFRONET AGH
- Gdansk University of Technology CI TASK
- The National Center for Nuclear Research
- Wroclaw University of Science and Technology—Wroclaw Center for Networking and Supercomputing

The research infrastructure hardware and software platform will be created as part of joined development under the following laboratories:

- HPC e-infrastructure
- service platforms
- next-generation computing services
- large-scale data analysis services.

<http://prace-lab2.pl/>

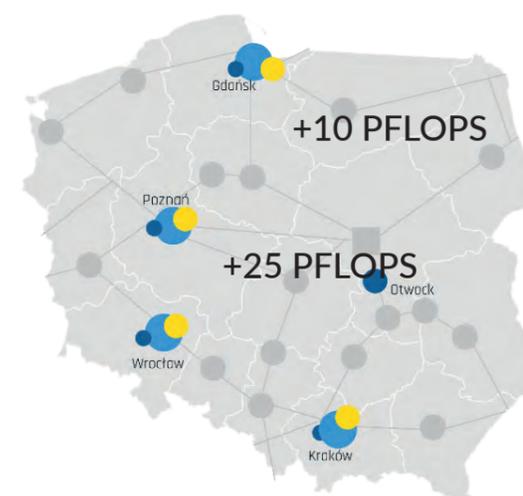


Fig. 13. HPC e-infrastructure upgrades in PRACE-LAB2

National Data Storage



Universal infrastructure for data storage, access, and potent processing of large data volumes in HPC, Big Data, and Artificial Intelligence computing models

The core functionality of National Data Storage provides research infrastructure, crucial for R&D, as well as a trusted production environment to be used by science, economy, and administration entities.

The immediate idea behind the NDS project is to devise and provide production services for storing, accessing and securing data, managing meta-data, and integration of solutions for processing big and complex data volumes based on distributed e-infrastructure. This will allow us to integrate various analytics platforms with machine learning and AI solutions in data infrastructure, and rigorously integrate infrastructure with HPC and HTC systems in HPC centers in order to effectively process big and complex data volumes and sets. In addition, NDS focalizes support for the Polish economy on the competitive international arena by consolidating the partnership of the private sector and scientific institutions with help of innovative solutions.

Moreover, the NDS will provide a national service platform created within the R&D portion of the project, allowing us to safely store digital and IoT experimental data in the long-term time horizon.

PROJECT CONSORTIUM:

- The Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- The Academic Computer Center CYFRONET AGH
- Bialystok University of Technology
- Czestochowa University of Technology
- Gdansk University of Technology CI TASK
- Lodz University of Technology
- Kielce University of Technology
- The National Center for Nuclear Research
- Wroclaw University of Science and Technology—Wroclaw Center for Networking and Supercomputing

Data infrastructure facilities in PSNC



The system architecture of data storage will be designed into a fully open, modular, and scalable data repository equipped with a range of access protocols. An open architecture will enable extending the system with a whole palette of data access and presentation services as well as other functionalities built on top of the basic storage layer. For instance, converting the data object from the raw storage format into the presentation format will be integrated within the data access and presentation services.

The storage system will implement the model and architecture of the so-called Data Lake, adopted by multiple leading vendors in the IT industry, but also used by scientific institutions, including CERN. The second crucial feature of the architecture is that it will follow the open data access rules defined by the European Commission under the European Open Science Cloud (EOSC).

The NDS e-Infrastructure with the essential regional and national support networks will make a national data storage platform and will be created in conjunction with the existing scientific and research IT infrastructure in Poland. By the end of 2022, the data infrastructure built by the consortium members will enhance its capacity by 1 Exabyte, including archiving and long-term storage.

The hardware and software platform of the developed research infrastructure will be designed as part of development works, including:

1. Data storage infrastructure and systems laboratory
2. Services embedded in storage laboratory
3. Services and applications for data access laboratory
4. Repository services laboratory
5. Edge computing laboratory

<http://kmd.pionier.net.pl/>

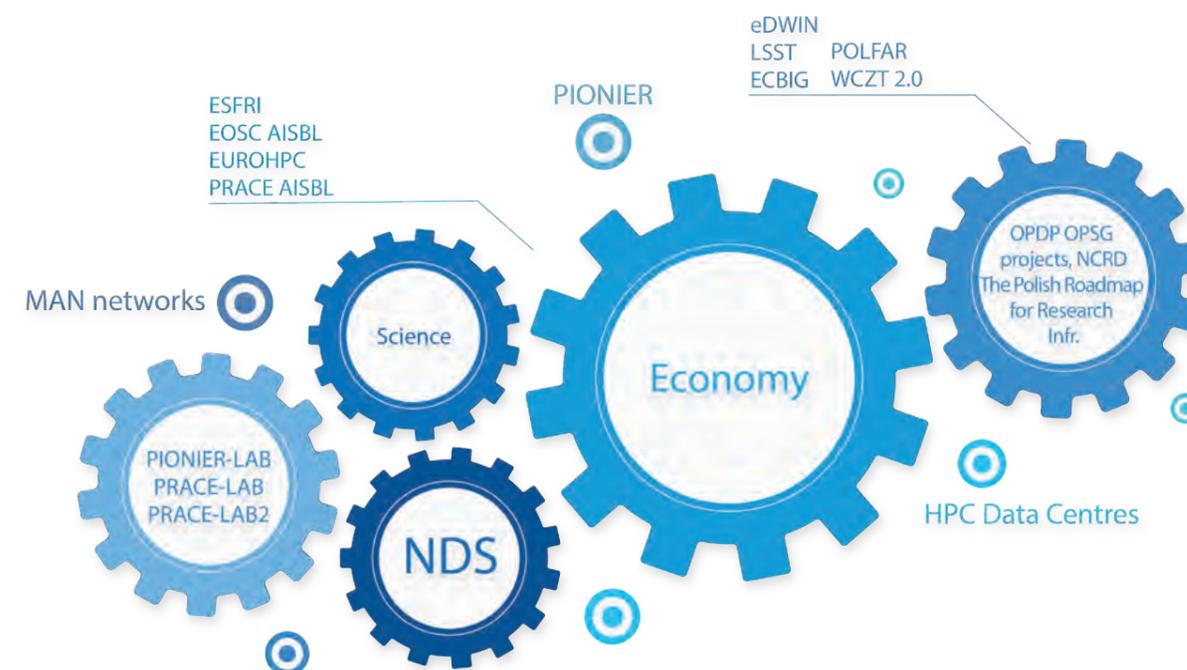


Fig. 14. The ecosystem supported by NDS

Digital Research Infrastructure for the Arts and Humanities

The DARIAH-PL project aims to build a Dariah.lab infrastructure which will provide hardware and software tools with state-of-the-art technological solutions and integrated digital resources from various fields of the arts and humanities.

A network of distributed research laboratories constituting Dariah.lab (<https://lab.dariah.pl/>) is designed on the grounds of a research agenda developed by the project consortium members. Dariah.lab will offer comprehensive support for data acquisition, enrichment, integration, analysis, and visualization.

The infrastructure will permit extensive research, particularly in three key areas identified by means of analysis of the DARIAH-PL working groups experience:

- geoarchaeology, covering broadly understood non-invasive analysis and documentation of soil, landscape, and monuments
- cultural data, including a wide range of interdisciplinary research on culture and phenomena occurring in it
- musicology, involving research on music as an acoustic, cultural, historical and social phenomenon, and its perception.

Dariah.lab consists of five distributed laboratories and a number of mobile digital research stations. The laboratories are dedicated to different groups of functionalities related to the

PROJECT CONSORTIUM:

- Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- Academy of Fine Arts in Warsaw
- Adam Mickiewicz University
- Institute of Art, Polish Academy of Sciences
- Institute of Computer Science, Polish Academy of Sciences
- Institute of History, Polish Academy of Sciences
- Institute of Literary Research, Polish Academy of Sciences
- Institute of the Polish Language, Polish Academy of Sciences
- Institute of Slavic Studies, Polish Academy of Sciences
- Jagiellonian University in Krakow
- Maria Curie-Skłodowska University
- Nicolaus Copernicus University in Torun
- Poznan University of Technology
- University of Warsaw
- University of Wrocław
- Wrocław University of Science and Technology

stages of data processing, from acquisition of digital material, through its enrichment and analysis, to sophisticated visualization. Mobile research stations enable realization of specific functionalities in the field such as data acquisition and its preliminary analysis.

The purpose of building the Dariah.lab research infrastructure is to diversify research in the arts and humanities in Poland, both in a purely scientific context and in the area of economic applications.

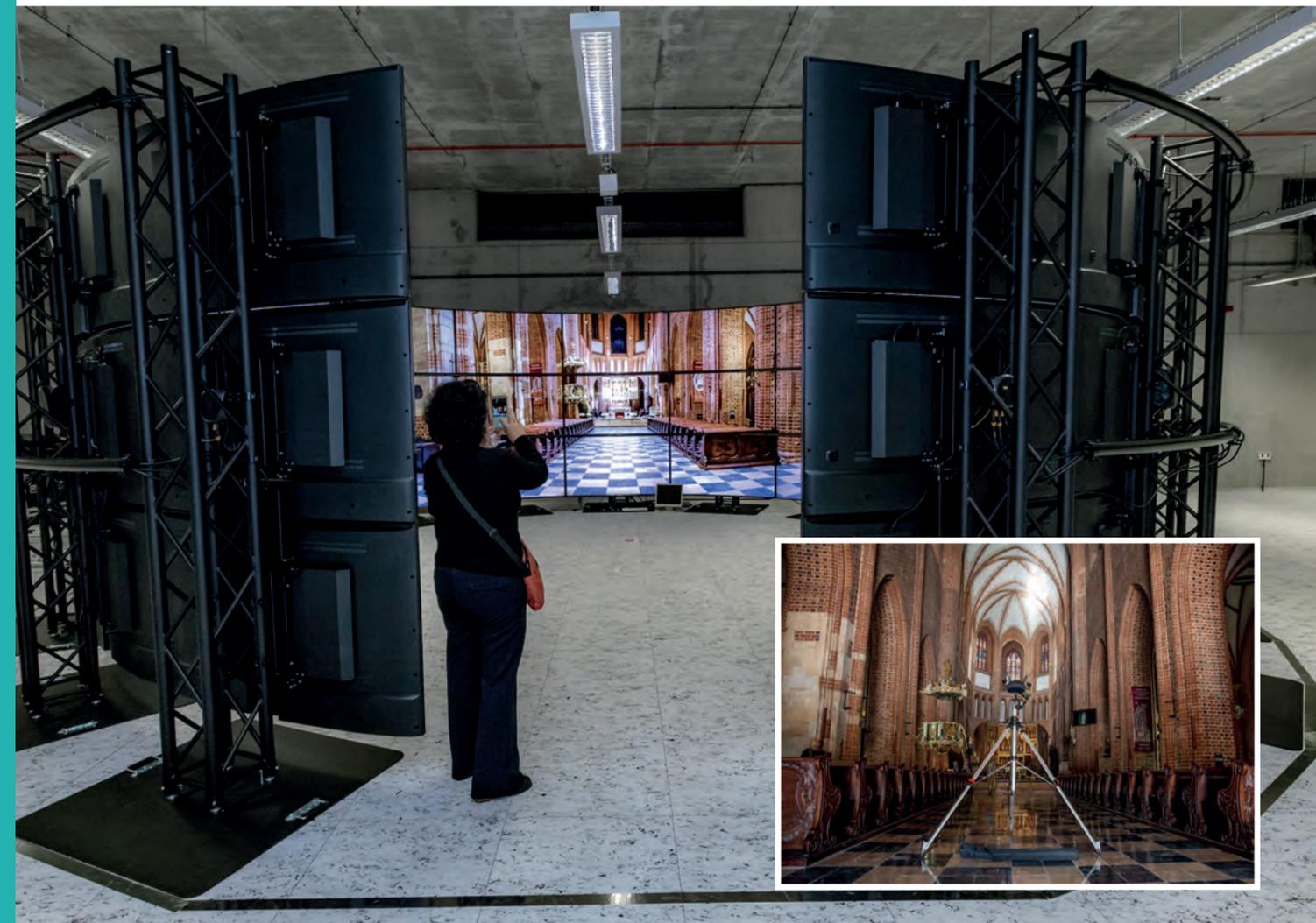
The infrastructure makes it possible to work with multimedia content including textual, musical, visual, and spatial resources (e.g., monu-

ments). The resources can be accessed through individual objects, sets, or collections (e.g., multimodal data) as well as interlinked resources. As a result, the implementation of interdisciplinary research that requires a variety of materials is far easier and linked more strongly to business.

The Dariah.lab infrastructure is built to favor the research potential of scientific institutions in the arts and humanities, support education, preserve cultural heritage, intensify economic development, and strengthen local and national tourism in Poland.

<http://lab.dariah.pl/>

The Archcathedral Basilica of St. Peter and St. Paul in Poznan – 3D scanning and immersive visualization in CAVE 2.0



MOSAIC

The European Center for Bioinformatics and Genomics

The main objective of the project is to provide a research platform enabling the acquisition of multidimensional biomedical and clinical data as well as their standardization, integration and analysis with the use of artificial intelligence algorithms.

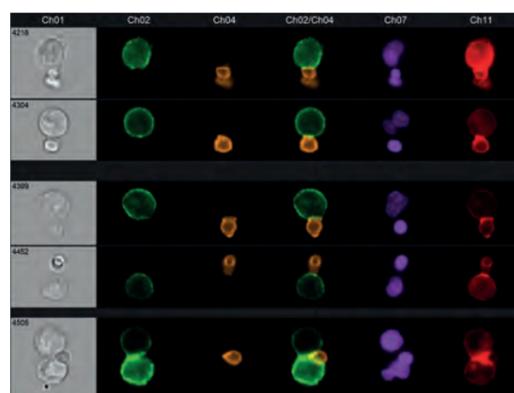
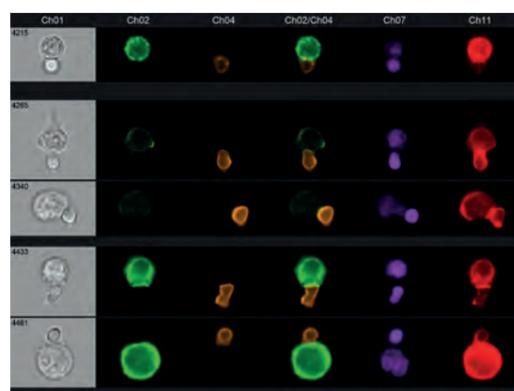
The infrastructure of the MOSAIC platform will create a highly calibrated ecosystem to conduct innovative biomedical research combining high-throughput multiomic analysis and data analysis by means of artificial intelligence methods, and will also become a source of knowledge and tools enabling the development of new preventive, diagnostic, and therapeutic approaches.

Establishment of the MOSAIC platform represents a utilitarian implementation of the key elements of a disruptive strategy for the evolution of biomedical and clinical research in Europe, developed by the LifeTime consortium, whose founding member is the Institute of Bioorganic Chemistry of the Polish Academy of Sciences. This strategy has been presented elaborately in the Nature journal. Implementation of the ECBiG-MOSAIC project is to create conditions in Poland for the development of a new type of interceptive medicine focused on identifying undesirable shifts occurring in individual cells and forestalling their persistence before they lead to the spread of disease.

<http://mosaic.ichb.pl/>

PROJECT CONSORTIUM:

- Institute of Bioorganic Chemistry, Polish Academy of Sciences
- Cardinal Stefan Wyszyński Institute of Cardiology
- Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- Maria Skłodowska-Curie National Research Institute of Oncology
- Poznan University of Technology



High-throughput single-cell analyses such as imaging flow cytometry help to gain a detailed look into the state of tissue, an organ, or the whole organism.
Credit: IBCH PAS

PL-5G

National Laboratory for Advanced 5G Research

The main objective of the project is to set up a nationally-unique research infrastructure for the practical investigation of new techniques and solutions in the area of next-generation 5G networks and services.

The project assumes a new multitier architecture with three fundamental levels. The resource and functional level comprises a network and computing infrastructure using virtualization techniques. The network level creates a series of specialized network slices, each of which employs a dedicated network and computing resources. The service level performs orchestration of services offered in the “end-to-end” relation, particularly with respect to the following groups: eMBB, URLLC, and mMTC.

The research infrastructure will follow the 5G architecture and consists of three complementary laboratories:

1. **5G network laboratory** will be built using state-of-the-art 5G solutions (wireless and wired access networks, edge cloud computing, core network, and central cloud computing).
2. **Laboratory of 5G simulators and measurement tools** will provide 5G simulators and corresponding measurement tools.
3. **5G environment laboratory** will supply a research infrastructure supporting users in developing new 5G-ready network solutions, platforms, and applications.

PROJECT CONSORTIUM:

- Warsaw University of Technology
- The AGH University of Science and Technology
- Gdansk University of Technology
- The Institute of Bioorganic Chemistry PAS – Poznan Supercomputing and Networking Center
- The National Institute of Telecommunications – National Research Institute
- Wrocław University of Science and Technology



Access to the PL-5G network will be available to all interested parties and managed by a dedicated platform. The platform will support end users with experiment setup and configuration. On top of that, it will provide remote access to the research infrastructure, allowing users to run experiments from various locations.

NEBI

National Center for Advanced Analysis of Biological and Biomedical Imaging

The project aims to set up the National Center for Advanced Image Analysis in Biological and Biomedical Sciences—a sophisticated IT infrastructure for data collection and processing.

Project implementation will be possible through building three groups of distributed laboratories: the Laboratory of Biological and Biomedical Imaging with High Passage Technique, the Laboratory of Imaging of Structures and Functions of Cells and Tissues with High Passage Techniques, and the Laboratory of Modelling and Visualization of the Dynamics of Complex Biological Processes. These facilities will be dispersed between two locations: Poznan and Mikołajki. The latter will house a modern two-storey scientific and research infrastructure and finally, for the sake of the environment, two renewable energy installations will be built in Poznan and Kąkolewo.

PROJECT CONSORTIUM:

- Nencki Institute of Experimental Biology
- Institute of Bioorganic Chemistry, Polish Academy of Sciences
- Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- Jagiellonian University in Krakow, Faculty of Biochemistry, Biophysics and Biotechnology
- Mossakowski Medical Research Center, Polish Academy of Sciences

Together, this will create a state-of-the-art integrated platform for multidimensional imaging of biological processes that are crucial for appropriate functioning of the organism as well as underlying diseases of civilization.



NLPQT



National Laboratory of Photonics and Quantum Technologies

At its core, the project is to develop a modern research infrastructure in quantum technology, photonics in general, with particular emphasis on industrial needs.

Photonics is a well-established yet still rapidly evolving field of research and technology. In fact, it is behind numerous innovations that have drastically changed our lives. Lasers, fiber optics for telecommunications, phone cameras, LED lighting in our homes, computer screens and televisions are just a few examples of how photonics has impacted our day-to-day functioning.

Since the development of photonics can bring further innovative solutions across multiple industries, it has been included in the European list of Key Enabling Technologies of the 21st century. Research and development in photonics and quantum technologies requires appropriate tools.

PROJECT CONSORTIUM:

- The University of Warsaw
- The Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- The Institute of Physical Chemistry
- The Maria Curie-Skłodowska University
- The Nicolaus Copernicus University in Torun
- The Silesian University of Technology

Furthermore, their creation is the main objective of the investment project National Laboratory of Photonics and Quantum Technologies (NLPQT), which will seek to establish new research laboratories along with a nationwide infrastructure for the distribution of standard optical frequency and quantum key distribution systems.

When completed, the entire infrastructure will also supply research services to the photonics and quantum industry. Potential recipients of the project outturns and research infrastructure built within the NLPQT project are both other research institutions and commercial recipients from the industry, looking for hi-tech solutions.



<http://nlpqt.fuw.edu.pl/>

EuroHPC PL



National Supercomputing Infrastructure for EURO HPC PL

Computing simulations of various phenomena, analysis of extensive collections of scientific data or cutting-edge visualizations requiring highly efficient computational and data storage resources have become essential tools for conducting scientific endeavors and supporting production processes. The EuroHPC PL project aims to establish a cross-sectoral, general-purpose infrastructure for large-scale computing to address research challenges in areas of crucial importance to the Polish society, the scientific communities, and the economy.

The EuroHPC PL project will supplement conventional supercomputing resources with specialized hardware, including neuromorphic accelerators, a quantum simulator, and dedicated services. As part of the project, PSNC will be responsible for creating and integrating technological solutions based on quantum processing technologies which represent a major leap in elaborating new data processing methods and, in particular, solving optimization problems. Practical application and effective use of such heterogeneous computing resources will represent a major contribution to increasing the efficiency of R&D efforts.

Since the quantum solutions differ significantly from the existing algorithmic approaches, the project aims to design reliable methods and adapt quantum computing tools to on-going problems or translate the original problem to the new form of quantum techniques.

PROJECT CONSORTIUM:

- Academic Computer Center CYFRONET AGH
- Gdansk University of Technology
- Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- National Center for Nuclear Research
- University of Warsaw
- Wroclaw University of Science and Technology

The project plans to use a hybrid approach, in which quantum computing itself will be reduced to the role of a processing element supported by classical HPC computing resources.

Building upon the previous experience and competence of PSNC teams, the project plans to develop and test new software tools and services for designing, implementing and conducting computational experiments based on hybrid heuristic methods and discrete optimization algorithms using adiabatic quantum annealing processes.

<http://eurohpc.pl/>



ELIXIR.PL

Distributed Infrastructure for Life-Science Information



The ELIXIR infrastructure was created in response to the claim that the dynamics of the data stream produced by high-throughput experiments in biology far exceeds both the dynamics of computational power growth and the ability to securely store this data.

The ELIXIR.PL initiative was launched by prominent bioinformatics centers in Poland. It was a natural response to the increasing data streams provided by high-throughput experimentation in biology (-omics). The data streams considerably exceed the dynamic growth of computer processing power and the capacity for secure data storage and data sharing offered by a single center, even if it is well-equipped. Research activities address the major challenges facing our society. Food security, ever-changing ecosystems, and provision of sustainable health care rests on our ability

PROJECT CONSORTIUM:

- The Adam Mickiewicz University in Poznan
- The Institute of Biochemistry and Biophysics, Polish Academy of Sciences
- The Institute of Bioorganic Chemistry, Polish Academy of Sciences
- The Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- The International Institute of Molecular and Cell Biology in Warsaw
- Poznan University of Technology
- The University of Warsaw

to connect and compare data from many countries, disciplines, and experiments.

But that's not all. PSNC is affiliated to the Institute of Bioorganic Chemistry and now acts as the national data hub responsible for the COVID-19 Data Platform in Poland (see more on page 57). The rapidly created and deployed integrated platform combines national scientific, medical, and epidemiological data repositories and joins them with the COVID-19 Data Platform at the European level. The Polish COVID-19 Data Platform is a shining example of a new data storage and processing repository, which will be updated to be fully compliant with the European ELIXIR infrastructure and data management requirements defined in the framework of the EU ELIXIR-CONVERGE project.

<https://elixir-europe.org/>



Polish LOFAR

A Low Frequency Radio Interferometer

The carrying theme for the project is participation in the establishment and use of the European LOw-Frequency ARray (LOFAR) radio interferometer in Poland—a new instrument operating in the 10–240 MHz frequency range, which consists of several dozen stations located in western and central Europe. Currently, the LOFAR system covers 52 stations spread across various places in Europe. All 52 European stations operate as one observational instrument.

PROJECT CONSORTIUM:

- University of Warmia and Mazury in Olsztyn
- Institute of Bioorganic Chemistry PAS—Poznan Supercomputing and Networking Center
- Jagiellonian University in Krakow
- Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences in Warsaw
- Nicolaus Copernicus University in Torun
- Space Research Center of the Polish Academy of Sciences in Warsaw
- University of Szczecin
- University of Zielona Gora
- Wroclaw University of Environmental and Life Sciences



With expected sensitivity and resolution capacity exceeding the largest radio telescopes operating today by a few dozen times, LOFAR2.0 does not just lead to spectacular discoveries, but goes as far as to entirely revolutionize our knowledge about space. It will also comprise a complementary research infrastructure for the SKA project in the southern hemisphere, present on the ESFRI road map. In addition, in the decade to come, LOFAR may remain the most potent instrument for radio astronomy of extremely low frequencies (LBA range), as SKA will not achieve such high distribution capacities at low frequencies, which in turn will

be provided by international LOFAR stations (including the Polish one). In relation to the planned upgrade of the entire LOFAR system to version 2.0, there are also plans, along with the modernization of the observational infrastructure in three Polish stations, to enhance the speed at which Polish stations connect with the infrastructure of the PIONIER network and the ILT to at least 100 Gbit/s. This will enable a considerable, 10-fold rise in the transfer speed of data generated by the new LOFAR2.0 system and thus also represent a major leap in the temporal and spatial resolution of conducted radio astronomical observations.



Fig. 15. International LOFAR Telescope (ILT)

DIGITAL TRANSFORMATION

Big data has become crucial not only to engineering and technical sciences, but is also increasingly influencing the advancement of life sciences, medical sciences, and even the humanities and social sciences. In response to new user needs, we support the digital transformation of data-driven science.

Climate and Energy

The European Commission's aim is to achieve climate neutrality by 2050.

REnergetic H2020-LC-SC3-2020-EC-ES-SCC

REnergetic empowers renewable energy communities to inhabit energy islands based on an economy of quality (attributed to the value of living and working in a clean energy society), fueling their involvement in processes that traditionally remain hidden for local communities such as heat supply. Project REnergetic aims to demonstrate the improvement of efficiency and energy autarky, community involvement and the socio-economic viability of three urban energy islands: the New Docks in Ghent, the Warta Campus in Poznan, and the Hospital and Research campus in Segrate-Milan. Pathbreaking technologies and approaches, in particular Digital Twins and Artificial Intelligence, will aid in achieving these goals, and REnergetic will provide a societal and community view. An energy island will hence comprise a virtual community of prosumers, extended by one or more digital twins which exploit cross-sectorial energy vectors for the sake of CO₂ neutrality and the best possible socioeconomical values to be achieved under the premises of the island mode of operation.

For the immediate future, artificial intelligence and smart control strategies (machine learning) at the edges of the power grid will play an increasingly vital role. This will lead to a cog-

native system where artificial grid intelligence and human intelligence blend within sustainable energy communities, predominantly characterized by the qualities of renewable energy.

RECIPE H2020-FETHPC-2017

In the years ahead, current HPC facilities will need to grow by an order of magnitude in order to reach the Exascale range. The dedicated middleware required for managing the enormous complexity of future HPC centers, where deep heterogeneity is necessary to handle the whole spectrum of applications within reasonable power budgets, will be one of the most critical aspects in the evolution of HPC infrastructure towards Exascale. This middleware is left with no other choice but to address the vital issue of reliability in face of the increasing number of resources, and therefore decreasing mean time between failures.

To close this gap, RECIPE provides a hierarchical runtime resource management infrastructure optimizing energy efficiency and ensuring reliability for both time-critical and throughput-oriented computation; a predictive reliability methodology to support the enforcing of QoS guarantees in face of both transient and long-term hardware failures, including thermal, timing and reliability models, as well as a set of integration layers allowing the resource manager to interact with both the application and the underlying deeply heterogeneous architecture, addressing them in a disaggregate manner.



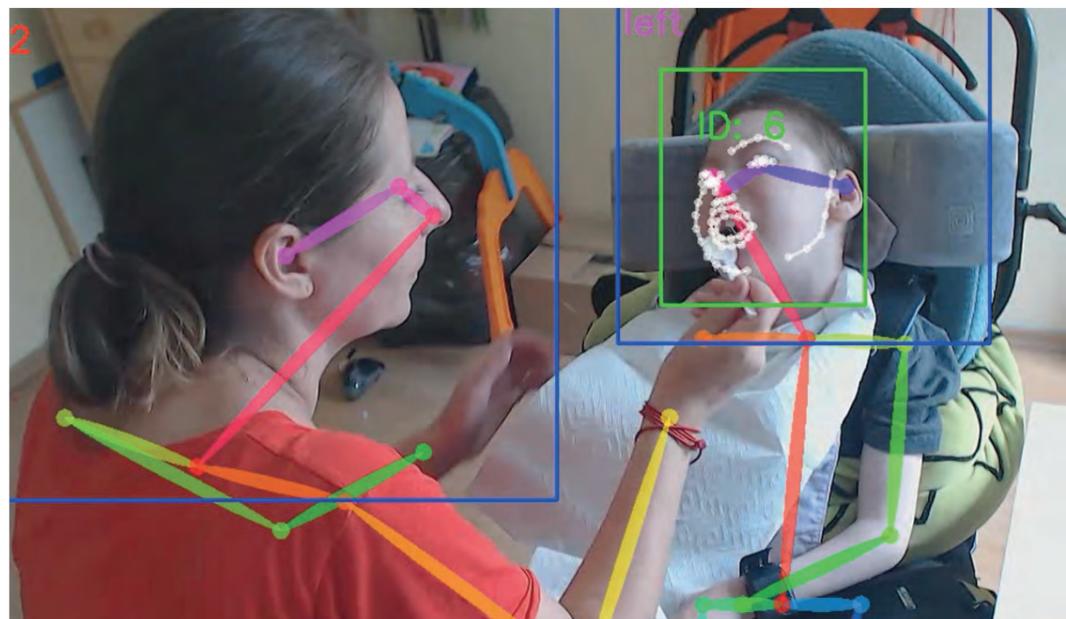
Personalized Medicine

The medicine of today is increasingly employing IT technologies to better understand the observed processes and support diagnostic and individual therapeutic procedures based on digital models.

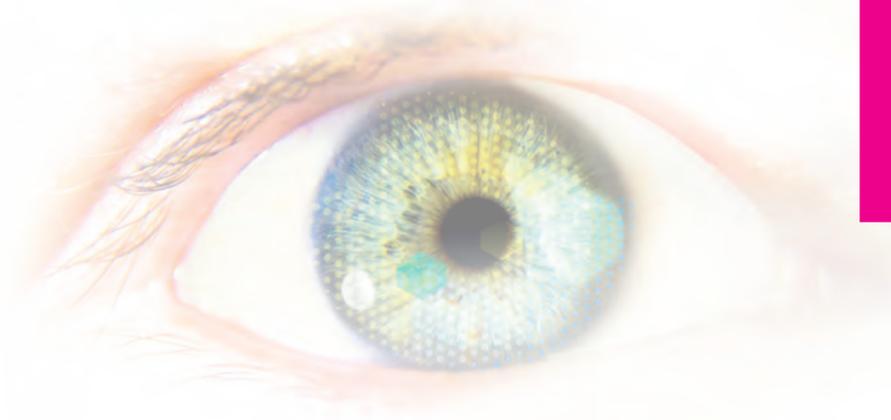
INSENSION H2020-ICT-2017-1

The INSENSION project consists in developing an ICT platform capable of recognizing non-symbolic behaviors of people with profound intellectual and multiple disabilities (PIMD), and interpreting them in the situational context as intentions of the given individual with PIMD. This way, patients with PIMD can trigger specialized assistive applications to undertake actions reflecting their

current needs. Thanks to this, people affected by this type of disability receive an opportunity to increase their self-determination and, as a consequence, enrich and improve their quality of life. To construct such a platform, the INSENSION project employs a range of sophisticated ICT technologies from the area of artificial intelligence, computer vision, and distributed systems.



Recognizing non-symbolic behaviors of people with PIMD



Glaucoma Progression Risk Assessment – GlaucomAi

One of our recent achievements in leading-edge research activities that apply machine learning methods to the area of personalized diagnosis and therapy is the GlaucomAi project. The goal was to develop a more efficient and unerring approach to determining the risk of glaucoma. The results will allow physicians to simplify patient examination and provide a prompt and reliable diagnosis.

Work conducted at PSNC in collaboration with the [W] eye clinic consisted in collecting and analyzing a large data set from patient examinations. Thanks to the holistic approach and

knowledge of the subject-matter expert, the parameter set was extended in many research experiments to find the best feature set for particular reference periods of 24-hour patient monitoring. The diagnostic capabilities of the model achieved an efficiency above 80%.

The work on the glaucoma problem conducted in PSNC goes beyond the design of a digital diagnostic model. The challenge, which determines the further direction in this topic, represents an attempt to propose an optimal individual therapeutic path for patients, based on prediction of disease development.

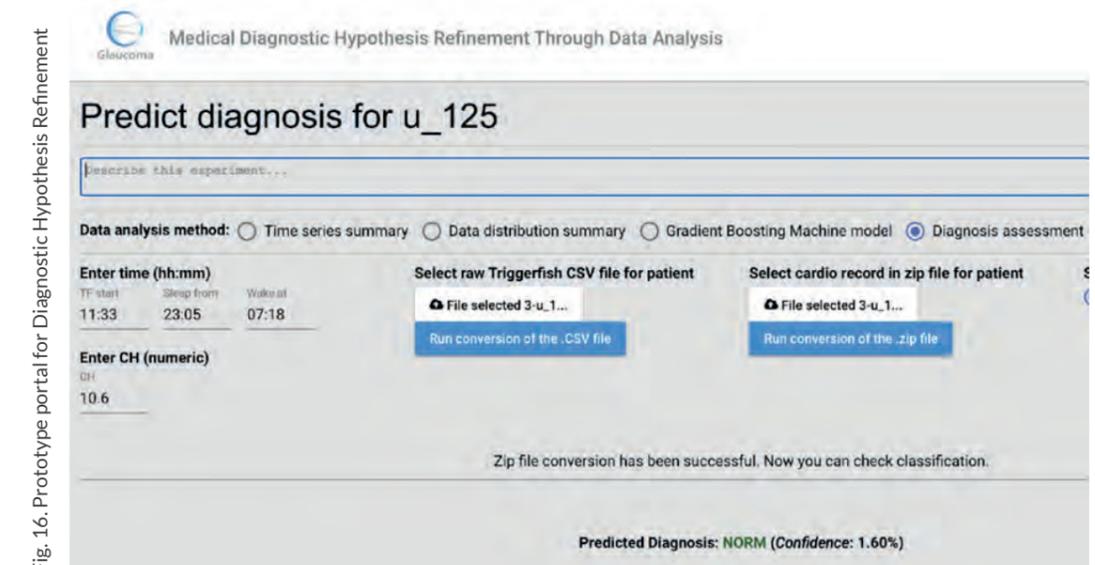


Fig. 1.6. Prototype portal for Diagnostic Hypothesis Refinement

PELOSHA AAL 2017



PELOSHA aims to create an integrated solution that can support older adults in managing their health as they age. The system will offer a personalizable environment in which all key aspects of older adults' health can be addressed with specialized AAL services and applications. The package will allow for smartly selecting services adequate to the current needs of the end user, ranging from assisting them in preventing diseases, detecting symptoms

of increased risk of health deterioration, up to the management of life with chronic diseases. The project reaps the full benefits of advances in mobile- and tele-health, artificial intelligence and the Internet of Things to build a comprehensive and user-friendly solution.

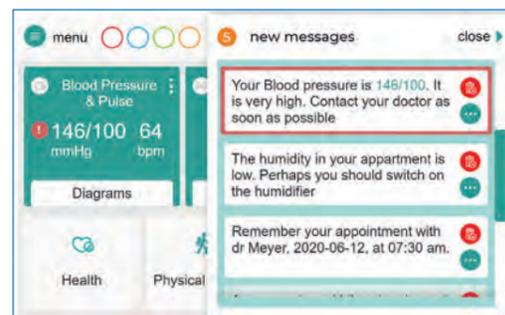
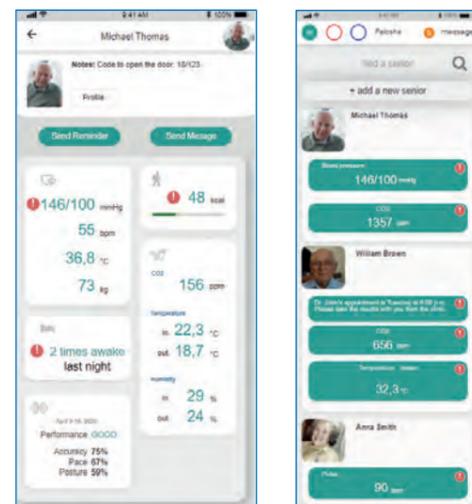


Fig. 17. The PELOSHA user interface



SELF AAL 2019

The SELF project aims at developing a technological solution based on smart T-shirts with high wearability, equipped with polymer sensors capable of improving the quality of life of older adults. Composed of smart T-shirts, user-friendly apps, and a data management platform, the innovative solution will enable real-time monitoring of vital parameters. This, in consequence, shall enable its integration in the daily routines of target end users, positively impacting their lifestyles and wellbeing. The full effectiveness of the solution will be evaluated for several target user groups, including "baby boomers" (retiring people aged 60–70), persons in the so called "alert stage"

(people aged 70+ with higher health risks) and –as a response to the current situation– people recovering from COVID-19.



Fig. 18. Real-time monitoring of vital parameters in the SELF project

National COVID-19 Data Platform in Poland

The ongoing COVID-19 pandemic caused by the severe acute respiratory syndrome 2 virus (SARS-CoV-2) represents a direct threat to human health and life worldwide. An effective response requires coordinated cooperation of the international scientific community. To facilitate the exchange of information and allow research to gain momentum at the EU level, the European Bioinformatics Institute (EMBL-EBI) and partner institutions have launched the European COVID-19 Data Platform—a shared space for exchanging and analyzing data on SARS-CoV-2 and COVID-19.

As part of this initiative, PSNC together with the Institute of Bioorganic Chemistry PAS acts as the national data hub responsible for monitoring ongoing research activities related to COVID-19. It is used to construct and integrate national scientific, medical, and epidemiological data repositories and merge them with the European COVID-19 Data Platform. The Polish COVID-19 Data Portal provides both open-access and restricted data. Additionally, as an open hub, the platform supports research on COVID-19 by providing comprehensive solutions for data analysis.

The European COVID-19 Data Portal includes a federation of national data portals hosted in those nations. As of early 2021, this includes Italy, Japan, Norway, Poland, Slovenia, Spain, Sweden, and Turkey.

<http://covid19dataportal.org>

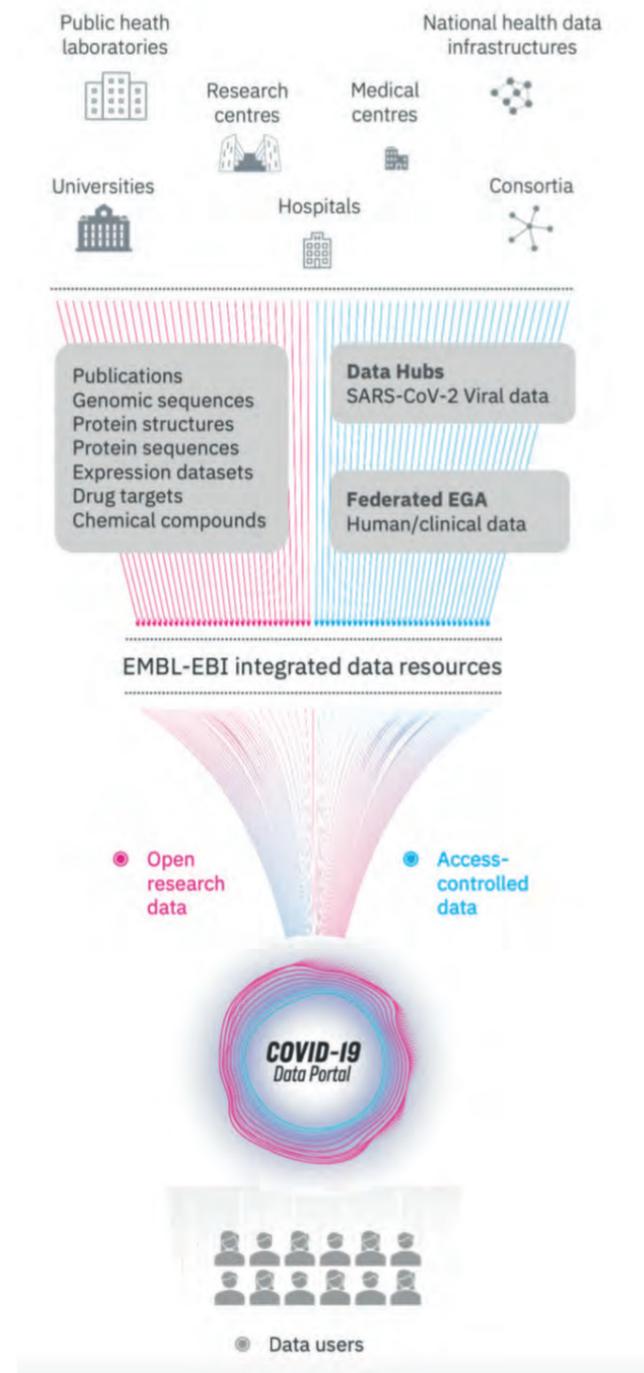


Fig. 19. Flow of SARS-CoV-2 patient and research data into the COVID-19 Data Portal

Source: The European COVID-19 Data Platform: open science for human health. Impact Case Study.

Credit: Xènia Pérez Sitjà/ELIXIR and Communication team/EBI

Precision Agriculture

Access to accurate agricultural data is vital to develop digital farming and to support cultivators and cooperatives in producing more whilst using fewer resources.

We are deploying the IoT area research results in projects related to monitoring and protecting the natural environment and smart agriculture. Our expertise in this field encompasses the construction of control electronics, support for measurement sensors, imaging systems (photographic, video streams, thermal imaging), and software development. Our solutions are based on tested technologies and communication protocols such as LoRaWAN, WLAN, and BLE. We create e-services in the form of web applications and mobile devices

addressed to farmers, agricultural advisors and industry. We have developed several services using a set of drones, including a multi-rotor aircraft with high take-off mass and flying wings with high dynamics capable of carrying out missions along a given trajectory with a set of multispectral and thermal sensors capable of assessing the condition of extensive surfaces or selected objects. We also provide services in field mapping, creating NDVI vegetation indexes, and monitoring climatic and soil conditions (comprehensive measurement stations).

SmartAgriHubs H2020-RUR-2018-1

The core objective of the SmartAgriHubs project is to consolidate and foster a European-wide network of Digital Innovation Hubs for Agriculture to enhance the Digital Transformation for Sustainable Farming and Food Production. Following this line of thought, SmartAgriHubs aim to establish a robust, multi-layered network of agricultural Digital Innovation Hubs (DIHs) and Competence Centers (CCs) to exchange knowledge and create a pan-European market for digital solutions for farming and food production. At its basis lie network CCs that are connected to a regional layer of adjacent DIHs. These DIHs are coordinated by regional clusters and managed at a European project level. SmartAgriHubs has established 9 regional cluster and selected a well-balanced set of 28 Flagship Innovation Experiments (FIEs), putting particular emphasis on the reusability of DIH services.

PSNC is the co-leader of SmartAgriHubs Regional Cluster. This Regional Cluster (RC) acts as a crucial first point of contact and a link between farmers and technology providers across North East Europe. Its goal is to bridge the gap between the needs, challenges, interests and expectations of actors in the agri-food sector. To make this possible, the RC advocates for a multi-actor approach, exploiting complementary competencies, and interactive innovation models to bring together science and practice as well as public and private. Therefore, it establishes collaboration and communication channels for all stakeholders along the agri-food chain ranging from academia, farmers, and their respective organizations to local and regional authorities.

Internet Platform of Advisory and Decision Support in Integrated Plant Protection – eDWIN



The eDWIN project is coordinated by the Wielkopolska Agricultural Advisory Center in Poznan, which has invited other partners, including PSNC, the Institute of Plant Protection—National Research Institute, the CDR in Brwinow, and all other regional agricultural advisory centers (19 in total).

The aim of the project is to conceive a national IT system for plant protection—a system that will relevantly affect the quality of food produced in Poland. The project advocates for implementation of the EU directive on the obligation to apply the principles of integrated pest management. It aims at rationalizing the use of plant protection products by agricultural producers and supporting decision-making in plant protection (such as wheat, barley, potatoes or beetroot).

Four e-services will be made available to recipients:

- Virtual farm
- Tracing the origin of products labeled as agricultural and plant protection products used
- Threat reporting
- Provision of meteorological data (extension of agrometeorological to over 600 in the whole country).

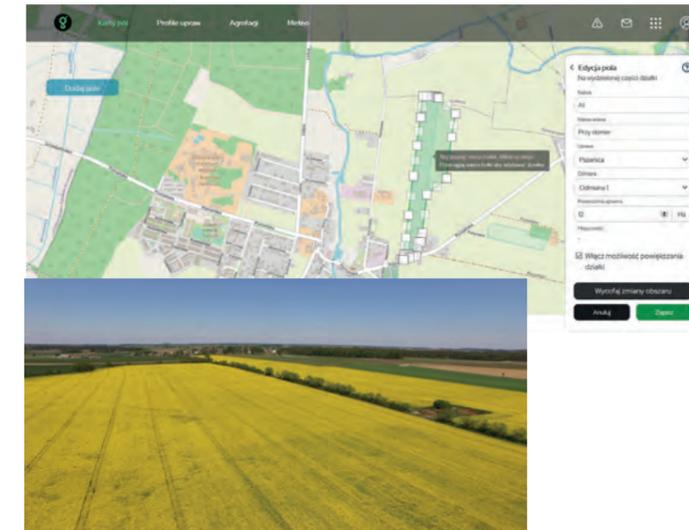


Fig. 20. Editing a crop field on a subdivided part of a land plot

PSNC as a technology partner is responsible for preparing a digital platform to integrate farmers' applications, agricultural data sources, mathematical models of plant diseases, and measurement infrastructure (meteorological and phenological stations).

PSNC is currently actively involved in several projects and initiatives in the field of intelligent agriculture. One of the elements of a broader IT platform is eDWIN, which comprises services created in the field of fertilization, biodiversity, and selection of varieties, economic management of the farm, protection of bees, and remote sensing.

CYBELE H2020-ICT-2018-2

Connecting Farming with Innovative Technology

The CYBELE project aims to demonstrate how the convergence of HPC, Big Data, Cloud Computing, and IoT can revolutionize farming, reduce scarcity, and increase food supply, bringing social, economic, and environmental benefits. CYBELE provides integrated, unmediated access to large-scale and broadly-based datasets from a multitude of distributed data sources. A data- and service-driven virtual HPC-enabled environment supports the execution of multi-parametric impact model experiments linked to agri-food.

The final result allows users to boost responsiveness and enables automation-assisted decision making, empowering the stakeholders to employ resources in a more environmentally responsible manner, improve sourcing decisions, and introduce circular-economy solutions in the food chain. PSNC provides major contributions to the data services tasks, particularly those related to semantic models, data access and query, and data harmonization and enrichment.

CYBELE Demonstrators:

- Organic Soya yield and protein-content prediction
- Climate Smart Predictive Models for Viticulture
- Climate Services for Organic Fruit Production
- Autonomous Robotic Systems within Arable Frameworks
- Optimizing computations for crop yield forecasting
- Pig Weighing Optimization
- Sustainable Pig Production
- Open Sea Fishing
- Aquaculture monitoring and feeding optimization

STARGATE H2020-SFS-2018-2

Visualizing Modern Farming with Microclimate Tools

The STARGATE project aims at developing, testing, implementing, and showcasing a framework that will streamline resilience of farming systems to variable climatic conditions and extreme weather events. The project is driven by a Living Lab approach in 9 pilot areas. PSNC is one of the major contributors to data management and integration activities, including the provision of mechanisms for processing incoming datasets with particular focus on Linked Data and FAIR principles. On top of that, PSNC will contribute to the provision of climate services for microclimate management and climate smart-farm decisions.

SIEUSOIL H2020-SFS-2018-2

Studying Soil Management in the EU and China

The SIEUSOIL project is all about designing, implementing and testing a shared China-EU Web Observatory platform that will provide Open Linked Data to monitor the status and threats of soil and assist in decision making for sustainable support of agro-ecosystem functions in the wake of the projected climate change. By means of customizable modules, the Observatory platform will support the smart management of soil at the field level and provide a showcase of good practices on soil management both for the EU and China. PSNC is one of the major contributors to the implementation of the Eurasian Soil platform.

OPEN IACS CEF-TC-2018-5

Linked Open Data Platform based on HPC

The OPEN-IACS project aims to foster data use and reuse in the context of the European Common Agricultural Policy (CAP) in order to ensure streamlined accessibility and usability by farmers, policy makers, and third parties like SMEs. The project centers around enriching HPC European capabilities by bringing into existence a common infrastructure for agri-environmental governance of the CAP. The goal of the project is to provide an open community platform for exchanging solutions in the Integrated Administration and Control System (IACS) domain for the CAP through the Linked Open Data paradigm. PSNC has two major roles: i) HPC infrastructure provider, and ii) semantic data modeler and end-point provider. Accordingly, PSNC will contribute to the implementation of the model's parallelization specification of the service level management platform as well as to the design and implementation of data models, vocabularies, and ontologies for a common semantic model.

DEMETER H2020-DT-2018-2

IoT-based Data Analysis to Improve Farming

The DEMETER project is a large-scale deployment of smart farming-IoT based platforms delivered through a series of 20 pilot installations across 18 countries. This endeavor aims to adapt and extend the existing standards into an overarching Agricultural Information Model, ensuring security, privacy, and business confidentiality across the full value chain in multiple agri-food operational environments. PSNC is one of the vital key contributors to the data and knowledge activities, including leading data management and integration tasks, as well as a playing a major role in the specification of common data models (AIM) and semantic interoperability, and supporting mechanisms for extracting AIM-based semantic descriptions from specific raw data. Moreover, PSNC will carry the ball in the Polish pilot "Pollination Optimization in Apiculture" and contribute to the second Polish pilot "Benchmarking at Farm Level Decision Support System".



Space and Air Traffic

The Single European Sky ATM Research (SESAR 2020) is a EU research and innovation program which aims to transform air traffic management into a more modular, scalable, automated, and interoperable system that draws on the benefits of advances in digital and virtualization technologies.

GOF2.0 H2020-SESAR-2020-1

The GOF2.0 Integrated Urban Airspace VLD (GOF2.0) is an extensive demonstration project that will safely, securely, and sustainably showcase the operational validity of serving combined UAS, eVTOL, and manned operations in a unified, dense urban airspace using the latest ATM and U-space services and systems.

PJ13 – W2 ERICA

H2020-SESAR-2019-1

Remotely Piloted Aircraft Systems (RPAS) have positively impacted civil and military applications. The goal of the project “Enable RPAS Insertion in Controlled Airspace” is centered around multiple benefits including developing recognized European RPAS operations in non-segregated airspace and increasing RPAS access to the airspace and equity with conventional traffic.

PANSA

Polish Air Navigation Services Agency

PANSA is a state agency whose philosophy is to provide safe and seamless air traffic by means of effective airspace management. As partners of the NAVIHUB initiative, PANSA and PSNC have engaged in collaborative work aimed at automating ATM and seamless incorporation of pilotless vehicles into airspace. Both entities share work across several EU and national projects, with the prominent use of NaviSpot in Kakolewo Airport, a one-of-its-kind experimentation testbed with air traffic and robotics at its core.



POLSKA AGENCJA ŻEGLUGI POWIETRZNEJ
POLISH AIR NAVIGATION SERVICES AGENCY



PSNC Aerospace Lab

To foster internal and external R&D endeavors under the SESAR framework, PSNC has partnered with Poznan University of Technology and Poznan Aeroclub and other partners to establish a new experimentation facility in Kakolewo called PSNC AerospaceLab. The whole experimental space has already been connected via high-speed LAN/WLAN optical networks to PSNC data center through the optical PIONIER network and integrated with the Pan-European GÉANT network. Thus, all the cloud-based, edge-based computing, and storage resources based in Kakolewo are remotely available for testing in real-time operations, including but not limited to smart mobility, autonomous flying, command, and control scenarios. Moreover, by 2022 new edge and 5G networks will gradually be set up and extend the available communication capabilities. Consequently, students and researchers will be able to design and validate proofs of concepts, in many cases also remotely, encompassing a number of different cyber-physical systems, e.g., UAVs and robots together with high-end sensors, IoT instruments, cloud-based systems, and supercomputers through LAN, WLAN, and 5G networks.

The rapid spread of low-cost, suitable quality sensors, IoT devices mounted on UAVs, autonomous vehicles, and robots creates entirely new opportunities for designing and employing cyber-physical systems in our day-to-day lives. Naturally, there has also been an increasing need for computing power on energy-constrained computing platforms, from edge sensors to cloud and HPC systems. Thus, one of the most critical motivations for setting up new testing facilities called AerospaceLab in an open airfield space was to support the complex process of designing and running proofs of concept and demonstrations on a far greater scale within natural conditions.

Initially, the following key priorities and areas have been identified for conducting R&D activities in the AerospaceLab located remotely at the Kakolewo Airport (EPPG):

- U-Space and urban mobility
- Connected and automated ATM/UTM
- AI & Big Data for Aviation 4.0
- Virtualization and cyber-secure data sharing for remote systems
- Air-ground integration and streamlined cyber-physical systems autonomy
- 5G and edge computing

The PANSA mobile air traffic control tower at the airport in Kakolewo



Smart Cities

It is anticipated that from the perspective of 2050, 68% of Europeans will be living in cities. In Europe, it is even estimated that this number will reach 85%.

Global development trends for the urban setting, as well as the future vision of cities, have led to recommendations for the Development Strategy of the City of Poznan. This document outlines strategic actions, many of which relate to technology, innovative application areas (verticals) as well as new collaboration models.

In this context, the strategy provides a definition of a Smart City as a new-generation intelligent urban environment that uses cutting-edge information and communication technologies and modern participatory management methods to improve the quality of life based on the potential of social capital and involving residents in the process of putting into effect intelligent urban solutions.

The consequent pursuit of this strategy has been supported by PSNC. The fruitful partnership between PSNC and the City of Poznan in applying state-of-the-art ICT to introduce novel models of municipal community development was established in 1997, and continues to result in a number of practical smart city solutions.

Open Data Platform

Thanks to the collaboration with PSNC, Poznan was the first city in Poland to introduce open data. First data resources were already open to citizens and business in 2011 and included not only public transportation schedules but also others, e.g., geo-data. Today, the platform covers multiple distributed data resources, among others those derived from IoT-based systems such as real-time tram and bus monitoring.

Data Analytics

Growing data has enabled us to launch efforts for advanced analysis in order to better the functioning of various aspects of the urban setting. The analyses concerned, for example, the use of the city bike system by citizens or the needs expressed within the projects submitted through the civic budget mechanism. Core efforts are now devoted to constructing a comprehensive platform allowing to dynamically integrate, analyze and visualize city data.

Applications

Over the years the partnership of the City of Poznan and PSNC has succeeded in introducing the constantly extended ecosystem of applications for citizens and other city stakeholders. The primary entry point to these applications is the Multimedia City Guide: the city portal that features e-services for citizens and visitors. Other services that are loosely coupled with the portal include air quality monitoring (Atmosfera dla Poznania), enrollment to educational institutions (Nabór) or enrichment of the city zoo experience (Smart Zoo). Most recent developments include the video publication and streaming platform or electronic identification and authorization for Poznan citizens. A fair number of applications were first conceptualized during multiple hackathons co-organized by PSNC, dedicated to practical usage of the city's open data for supporting the needs of citizens.

MARVEL H2020-ICT-2020-1

The "Smart City" paradigm aims to support new forms of resource monitoring and management and conveys situational awareness in decision-making which fulfills the objective of serving the citizen, while ensuring that it meets the needs of present and future generations with respect to economic, social, and environmental aspects. It considers the city as a complex and dynamic system which encompasses a whole spectrum of interconnected spatial, social, economic, and physical processes subject to temporal changes, continually modified by human actions. Big Data, fog, and edge computing technologies share an enormous potential in a variety of scenarios which consider each city's individual tactical strategy. That said, one critical aspect is to encapsulate the complexity of a city and support accurate, cross-scale, and in-time predictions based on the ubiquitous spatio-temporal data of high-volume, high-velocity, and high-variety.

To address this challenge, MARVEL delivers a disruptive Edge-to-Fog-to-Cloud ubiquitous computing framework that enables multi-modal perception and intelligence for audio-visual scene recognition and event de-

The island of Ostrow Tumski, the oldest part of the city of Poznan – the headquarters of PSNC are located in its vicinity

tection in a smart city setting. MARVEL aims to collect, analyze, and data mine multi-modal audio-visual data streams of a Smart City and help decision makers to improve the quality of life and services for citizens without violating ethical and privacy boundaries in an AI-responsible manner.

City of Poznań

Almost three decades of successful collaboration of PSNC with the City of Poznan has resulted in a number of service systems to support the municipal government and offer innovative services to the citizens of Poznan, including an official website (Multimedia City Guide), a system that stands behind school recruitment (NABÓR), but also an online platform for the Poznan Civic Budget or a municipal Platform for Open Data. As part of a wide array of initiatives, PSNC is also working very closely with the Wielkopolska Province, as well as with the Marshal of the Wielkopolska Province and the Board of Education in Poznan.



Industry 4.0

DIH HPC4Poland

By triggering the first Digital Innovation Hub in Poland back in 2016, PSNC has expanded its open innovation strategy to encompass the industrial sector. By merging resources and engineering competencies of 21 hub members—including competence centers and business partners—HPC4Poland DIH has never stopped developing groundbreaking Industry 4.0 solutions ever since.

The recent E-DIH approval from the Polish Ministry of Economic Development, Labor, and Technology has brought our DIH to the

next level of international collaborations: the €7 billion Digital Europe Program and Horizon Europe.

HPC4Poland DIH makes it a top priority to improve innovativeness of the industrial and public sectors in the region by raising the availability of advanced, collaborative services. Never before has the Polish industry been this close to ordering sophisticated science-to-business services locally and at reasonable cost.

<http://hpc4poland.pl/>

SHOP4CF H2020-DT-2019-1

Our long-standing collaboration with VW Poznan has brought about this compelling project, where AI, predictive maintenance and advanced image recognition technologies are engaged in optimizing the paint shop and assembly line lead times, data sharing, and workstation ergonomics.

The resulting Smart Human Oriented Platform for Connected Factories will standardize data interfaces and short-circuit adding new Industry 4.0 components across locations of a single

manufacturer as well as across various entities. The combined forces of Volkswagen, Bosch, Siemens, Arcelik, and leading-edge European technology centers shall deliver a number of technological pilots to further be uptaken by external partners, selected in five competitive open calls.

Additionally, the new Industry 4.0 components along with never-before-seen architecture will give grounds for the SHOP4CF marketplace via which innovating SMEs will gain access to shared landmark solutions.

Change2TWIN H2020-DT-2018-2020

In this project we are looking for manufacturing SMEs and midcaps that seek to improve their competitiveness by implementing Digital Twinning Technology. Built on top of PSNC's computational resources, the project services are delivered to SMEs and midcaps whose innovation potential justifies their choice.

Moreover, by participating in open calls, high-achieving manufacturers will receive assessment and guidance from certified Digital Innovation Hubs (DIH) helping them to minimize innovation investment risks by taking conscious and fact-based decisions on which digital twin to choose and how to put it into place in their processes.

DIH4CPS H2020-DT-2019-1

The initiative for Fostering DIHs for Embedding Interoperability in Cyber-Physical Systems of European SMEs (DIH4CPS) will foster an embracing, interdisciplinary network of DIHs and solution providers, focused on cyber-physical and embedded systems, interweaving know-how and technologies from different domains, and connecting regional clusters with the pan-European expert pool of DIHs.

EUHubs4Data H2020-DT-2019-2

The European federation of Data Driven Innovation Hubs aims to consolidate as the European reference for data driven innovation and experimentation, fostering collaboration between data-driven initiatives in Europe, federating solutions in a global common catalog of data services, and sharing data on a cross-border and cross-sector basis.

Digital Culture and Humanities

EnrichEuropeana+

The EnrichEuropeana+ project comprises an initiative to combine citizen science and artificial intelligence to explore 19th-century manuscripts and make them available to researchers, students or amateur historians. Apart from PSNC, the ranks of this initiative were joined by partner institutions from Poland, the Netherlands, Germany, Ireland, Austria, and Croatia.

There is a wealth of information about 19th-century history, which remains mostly dormant in archives. The majority of original sources are available merely in the form of manuscripts, making it impossible to access on a wider scale. To address this issue, the project will seek to digitize important and noteworthy documents, while the use of artificial intelligence, paired with the contribution of the community acting as "Scientists-Citizens", will aid in transcribing these handwritten documents.

EnrichEuropeana+ is based upon previous EU-funded projects that have developed the Europeana platform, the Transcribathon platform for crowdsourcing transcriptions in Europeana, and the Transkribus automated transcription tool. The project will apply natural language processing and big data analytics technologies to the analysis of transcriptions and their translations, providing support for semantic enrichment of metadata, clustering, and classification.

As a participant of the first edition of the project, PSNC will continue to develop the document delivery software for the Transcribathon platform. The work also includes planned extensions in other systems centered around our national cultural heritage metadata aggregator, the Digital Libraries Federation.

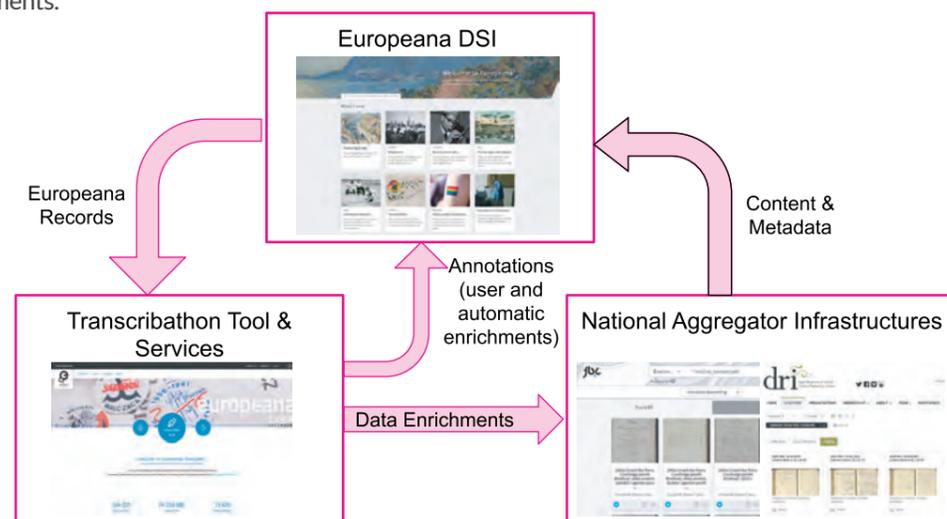


Fig. 21. Document workflow for the Transcribathon platform

Progressive Visual Decision-Making in Digital Humanities PROVIDEDH

CHIST-ERA-2016-VADMU

The primary sector of interest of the PROVIDEDH project is geared toward creating visualization systems that aid the handling of uncertainty in Digital Humanities (DH) datasets. Our tools on the collaborative platform were developed against a background of human-centered design with a focus on easing uncertainty annotation, and visualiza-

tion, promoting the use of TEI standards and making doubtfulness play a more active role in the research process. The project delivers visualization of links between entities in different project files. These visualizations will allow users to interact with data in a more intuitive way and to get a clearer sight of any connections, trends and anomalies.

Polish Digital Libraries Federation

The Polish Digital Libraries Federation (FBC) is a national metadata aggregator of cultural heritage and scientific content. Its day-to-day activity consists in harvesting more than 120 data sources such as digital libraries, archives, data repositories or museums that FBC is connected to. The aggregated content is consolidated, normalized, enriched, and cleaned to provide various services to its end users. FBC provides search, browse, and data access/discovery services for a broad community, including DH researchers, teachers, curators, and art creators, as well as hobbyists. This service, developed in 2007, can be attributed to the endeavors of Poznan Supercomputing and Networking

Center (PSNC); it has a worldwide reach and serves more than 1 million unique users annually. The FBC holds information on over 7 million digital assets. It has been an accredited national aggregator for Europeana since 2019.

Digital Skills and Education

Educational Programs in AI

PSNC has been actively involved in the digital revolution through educational initiatives seeking to impact the evolution of the information society. Numerous educational projects and programs conducted independently or in tight cooperation with other academic facilities and businesses focus on developing digital skills for young people, being one of the key activities of PSNC in the area of education. Preparation and implementation of modern teaching programs within IT education, programming, and artificial intelligence are the main challenges undertaken by PSNC.

Today, the labor market has a deficit of employees specialized in artificial intelligence (AI). Artificial intelligence is projected to be developed intensively across many areas, becoming the main impetus behind economic advancement worldwide. Whether young people will feel

comfortable in such a reality in a few years' time depends on their skillset and expertise. That is why it is so vital to adjust teaching curriculums to the needs and requirements of the current labor market.

The educational programs implemented by PSNC have been participated by over 10,000 students and 1,000 teachers in programming courses, with dozens of educational materials prepared. In cooperation with Intel Polska, Poznan Supercomputing and Networking Center implements educational programs Intel® AI for Future Workforce and Intel® AI for Youth in several European countries. Their goal is to prepare young people for the AI revolution. These curriculums encompass a never-before-seen environment for AI cloud education—AI PIONIER Research & Classroom.

Drawing on past experiences and lessons learned, together with a dedicated Innovative Education Laboratory, PSNC will train 1,800 students and 120 teachers from 60 high schools in Poland. Furthermore, PSNC will offer them technical expertise, support, and help them troubleshoot in real time and with advanced technologies.

<http://classroom.pionier.net.pl/>

Each of the implemented programs include the following stages:

- **Inspiration by Artificial Intelligence:** At this stage, young people are inspired by AI possibilities and capabilities. They learn which problems can be solved using AI to develop projects that may influence society. They also discuss potential threats as well as the ethical and social consequences of AI application.
- **Acquiring Skills:** At this non-technical stage, young people develop fundamental skills essential for the organization and development of their own AI projects (from idea to implementation). This helps explain AI domains (DATA), computer vision (CV), and natural language processing (NLP).
- **Development of Experience:** Participants spend most of their time building their technical expertise in specific AI fields, particularly in DATA, CV, NLP.

- **Use of Skills:** At this final stage, participants have a chance to make the best use of their skills to solve current issues, keeping the social and ethical impact in mind.

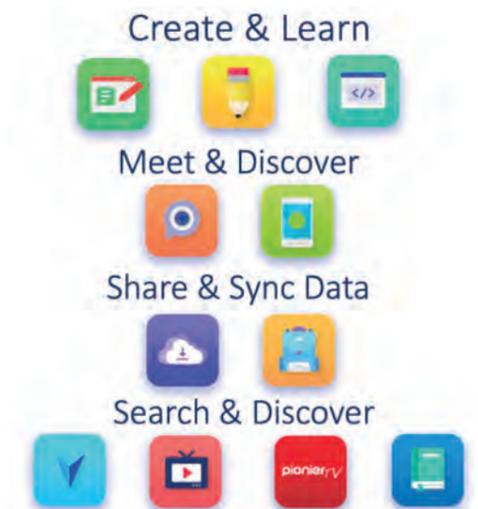


Fig. 22. The PIONIER Research & Classroom service scenarios

Training Courses, MOOCs, and e-Training Services

The COVID-19 pandemic has forced changes across a whole palette of areas, from work and leisure to school education. Professional activity and the process of education were moved to locations that had previously served as a space free from work and learning.

Even though educational activities were continued thanks to technological advancement, Internet access, and essential tools, at the same time the weakness of educational systems, shortage of national open educational services, and insufficient education within the development of engaging educational content have been revealed worldwide.

The infrastructure developed by PSNC—PIONIER Research & Classroom – has supported remote work for years. PSNC provides online training courses aiming to streamline digital skills and

has launched new e-services that assist in remote work. In partnership with numerous academic and cultural facilities and public administration, we also hold training courses which seek to improve digital skills involving not only the young, but also the old, as well as people with disabilities.

The new laboratory and e-training services developed under the framework of the PIONIER-LAB project—the National Platform for Integration of Research Infrastructures with Innovation Ecosystems—will enable research on boosting the efficiency of the education process. The laboratory will provide support in the preparation, analysis, and evaluation of e-training. On top of that, it will enable entrepreneurs and institutions specialized in e-learning to acquire data regarding the selection of educational content and to adjust their teaching methods, tools, and products.

Next Generation Media

In recent years, hidden away in the laboratory of the New Media Department, PSNC has been conducting R&D activities related to new multimedia technologies such as immersive formats, ultra-high resolution, stereoscopic, or immersive sound and VR/360 video.

Since 2011, the team has participated in research projects devoted to next-generation media. The VISIONAIR project focused on providing European researchers with visualization and networking infrastructure for research and experimentation. The ImmersiaTV project dealt with combining and streaming a traditional TV signal with 360° omnidirectional video and interaction mechanisms, while the Immersify project focused on encoding and transmission of high-resolution immersive formats. Meanwhile, the GÉANT project centers around developing videoconferencing tools such as eduMEET.



8K live streaming demo to Ars Electronica Festival

That said, new formats for high-quality multimedia content also require the recording of high quality reference content for research

and demonstration. Since such material is usually unavailable, there is a compelling need to produce it using modern 8K cameras or in-house prototype equipment.



8K camera during live streaming to Japan

The TV team was able to produce experimental content using a variety of techniques. The crew recorded 8K video footage in a variety of conditions and with various equipment, whether it was climbing the peaks of the Karkonosze Mountains and filming nature in winter weather, recording cars on a race track with a special rig mounted on another car, shooting underwater footage with a dedicated housing, or taking aerial photos with a drone camera. The use of slow-motion cameras enabled recording fast-moving processes in 3D, and the construction of a special 360° rig composed of eight high-resolution cameras paved the way for recording high-resolution concerts and music events.

The latter was combined with research on the Ambisonic sound recording and processing which, instead of acquiring multiple sound channels, records the entire sound field. This has made it possible to recreate the atmosphere from concerts and combine this sound with 360° video. One such experiment was recorded on the roof of the PSNC building.

The team also dealt with the acquisition of point clouds from laser scanners and visualization of this data in the form of high-resolution movies and applications. The results are scans of the Poznan Cathedral and the fallout shelter in Poznan, as well as scans of skulls of Polish dukes, which are related to research on the first members of the Piast dynasty.

The recorded content is not just presented in the laboratory. In order to promote and share the works, an initiative called PIONIER TV was created. PIONIER TV is a portal that promotes popular science films related to the entities associated with the PIONIER network.

Media control room during broadcasting an immersive content



There are also several demonstrations and TV productions. PSNC took part in the pioneering demonstrations of 8K transmissions from Poznan to Japan, the U.S.A. and Brazil with low latency. Other occasions involved the use of satellite or 5G transmissions. Drawing on the benefits of recording and streaming technologies employed during the pandemic, PSNC has also supported cultural institutions such as theaters and operas by realizing on-line transmissions of performances closed for the audience.

That said, it is equally important to cooperate with artists. Among others, artistic residencies for students of the Poznan Academy of Music related to Ambisonic sound are held, and the co-created project "Concert Machine" has enabled interactive music-making via the Internet together with a music band.

Plans for the near future include extending the laboratory with new areas related to scanning, photography and visualization in connection with the implementation of the infrastructure project "Digital Research Infrastructure for Humanities and Arts DARIAH-PL".

SOLUTIONS AND PRODUCTS

The development of dedicated services that simplify the business use of research infrastructure is a precondition for successful and timely projects aimed at transforming the economy and administration. National and international projects often open up opportunities for us to deploy our products and tools to strengthen data organization, management, and processing.

ROHUB

ROHUB enables the management, sharing, and preservation of research artefacts related to a particular investigation/research challenge as a single information unit through the Research Object (RO) concept and model. In this line, ROHUB supports scientists and related stakeholders (e.g., corporate R&D department directors) throughout the research lifecycle to create high-quality research objects that can be interpreted, shared and potentially repro-

duced. It allows for the management and tracking of their evolution, to collaborate along this process, to search and discover them or their aggregated resources.

ROHUB provides access control and different collaboration features (quality management, evolution and version control), release and publication of research objects and assignment of DOIs to investigation snapshots.

<http://rohub.org/>

QCG

The QosCosGrid (QCG) infrastructure comprises a set of integrated, high-performance services and access tools for managing resources and tasks in multi-cluster and grid computing settings. QosCosGrid fosters a variety of scenarios for applications, including wide-ranging parallel applications, parametric applications, and complex workflow applications. QosCosGrid services enable logical merging of computing resources from multiple

clusters into a single distributed computing system. This permits shortening the waiting time for resource allocation and running a variety of computing tasks with requirements exceeding the capacity of a single cluster. By using mechanisms for advanced resource reservation, QosCosGrid services guarantee that its users receive the required quality of computing services, including task execution time.

<http://qoscosgrid.org/>

conference4me



The conference participant's assistant, designed and developed by PSNC experts, accompanies a whole spectrum of international events. It offers relentless access to the regularly updated meeting agenda and other information materials, e.g., allowing to plan participation in particular sessions and follow the currently running ones. It also reminds participants of upcoming

sessions, provides them with a guide, it shows them the way to appropriate rooms or facilitates host cities (possibility of marking key locations, such as hotels, official dinner venues, conference dinner locations, conference locations, etc.). This application is designed for mobile devices and based upon the latest technologies.

<http://conference4me.psnk.pl/>

dingo

Providing comprehensive IT solutions to public and private entities that are after efficient management of digital resources is the main goal of DInGO. IT tools can be used to build libraries, archives or digital repositories. PSNC also supports scientific and cultural institutions which publish documents, works of art,

or archives in digital form on the Internet. Our solutions cover the whole process of publishing digital objects and scientific data, including stewardship of the digitization process, long-term storage of source data, making the objects available, as well as managing them

<http://dingo.psnk.pl/>

ARM

ARM is a Large Vocabulary Continuous Speech Recognition engine for the Polish language. The main engine component, i.e., the acoustic model, is an example of a hybrid approach in which a more traditional Hidden Markov Model is combined with the latest technology, namely Deep Neural Network. The engine can process recordings of-line and live audio stream online. It is the heart of a number of applications supporting dictation

and recording processing for conference speech transcriptions, document production and video subtitling, to name just a few examples. An important area of ARM application is audio content retrieval. The ARM engine also constitutes the main component of the speech recognition service that can be integrated with various end users' systems such as Interactive Voice Response.

<http://speechlabs.pl/>

Nabór Nabór

The NABÓR Recruitment System is the first of its kind combining recruitment and student management at all levels of childcare and education, i.e., for nurseries, kindergartens, elementary schools, junior high schools, high schools and dormitories. It is divided into two modules: Recruitment and Student Management. The Recruitment Module covers

the entire admission process from an on-line application submission, through application evaluation to automatic student-to-school assignment that yields an optimal solution to the assignment problem. The Student Management Module offers functionality for administering students attending schools

<http://nabor.pcsc.pl/>

ROHUB	QCG	conference4me	dingo	ARM	Nabór
2500 objects	200 clients	173,537 users	306 licenses	4 deployments	19,362 licenses

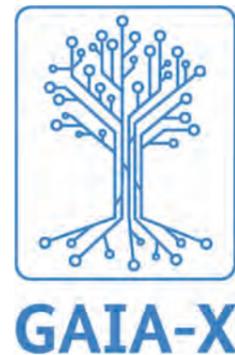
INTERNATIONAL PARTNERSHIPS

PSNC growth remains closely related to the activity of our teams in international associations, partnerships and working groups. Numerous projects have become, in many cases, the beginning of our permanent cooperation within such organizations. One of the latest such initiatives is the Gaia-X Association, which PSNC has reinforced as the first scientific entity from Poland.

Gaia-X A Federated Data Infrastructure for Europe

The Gaia-X project was created in 2020 by a French-German initiative to create the next generation of data infrastructure: an open, transparent, and secure digital ecosystem where data and services can be made available, segregated, and shared in an environment of trust. Representatives from business, politics, and science from Europe and around the globe are working together to create a federated and secure data infrastructure. Companies and citizens will collate and share data—in such a way that it can be controlled. They should be the ones to decide what happens to it, where it will be stored, and always retain data sovereignty. The architecture of Gaia-X is based on the principle of decentralization. Gaia-X is the result of a multitude of individual platforms that are all guided by a common standard—the Gaia-X standard. What emerges is therefore not a cloud, but a networked system that links a variety of cloud services providers together. The Gaia-X Association recently announced that it has now welcomed a total of 300 members, including small, medium and large enterprises as well as business associations and research institutions.

Within the framework of the Gaia-X initiative, PSNC actively participates in working groups contributing to the standards and guidelines for the newly-established European data infrastructure and on the basis of its own competences and resources, it develops, deploys, and offers pathbreaking services and tools for digital transformation of sectors such as Health, Agriculture, and Industry 4.0.



Alliance for Internet of Things Innovation (AIOTI)

AIOTI aims to enhance innovation and economic development across the Internet of Things in Europe. Together with its partners, it aims to lead, promote, bridge, and collaborate in IoT & Edge Computing and other converging technologies, research and innovation, standardization, and ecosystem building, providing IoT deployment for European businesses and creating benefits for European society. PSNC actively participates in several working groups of the AIOTI such as Agriculture, SCo-DIHNet, Urban Society, and Research&Partnerships.



Artificial Intelligence DIH Network

The European Network of Digital Innovation Hubs with focus on AI sets a blueprint for cross border collaboration based on thoroughly assessed hub business models, common systems, collaboration and governance structures (including financial and legal aspects of the collaboration). PSNC orchestrates HP-C4Poland DIH in collaboration with other AI DIHs to unlock their collaboration and networking potentials by means of mentoring endeavors and developing shared business scenarios.



Big Data Value Association (BDVA)

The mission of BDVA is to develop an Innovation Ecosystem that will enable data and AI-driven digital transformation in Europe and deliver maximum economic and societal benefit, achieving and sustaining Europe's leadership in the creation of Big Data Value and Artificial Intelligence. PSNC is acting as a full member of this organization and has been labeled as a silver BDVA iSpace.



EUDAT Collaborative Data Infrastructure

EUDAT CDI is a consortium and legal organization delivering data services, which aims to build a European data infrastructure. It is sustained by a network of over 20 European research organizations, as well as data and computing centers. PSNC supports a long-term sustainability plan, and commits to develop, maintain and deploy pan-European research data services whilst promoting the harmonization of research data management practices.



European Cluster Collaboration Platform (ECCP)

ECCP is the European hub for industry clusters with a mission to strengthen the European economy through collaboration. PSNC has co-created and supports the Wielkopolska ICT Cluster in their collaborative efforts with other EU clusters to raise the competitiveness of EU regions by fueling them with hi-tech digital tools and services.



European Network of Living Labs (ENoLL)

ENoLL is the worldwide federation of 200+ benchmarked living labs providing co-creation, user engagement, experimentation methods and facilities targeting innovation across different domains such as healthcare, art, smart city, agri-food and many more. As an effective member of ENoLL, PSNC Future Labs run social innovation workshops, hackathons, and interdisciplinary design thinking courses. This mutually inspiring collaboration helps to scale our local activities globally and provides a feedback loop with foreign partners.



European Open Science Cloud (EOSC)

The EOSC Association brings together key stakeholders in the European research environment such as research funders, service providers, representatives of the research community, and intergovernmental organizations to agree on strategies for the advancement of Open Science and for optimizing the conditions for research outcomes to benefit the European society. PSNC is strongly involved in work for EOSC and in promoting the activities of the Association in the PIONIER network. More details about this cooperation can be found on page 22.



European Technology Platform for HPC (ETP4HPC)

ETP4HPC is a private, industry-led and non-profit association with a mission to promote European HPC research and innovation in order to maximize the economic and societal benefit of HPC for European science, industry and citizens. As an R&D organization and HPC data center, PSNC has co-organized EuroHPC Summit Week 2019 in Poznan together with EuroHPC, ETP4HPC and PRACE, playing the role of a hosting site. As a PRACE-6IP partner, PSNC is also directly co-operating with ETP4HPC working groups by publishing technical reports.



FIWARE Foundation & iHUBs

FIWARE Foundation develops an open sustainable ecosystem around public, royalty-free, and implementation-driven software platform standards that ease the creation of smart applications across multiple sectors. Acting as the Gold Strategic Member of the FIWARE Foundation, PSNC contributes its engineering competence and computational resources to the Foundation efforts. Also being one of FIWARE iHUBs, PSNC stands behind local digital businesses to be more competitive in the current digital economy.



GÉANT Association

European NRENs are collaborating under the umbrella of the GÉANT Association to deliver the pan-European GÉANT network for scientific excellence, research, and innovation on a global scale to advance research and education. The GÉANT Association ecosystem consists of infrastructures and services (from GÉANT and the NRENs) that are employed in communication, collaboration, exchange of data and access to repositories, services, and facilities. The GÉANT Association serves the NRENs, which deliver their own national infrastructure and add services specific to the needs of their users—R&E organizations. More details about the collaboration of PSNC within the GÉANT Association can be found on page 14.



Internet2

Internet2 encompasses a community that provides a secure high-speed network, cloud solutions, research support, and services tailored for research and education. The whole includes higher education, research institutions, government entities, and cultural organizations in the United States, as well as similar entities around the world. PSNC is actively collaborating with Internet2 in the scope of supporting hi-tech research applications, and trust and identity services, as well as end to end performance monitoring tools. On top of that, our teams are contributing to the community-developed, open-source perfSONAR toolkit.



Next Generation Internet (NGI)

The overall mission of the NGI initiative is to re-imagine and re-engineer the Internet for the third millennium and beyond. NGI connects the ICT industry leaders and national representatives of EU Member States. PSNC represents the interests and perspectives of Poland in the collaborative efforts to maximize the performance of future Internet-related benefits.



Open and Agile Smart Cities (OASC)

The OASC network brings together smart cities and communities worldwide to shape the global market for digital services. PSNC supports the City of Poznan in fueling the joint vision of smart cities by co-designing sharable tools and services based on open, interoperable data, related mechanisms, and platforms.



Partnership for Advanced Computing in Europe (PRACE)

PRACE is established in Brussels as an international non-profit association (aisbl). It joins together 26 member countries whose representative organizations form a pan-European supercomputing infrastructure, providing access to computing and data management resources and services for large-scale scientific and engineering applications at the highest performance level. PRACE offers a wide range of opportunities and develops future services, especially in the area of federated Big Data analysis, joining with GÉANT to coordinate activities and to support the European Data Initiative. The PRACE research infrastructure is enriched by PSNC's computing resources. Poland's participation in the PRACE partnership is co-financed by the Ministry of Education and Science.



Editing:

PSNC Team



Poznan Supercomputing
and Networking Center

ul. Jana Pawła II 10
61-139 Poznań

www.pcsc.pl

Cooperation:

www.munda.pl

Printing:

Printing Company
Moś and Łuczak

www.mos.pl



www.psnk.pl

Poznan Supercomputing
and Networking Center
is affiliated to the
Institute of Bioorganic Chemistry
Polish Academy of Sciences

