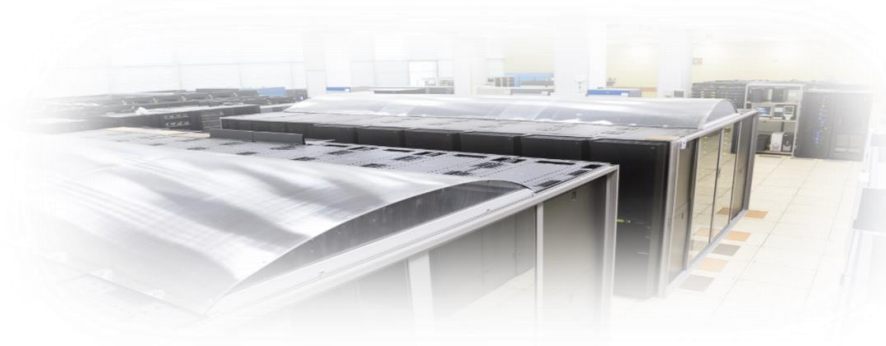
JOINT INSTITUTE FOR NUCLEAR RESEARCH
ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

Status and perspectives of the JINR Multifunctional Information and Computing Complex (MICC)

Korenkov Vladimir (MLIT, JINR)



The 10th International Conference "Distributed Computing and Grid Technologies in Science and Education" (GRID'2023)
3 – 7 July, 2023
Dubna, Russia

Grid technologies - a way to success

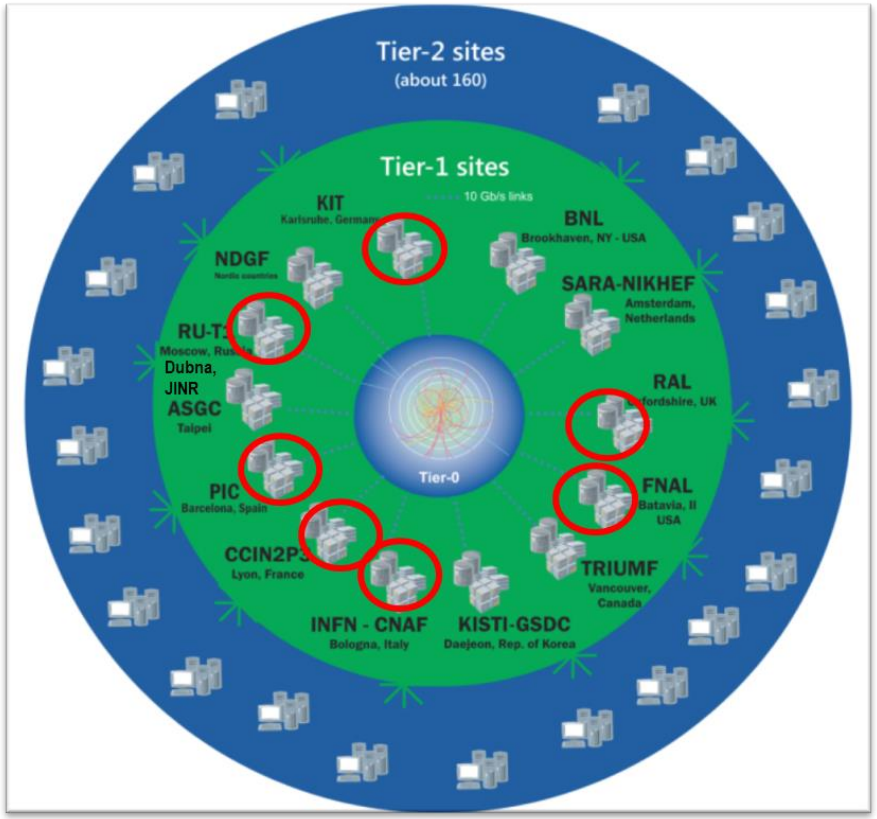
On a festivity dedicated to receiving the Nobel Prize for discovery of Higgs boson, CERN Director professor Rolf Dieter Heuer directly called the grid-technologies one of three pillars of success (alongside with the LHC accelerator and physical installations).

Without implementation of the grid-infrastructure on LHC it would be impossible to process and store enormous data coming from the collider and therefore to make discoveries.

Nowadays, every large-scale project will fail without using a distributed infrastructure for data processing.

The Worldwide LHC Computing Grid

WLCG: an International collaboration to distribute and analyse LHC data. Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists



The mission of the WLCG project is to provide global computing resources to store, distribute and analyze the ~50-70 Petabytes of data expected every year of operations from the Large Hadron Collider.

WLCG computing enabled physicists to announce the discovery of the Higgs Boson.

170 sites

42 countries

> 12k physicists

~1.4 M CPU cores

1.5 EB of storage

> 2 million jobs/day

100-250 Gb/s links

Worldwide LHC Computing Grid - 2019

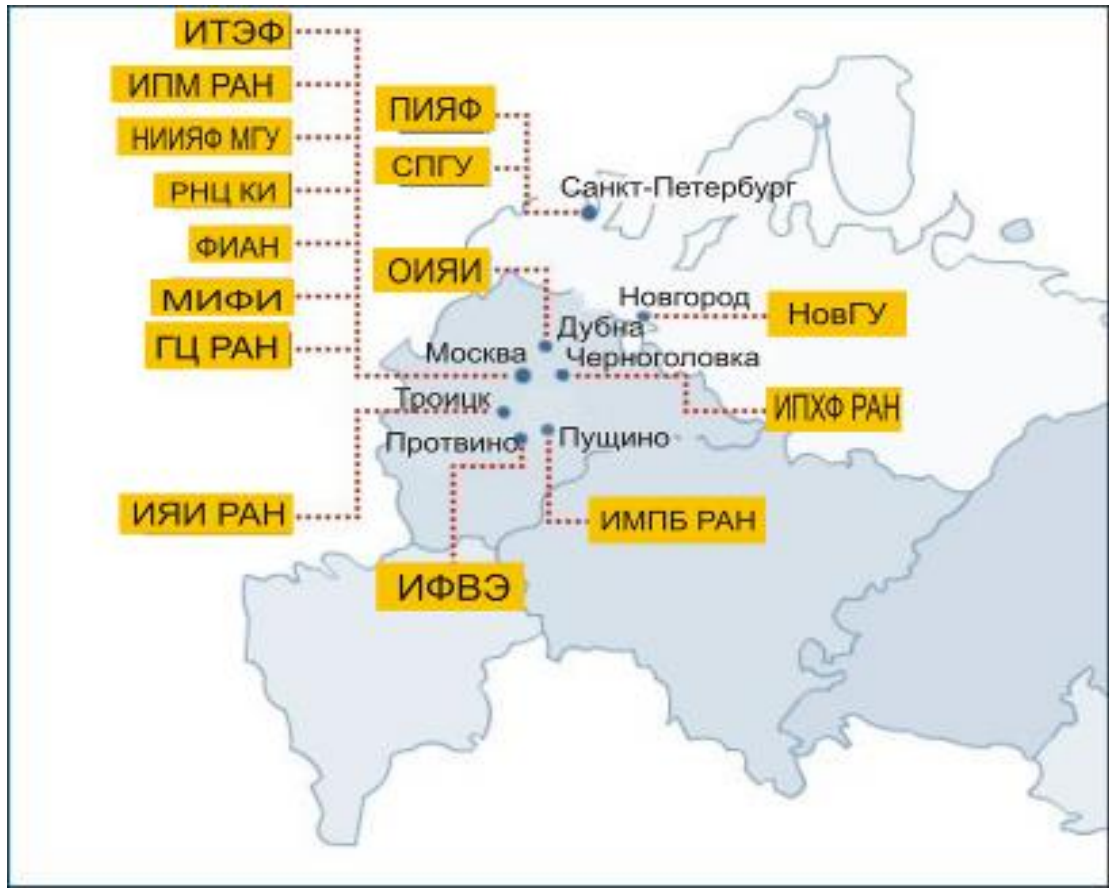
Tier0 (CERN): data recording, reconstruction and distribution

Tier1: permanent storage, re-processing, analysis

Tier2: Simulation, end-user analysis

Russian Data Intensive Grid infrastructure (RDIG)

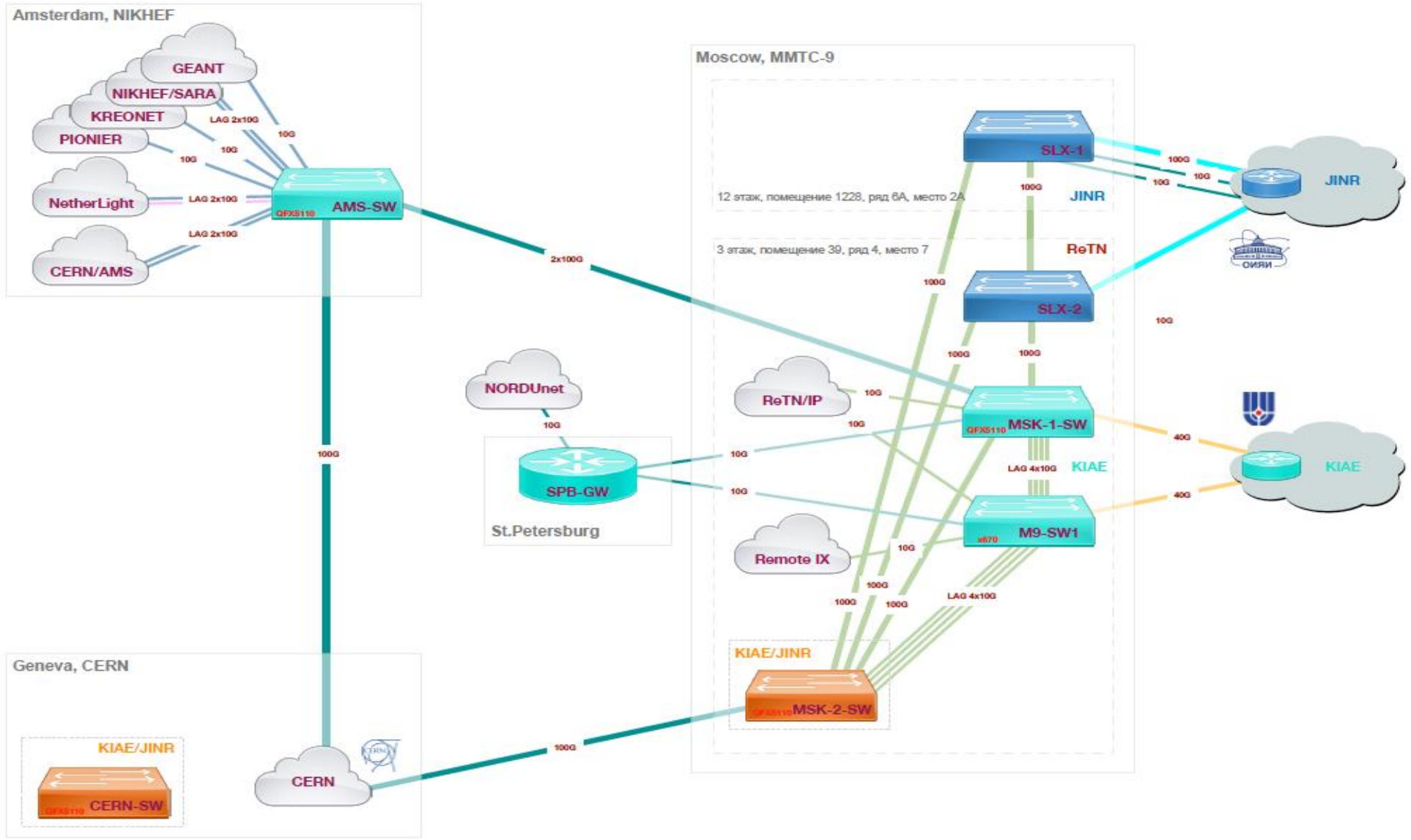
The Russian consortium RDIG (Russian Data Intensive Grid), was set up in September 2003 as a national federation in the EGEE project. A protocol between CERN, Russia and JINR on participation in the LCG project was signed in 2003.
MoU on participation in the WLCG project was signed in 2007.



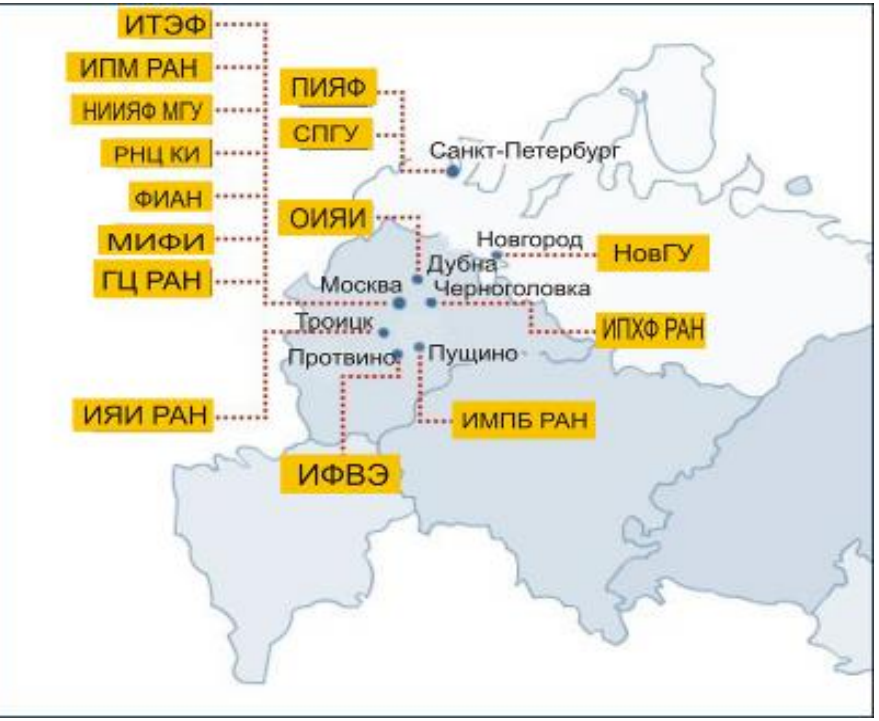
RDIG Resource Centres:

– ITEP
– JINR-LCG2 (Dubna)
– RRC-KI
– RU-Moscow-KIAM
– RU-Phys-SPbSU
– RU-Protvino-IHEP
– RU-SPbSU
– Ru-Troitsk-INR
– ru-IMPB-LCG2
– ru-Moscow-FIAN
– ru-Moscow-MEPHI
– ru-PNPI-LCG2 (Gatchina)
– ru-Moscow-SINP

Сеть RDIG-M для мегасайенс проектов



From RDIG to RDIG-M



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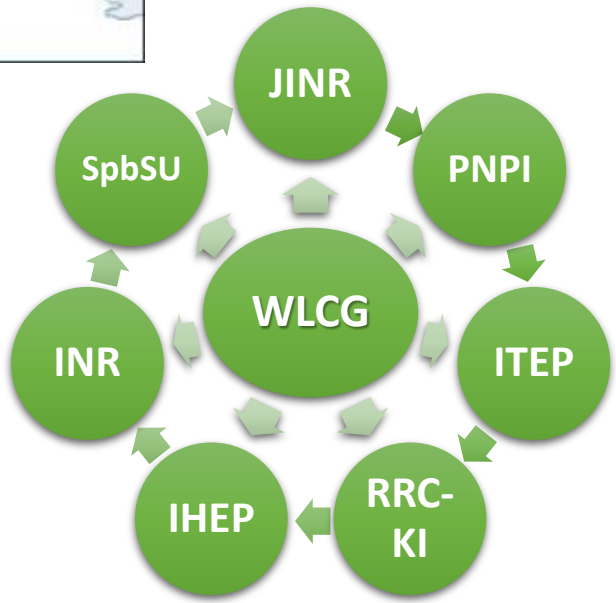
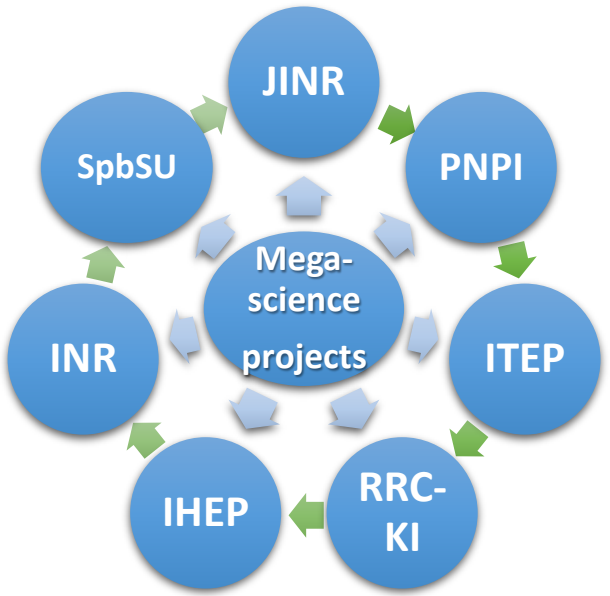
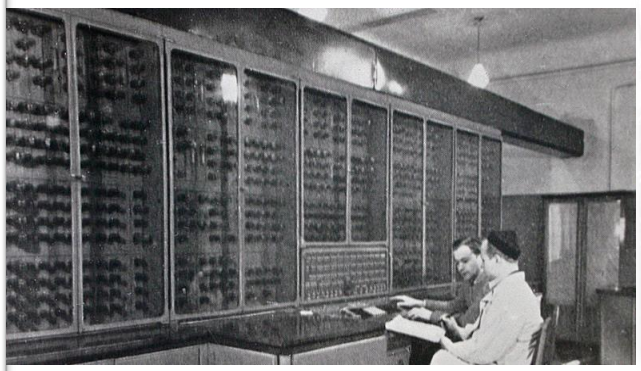
Consortium RDIG-M – Russian Data Intensive GRID for Megascience projects





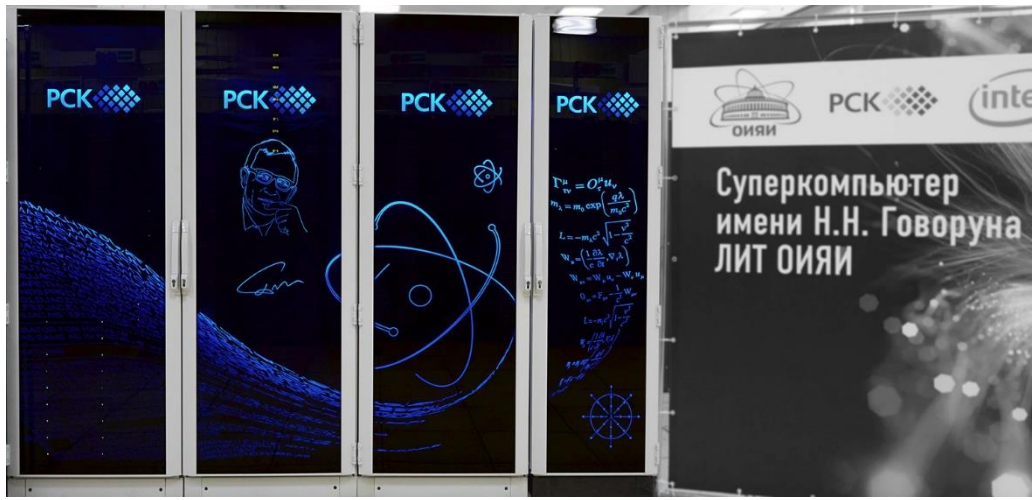
Meshcheryakov Laboratory of Information Technologies

M.G. Mesheryakov
(17.09.1910 - 24.05.1994)



N.N. Govorun
(18.03.1930 - 21.07.1989)

Meshcheryakov Laboratory of Information Technologies of the Joint Institute for Nuclear Research in Dubna was founded in August 1966. The main directions of the activities at the Laboratory are connected with the provision of networks, computer and information resources, as well as mathematical support of a wide range of research at JINR.



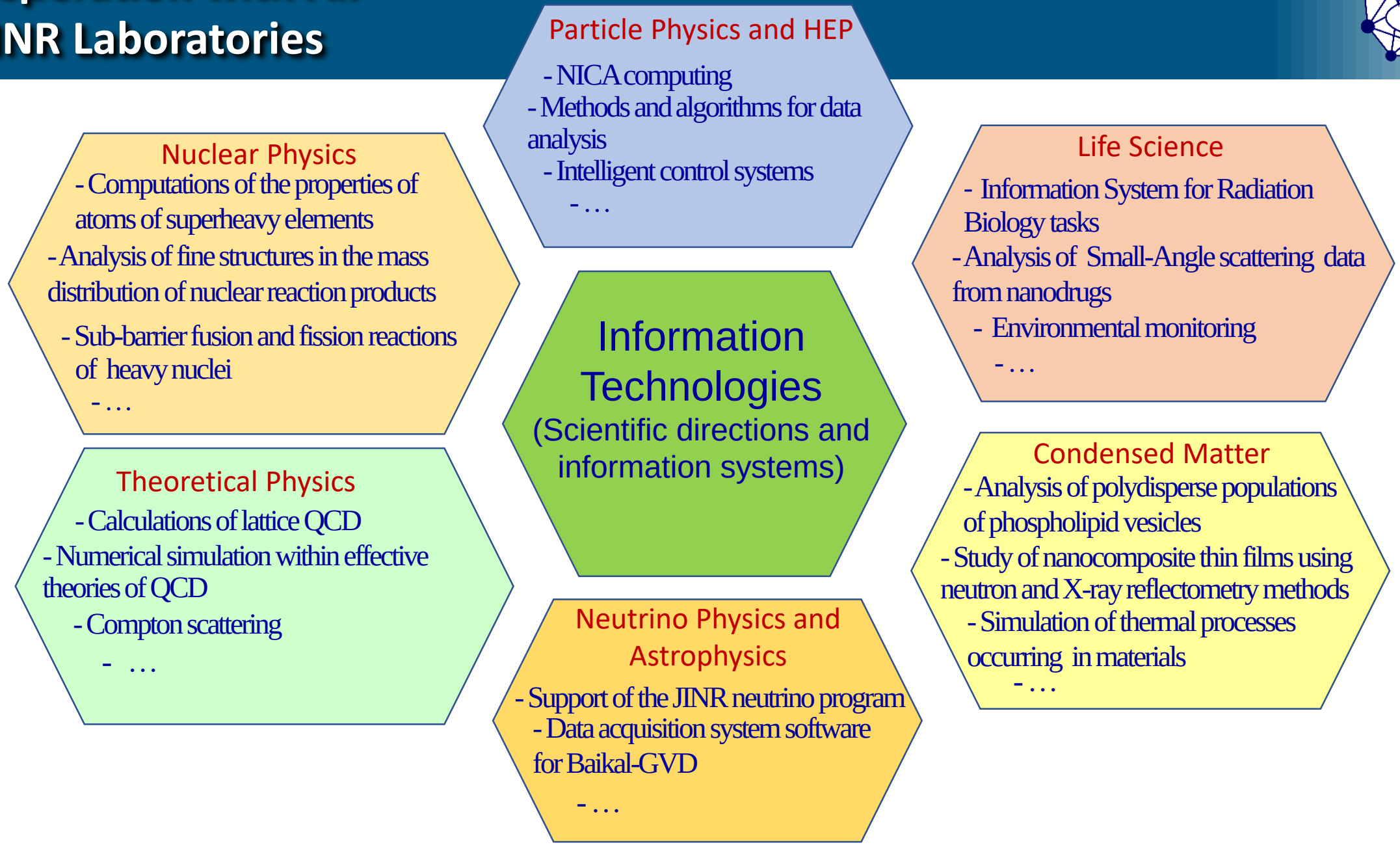
MLIT today

Staff: 325
Scientists: 100
Doctors of Science: 24
Candidates of Science: 61
Campus network 2x100 Gbps
Multisite network 4x100 Gbps
Telecommunication channel 3x100 Gbps
Grid Tier1 and Tier2 for global data processing
JINR Cloud computing
JINR Member States' Cloud environment
"Govorun" supercomputer

MLIT Fundamentals:

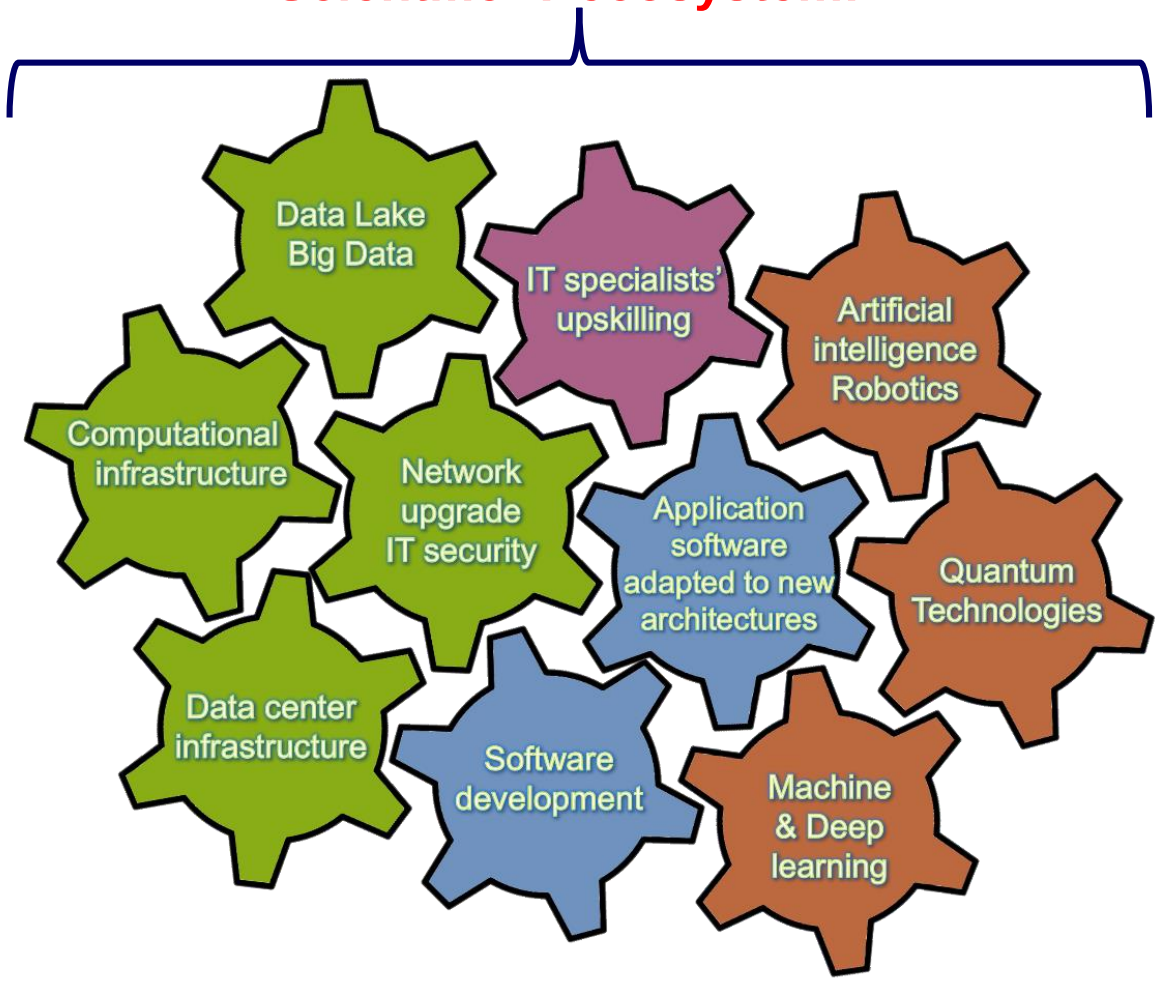
* **Provide** IT services necessary for the fulfillment of the JINR Topical Plan on Research and International Cooperation
* **Building** world-class competence in IT and computational physics
* **24/7** support of computing infrastructure and services such availability is called nonstop service.

Cooperation with All JINR Laboratories



Strategy for Information Technology and Scientific Computing at JINR

Scientific IT ecosystem:



Coordinated development of interconnected IT technologies and computational methods

It will be a **steady implementation/upgrades** of

- Networking (**Tb/s** range),
- Computing infrastructure within the Multifunctional Information & Computing Complex (MICC) and
- "Govorun" Supercomputer,
- Data center infrastructure,
- Data Lake & long-term storage

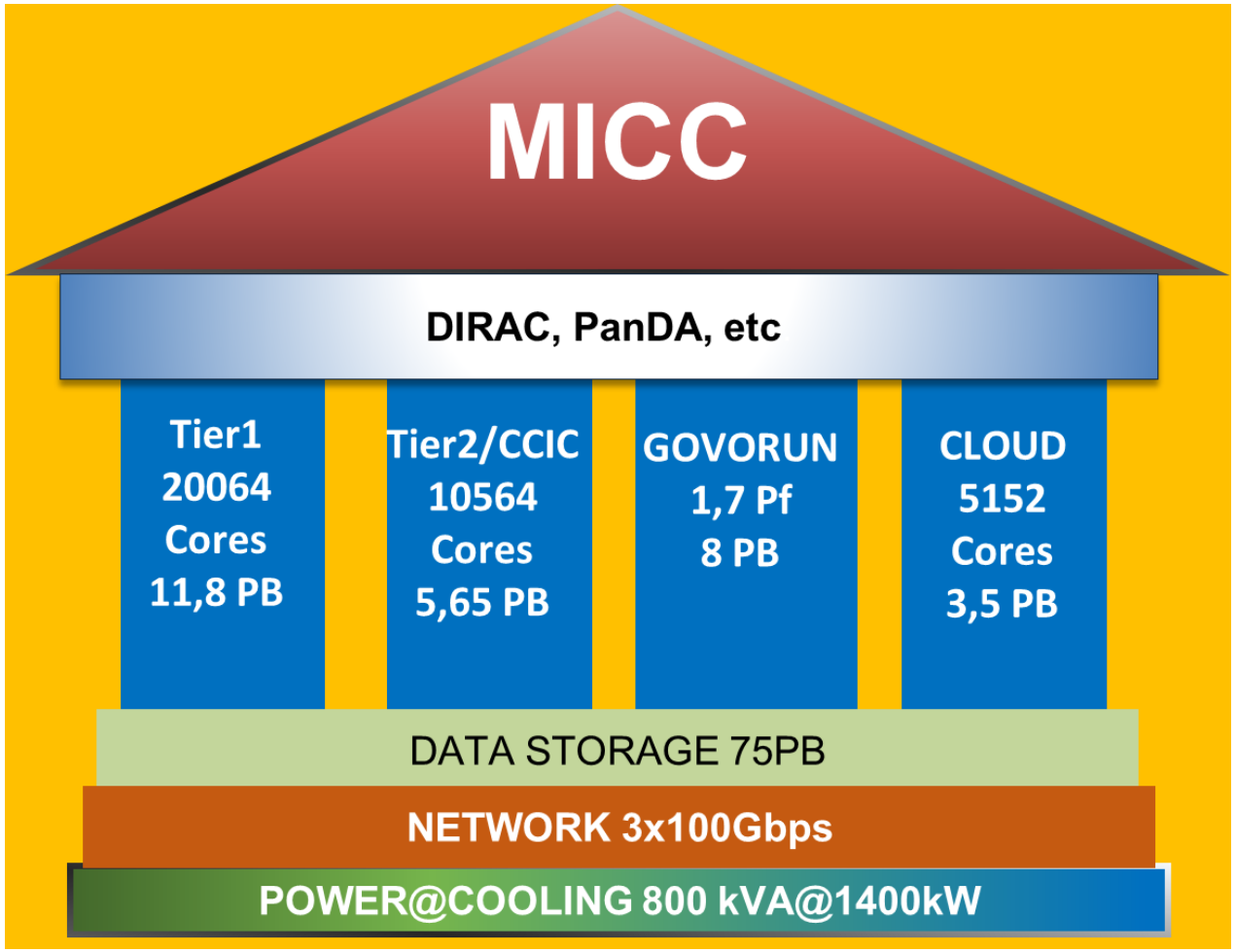
for all experiments.

The **development of new data processing and analysis algorithms** based on

- ML/DL,
- Artificial intelligence,
- Big Data
- Quantum technologies.

A variety of means will be used for IT specialists' upskilling.

Multifunctional Information and Computing Complex (MICC)



4 advanced software and hardware components

- Tier1 grid site
- Tier2 grid site
- hyperconverged “Govorun” supercomputer
- cloud infrastructure

Distributed multi-layer data storage system

- Disks
- Robotized tape library

Engineering infrastructure

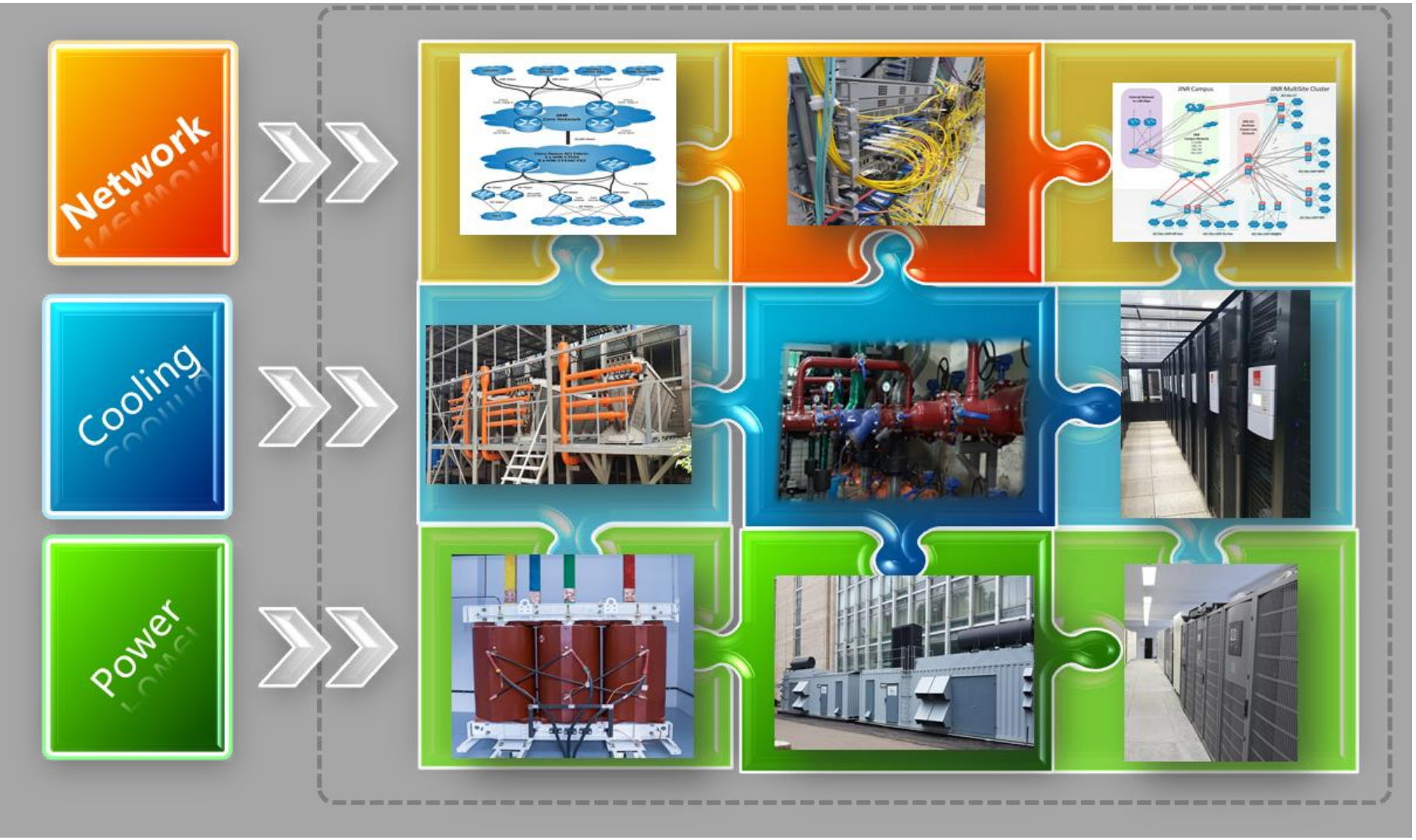
- Power
- Cooling

Network

- Wide Area Networkr
- Local Area Network

The main objective of the project is to ensure multifunctionality, scalability, high performance, reliability and availability in 24x7x365 mode for different user groups that carry out scientific studies within the JINR Topical Plan

MICC Power @ Cooling @ Network



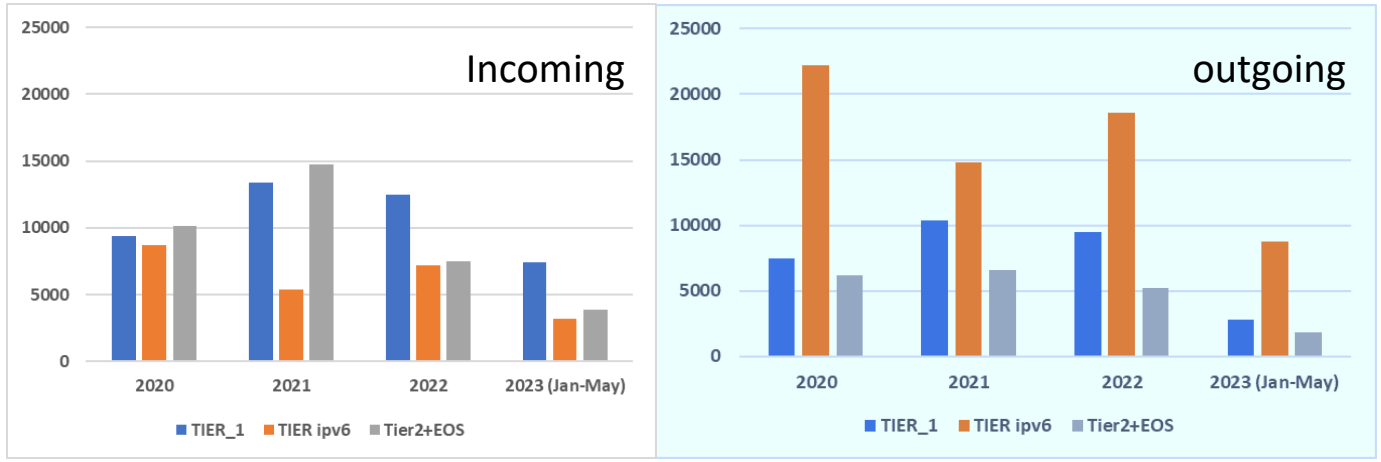
Wide Area Network 3x100 Gbps
Cluster Backbone 4x100 Gbps
Campus Backbone 2x100 Gbps

Dry chillers
InRow systems
Total cooling 1400 kW

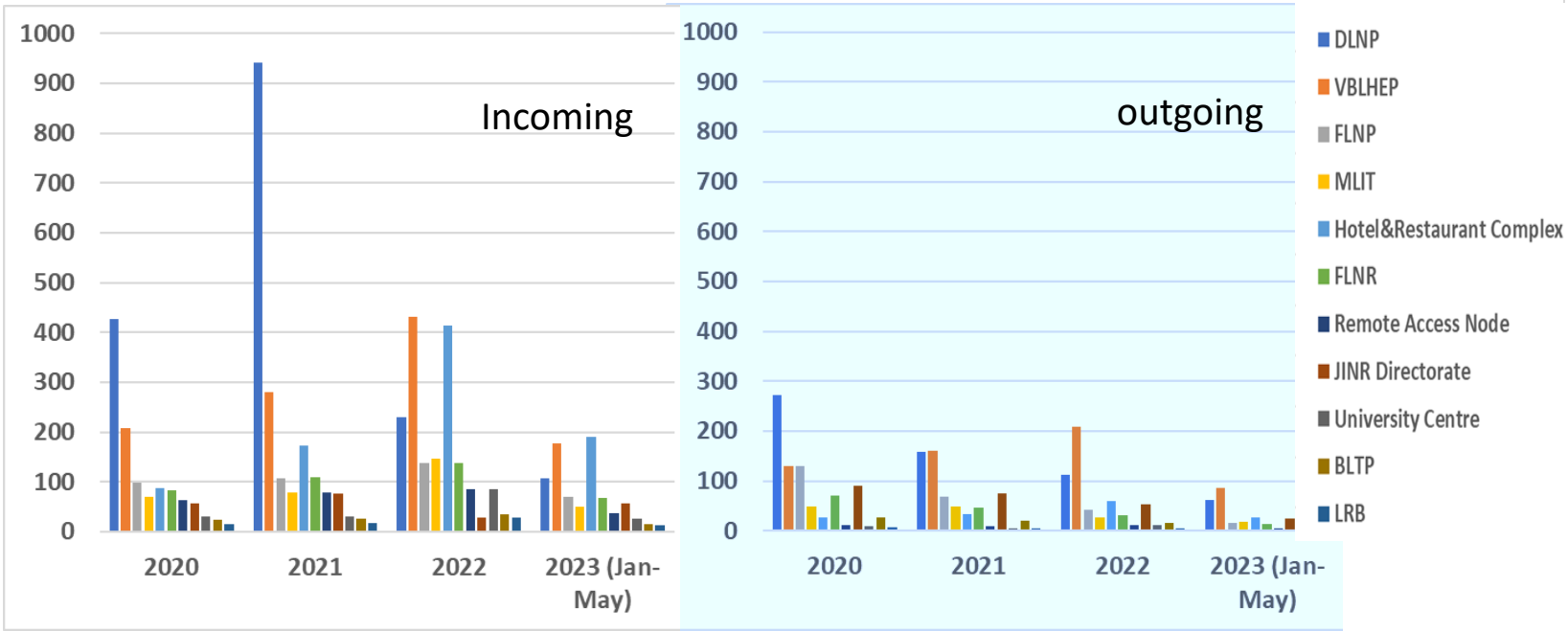
Uninterruptible power supplies
8 x 300 kVA
Diesel-generator units (DGU)
2x1500 kVA
Transformers2x2500 kVA

Networking @ Traffic

Distribution of the incoming and outgoing traffics by the JINR MICC in 2020-2023 (TB)

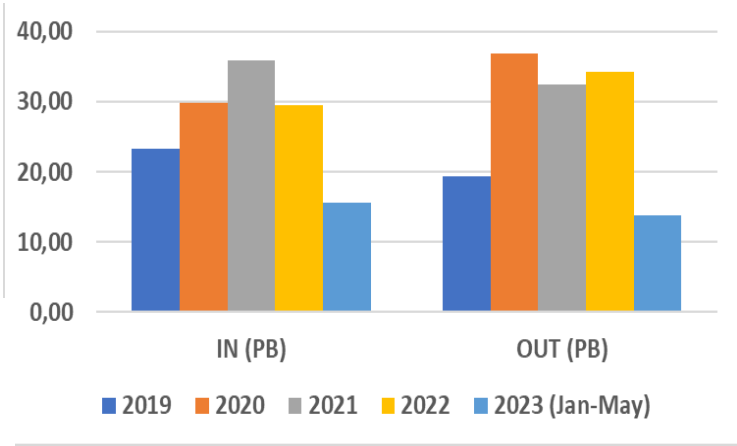


Distribution of the incoming and outgoing traffics by the JINR Subdivisions in 2020-2023 (TB)



Wide Area Network 3x100 Gbps
Cluster Backbone 4x100 Gbps
Campus Backbone 2x100 Gbps

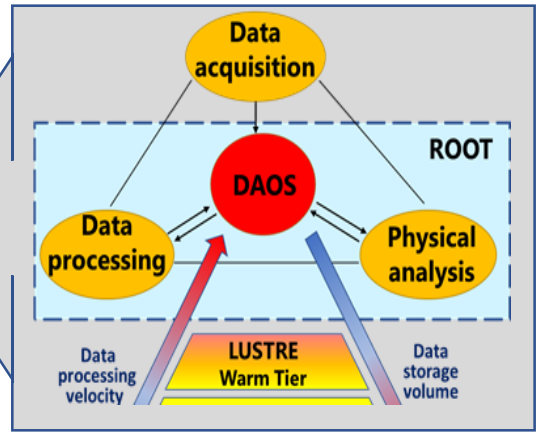
JINR Traffic in PB



Users - 6353
Network elements - 9327
IP addresses - 18163
Remote access - 911
E-library- 1464
VOIP - 121
EDUROAM - 116
Email @jinr.ru - 4579

Distributed Multilayered Data Storage System

- Limited data and short-term storage – to store OS itself, temporary user files
- AFS distributed global system – to store user home directories and software
- dCache is traditional for MICC grid sites – to large amounts of data (mainly LHC experiments) for middle-term period
- EOS is extended to all MICC resources – to store large amounts of data for middle-term period. At present, EOS is used for storage by BM@N, MPD, SPD, BaikalGVD, etc.
- Tape robotic systems – to store large amounts of data for long-term period. At present for CMS. BM@N, MPD, SPD, JUNO – in progress.



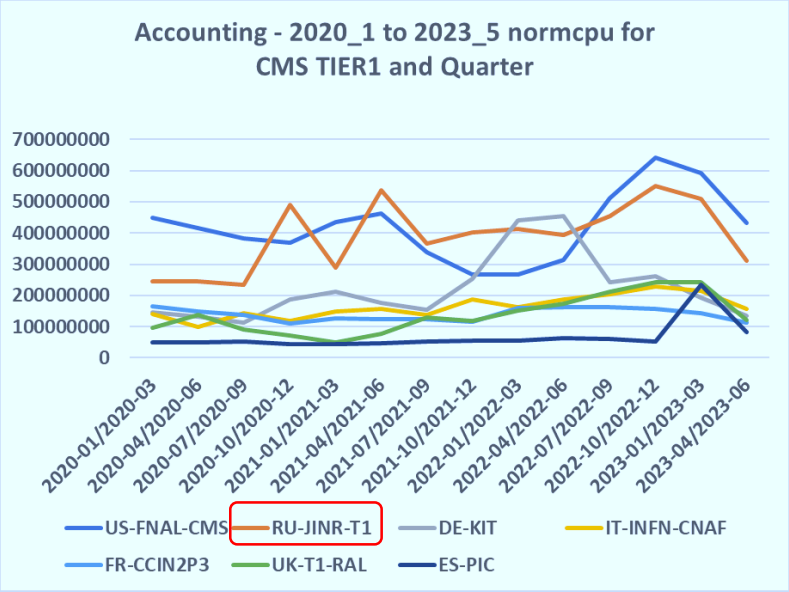
Special hierarchical data processing and storage system with a software-defined architecture was developed and implemented on the “Govorun” supercomputer.

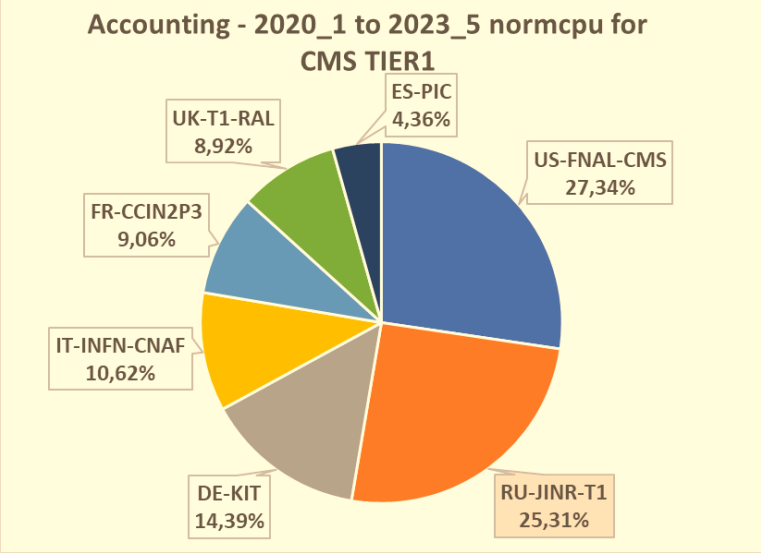
According to the speed of accessing data there are next layers:

- ✓ very hot data (DAOS (Distributed Asynchronous Object Storage)) ,
- ✓ the most demanded data (fastest access),
- ✓ hot data
- ✓ warm data (LUSTRE).

JINR Tier1 for CMS (LHC) and NICA

2020-2023

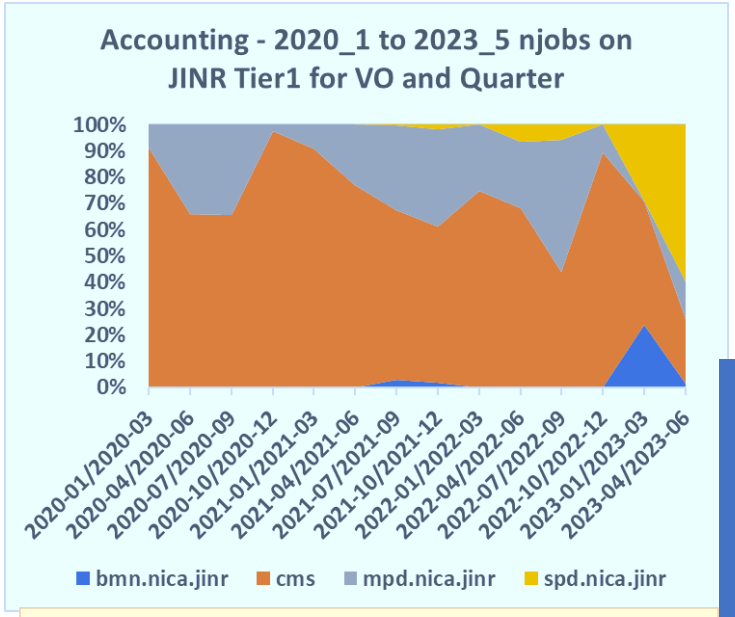


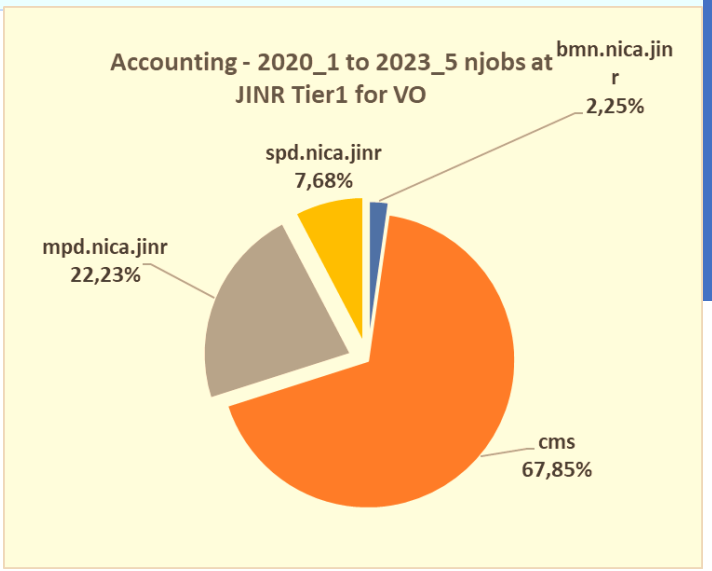


Since the beginning of 2015, a full-scale WLCG Tier1 site for the CMS experiment has been operating at MLIT JINR.

The importance of developing, modernizing and expanding the computing performance and data storage systems of this center is dictated by the research program of the CMS experiment, in which JINR physicists take an active part within the RDMS CMS collaboration.

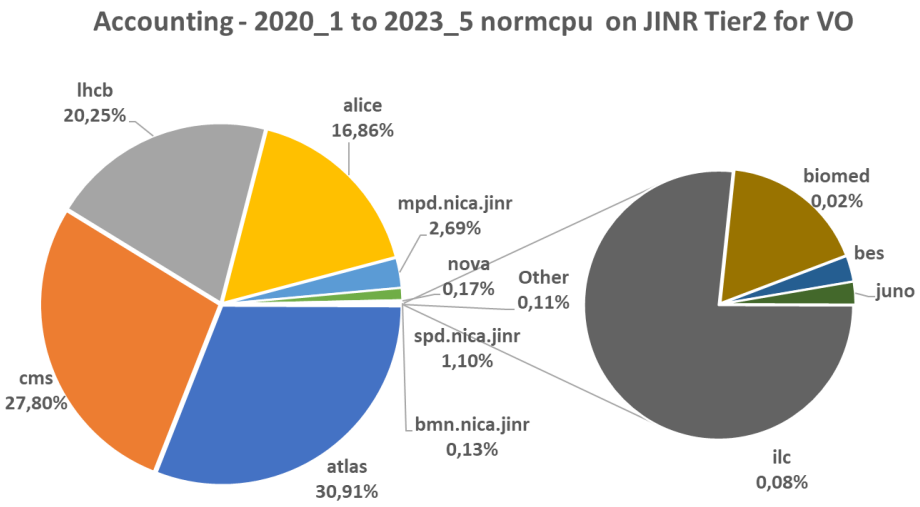
The JINR Tier1 is regularly ranked on top among world Tier1 sites that process data from the CMS experiment at the LHC.



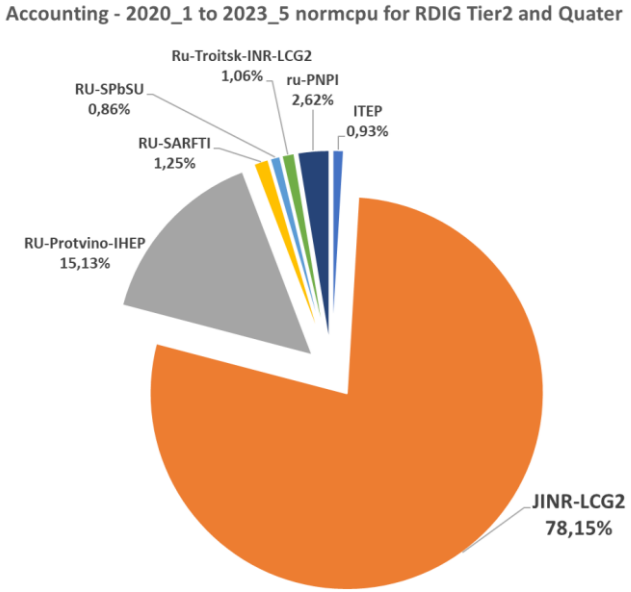


Since 2021 the JINR Tier1 center has demonstrated stable work not only for CMS (LHC), but also for NICA experiments.

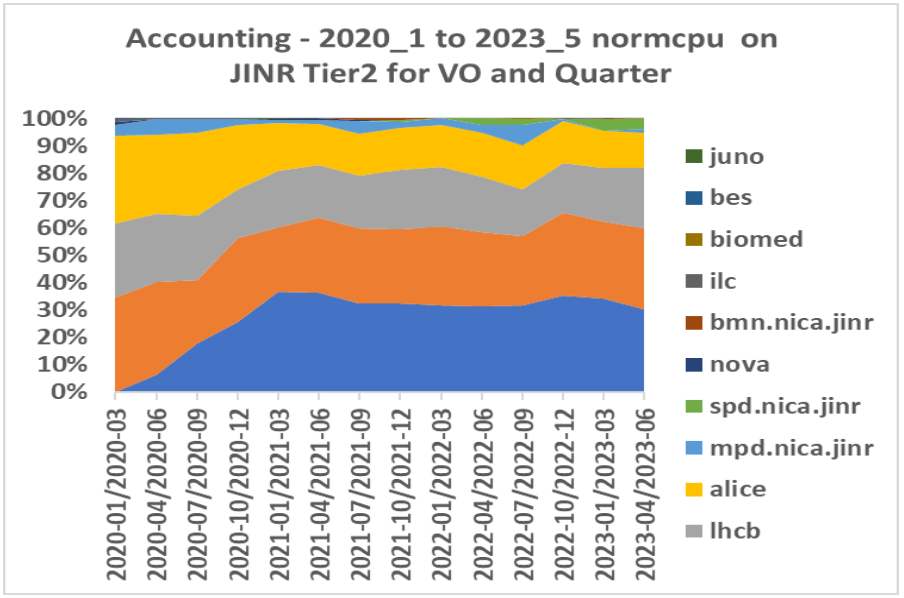
JINR Tier2 in WLCG & RDIG

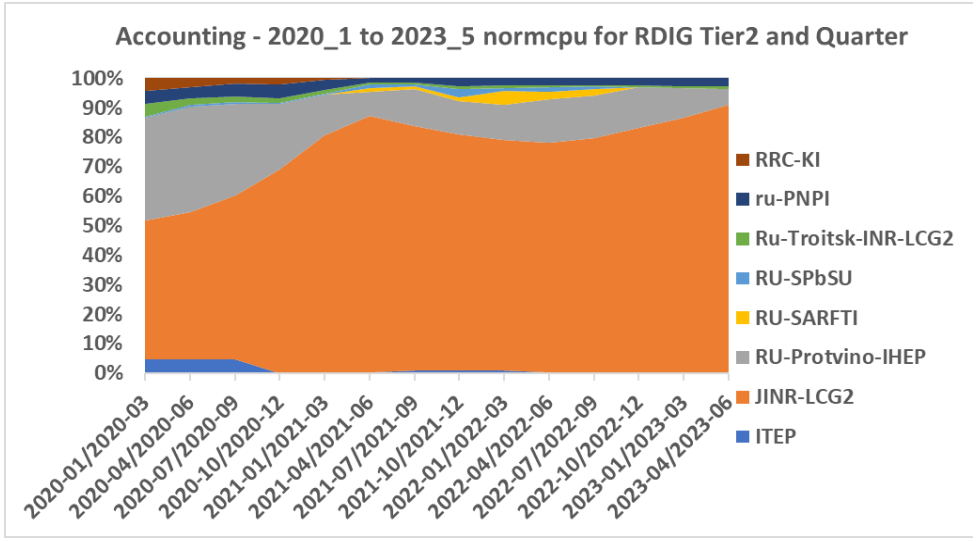


Tier2 at JINR provides computing power and data storage and access systems for the majority of JINR users and user groups, as well as for users of virtual organizations (VOs) of the grid environment (LHC, NICA etc.).



JINR Tier2 is the most productive in the Russian Data Intensive Grid (RDIG) Federation. More than 80% of the total CPU time in the RDIG is used for computing on our site.





Development of the heterogeneous HybriLIT platform

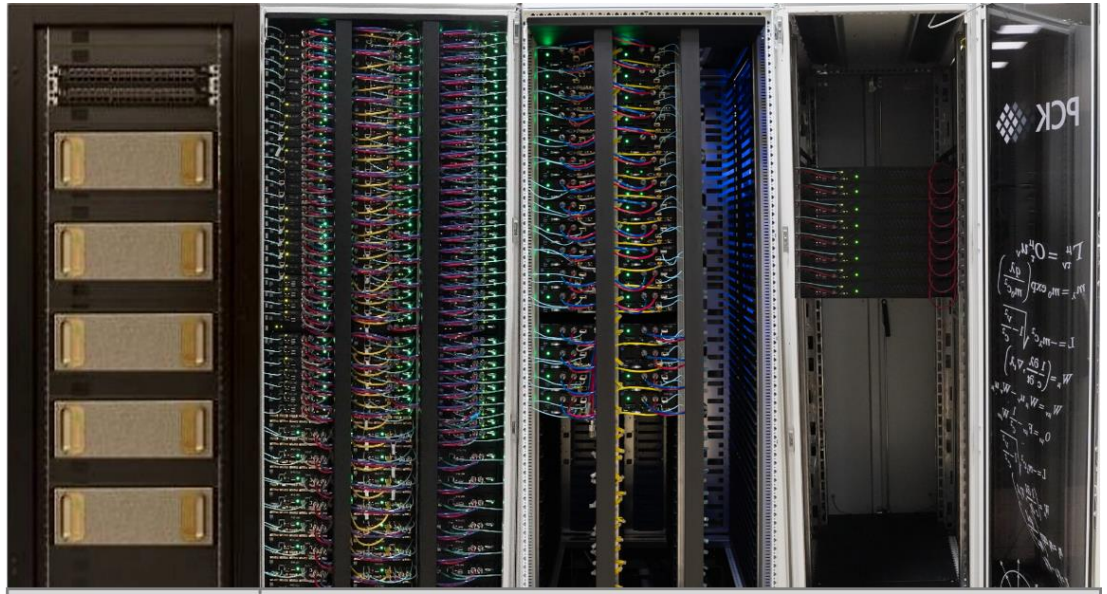
Cluster HybriLIT 2014:
Full peak performance:
50 TFlops for double precision

#18 в Top50
"Govorun" supercomputer
First stage 2018:
Full peak performance :
500 TFlops for double precision
9th in the current edition of the IO500 list (July 2018)

#10 в Top50
"Govorun" supercomputer
Second stage 2019:
Full peak performance :
860 TFlops for double precision
288 ТВ ССХД with I/O speed >300 Gb/s
17th in the current edition of the IO500 list (July 2020)

Russian DC Awards 2020 in "The Best IT Solution for Data Centers"

"Govorun" supercomputer modernization in 2022 - 2023



GPU-accelerator | Hyperconverged CPU and Distributed Storage Nodes

\+

5 servers with 8 NVidia A100 GPUs in each

\+

Computation field:
+32 hyperconverged compute nodes

\+

Hierarchical Storage:
+8 distributed storage nodes

+ 40 NVIDIA A100 GPU accelerators
Performance: + 600 Tflops DP

+32 hyperconverged compute nodes
+2 432 new computational cores
Performance: +239 Tflops DP
Performance "new cores"/"old cores" increase more than 1,5 times

+8 distributed storage nodes
Lustre, EOS increase: +8 PB
DAOS increase: +1.6 PB
+0,4 PB for the MPD mass production storages integrated into the DIRAC File Catalog
+1 PB for the MPD EOS storage

SC "Govorun" total peak performance: 1.7 PFlops DP
Total capacity of Hierarchical Storage: 8.6 PB
Data IO rate: 300 Gb/s

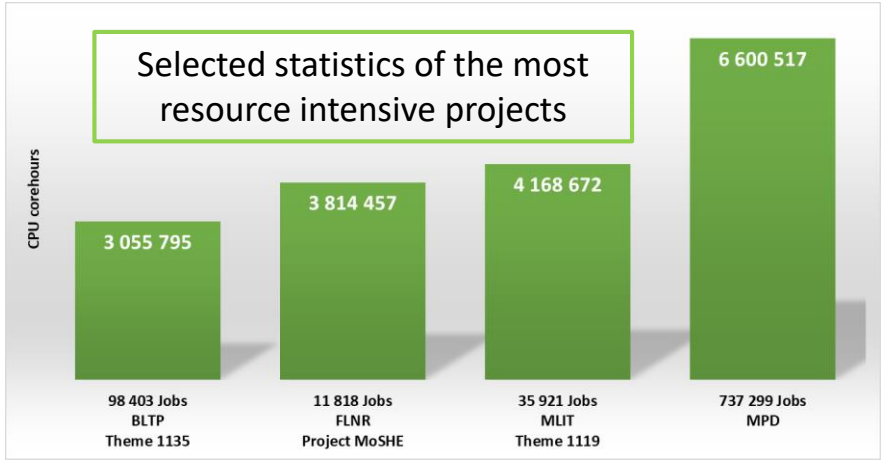
Using of the “Govorun” Supercomputer for JINR task in 2022

The projects that mostly intensive use the CPU resources of the “Govorun” supercomputer:

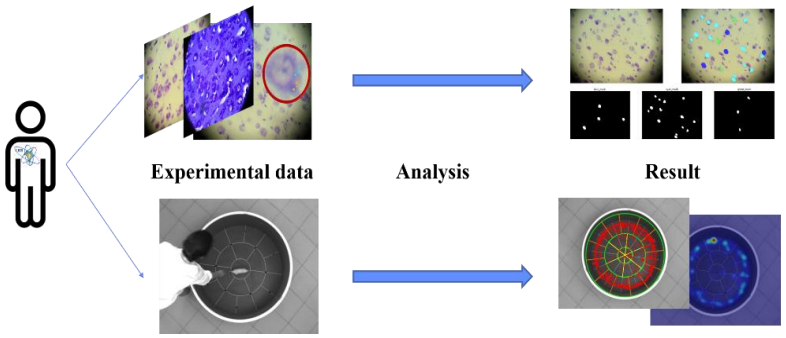
- NICA megaproject,
- simulation of complex physical systems,
- computations of the properties of atoms of superheavy elements,
- calculations of lattice quantum chromodynamics.

The GPU-component is activle used for solving applied problems by neural network approach:

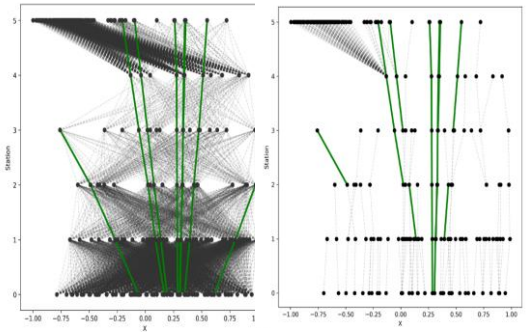
- process data from experiments at LRB,
- data processing and analysis at the NICA accelerator complex and ect.



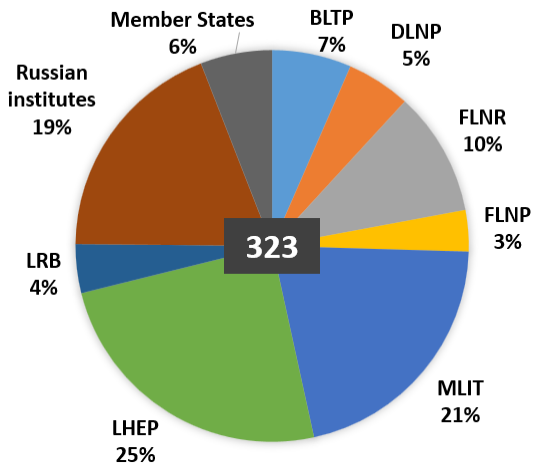
During 2022, **890 911** jobs were performed on the **CPU** component of the “Govorun” supercomputer, which corresponds to **18 543 076** core hours.



Information System for Radiation Biology Tasks



Neural network for data analysis

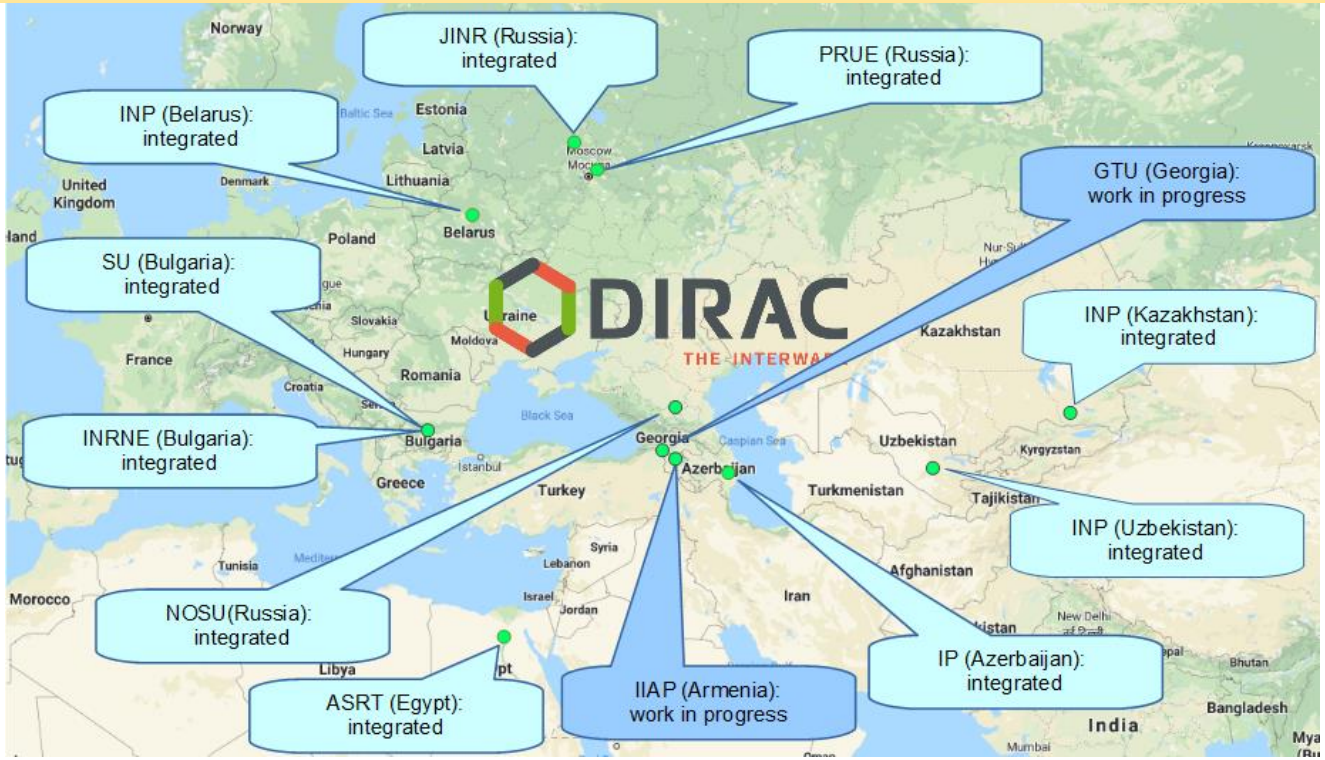


The resources of the “Govorun” spercomputer are used by scientific groups from all the Laboratories of the Institute within **25 themes** of the JINR Topical Plan.

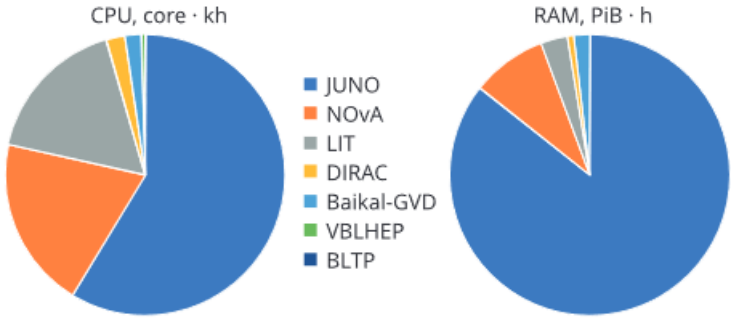
Cloud Infrastructure

- Computational resources for neutrino experiments:
- VMs for JINR users
- Testbeds for research and development in IT
- COMPASS production system services
- Data management system of the UNECE ICP Vegetation
- Service for data visualization, Gitlab and some others

DIRAC-based distributed information and computing environment (DICE) that integrates the JINR Member State organizations' clouds



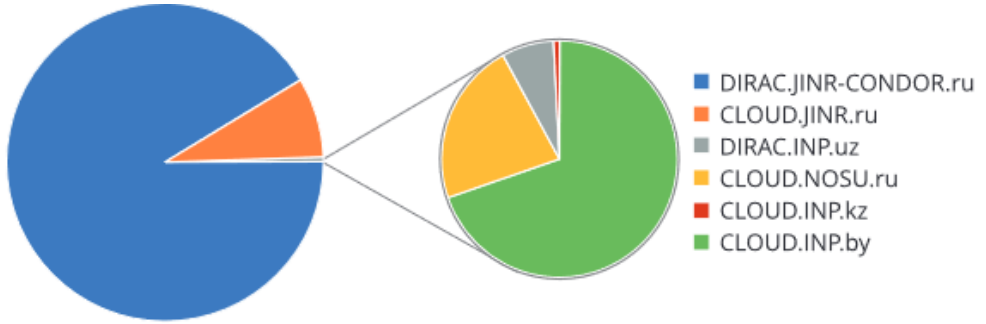
The Baikal-GVD, NOvA and JUNO experiments are the major users of the cloud infrastructure.



Use of cloud computing by experiments and JINR subdivisions in 2022

Most of the jobs in the JINR DICE in 2022 were performed on the neutrino computing platform (DIRAC.JINR-CONDOR.ru).

Distribution of the number of jobs completed in the JINR DICE by participants



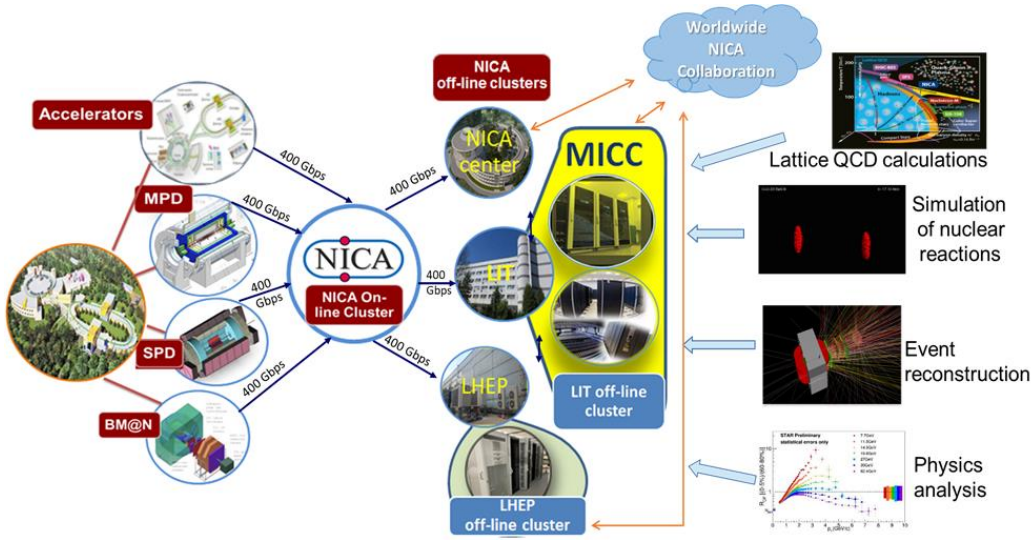
The main consumer of the JINR DICE resources in 2022 was the Baikal-GVD experiment (96%).

Development of the NICA Information and Computer Complex

The Seven-Year Plan provides for the creation of a long-term data storage center on the MICC resources at MLIT (Tier0). The process of modeling, processing and analyzing experimental data obtained from the BM@N, MPD and SPD detectors will be implemented in a distributed computing environment based on the MICC and the computing centers of VBLHEP and collaboration member countries.

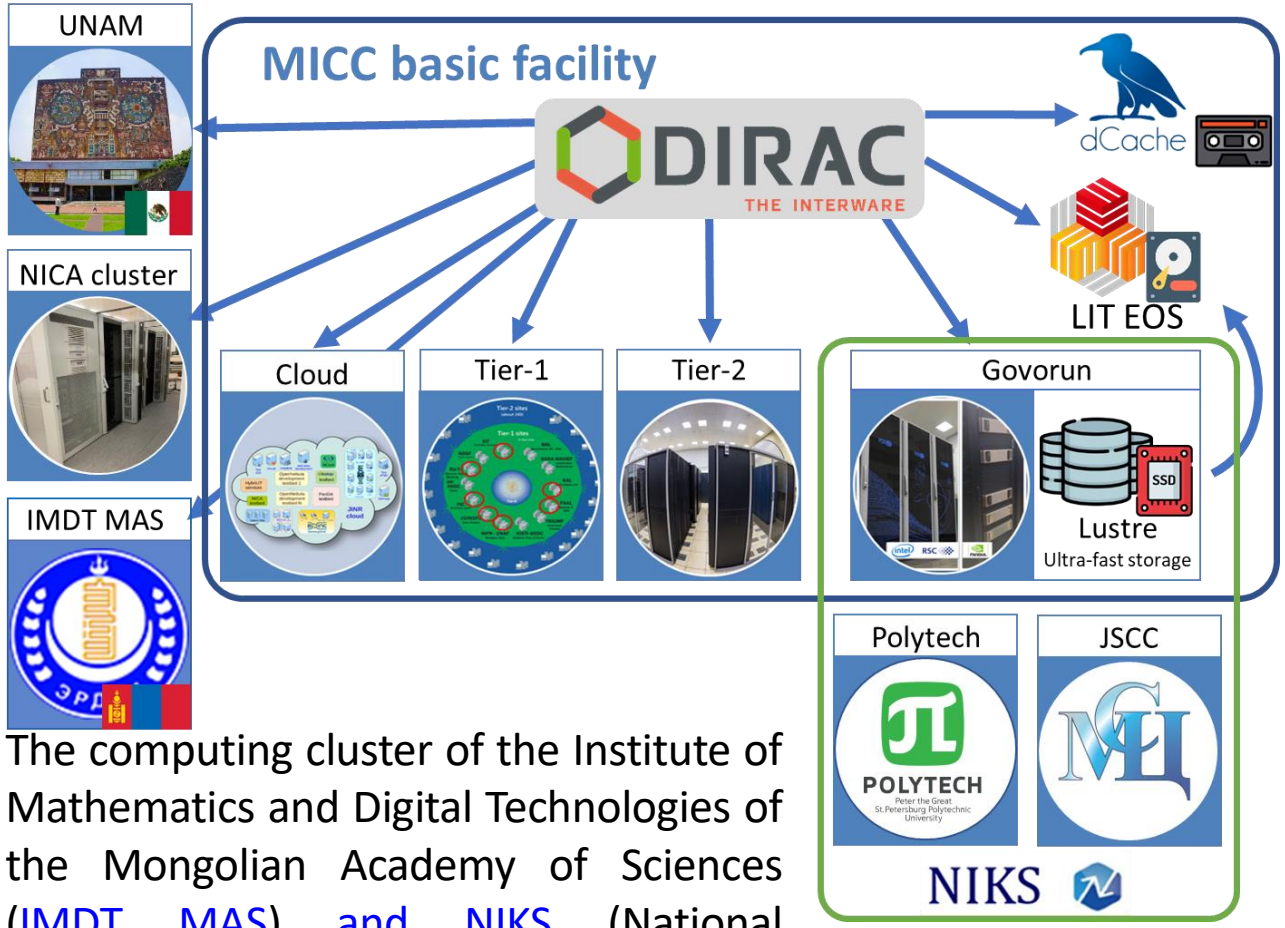
The information and computer unit of the NICA complex embraces:

1. **online NICA cluster**,;
2. **offline NICA cluster at VBLHEP**,
3. **all MICC components** (Tier0, Tier1, Tier2, “Govorun” supercomputer, cloud computing);
4. multi-layer **data storage system**
5. **distributed computing network**



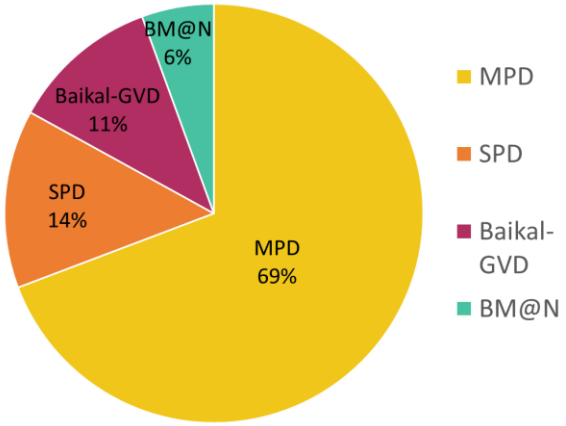
NICA Tier 0,1,2	2024	2025	2026	2027	2028	2029	2030
CPU (PFlops)	2.2	2.6	8.6	8.6	15.6	15.6	15.6
DISK (PB)	17	24	47	75	96	119	142
TAPE (PB)	45	88	170	226	352	444	536
NETWORK (Gbps)	400	400	800	800	800	1000	1000

DIRAC-based distributed heterogeneous environment

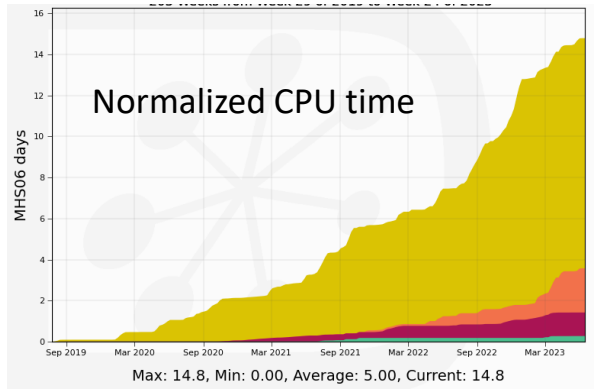


The computing cluster of the Institute of Mathematics and Digital Technologies of the Mongolian Academy of Sciences (IMDT MAS) and NIKS (National Research Computer Network, the Russia's largest research and education network) were integrated into the heterogeneous distributed environment based on the DIRAC platform.

Use of DIRAC platform by experiments in 2019-2022

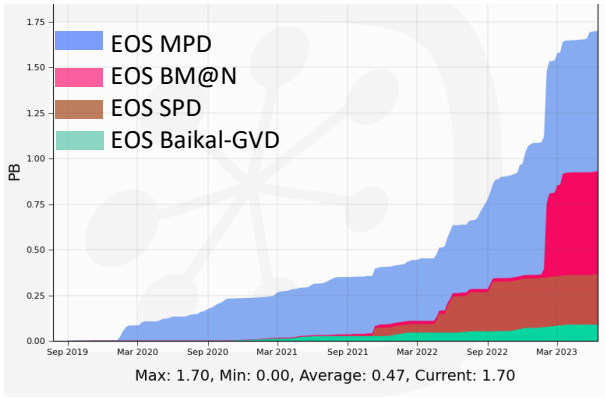


Total Number of executed jobs



The major user of the distributed platform is the MPD experiment

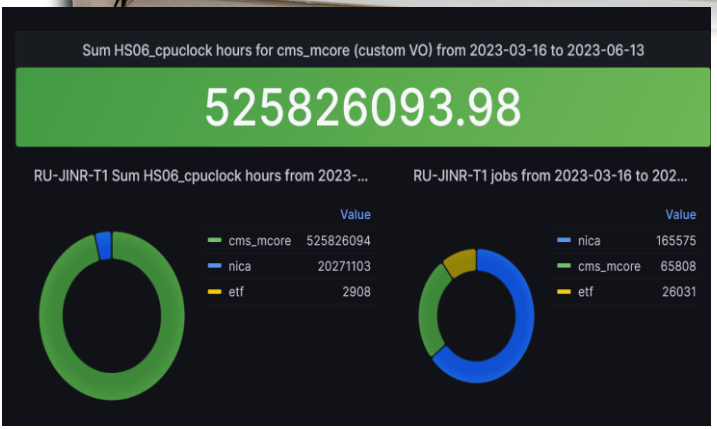
Data processed by experiments

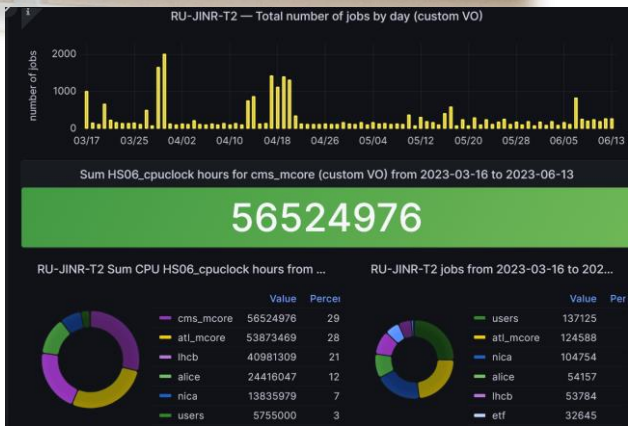


Summary statistics of using the DIRAC platform for MPD tasks in 2019-2022

31 data generation campaigns	1.283 B events generated	440M events reconstructed	1.5M jobs completed	1557 years total computation time	1.3 PB MPD data produced

MICC Monitoring @Accounting





- ❖ 3 monitoring servers
- ❖ About 1800 nodes
- ❖ About 16000 service checks

The successful functioning of the computing complex is ensured by the monitoring system of all MICC components/ We must

- ➢ to expand the monitoring system by integrating local monitoring systems for power supply systems into it (diesel generators, power distribution units, transformers and uninterruptible power supplies);
- ➢ to organize the monitoring of the cooling system (cooling towers, pumps, hot and cold water circuits, heat exchangers, chillers);
- ➢ to create an engineering infrastructure control center (special information panels for visualizing all statuses of the MICC engineering infrastructure in a single access point),
- ➢ to account every user job at every MICC component? account

We must to develop intelligent systems that will enable to detect anomalies in time series on the basis of training samples, which will result in the need to create a special analytical system within the monitoring system to automate the process.

Estimation of the Resources of the MICC Components

	2024	2025	2026	2027	2028	2029	2030
HybriLIT heterogeneous platform. "Govorun" supercomputer.							
Total number of CPU cores	11000	11000	11000	14000	14000	14000	17000
Total number of GPU accelerators	40	64	64	64	64	88	88
Total volume of the hierarchical data processing and storage system, PB	8	8	14	14	20	20	20
Tier1 grid site							
Tier1 performance HEPS06	350000	400000	500000	550000	650000	750000	850000
Total number of CPU cores	22000	23000	30000	32000	38000	45000	50000
Total data storage capacity, TB	14500	16000	18000	20000	22000	23000	25000
Tier2 grid site							
Tier2 performance HEPS06l	187000	204000	221000	238000	306000	408000	510000
Total number of CPU cores	11000	12000	13000	14000	18000	24000	30000
Data storage system							
Total volume of the Data Lake on EOS, PB	27	35	38	53	58	71	83
Total robotic tape storage capacity, PB	70	90	130	130	170	170	190
Cloud computing							
Total number of CPU cores	2072	3072	4072	5072	6072	7072	8072
SSD-based ceph storage capacity, TB	868	968	1068	1168	1268	1368	1468

Prices for equipment in 2022-2023 are taking inti account

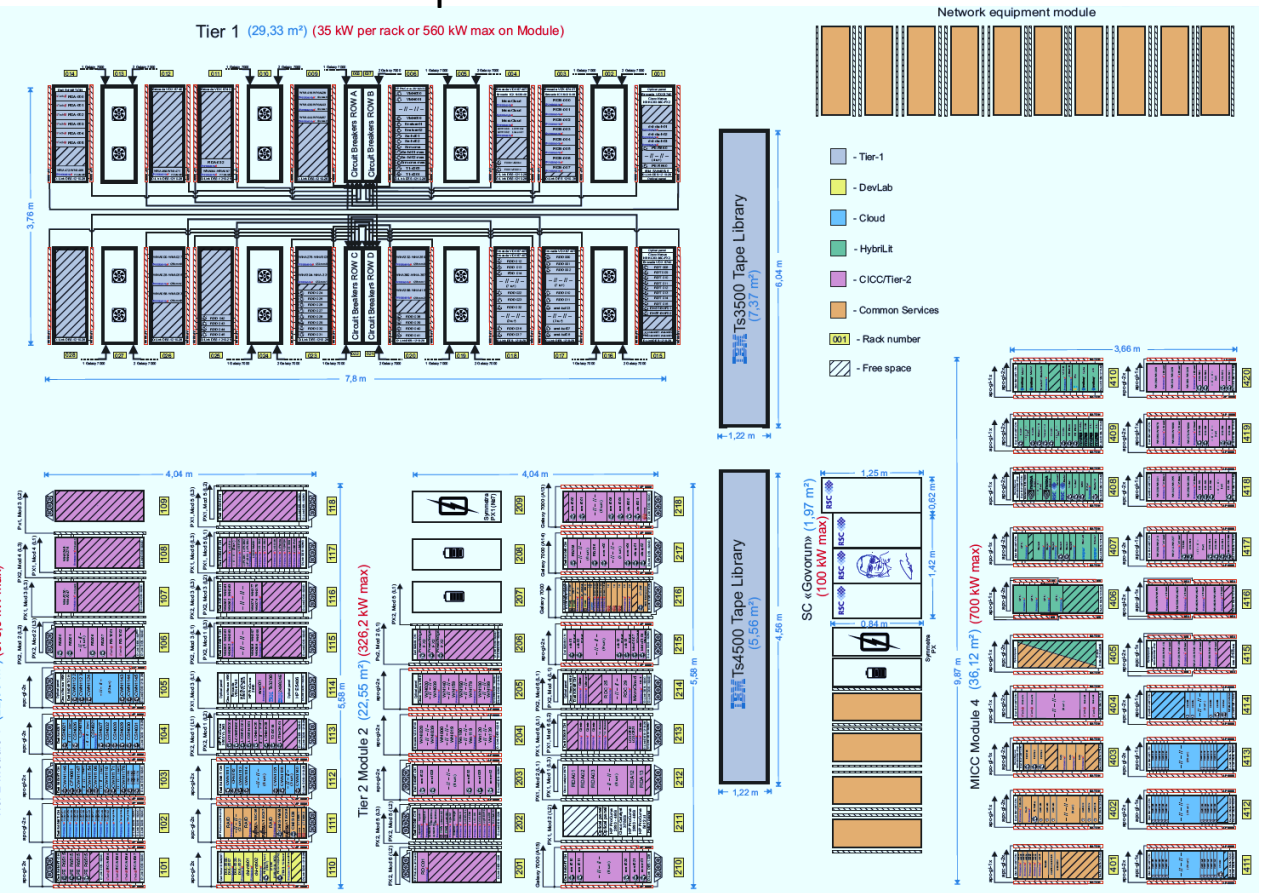
MICC Resources Development

- ✓ Increase in computing resources of Tier1 up to **50 000 cores**
- ✓ Increase in computing resources of Tier2 up to **170 kHS06**
- ✓ Expansion of the storage system of Tier1 on disks up to **16 PB**
- ✓ Expansion of the MICC storage system on EOS up to **60 PB**
- ✓ Increase in CLOUD total recourses up to **11000** cores, **~7PB** storage, ~7 TB **RAM**
- ✓ Year by year increase “Govorun” performance

MICC Servers Halls

Present (1000 kW)

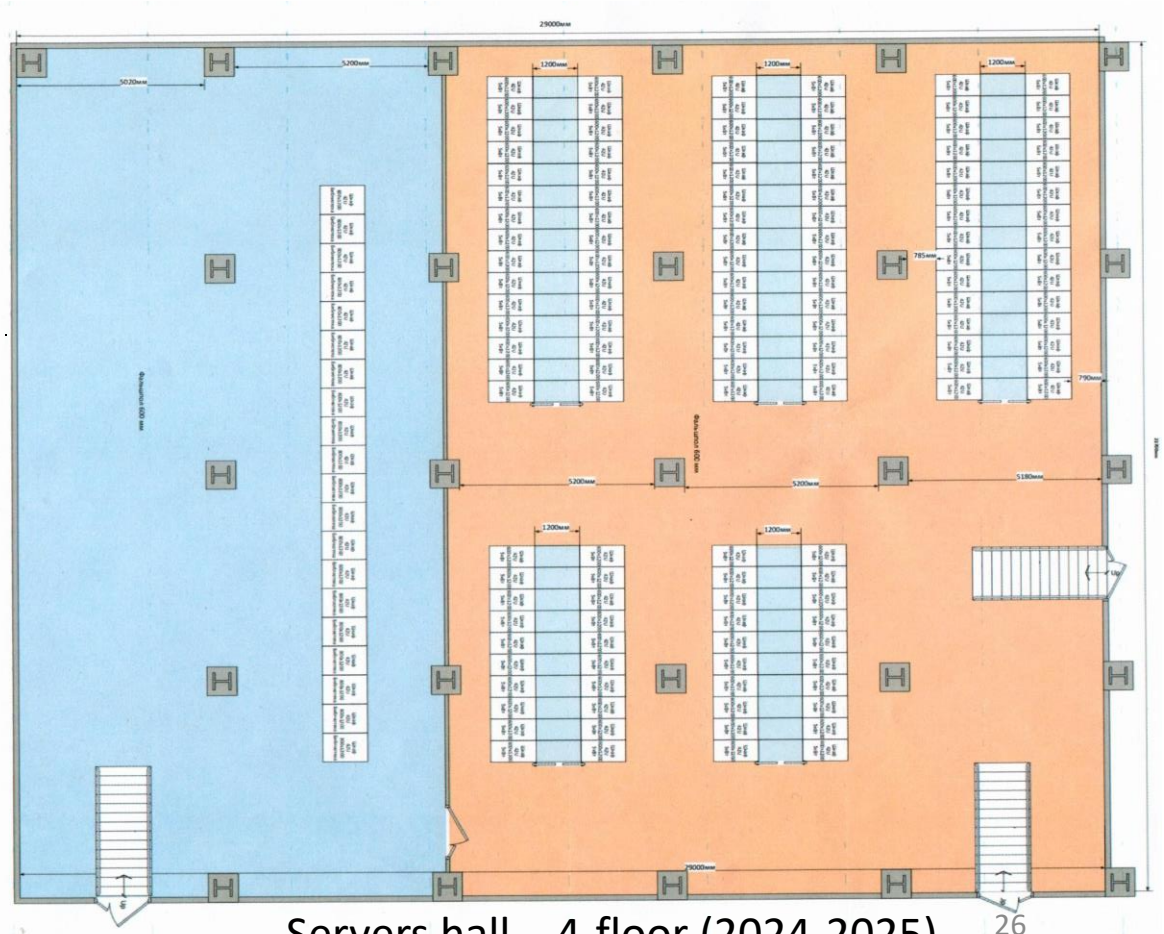
69 racks for servers
4 racks SC “Govorun”
10 racks for network equipment
4 racks for administrative services
2 Robotic tape libraries



Servers hall – 2-floor (2023)

Planning future – new servers hall for MICC (600 kW)

containment area for robotic tape libraries
130 racks for servers

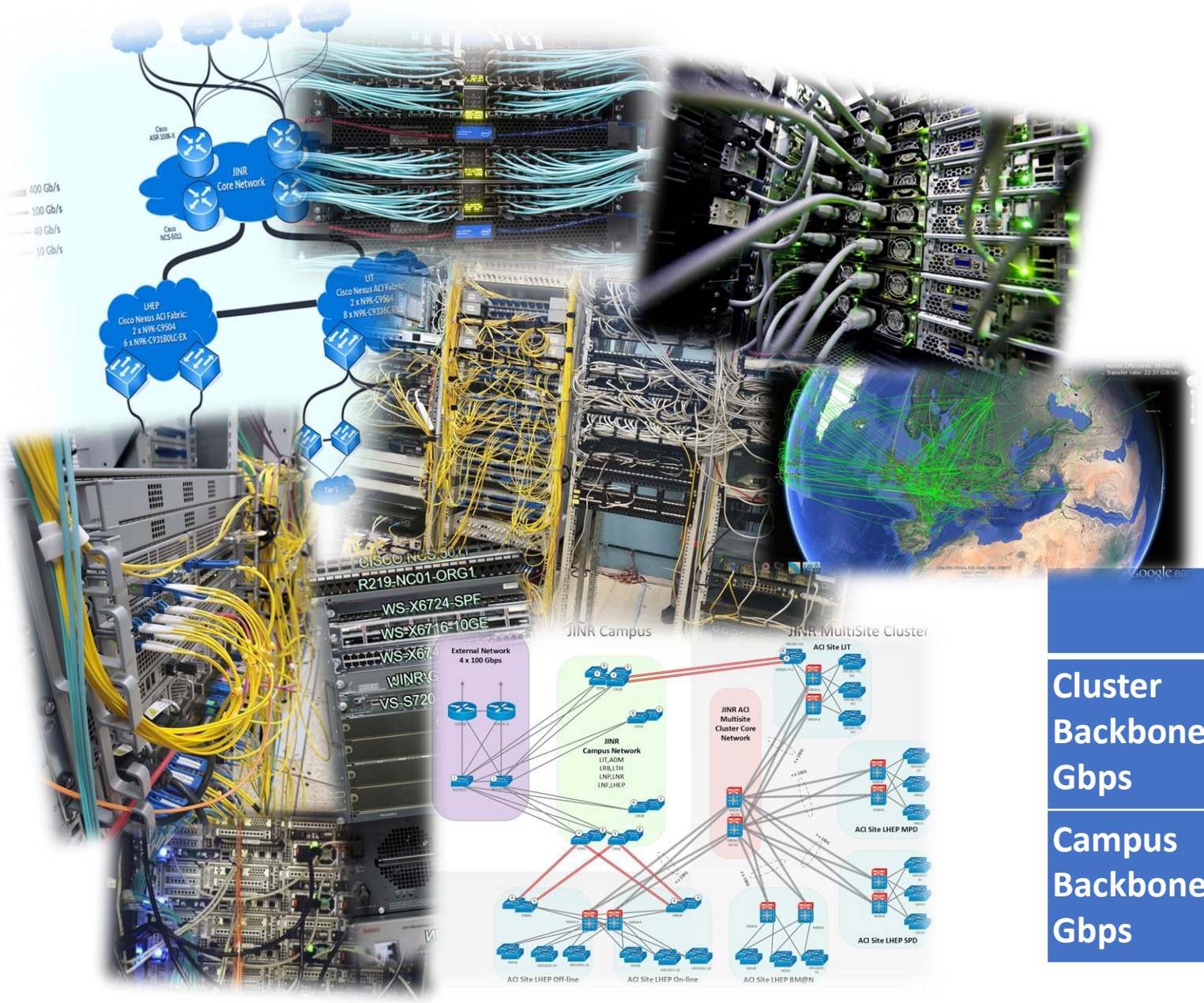


Servers hall – 4-floor (2024-2025)

Power & Cooling

	2024	2025	2026	2027	2028	2029	2030
Power consumption, kVA	800	1000	1200	1400	1600	1800	2000
Cooling, kW	1400	1700	2000	2300	2600	2800	3000

Networking



Main goals:

- **support for state-of-the-art networking technologies**
- **software-defined networks (SDN)**
- **content delivery networks (CDN)**
- **named data networks (NDN)**
- **technologies for building distributed data centers - Data Center Interconnect (DCI).**

	2024	2025	2026	2027	2028	2029	2030
Cluster Backbone, Gbps	400	400	400	800	800	800	800
Campus Backbone, Gbps	200	200	200	200	400	400	400

Activity: Digital ecosystem (Digital JINR)

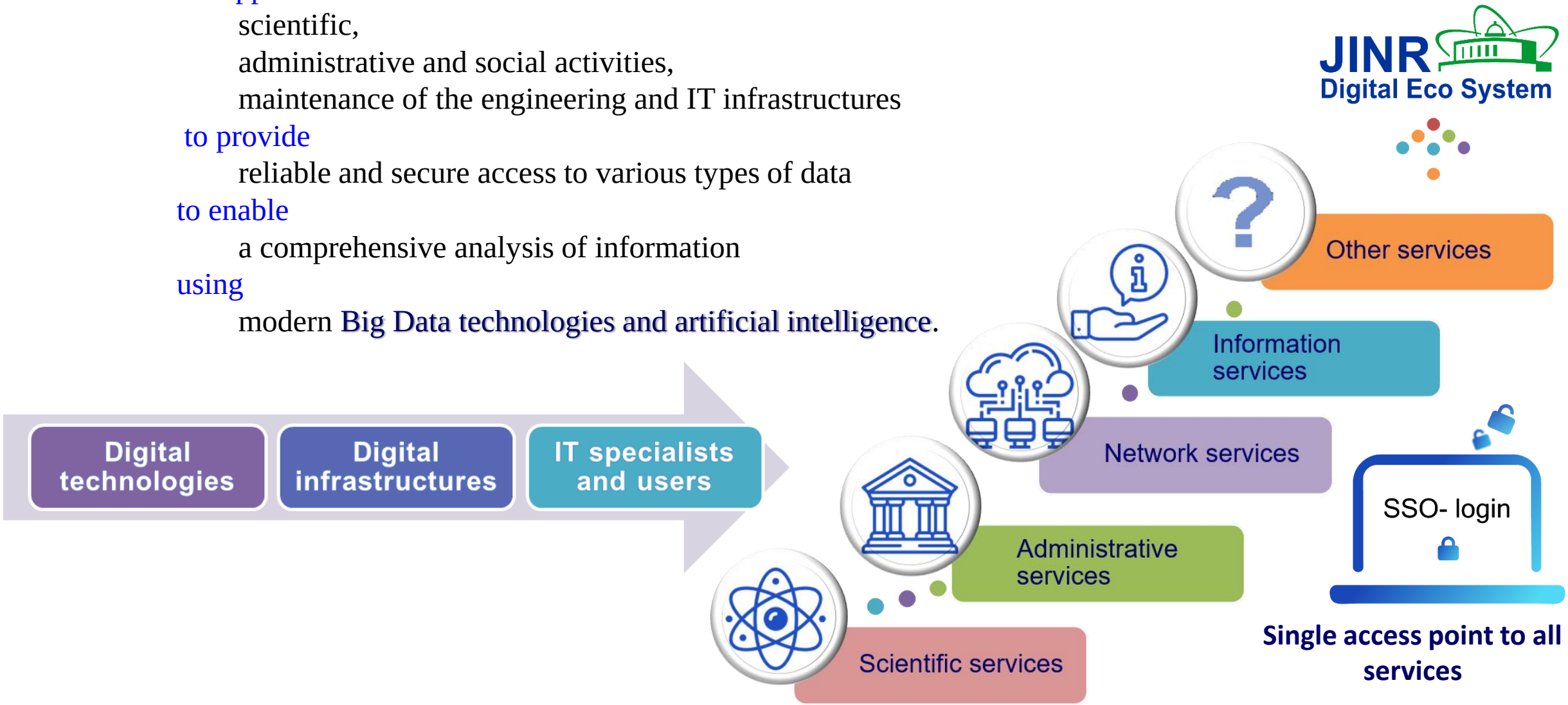
The digital platform "JINR Digital EcoSystem " integrates existing and future services

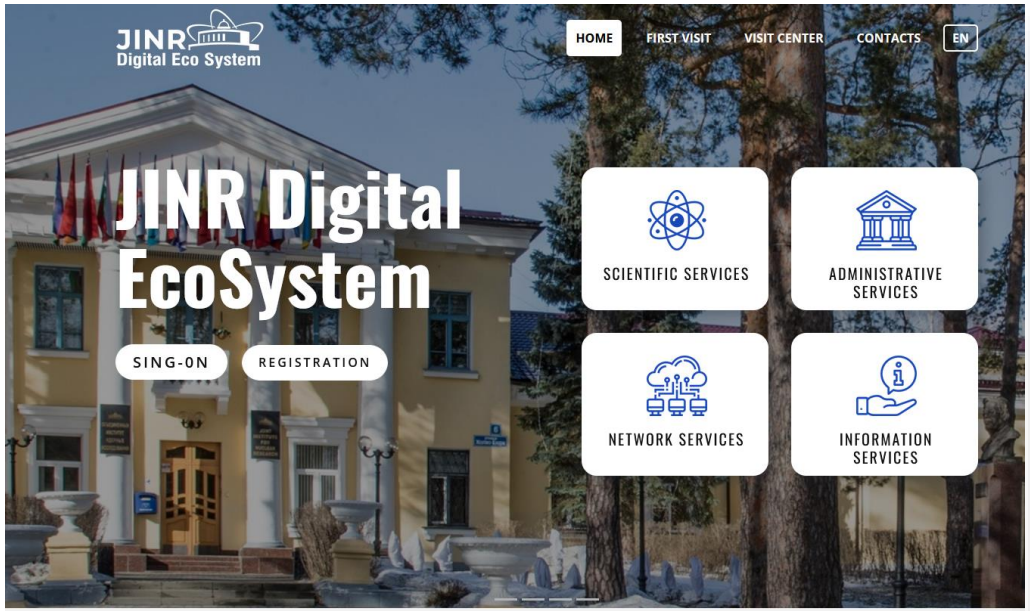
to support
scientific,
administrative and social activities,
maintenance of the engineering and IT infrastructures

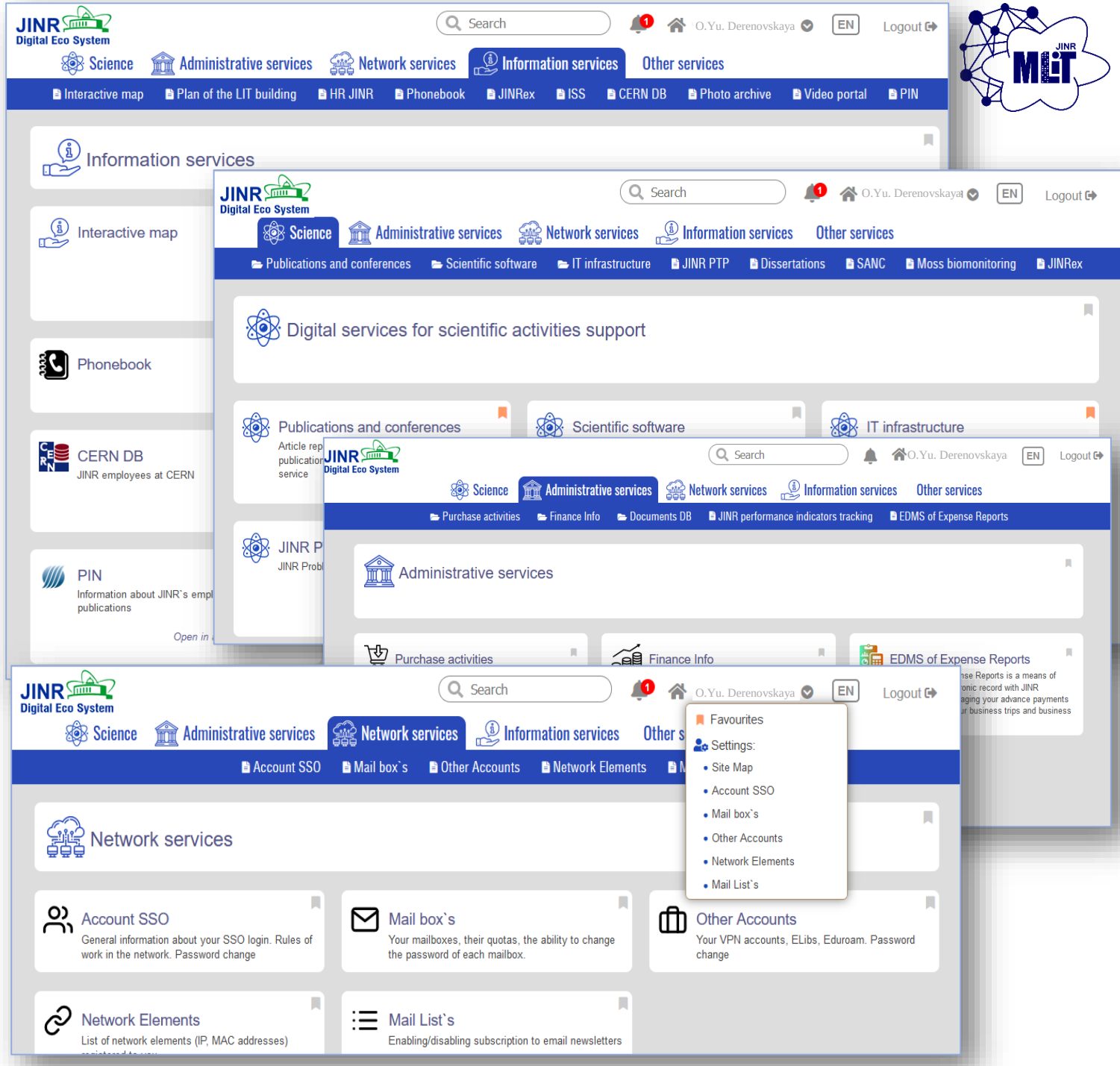
to provide
reliable and secure access to various types of data

to enable
a comprehensive analysis of information

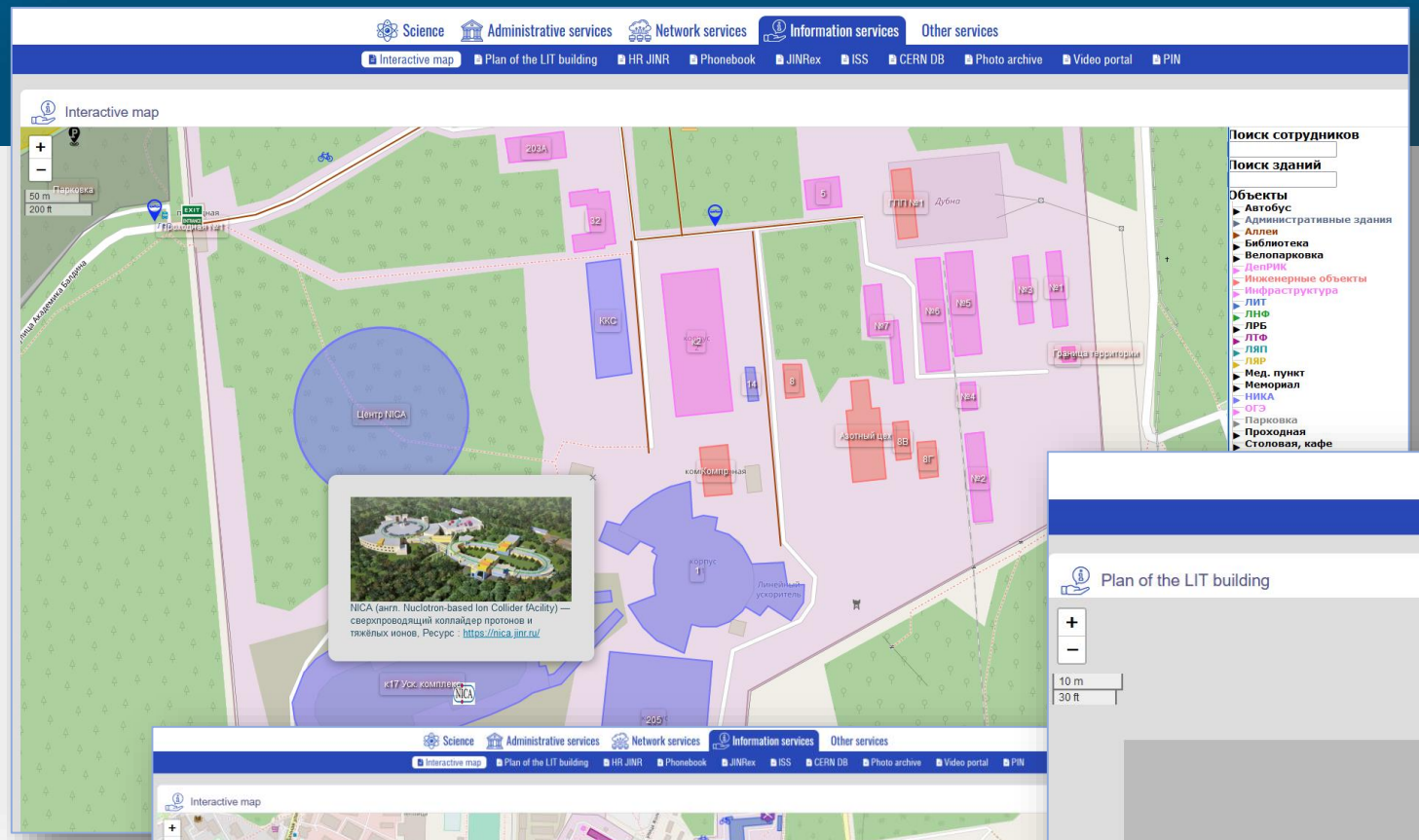
using
modern Big Data technologies and artificial intelligence.

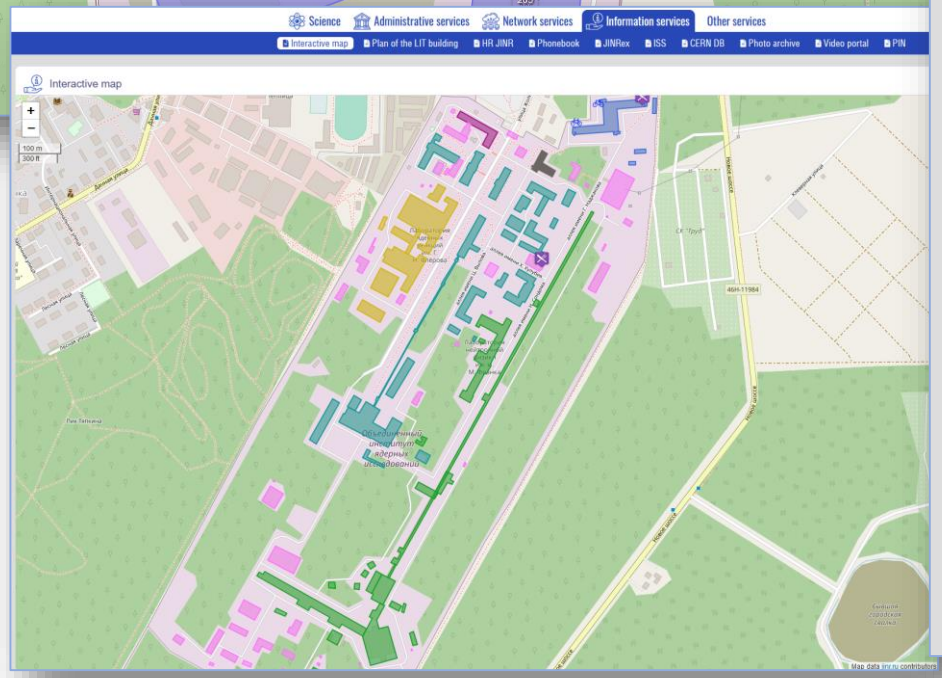


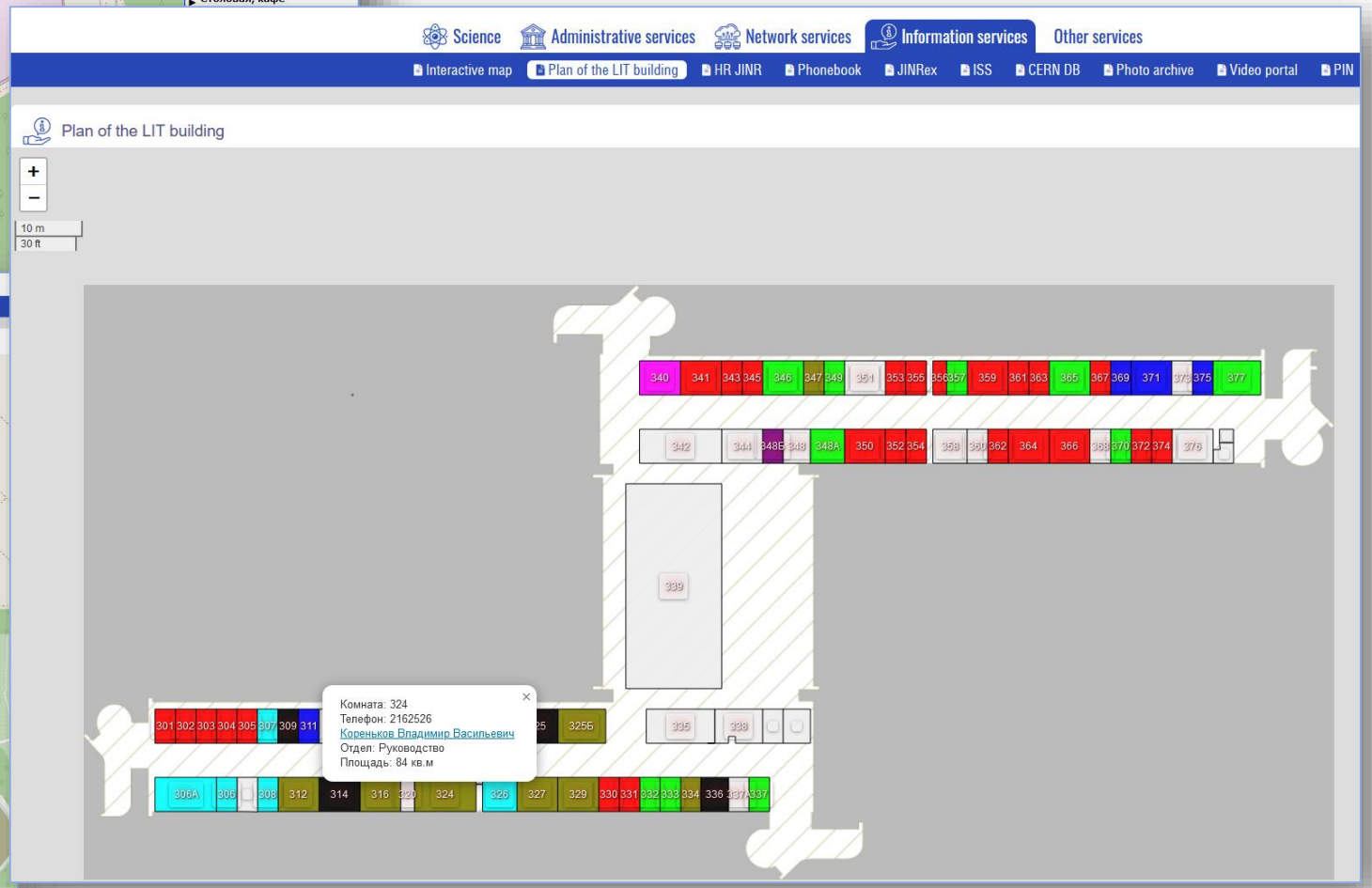




- ✓ Personal account of a JINR employee
- ✓ Notifications in a personal account
- ✓ Responsive interface, customizable by the user
- ✓ Easy access, convenient navigation and search for information on a large-scale network of a wide variety of JINR services

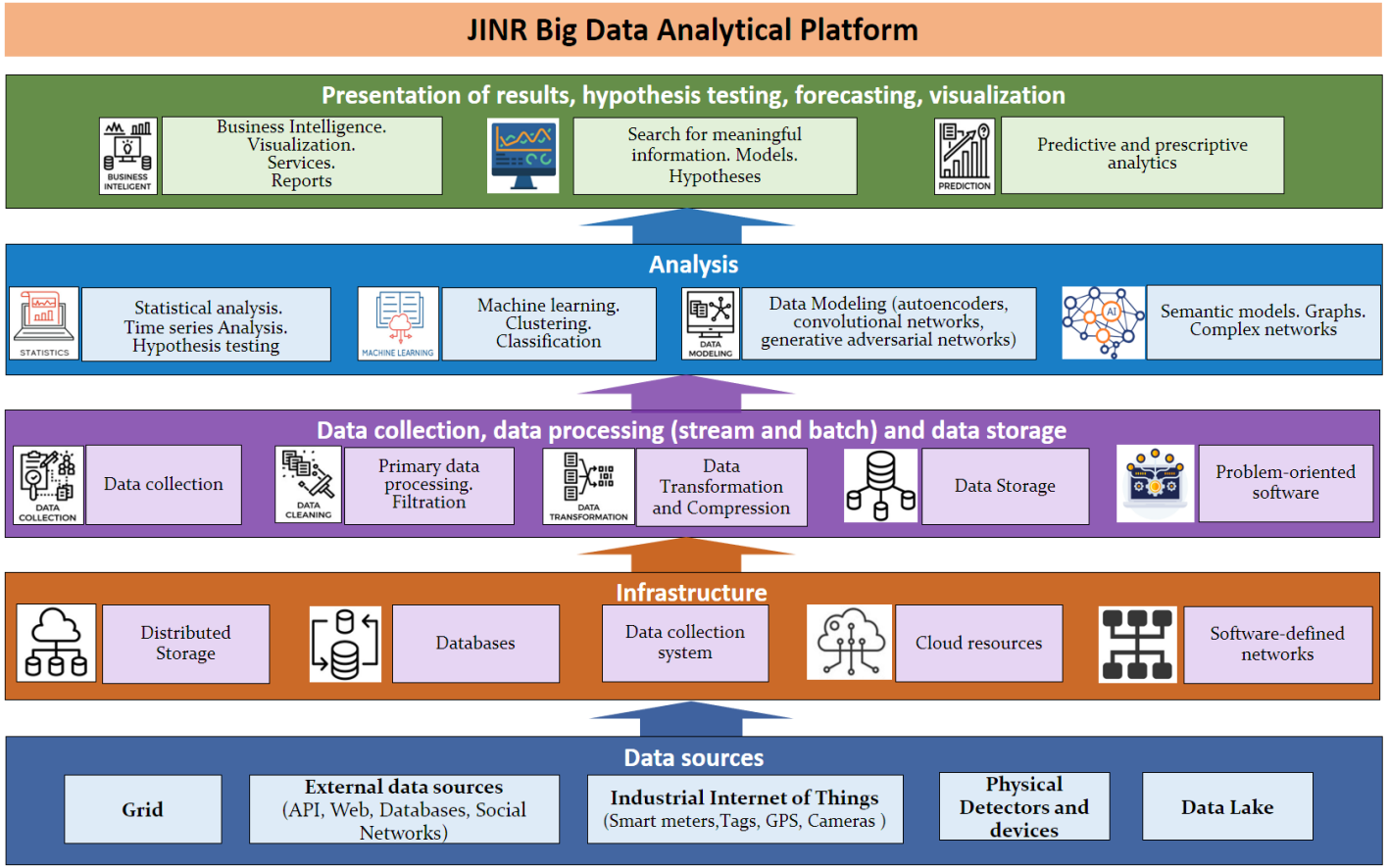






- ✓ Quick and easy search for information, both by services and by employees and buildings on an interactive JINR map

Activity: Multi-purpose Hardware and Software Platform for Big Data Analytics



Goal: the creation of a multi-purpose hardware and software platform for Big Data analytics based on hybrid hardware accelerators (GPU, FPGA, quantum systems); machine learning algorithms; tools for analytics, reports and visualization; support of user interfaces and tasks.

One of the tasks that is planned to be solved on the platform is the development of a unified analytical system for managing the MICC resources and data flows to enhance the efficiency of using computing and storage resources and simplify data processing within new experiments.

Development of the system for training and retraining IT specialists

Training courses, master classes and lectures

MLIT staff and leading scientists from JINR and its Member States

Leading manufacturers of modern computing architectures and software

Parallel programming technologies

OpenMP

MPI

OpenCL

NVIDIA CUDA

Tools for debugging and profiling parallel applications

Intel Cluster Studio

Work with applied software packages

COMSOL MULTIPHYSICS

Wolfram Mathematica

ROOT Data Analysis Framework

MATLAB

GEANT4

Maple

Frameworks and tools for ML/DL tasks

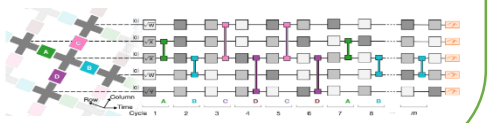
jupyterhub

TensorFlow

NumPy

scikit learn

Quantum algorithms, quantum programming and quantum control



JINR School of Information Technology 2022

DATA SCIENCE IT SCHOOL

60 students from 13 universities




- Dubna State University
- Far Eastern Federal University
- National Research Nuclear University MEPhI
- North Ossetian State University after K.L. Khetagurov
- Plekhanov Russian University of Economics
- St. Petersburg University
- The Bauman Moscow State Technical University
- The National University of Science and Technology (MISIS)
- The Peoples' Friendship University of Russia
- Tomsk Polytechnic University
- Tula State University
- Tver State University
- Vitus Bering Kamchatka State University

The International Conference "Distributed Computing and Grid Technologies in Science and Education"

- Distributed computing systems
- Computing for MegaScience Projects
- Distributed computing applications
- Data Management, Organisation and Access
- HPC
- Virtualization
- Big data Analytics and Machine learning
- Research infrastructure

NEC'2019

The International Symposium Nuclear Electronics and Computing

- Detector & Nuclear Electronics
- Triggering, Data Acquisition, Control Systems
- Distributed Computing, GRID and Cloud Computing
- Machine Learning Algorithms and Big Data Analytics new!
- Research Data Infrastructures
- Computations with Hybrid Systems (CPU, GPU, coprocessors)
- Computing for Large Scale Facilities (LHC, FAIR, NICA, SKA, PIC, XFEL, ELI, etc.)
- Innovative IT Education

MMCP

MATHEMATICAL MODELING AND COMPUTATIONAL PHYSICS

- ❑methods, software and program packages for data processing and analysis;
- ❑mathematical methods and tools for modeling complex physical and technical systems, computational biochemistry and bioinformatics;
- ❑methods of computer algebra, quantum computing and quantum information processing;
- ❑ machine learning and big data analytics;
- ❑ algorithms for parallel and hybrid calculations.

MLIT Schools

Thank you for your attention

http://lit.jinr.ru