INTERNATIONAL INTERGOVERNMENTAL ORGANIZATION
МЕЖДУНАРОДНАЯ МЕЖПРАВИТЕЛЬСТВЕННАЯ ОРГАНИЗАЦИЯ

JOINT INSTITUTE FOR NUCLEAR RESEARCH
ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

JINR MLiT

Многофункциональный информационно-вычислительный комплекс ОИЯИ

Кореньков Владимир Васильевич

Научный руководитель Лаборатории информационных технологий имени М.Г. Мещерякова ОИЯИ

I Всероссийская школа-семинар Национального центра физики и математики для студентов, аспирантов, молодых ученых и специалистов «Центр исследования архитектур суперкомпьютеров» Саров, 21-25 августа 2023 г.

Эволюция ИТ

- менялись концепции
- круг и сложность решаемых задач
- возникал новый технологический набор
- углублялась специализация разработчиков
- сокращалось время ввода новых продуктов и сервисов

первые цифровые платформы поддержки, работающих в реальном времени

Первое поколение (1960-е годы) — мейнфреймы

Второе поколение (1970-е годы) — универсальные ЭВМ

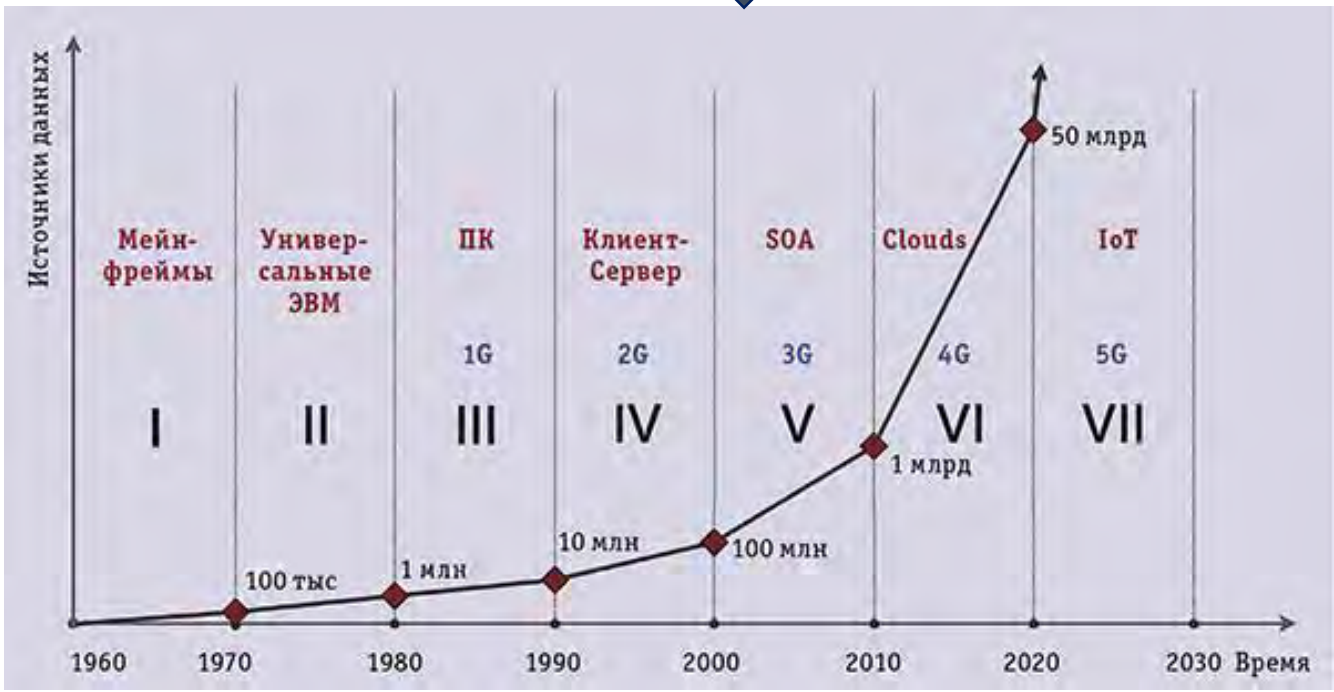
Третье поколение (1980-е годы) — персональные компьютеры

Четвертое поколение (1990-е годы) — клиент-сервер

Пятое поколение (2000-е годы) — сервисная архитектура

Шестое поколение (2010-е годы) — облака

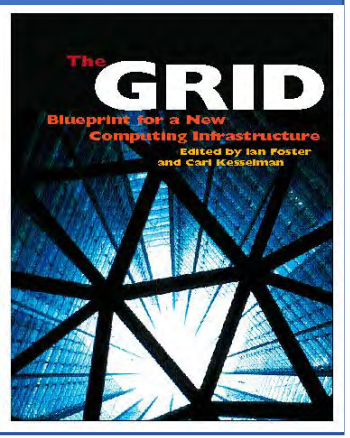
Седьмое поколение (2020-е годы) — IoT, искусственный интеллект, квантовые вычисления



Grids, clouds, supercomputers, Big data

Grids

- Collaborative environment
- Distributed resources

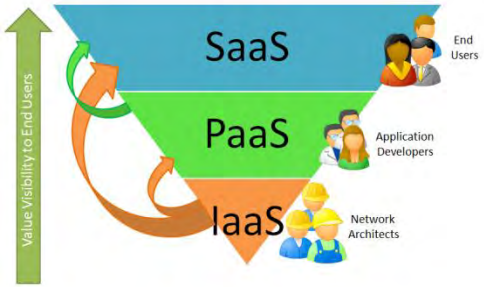


Supercomputers

Titan System (Cray XK7)			
Peak Performance	27.1 PF 18,688 compute nodes	24.5 PF GPU	2.6 PF CPU
System memory	710 TB total memory		
Interconnect	Gemini High Speed Interconnect	3D Torus	
Storage	Lustre Filesystem	32 PB	
Archive	High-Performance Storage System (HPSS)	29 PB	
I/O Nodes	512 Service and I/O nodes		

12 OLCF | 20

Clouds

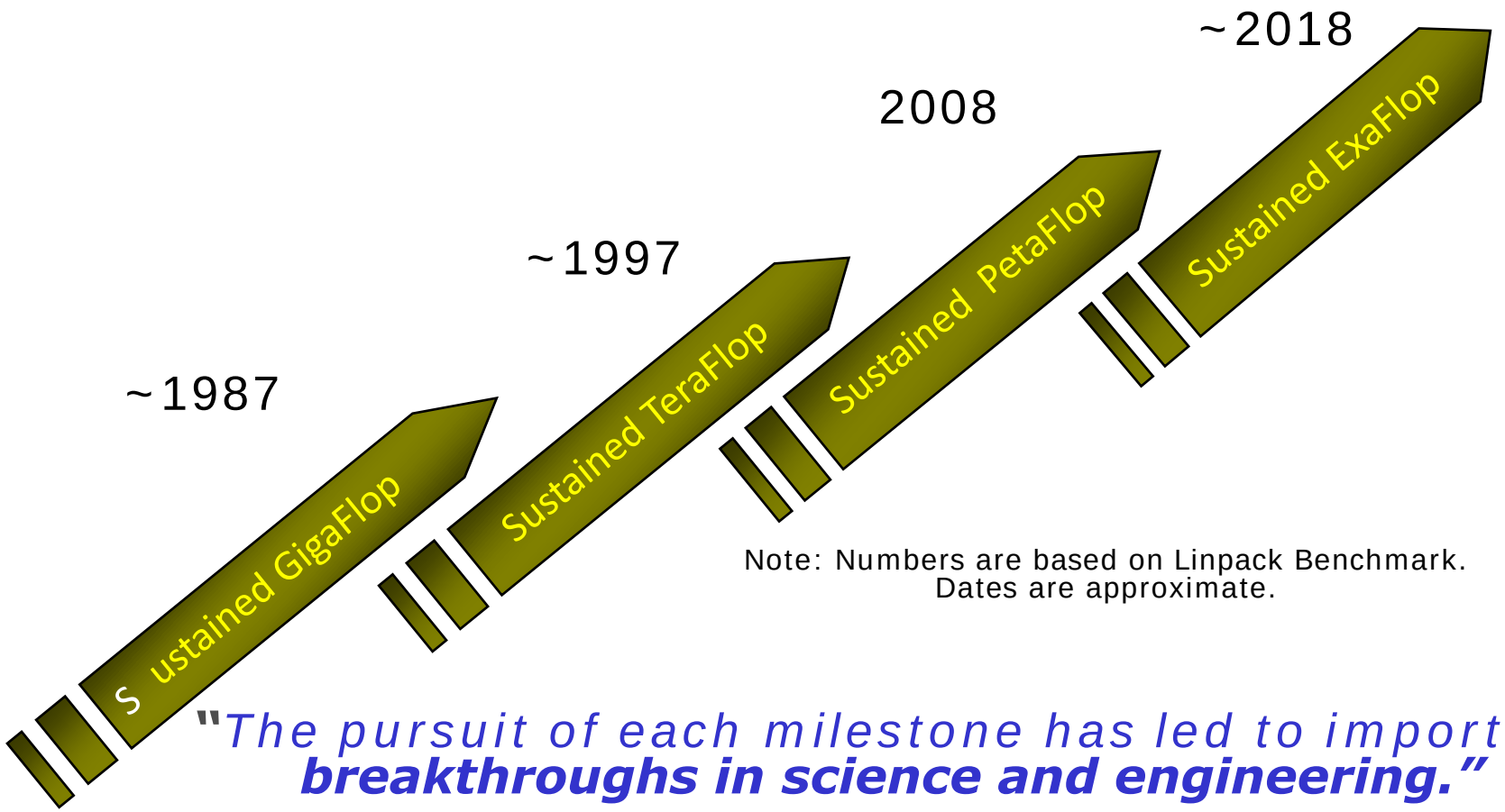


Big Data

- *Volume*
- *Velocity*
- *Variety*

Reach Exascale by 2018

From GigFlops to ExaFlops



Note: Numbers are based on Linpack Benchmark.
Dates are approximate.

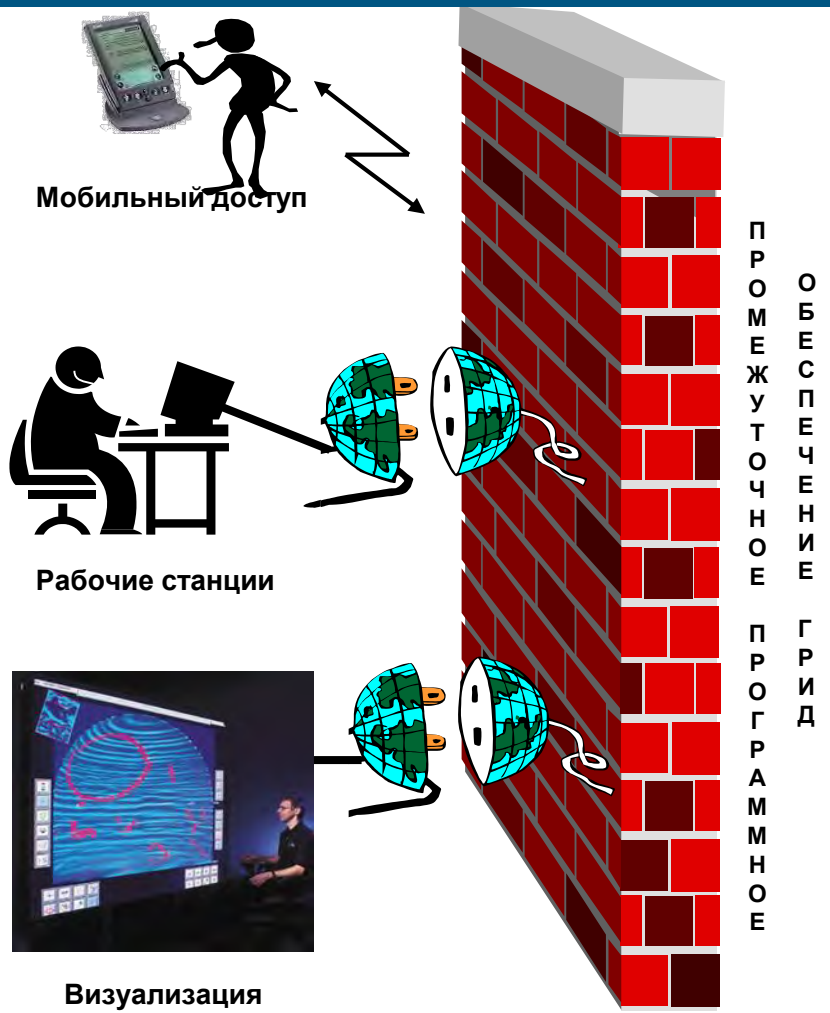
"*The pursuit of each milestone has led to important* ***breakthroughs in science and engineering.”***

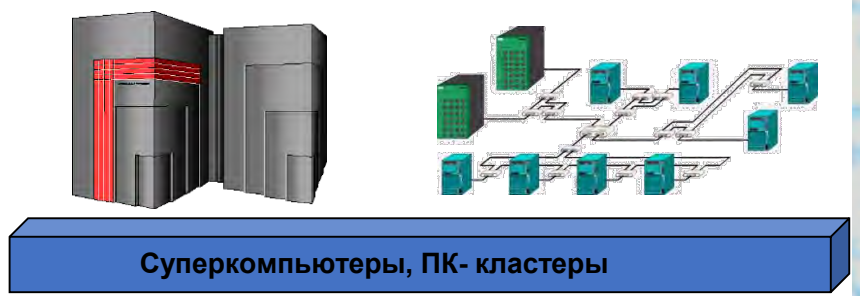
Source: IDC “In Pursuit of Petascale Computing: Initiatives Around the World,” 2007

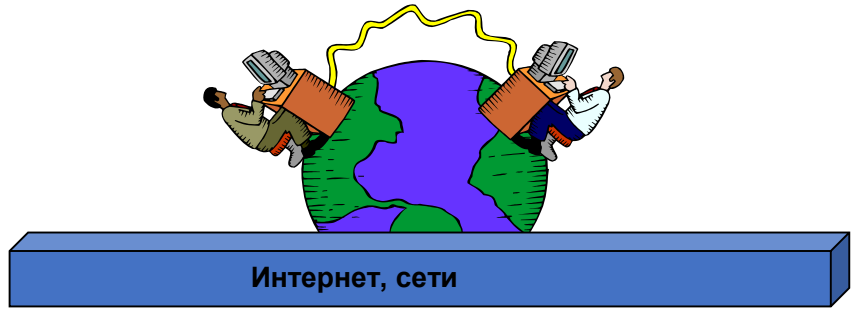
TOP500 List – June 2023

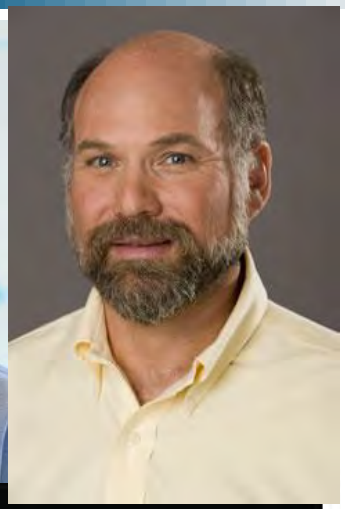
Rank	System	Cores	Rmax (PFlop/s)	Rpeak (PFlop/s)	Power (kW)
1	**Frontier** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, HPE DOE/SC/Oak Ridge National Laboratory US	8,730,112	**1,102.00**	1,685.65	21,100
2	**Supercomputer Fugaku** - Supercomputer Fugaku, A64FX 48C 2.2GHz, Tofu interconnect D, Fujitsu RIKEN Center for Computational Science Japan	7,630,848	**442.01**	537.21	29,899
3	**LUMI** - HPE Cray EX235a, AMD Optimized 3rd Generation EPYC 64C 2GHz, AMD Instinct MI250X, Slingshot-11, HPE EuroHPC/CSC Finland	2,220,288	**309.10**	428.70	6,016
4	**Leonardo** - BullSequana XH2000, Xeon Platinum 8358 32C 2.6GHz, NVIDIA A100 SXM4 64 GB, Quad-rail NVIDIA HDR100 Infiniband, Atos EuroHPC/CINECA Italy	1,463,616	**174.70**	255.75	5,610
5	**Summit** - IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband, IBM DOE/SC/Oak Ridge National Laboratory US	2,414,592	**148.60**	200.79	10,096
6	**Sierra** - IBM Power System AC922, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband, IBM / NVIDIA / Mellanox DOE/NNSA/LLNL US	1,572,480	**94.64**	125.71	7,438
7	**Sunway TaihuLight** - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway, NRCPC National Supercomputing Center in Wuxi China	10,649,600	**93.01**	125.44	15,371
8	**Perlmutter** - HPE Cray EX235n, AMD EPYC 7763 64C 2.45GHz, NVIDIA A100 SXM4 40 GB, Slingshot-10, HPE DOE/SC/LBNL/NERSC US	761,856	**70.87**	93.75	2,589
9	**Selene** - NVIDIA DGX A100, AMD EPYC 7742 64C 2.25GHz, NVIDIA A100, Mellanox HDR Infiniband, Nvidia NVIDIA Corporation US	555,520	**63.46**	79.22	2,646
10	**Tianhe-2A** - TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000, NUDT National Super Computer Center in Guangzhou China	4,981,760	**61.44**	100.68	18,482
27	**Chervonenkis** - YANDEX Y4N-GA1-TY25-ZB0, AMD EPYC 7702 64C 2GHz, NVIDIA A100 80GB, Infiniband, YANDEX, NVIDIA Yandex Russia	193,440	21.53	29.42	

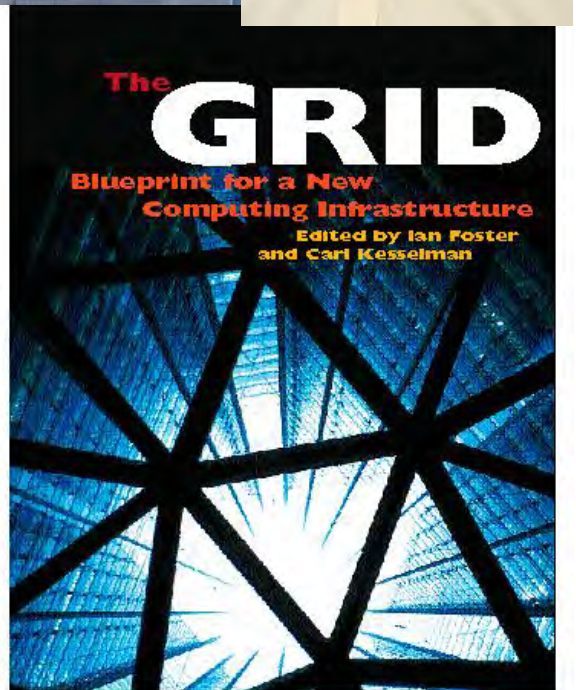
Грид - это средство для совместного использования вычислительных мощностей и хранилищ данных посредством интернета







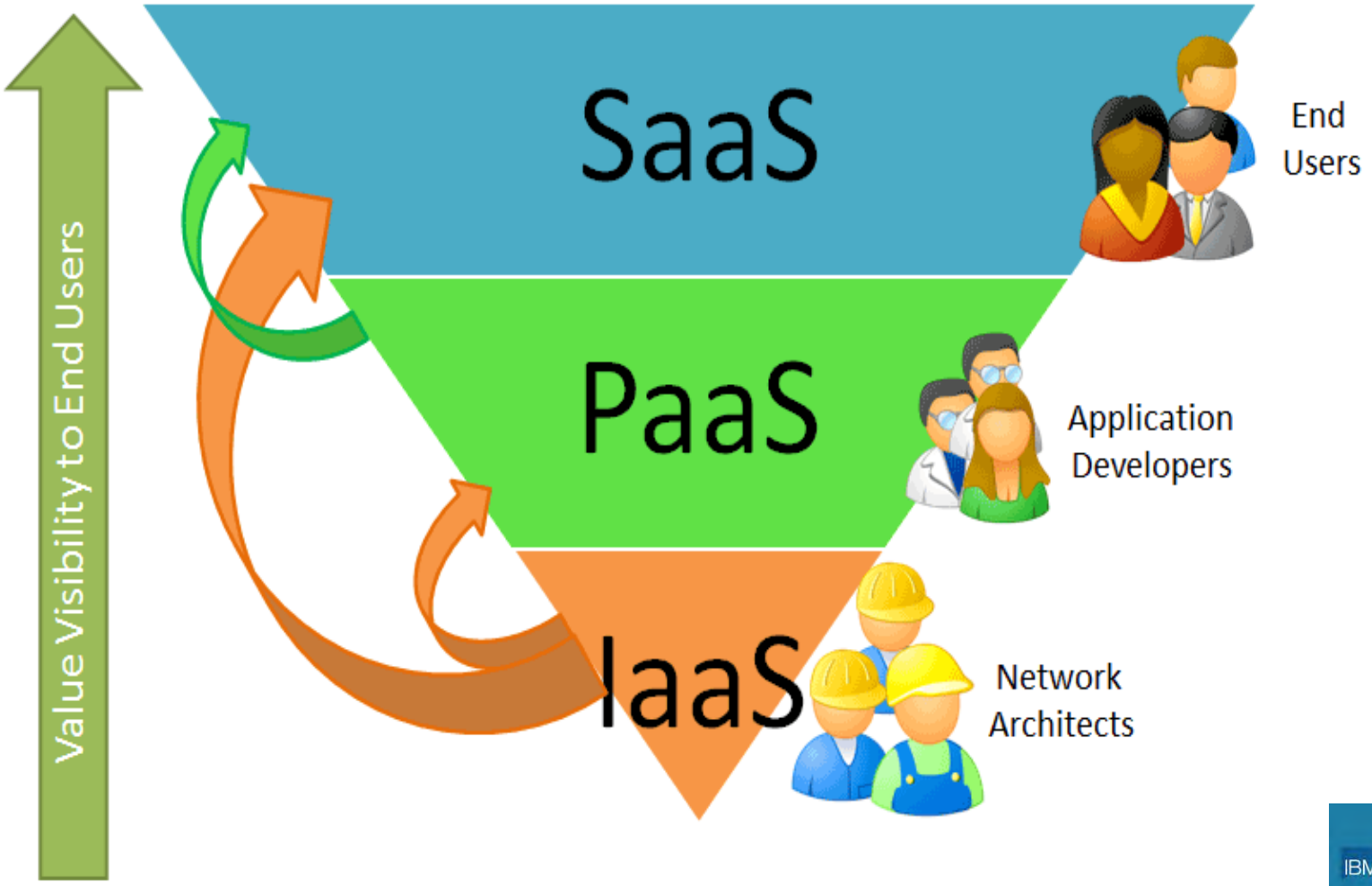




Облачные технологии

Облачные вычисления (англ. cloud computing) — модель обеспечения удобного сетевого доступа по требованию к некоторому общему фонду конфигурируемых вычислительных ресурсов (например, сетям передачи данных, серверам, устройствам хранения данных, приложениям и сервисам — как вместе, так и по отдельности), которые могут быть оперативно предоставлены и освобождены с минимальными эксплуатационными затратами или обращениями к провайдеру.

Cloud computing



Gmail by Google

Dropbox

YouTube

Google App Engine

Microsoft Azure

Google Compute Engine

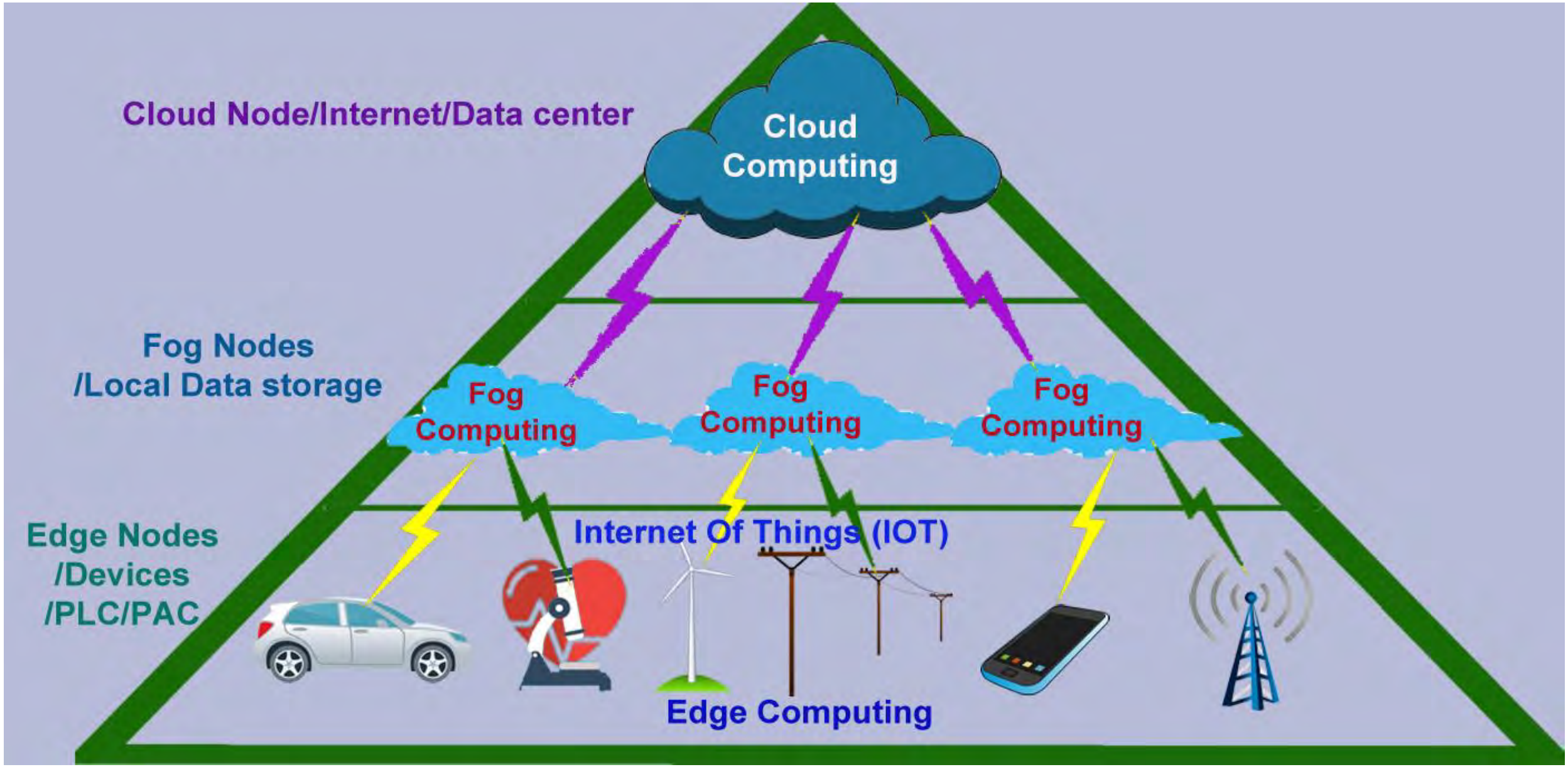
amazon

openstack

IBM SmartCloud Enterprise

OpenNebula.org

Cloud – Fog – Edge Computing



Грид технологии – путь к успеху

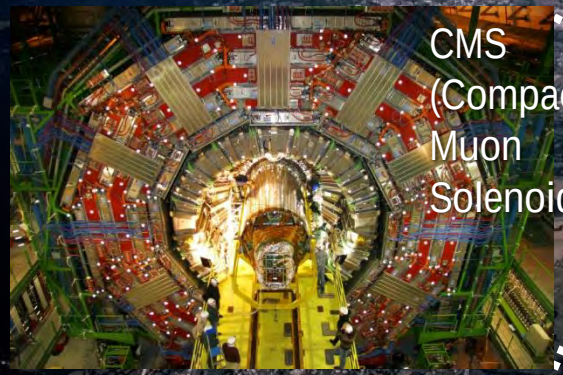
На торжестве по поводу получения Нобелевской премии за открытие бозона Хиггса директор ЦЕРНа Рольф Хойер прямо назвал **грид-технологии одним из трех столпов успеха** (наряду с ускорителем LHC и физическими установками).

Без организации грид-инфраструктуры на LHC было бы невозможно обрабатывать и хранить колоссальный объем данных, поступающих с коллайдера, а значит, совершать научные открытия.

Сегодня уже ни один крупный проект не осуществим без использования распределенной инфраструктуры для обработки данных.

Large Hadron Collider

The Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.

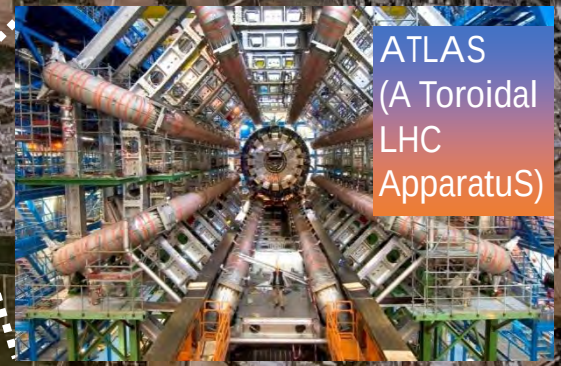


CMS (Compact Muon Solenoid)

LHCb (Large Hadron Collider beauty experiment)

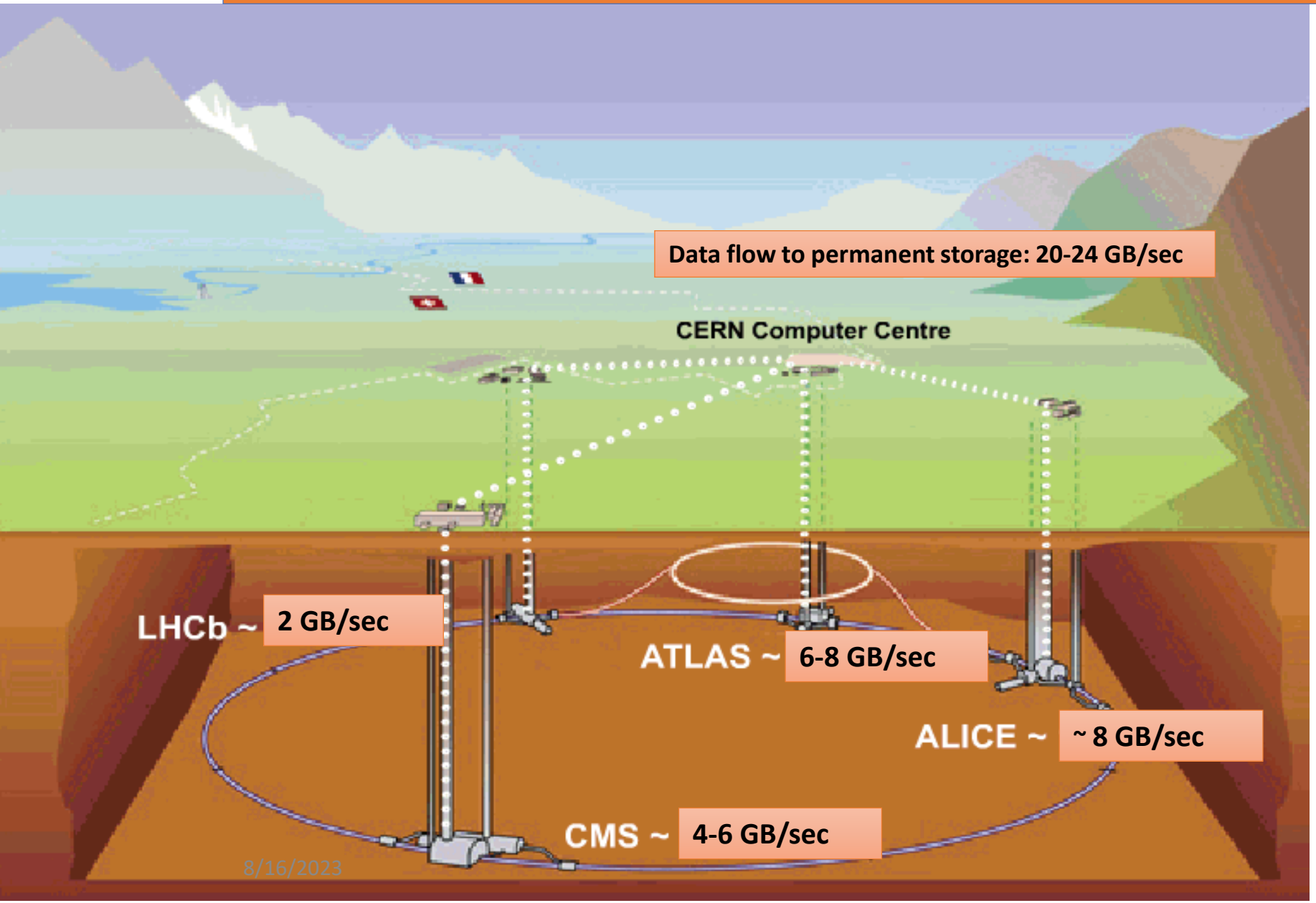
Data flow to permanent storage: 4-6 GB/sec

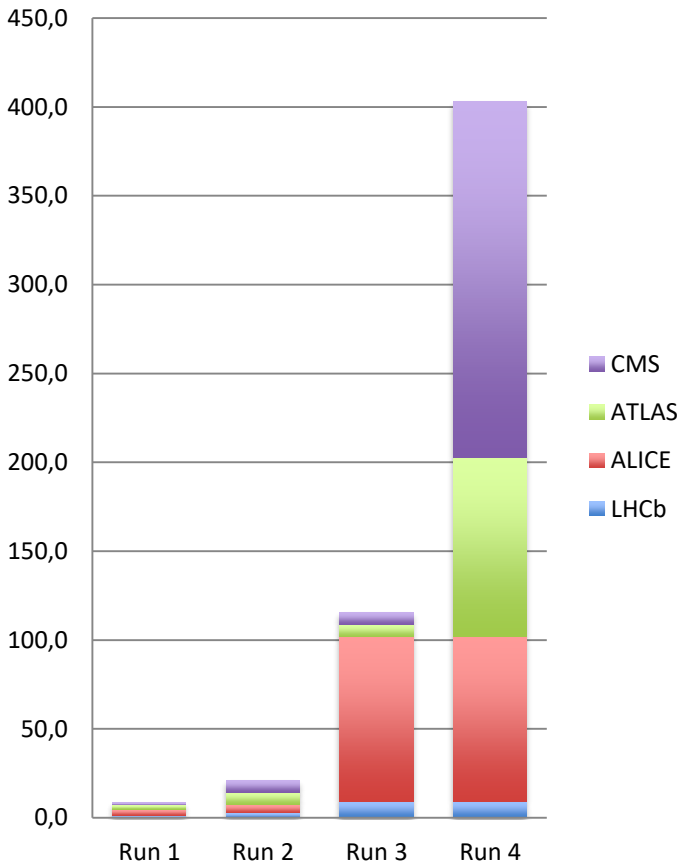
ALICE (A Large Ion Collider Experiment)



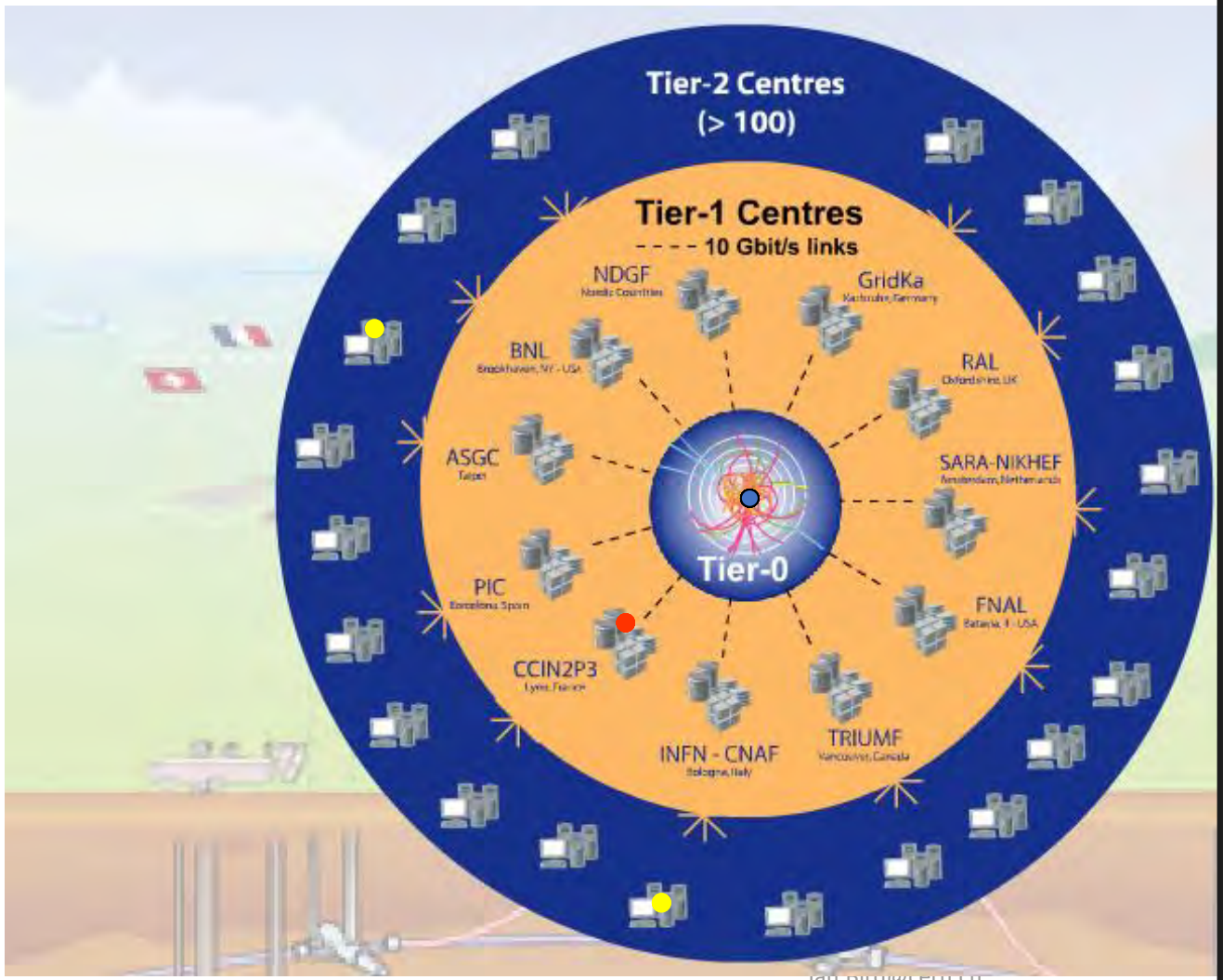
ATLAS (A Toroidal LHC ApparatuS)

Data Collection and Archiving at CERN





Tier Structure of GRID Distributed Computing: Tier-0/Tier-1/Tier-2



Tier-0 (CERN):
- accepts data from the CMS Online Data Acquisition and Trigger System
- archives RAW data
- the first pass of reconstruction and performs Prompt Calibration
- data distribution to Tier-1

Tier-1 (11 centers):
- receives a data from the Tier-0
- data processing (re-reconstruction, skimming , calibration etc)
- distributes data and MC to the other Tier-1 and Tier-2
- secure storage and redistribution for data and MC

Tier-2 (>200 centers):
- simulation
- user physics analysis

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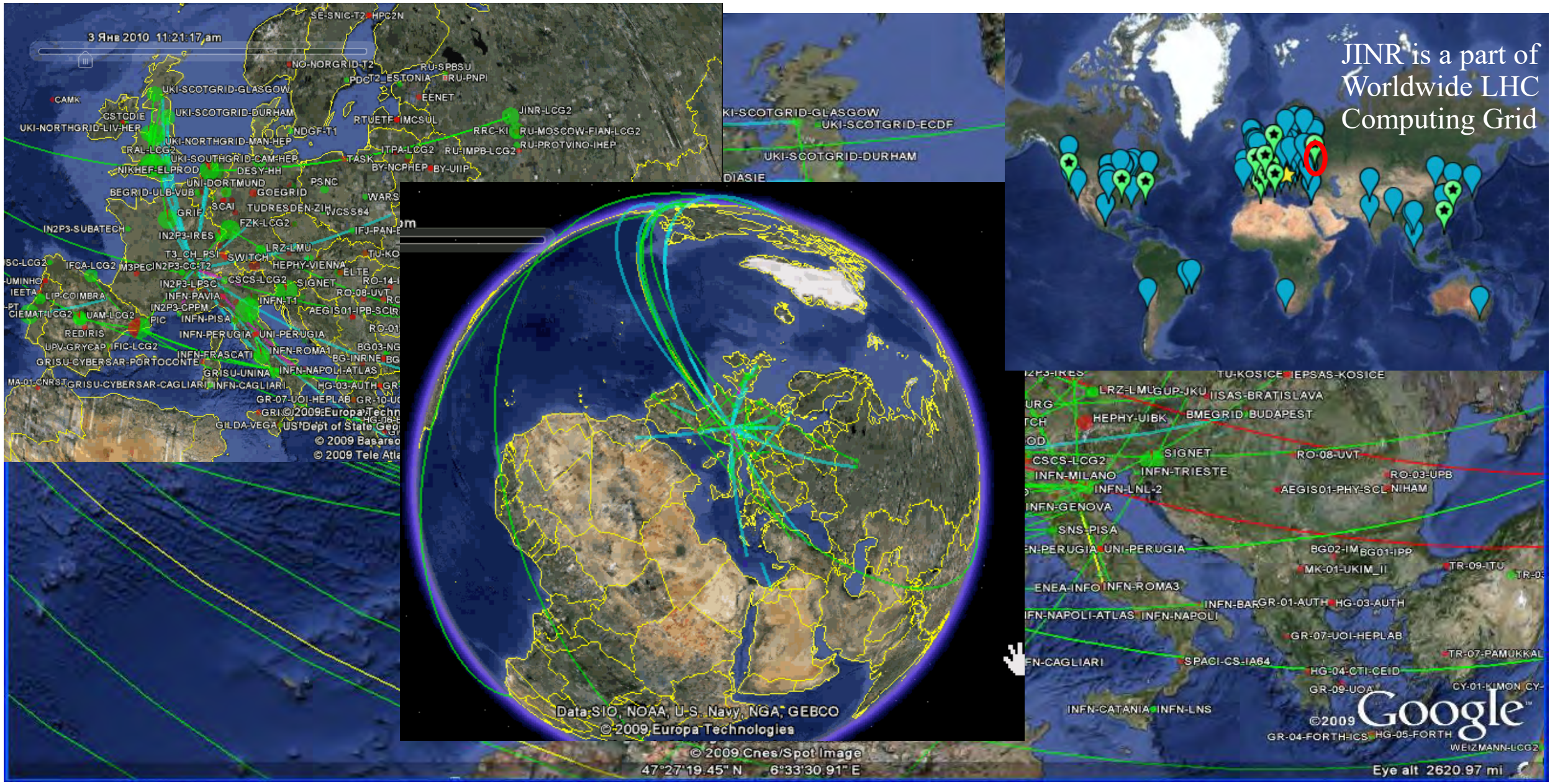
The Worldwide LHC Computing Grid (WLCG)

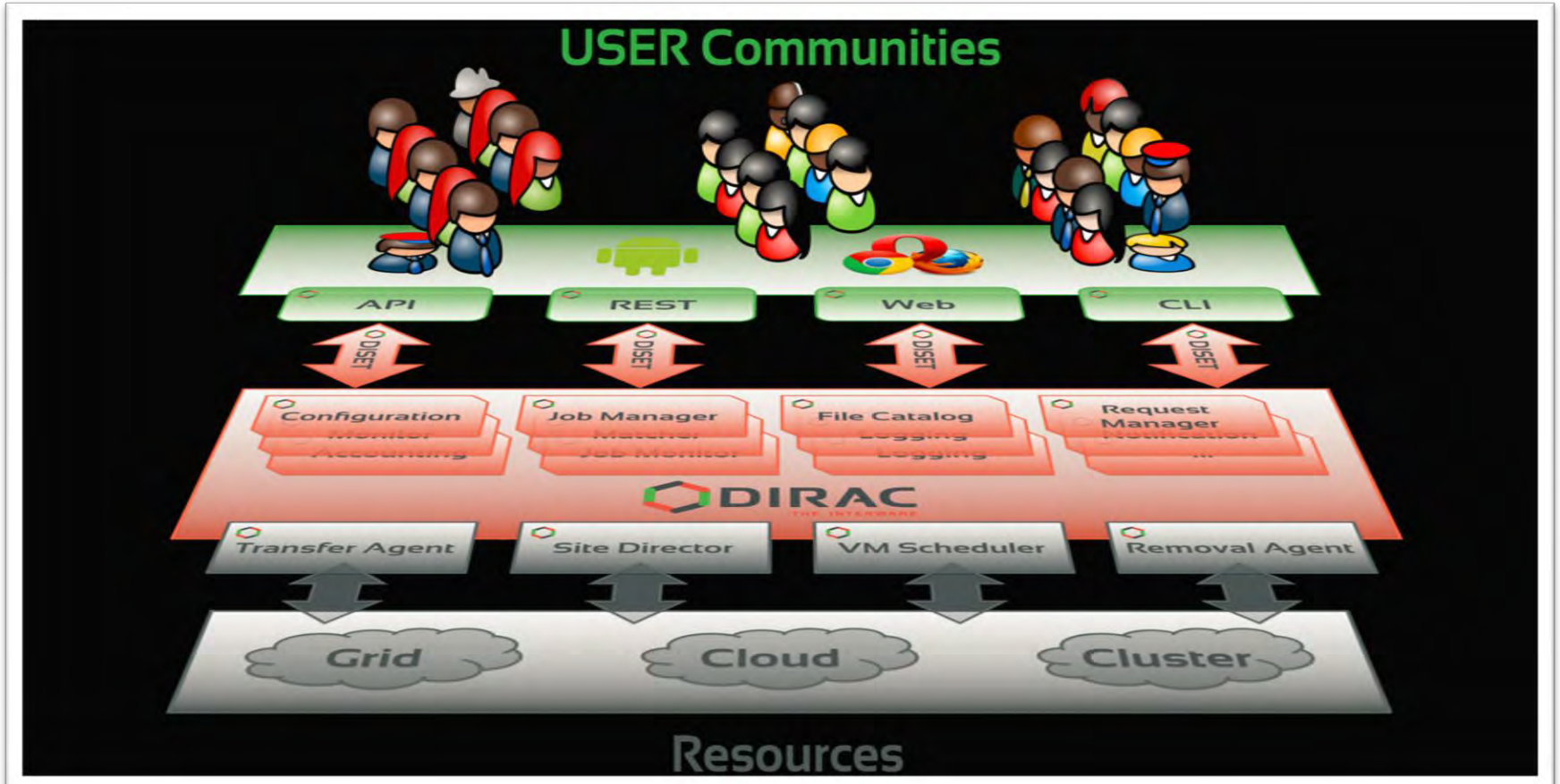


Эволюция модели компьютинга

- Расширение компьютерных ресурсов за счет использования внешних невыделенных ресурсов (HLT, Clouds, HPC…)
- Изменения модели компьютинга в каждом эксперименте, с целью оптимизации использования ресурсов
- Значительные усилия вкладываются в развитие программного обеспечения, чтобы улучшить общую производительность при использовании современных архитектур (многоядерность, GPU…)
- Оптимизации процессов обработки, количество хранящихся реплик данных и др.

Платформа DIRAC

- DIRAC has all the necessary components to build ad-hoc grid infrastructures **interconnecting** computing resources of different types, allowing **interoperability** and simplifying **interfaces**.
- This allows to speak about the DIRAC ***interware***.



* PanDa в эксперименте ATLAS

В эксперименте ATLAS на Большом адронном коллайдере разработана платформа для управления вычислительными ресурсами PanDA Workload Management System (WMS), которая обладает следующими возможностями:

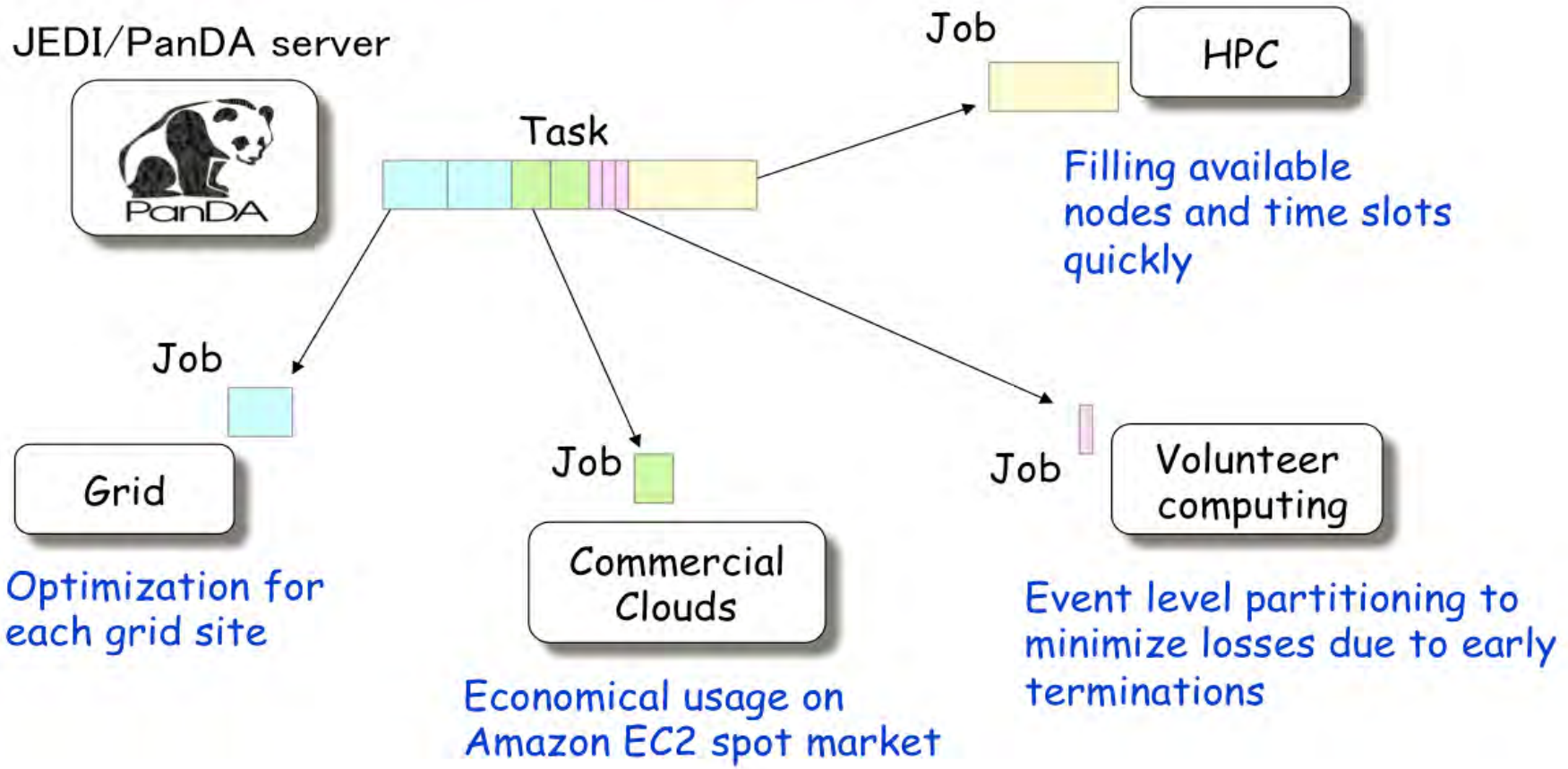
- Проект PanDA начался в 2005 году группами BNL и UTA - **P**roduction **an**d **D**ata **A**nalysis system.
- Автоматизированная и гибкая система управления заданиями, которая может оптимально сделать распределенные ресурсы доступными пользователю.
- С помощью PanDA, физики видят единый вычислительный ресурс, который предназначен для обработки данных эксперимента, даже если дата-центры разбросаны по всему миру
- PanDa изолирует физиков от аппаратного обеспечения, системного и промежуточного программного обеспечения и других технологических сложностей, связанных с конфигурированием сети и оборудования.
- Вычислительные задачи автоматически отслеживаются и выполняются. Могут выполняться групповые задачи физиков

В настоящее время PanDa контролирует:

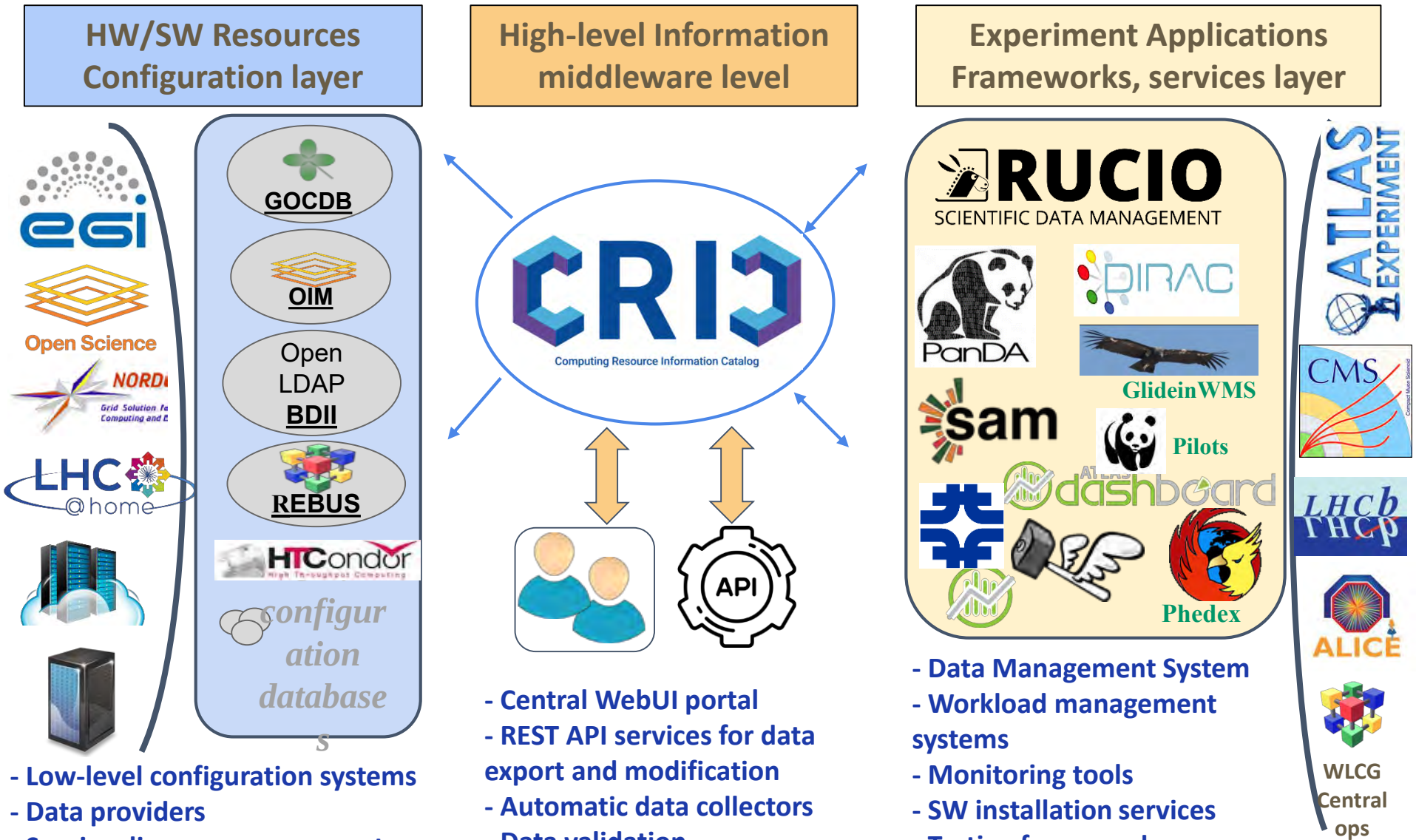
- **сотни дата - центров в 50 странах мира**
- **сотни тысяч вычислительных узлов**
- **сотни миллионов заданий в год**
- **тысячи пользователей**

Dynamic Job Definition in PanDA

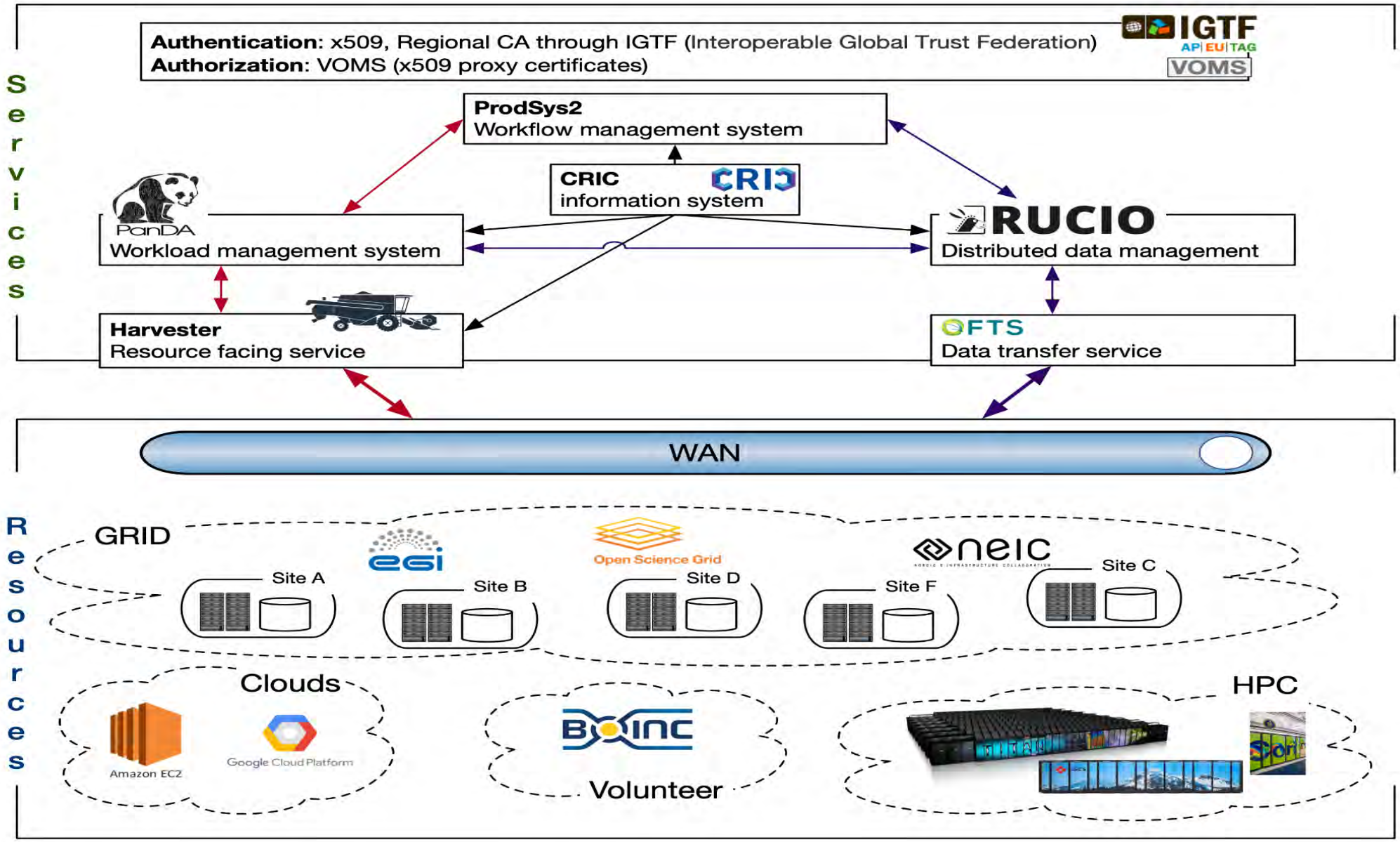
- Workload partitioning for traditional and opportunistic resources



CRIC: a unified topology system for a large scale, heterogeneous and dynamic computing infrastructure

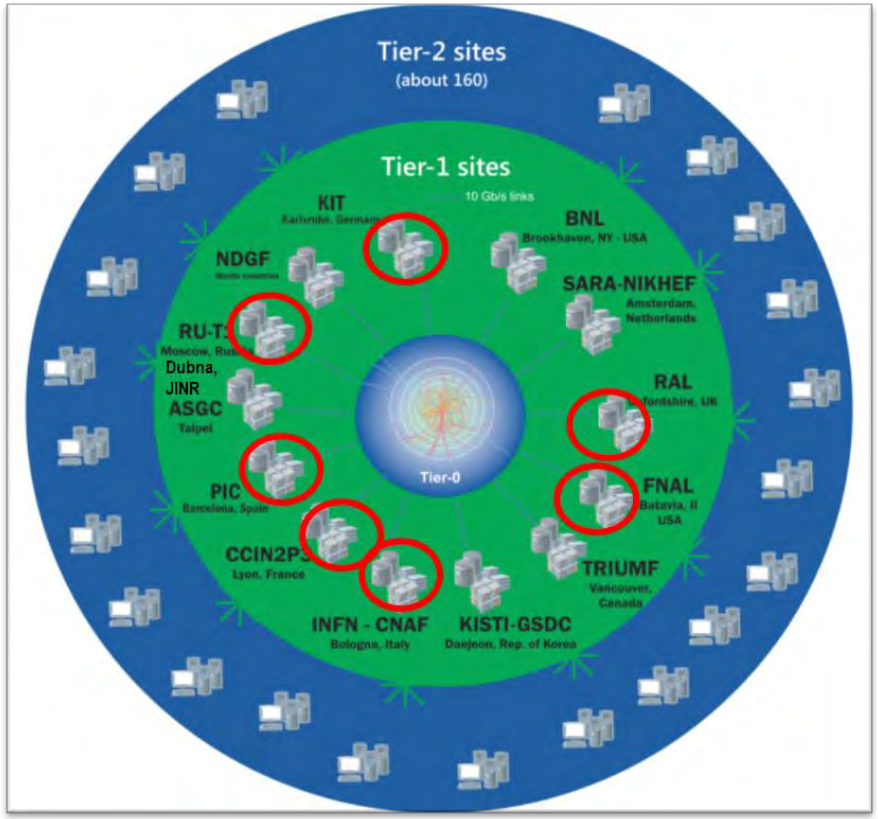


ATLAS computing



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

International Large-scale projects

Russian research institutes and universities actively participate in international large-scale projects:

- LHC, CERN (experiments: ATLAS, ALICE, LHCb, CMS)
- XFEL, DESY (European free electron laser)
- ESRF, France (European synchrotron center)
- FAIR, GSI, Germany (CBM, PANDA experiments)
- ITER, France …

International large-scale projects are being prepared in Russia:

- **NICA**, JINR, Dubna (proton and heavy ion collider)
- **PIK**, PNPI, Gatchina (high-flow reactor complex)
- **SKIF**, INP SB RAS Novosibirsk (Siberian ring photon source)
- **Super S-Tau Fabric**, Sarov (electron-positron collider)
- **Нейтринная программа (Байкал, JUNO, NOVA, DUNE …)**
- **синхротронно-нейтронная программа, науки о жизни**

Joint Institute for Nuclear Research
SCIENCE BRINGING NATIONS TOGETHER

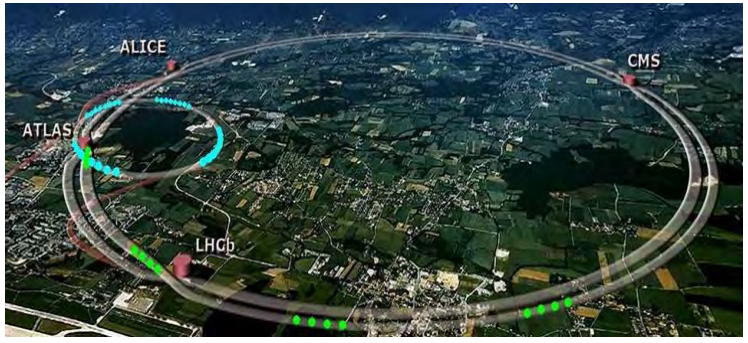
NICA

СКИФ
СИБИРСКИЙ КОЛЬЦЕВОЙ ИСТОЧНИК ФОТОНОВ

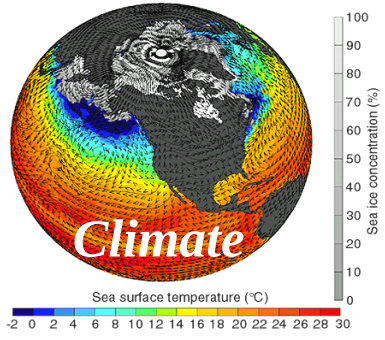
Институт ядерной физики имени Г. И. Будкера СО РАН

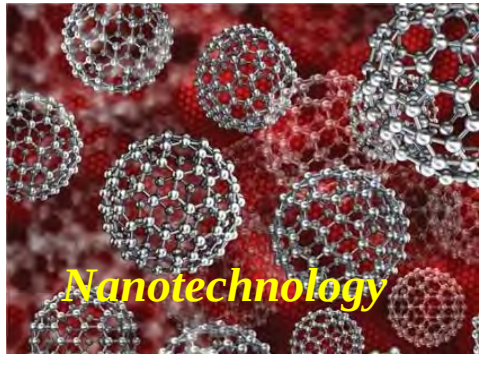
HPC+Big Data+Artificial intelligence

High Energy Physics

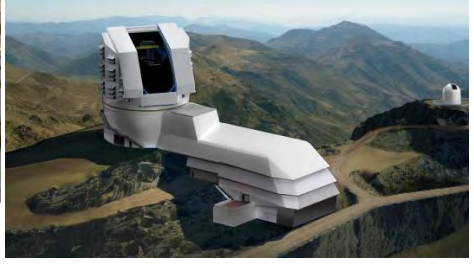


CERN Large Hadron Collider > 600 Pb/Year





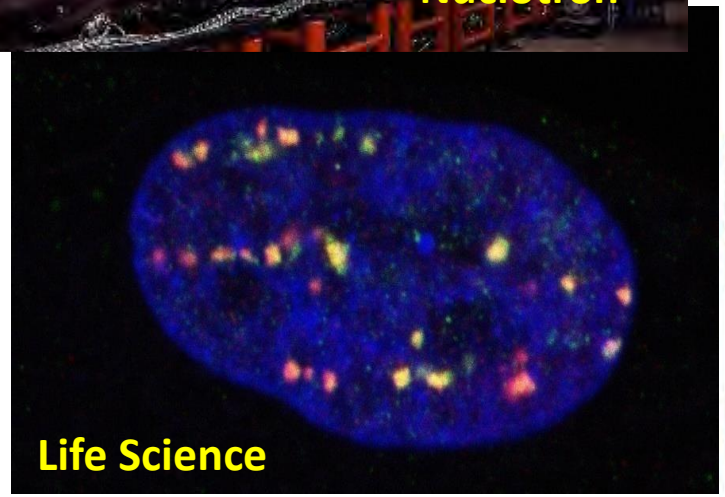
Square Kilometer Array radio telescope
> 1 Eb/Year ra
data (estimatic



Large Synoptic Survey Telescope > 10 Pb/Year (estimation)

... et cetera

Implementation of the JINR Development Program



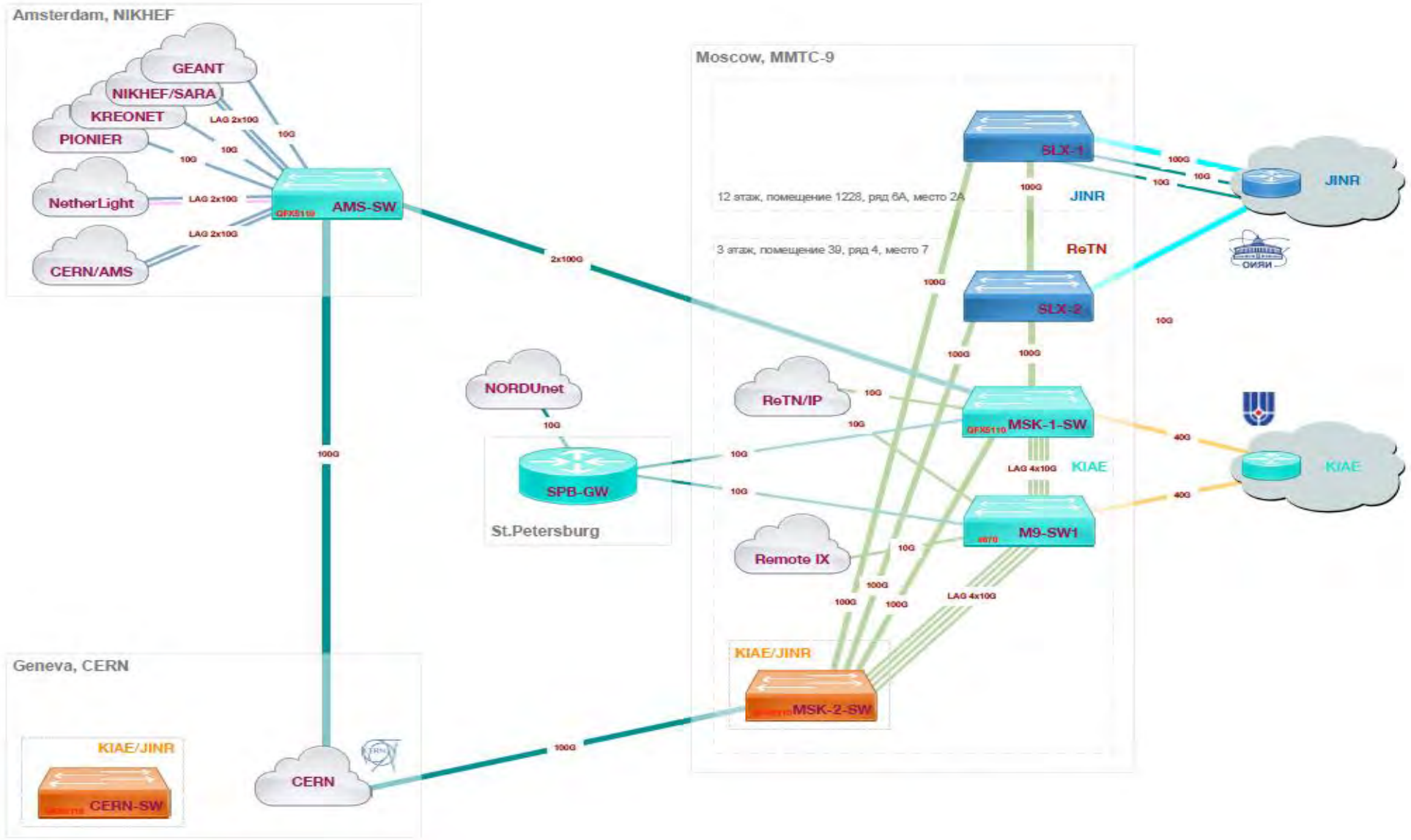
Russian Data Intensive Grid infrastructure (RDIG)

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



Tier1 – Tier2 in Russia 2023 (Sum CPU in HS06 hours)

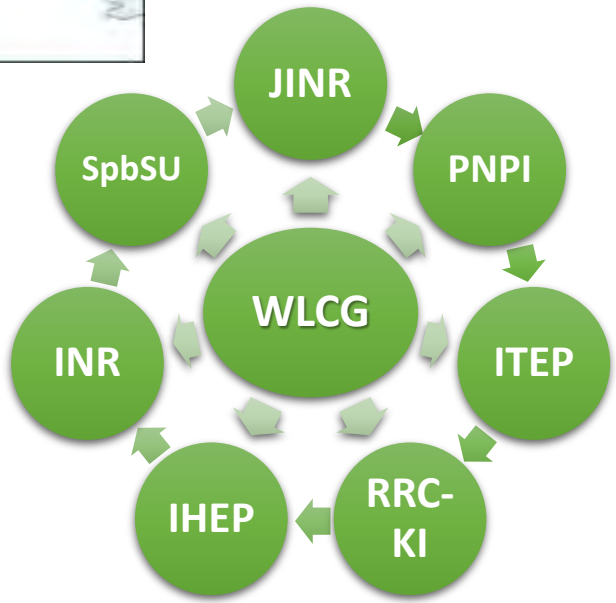
• JINR-T1	1,281,085,920	56.89%
• RRC-KI-T1	497,682,603	22.1%
• JINR-LCG2	421,577,464	18.72%
• RU-Protvino-IHEP	35,694,338	1.58%
• ru-PNPI	11,770,304	0.52%
• Ru-Troitsk-INR-LCG2	3,879,410	0.17%
• RU-SARFTI	300,168	0.01%
• RU-SPbSU	25,063	0%

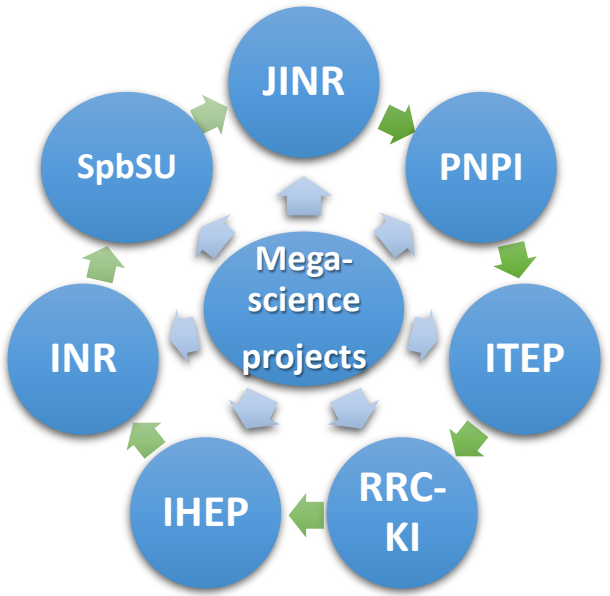
From RDIG to RDIG-M

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.

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





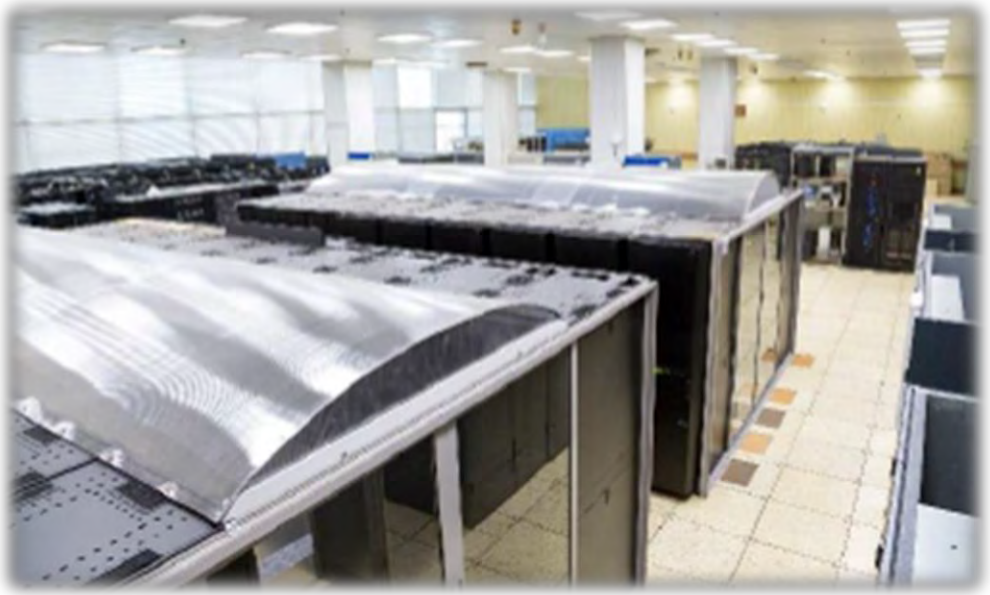
Meshcheryakov Laboratory of Information Technologies

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

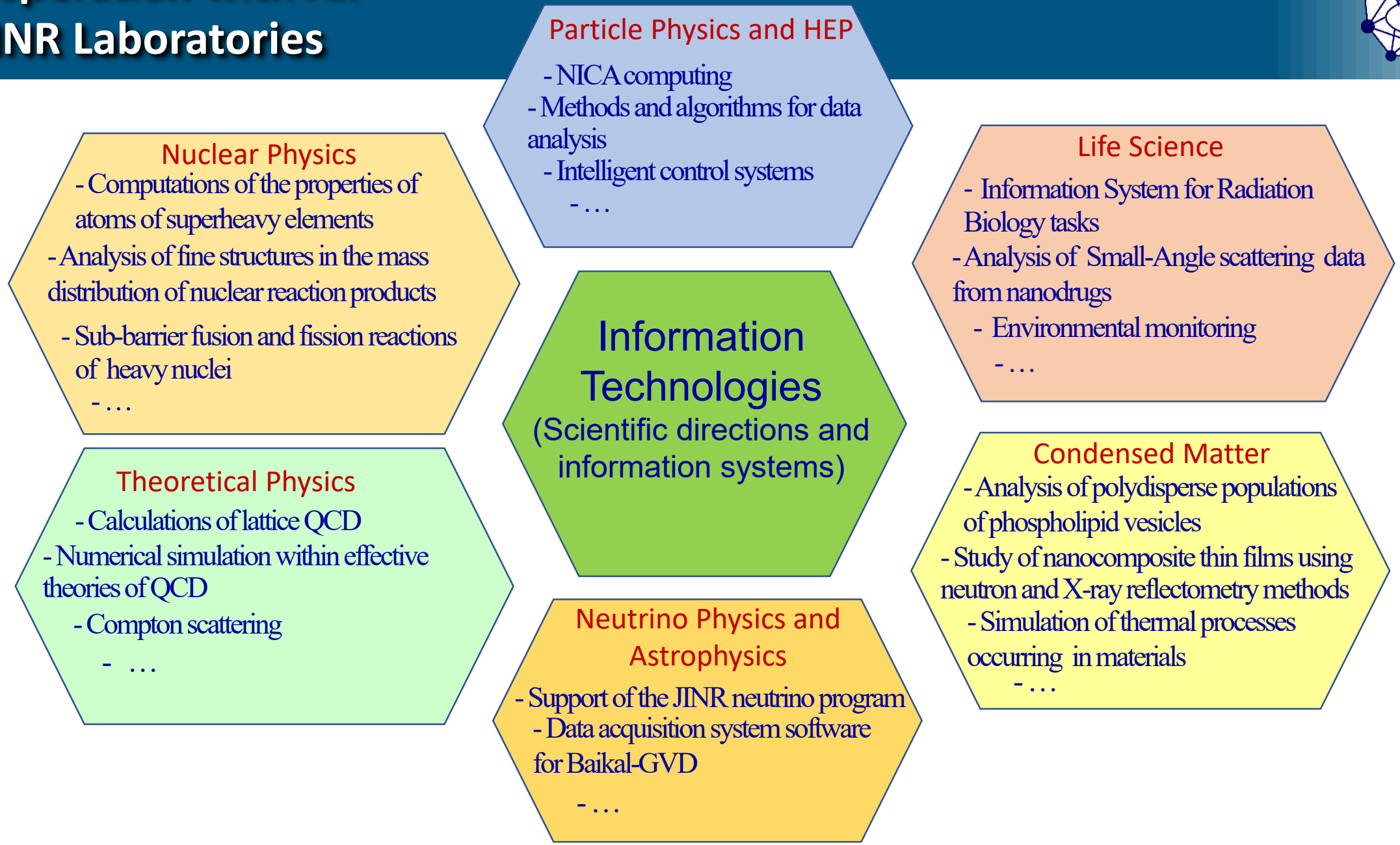


Staff: 325
Scientists: 100
Doctors of Science: 24
Candidates of Science: 61
Campus network 2x100 Gbps
Multisite network 4x100 Gbps
Telecommunication channel 3x100 Gbps
Grid Tier1 and Tier2 for global data processing
JINR Cloud computing
JINR Member States' Cloud environment
"Govorun" supercomputer

MLIT Fundamentals:

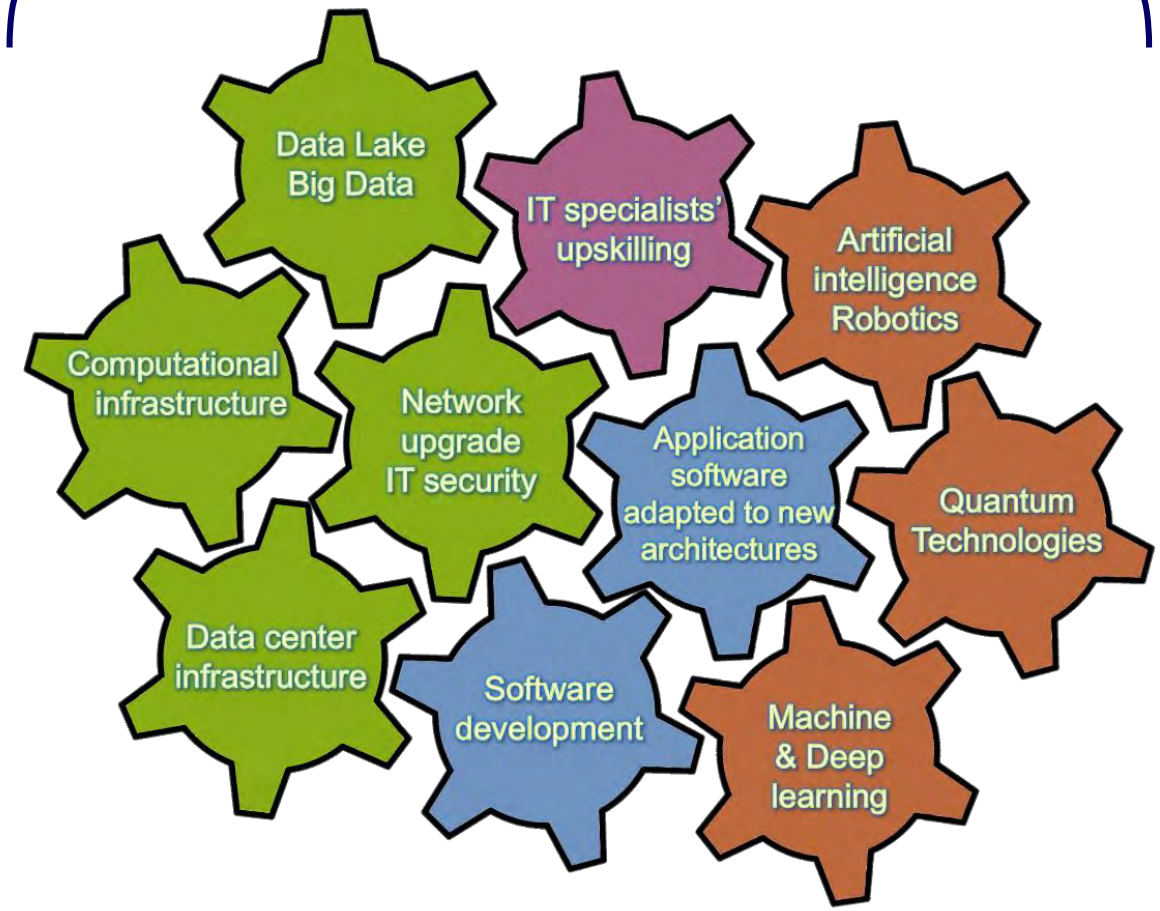
* **Provide** IT services necessary for the fulfillment of the JINR Topical Plan on Research and International Cooperation
* **Building** world-class competence in IT and computational physics
* **24/7** support of computing infrastructure and services such availability is called nonstop service.

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

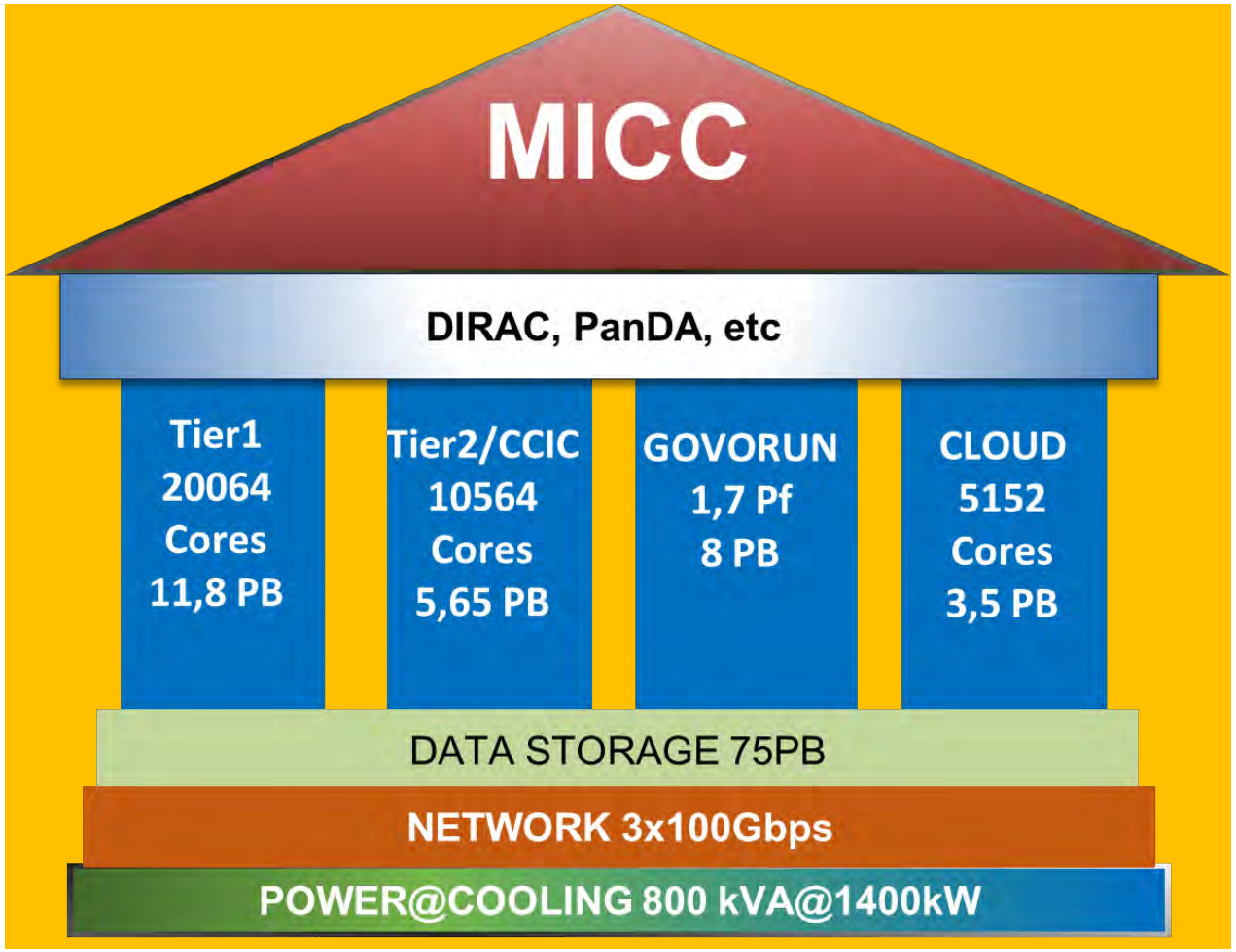
for all experiments.

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

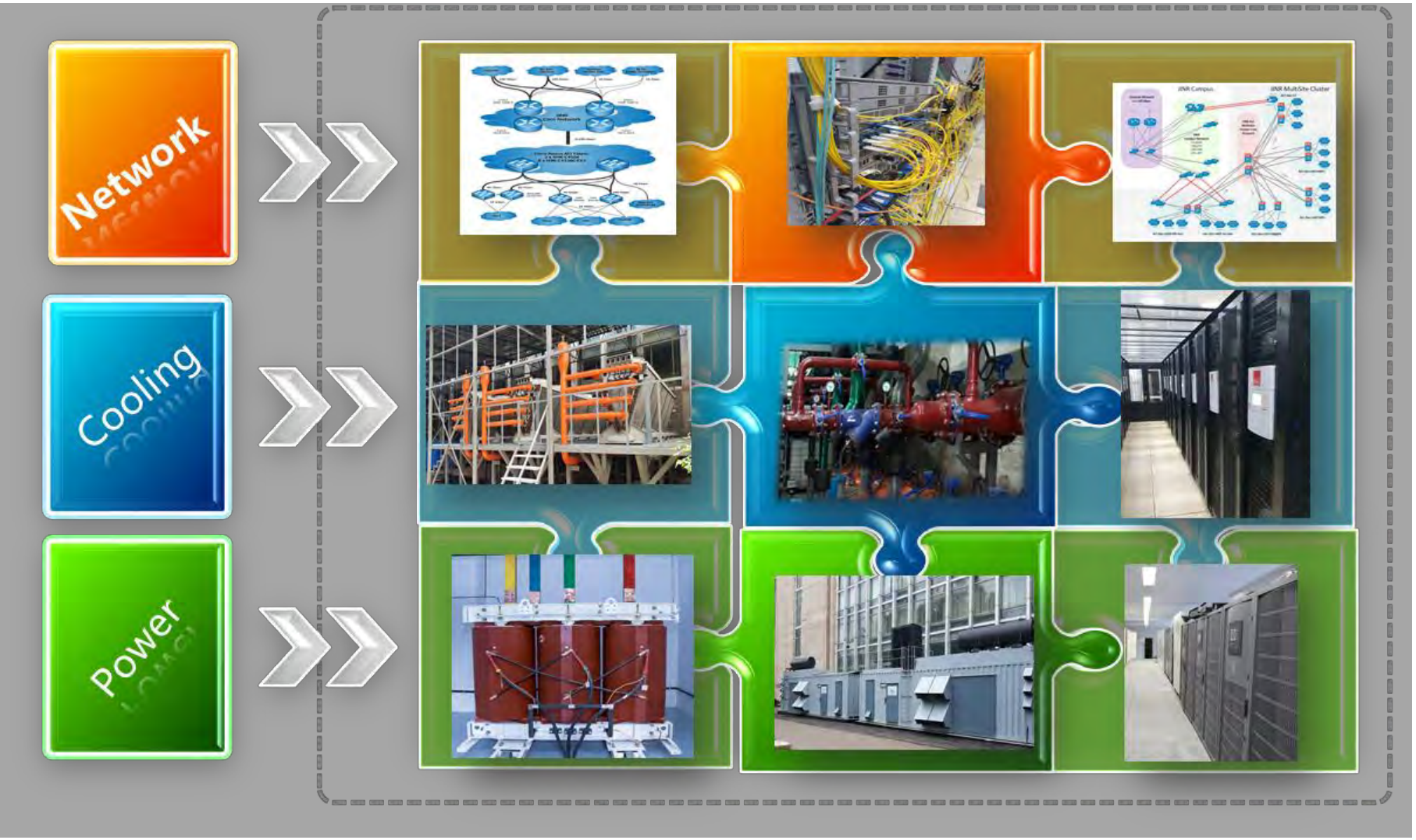
- Power
- Cooling

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

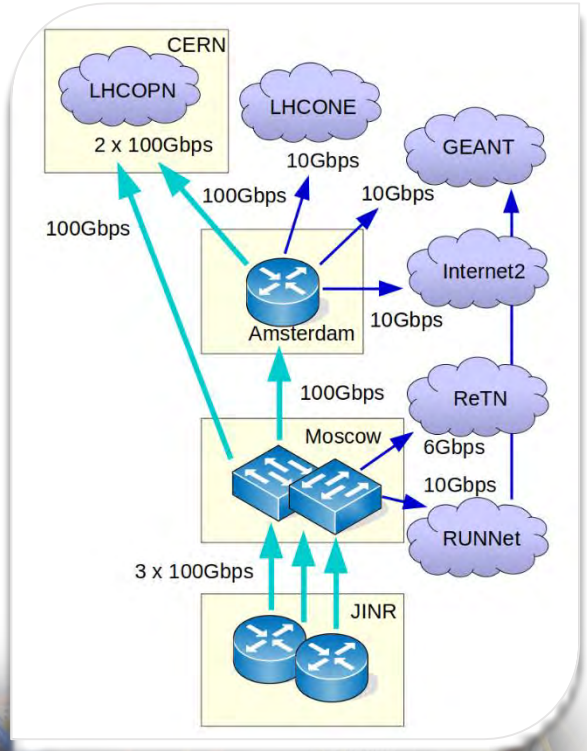


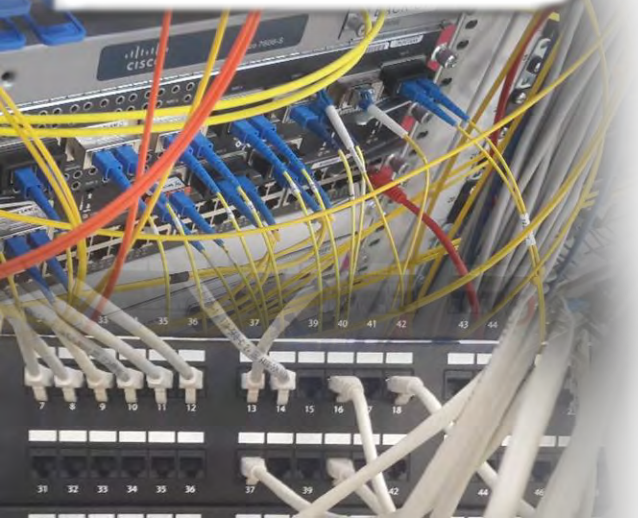
Wide Area Network 3x100 Gbps
Cluster Backbone 4x100 Gbps
Campus Backbone 2x100 Gbps

Dry chillers
InRow systems
Total cooling 1400 kW

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

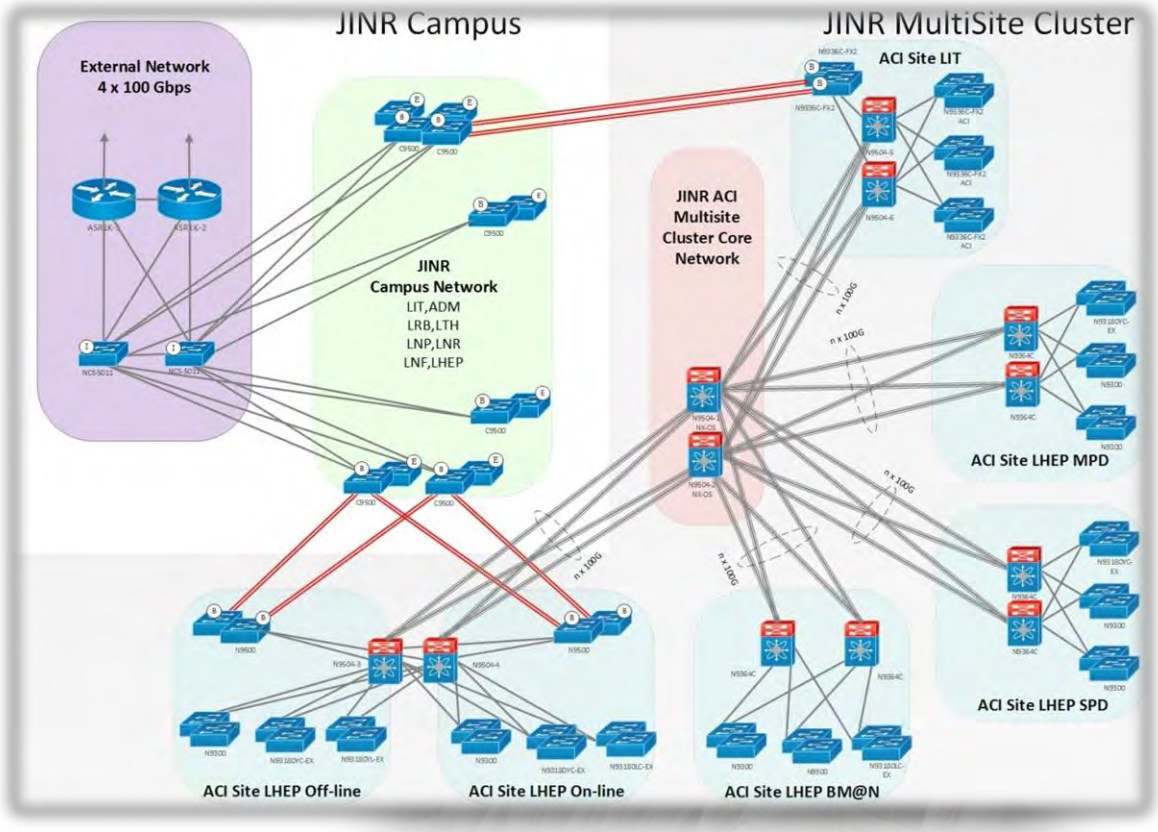
Networking





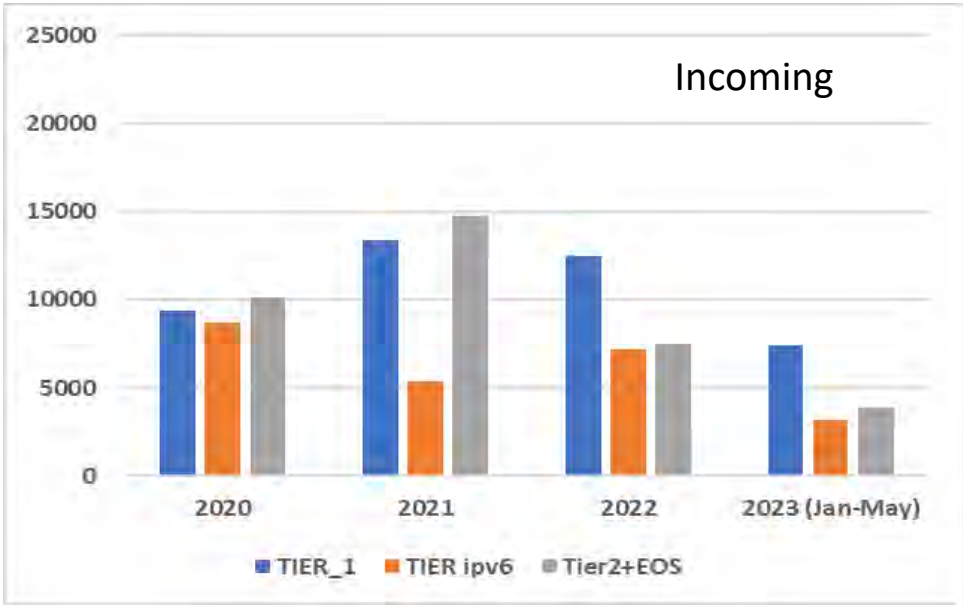
- JINR-Moscow 3x100 Gbit/s
- JINR-CERN - 100 Gbit/s and JINR-Amsterdam 100 Gbit/s for LHCOPN, LHCONE, GEANT networks
- Direct channels up to 100 Gbit/s for communication using RU-VRF technology with the collaboration of RUHEP research centers and with Runnet, ReTN networks
- The multi-site cluster network with a bandwidth 4x100 Gbit/s between VBLHEP and MLIT

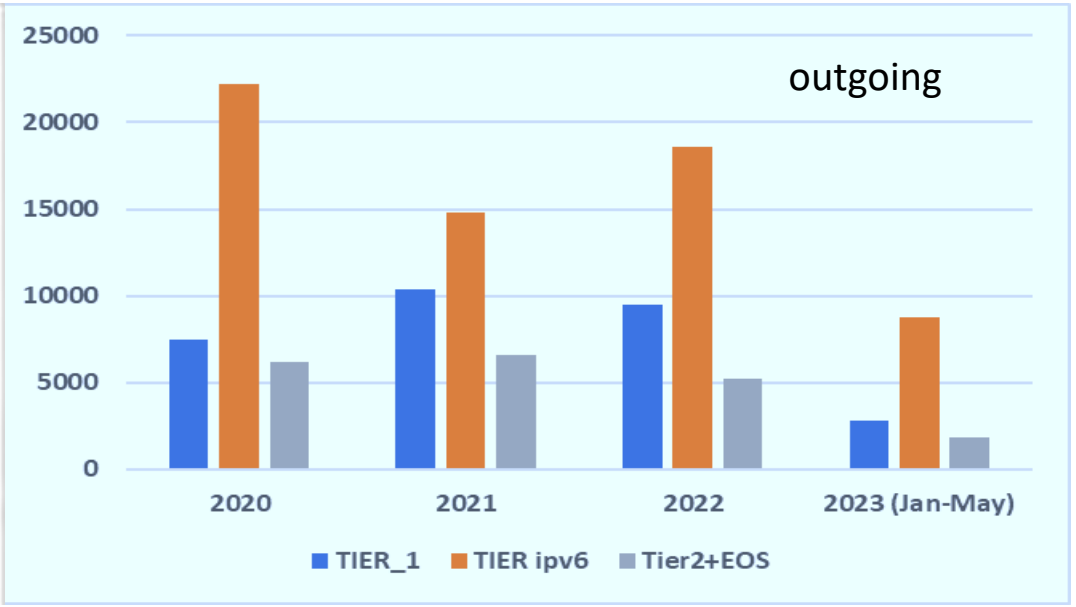
Users - 6353
Network elements - 9327
IP addresses - 18163
Remote access - 911
E-library- 1464
VOIP - 121
EDUROAM - 116
Email @jinr.ru - 4579



Networking @ Traffic

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

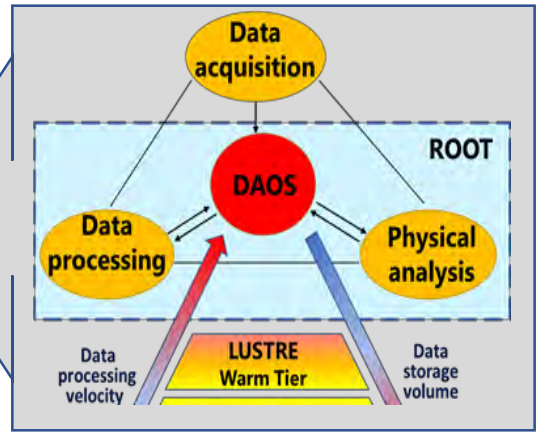




JINR Traffic in PB

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.



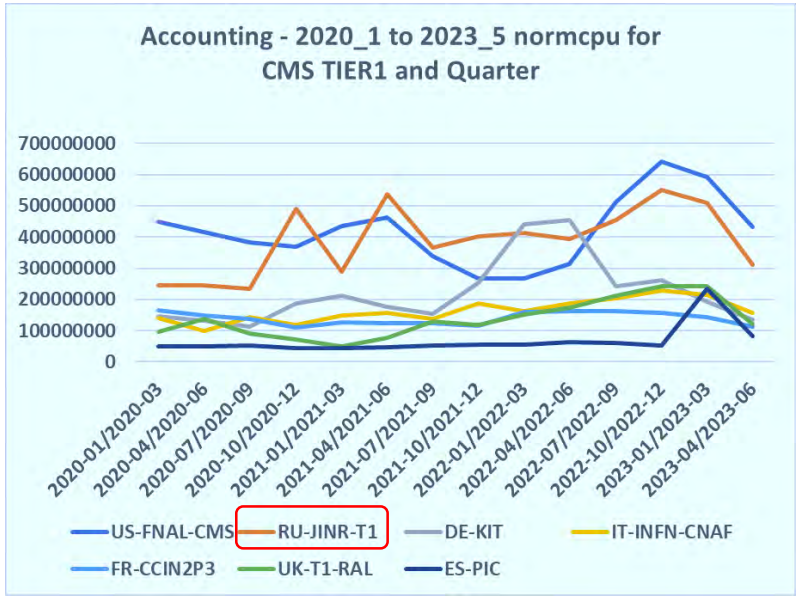
Special hierarchical data processing and storage system with a software-defined architecture was developed and implemented on the “Govorun” supercomputer.

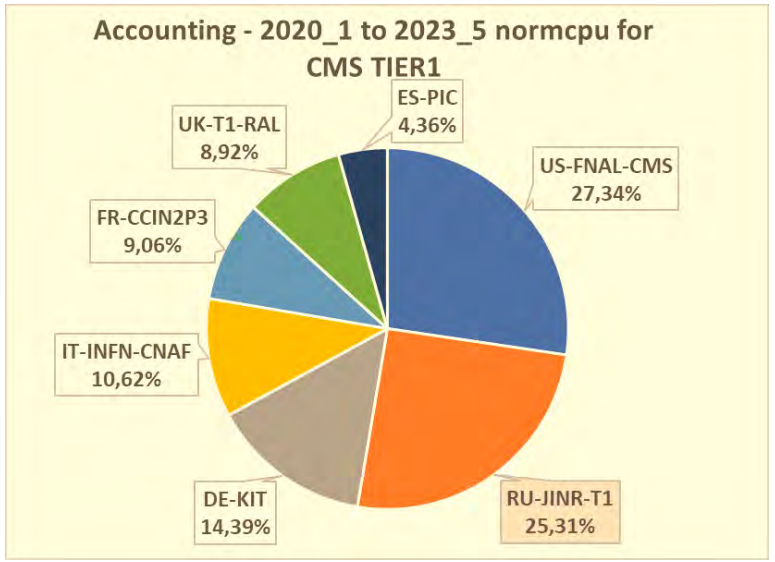
According to the speed of accessing data there are next layers:

- ✓ 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

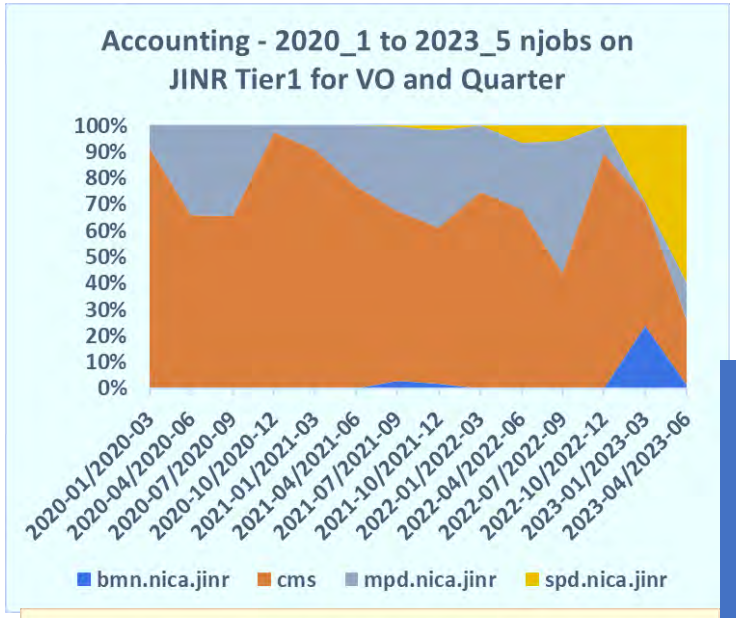


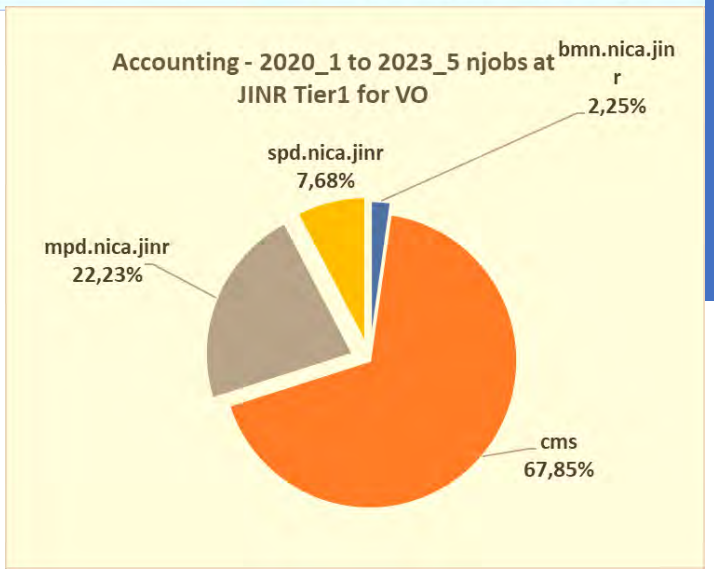


Since the beginning of 2015, a full-scale WLCG Tier1 site for the CMS experiment has been operating at MLIT JINR.

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.

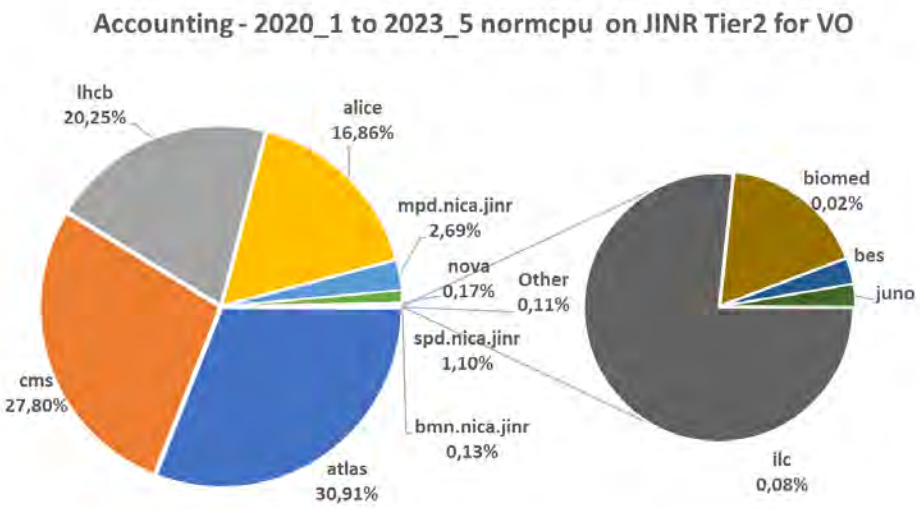
The JINR Tier1 is regularly ranked on top among world Tier1 sites that process data from the CMS experiment at the LHC.

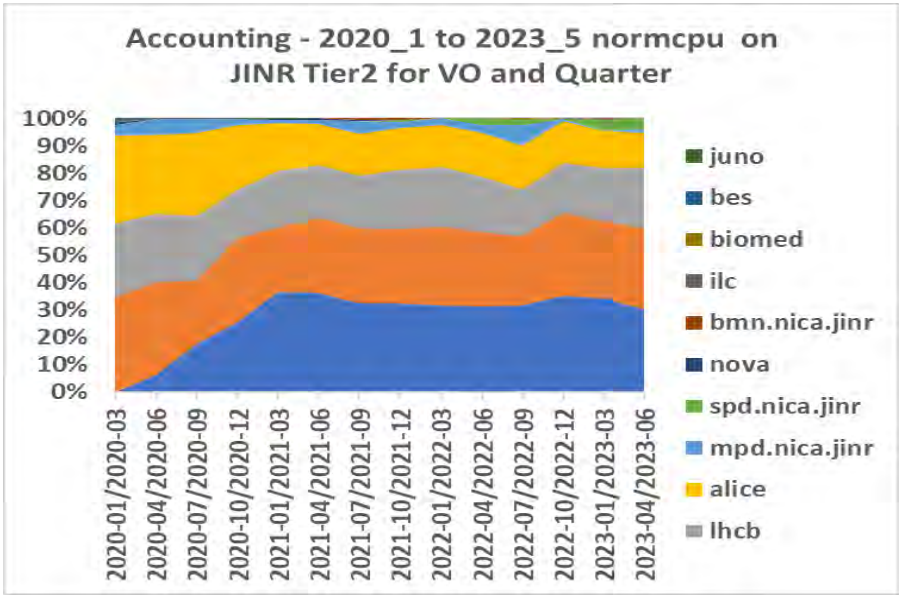




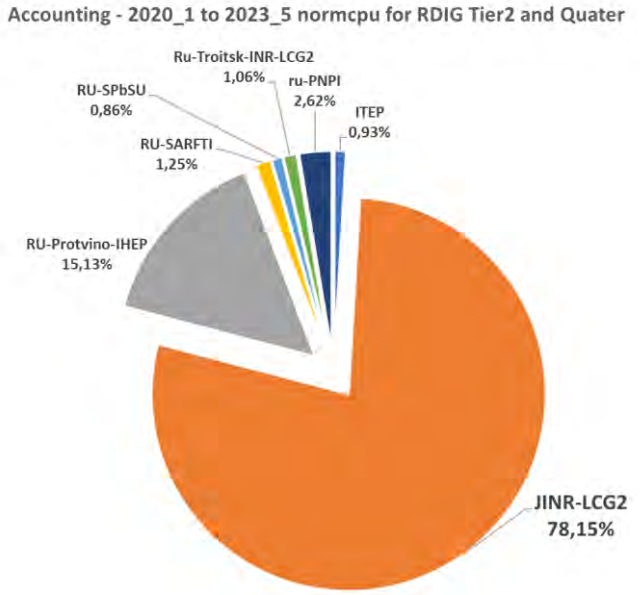
Since 2021 the JINR Tier1 center has demonstrated stable work not only for CMS (LHC), but also for NICA experiments.

JINR Tier2 in WLCG & RDIG

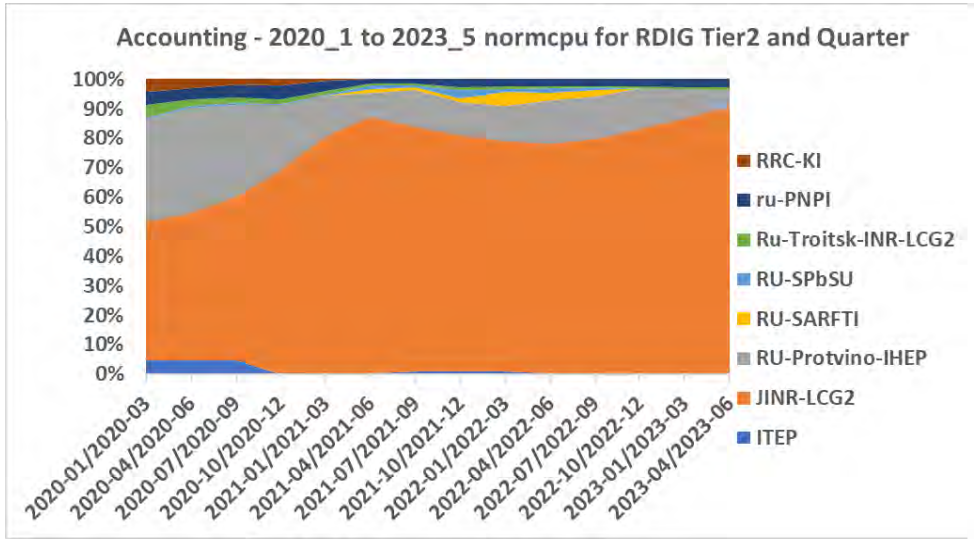




Tier2 at JINR provides computing power and data storage and access systems for the majority of JINR users and user groups, as well as for users of virtual organizations (VOs) of the grid environment (LHC, NICA etc.).



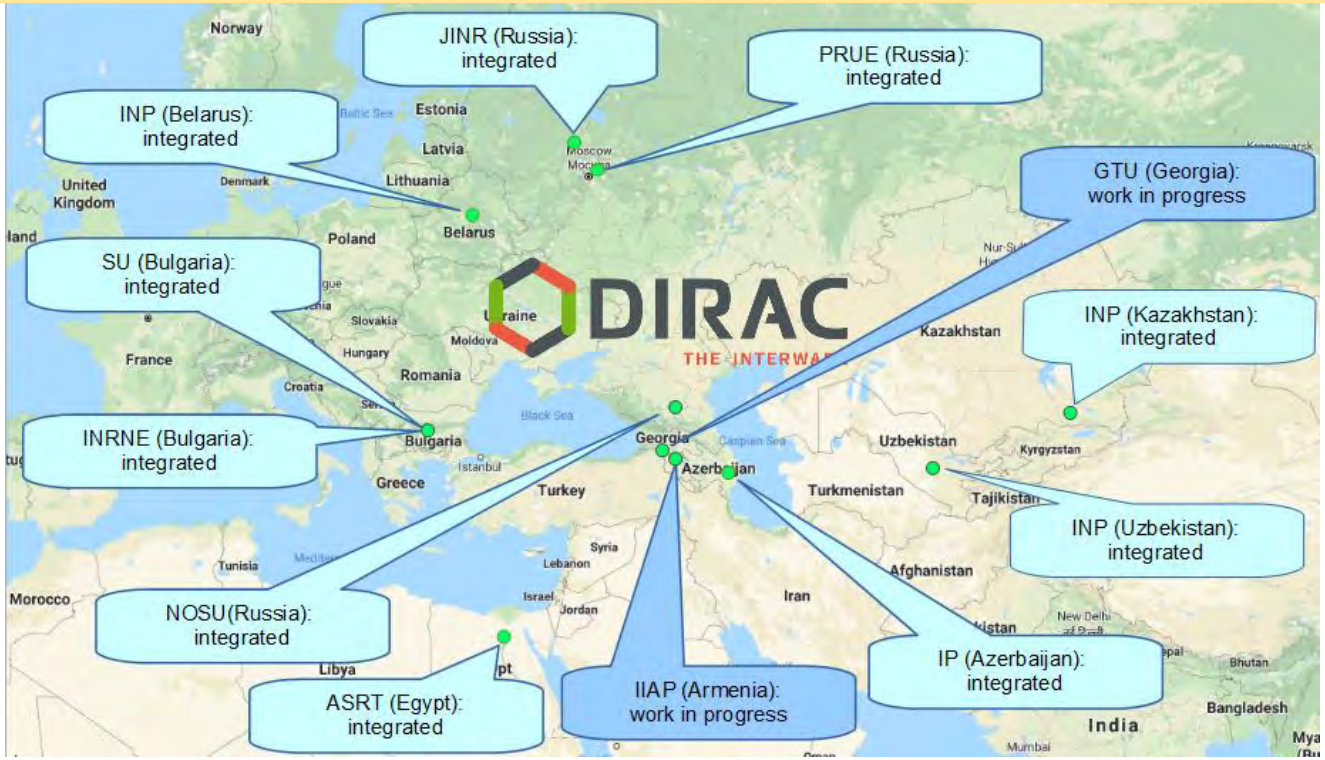
JINR Tier2 is the most productive in the Russian Data Intensive Grid (RDIG) Federation. More than 80% of the total CPU time in the RDIG is used for computing on our site.



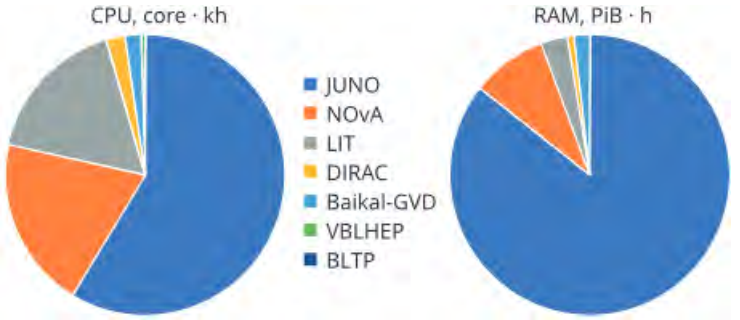
Cloud Infrastructure

- 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



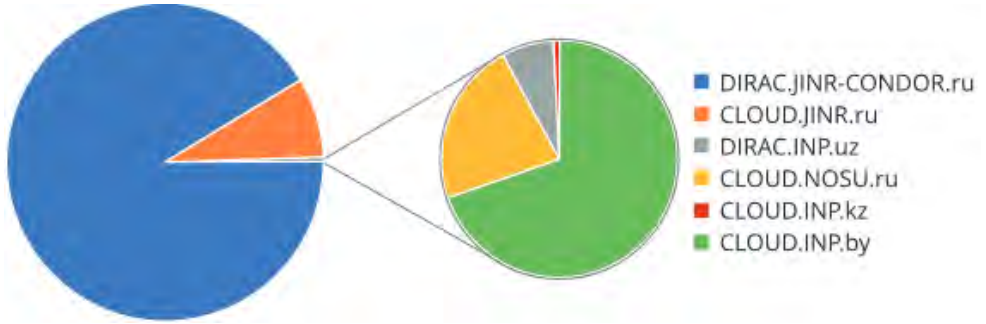
The Baikal-GVD, NOvA and JUNO experiments are the major users of the cloud infrastructure.



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 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

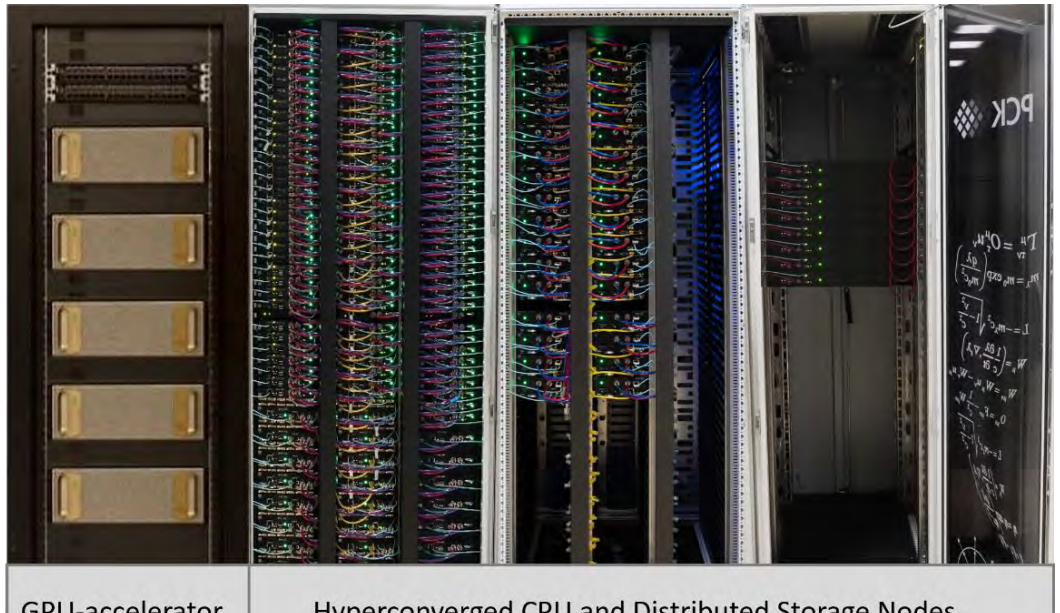
- Hyper-converged software-defined system
- Hierarchical data processing and storage system
- Scalable solution Storage-on-demand
- Total peak performance: 1.1 PFlops DP
- GPU component based on NVIDIA
- CPU component based on liquid cooling solutions
- The most energy-efficient center (PUE = 1.06)
- Storage performance >300 GB/s

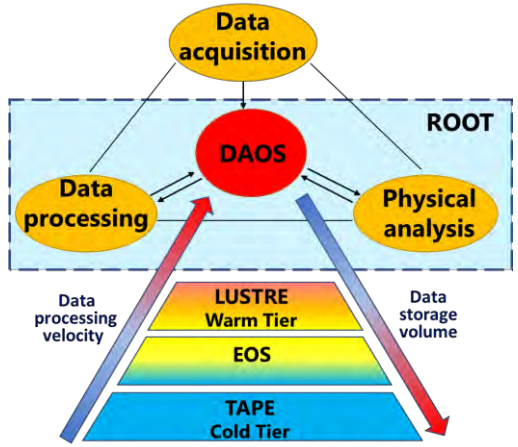
The expansion of the “Govorun” supercomputer by 32 hyperconverged compute nodes and 8 distributed storage nodes made it possible to:

- enhance its performance by 239 Tflops (Total peak performance: 1.1 PFlops DP);
- increase the DAOS data processing and storage subsystem to 1.6 PB;
- enlarge the volume of the "warm data" storage subsystem by 8 PB with support for the creation of dynamic storage systems such as Luster, DAOS, EOS, dCache, NFS.

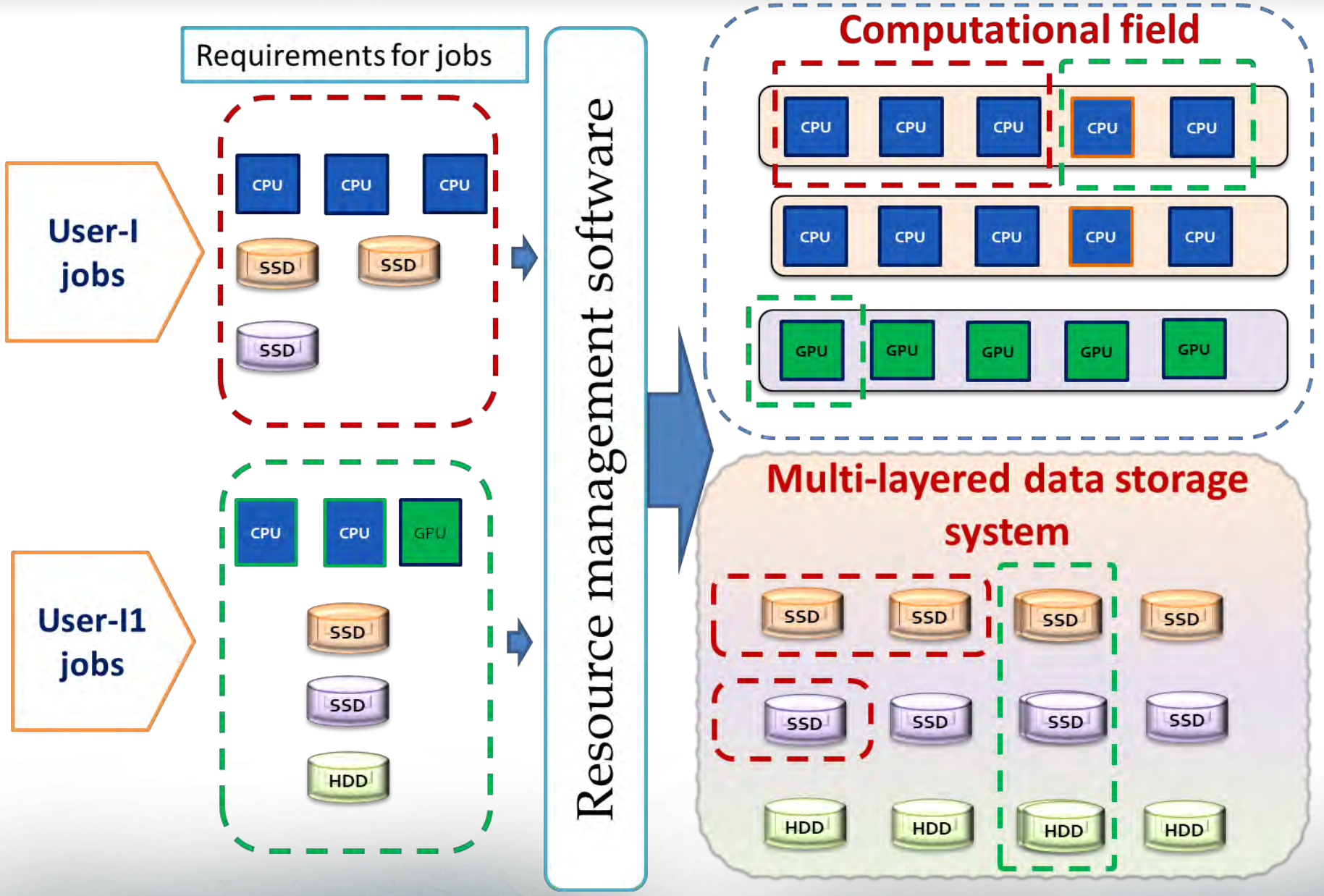
Key projects that use the resources of the SC “Govorun”:

- NICA megaproject,
- calculations of lattice quantum chromodynamics,
- computations of the properties of atoms of superheavy elements,
- studies in the field of radiation biology,
- calculations of the radiation safety of JINR’s facilities.





Orchestration and hyperconvergence on the SC “Govorun”



The SC “Govorun” has unique properties for the flexibility of customizing the user’s job.

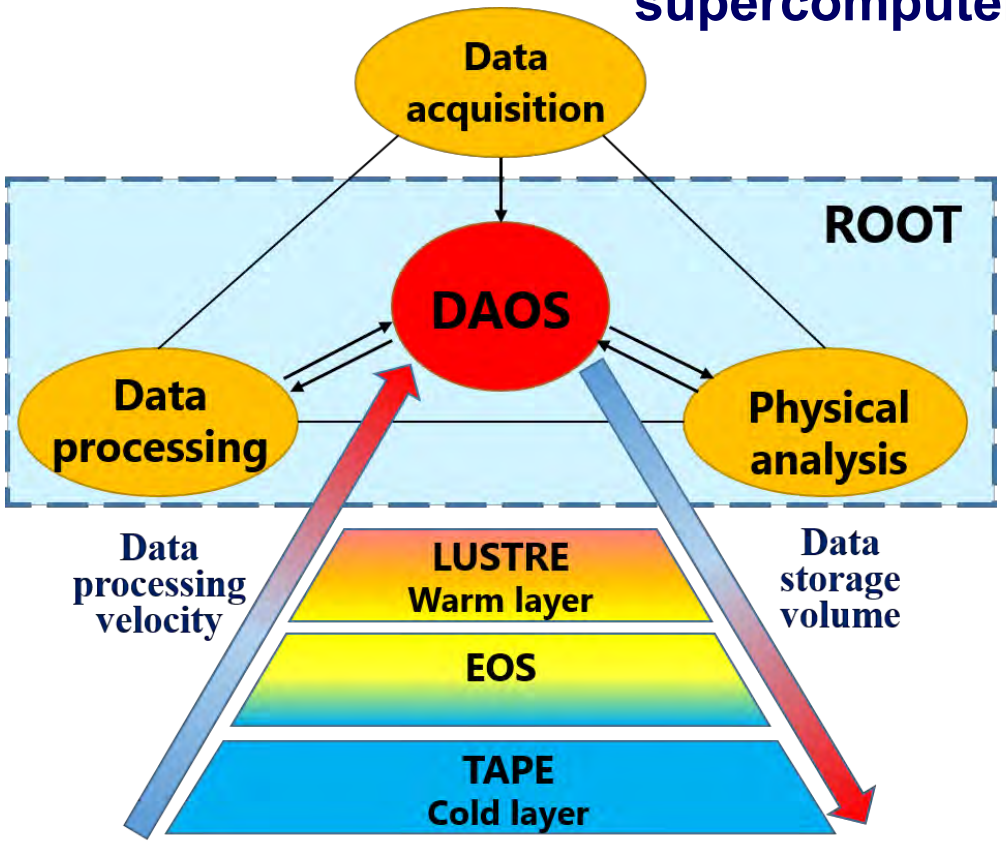
For his job the user can allocate the required number and type of computing nodes and the required volume and type of data storage systems.

This property enables the effective solution of different tasks, which makes the SC “Govorun” a unique tool for research underway at JINR.

DAOS polygon of the “Govorun” supercomputer for data processing and storage in experimental high-energy physics

To work with Big Data, including for the NICA megaproject, a hierarchical data processing and storage system with a software-defined architecture was developed and implemented on the “Govorun” supercomputer. The fastest layer of the hierarchical system is based on the latest DAOS (Distributed Asynchronous Object Storage) technology.

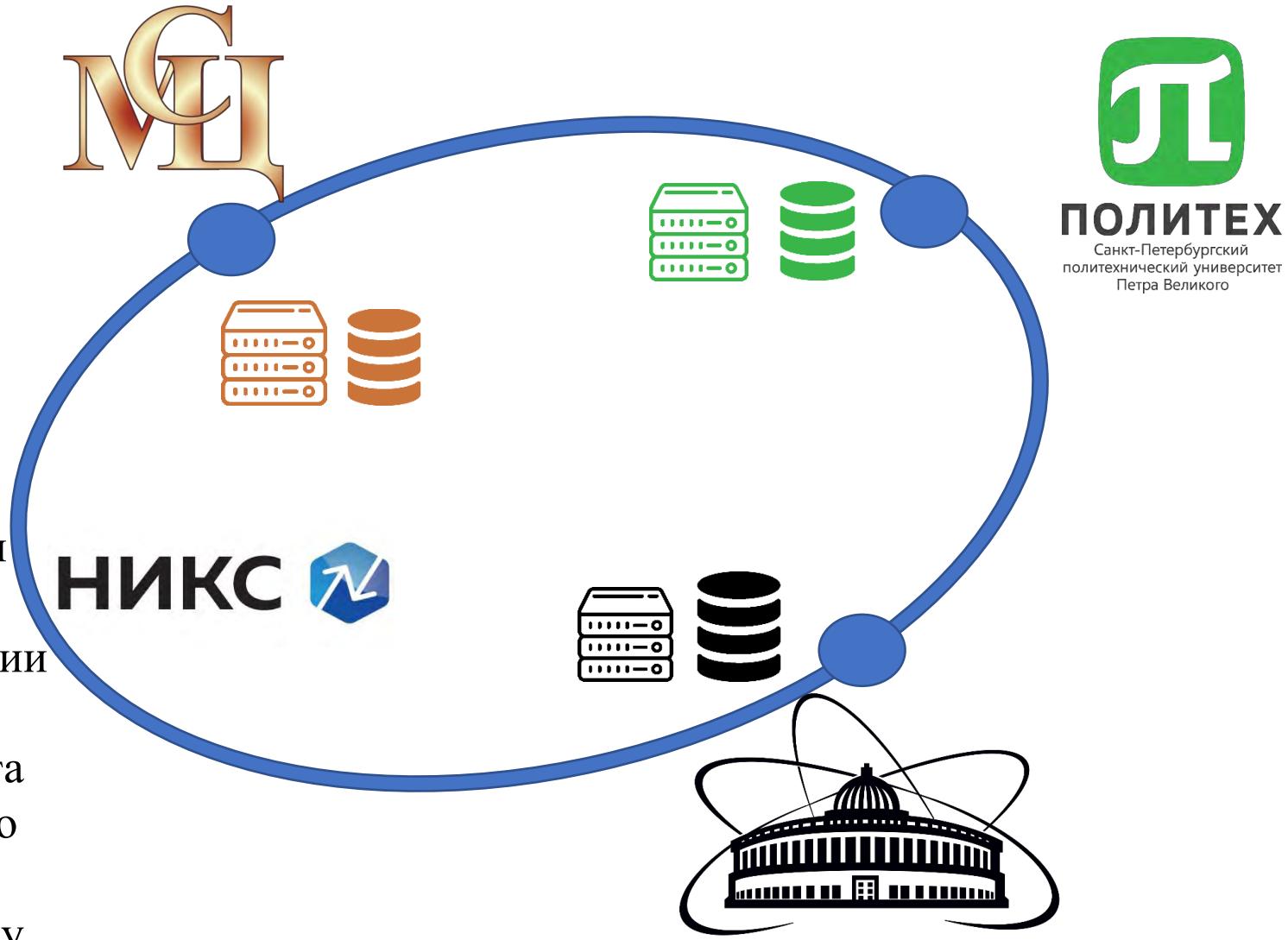
The DAOS polygon of the “Govorun” supercomputer takes the 1st place among Russian supercomputers in the current IO500 list.



The use of DAOS in high-energy physics enables to:

- Store and read multidimensional data structures of TB scale in a single address space
- Create a multi-user presentation layer for analyzing physics results
- Reduce hot storage costs in hundreds of times compared to using DDR (Double Data Rate) memory
- Significantly reduce the use of the GRID infrastructure (computing/storage/network) at the stage of physics analysis
- Easily integrate with other hot/warm storages

Объединенная географически распределенная суперкомпьютерная инфраструктура



В январе 2022 года успешно завершен первый совместный эксперимент по использованию объединенной суперкомпьютерной инфраструктуры для задач проекта NICA.

Всего было запущено 3000 задач генерации данных методом Монте-Карло и реконструкции событий для эксперимента MPD. Сгенерировано и реконструировано порядка 3 миллионов событий.

Полученные данные перемещены в Дубну для дальнейшей обработки и физического анализа

"Govorun" supercomputer modernization in 2022 - 2023

GPU-accelerator | Hyperconverged CPU and 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

\+

5 servers with 8 NVidia A100 GPUs in each

\+

Computation field: +32 hyperconverged compute nodes

\+

Hierarchical Storage: +8 distributed storage nodes

SC “Govorun” total peak performance: 1.7 PFlops DP

Total capacity of Hierarchical Storage: 8.6 PB

Data IO rate: 300 Gb/s

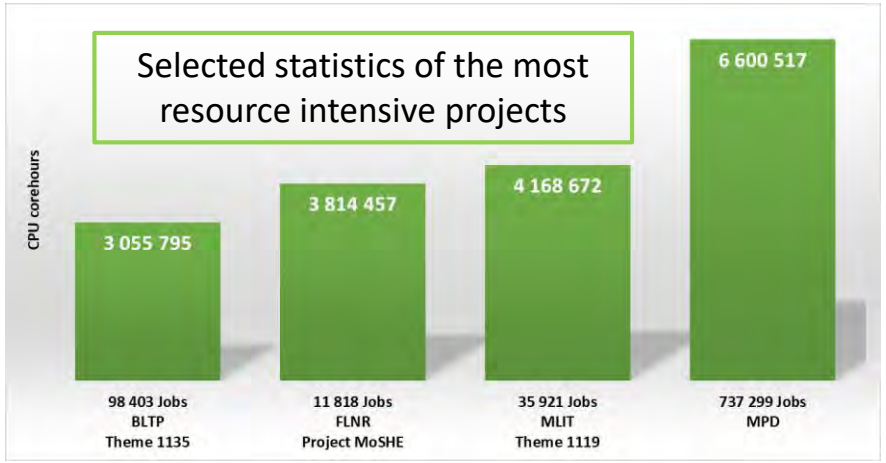
Using of the “Govorun” Supercomputer for JINR task in 2022

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

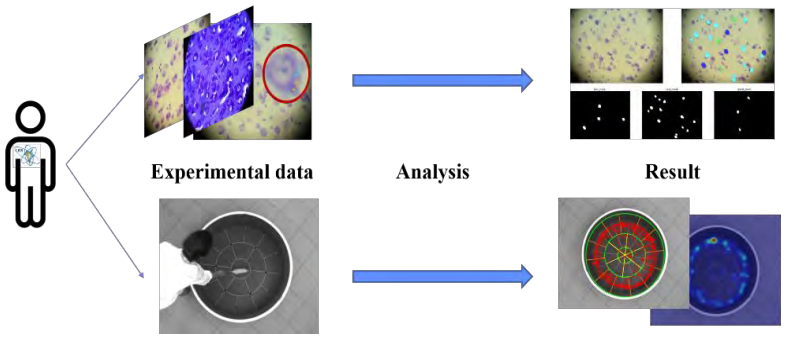
- NICA megaproject,
- simulation of complex physical systems,
- computations of the properties of atoms of superheavy elements,
- calculations of lattice quantum chromodynamics.

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

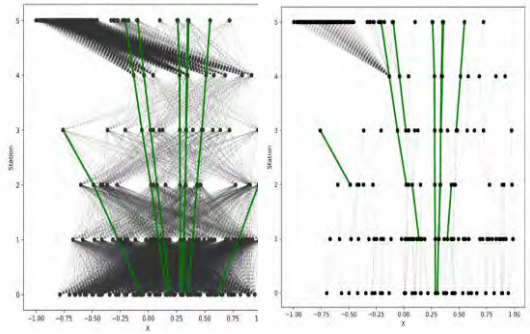
- process data from experiments at LRB,
- data processing and analysis at the NICA accelerator complex and ect.



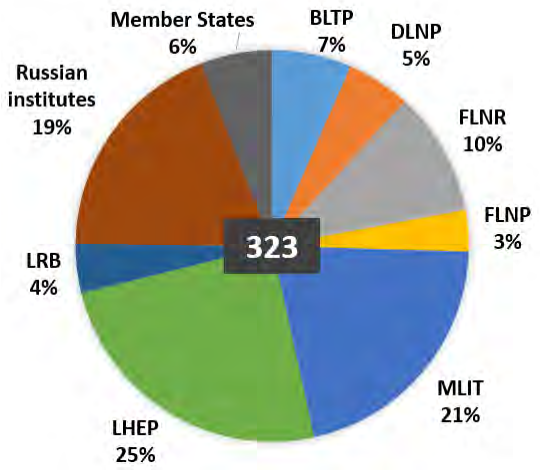
During 2022, **890 911** jobs were performed on the **CPU** component of the “Govorun” supercomputer, which corresponds to **18 543 076** core hours.



Information System for Radiation Biology Tasks

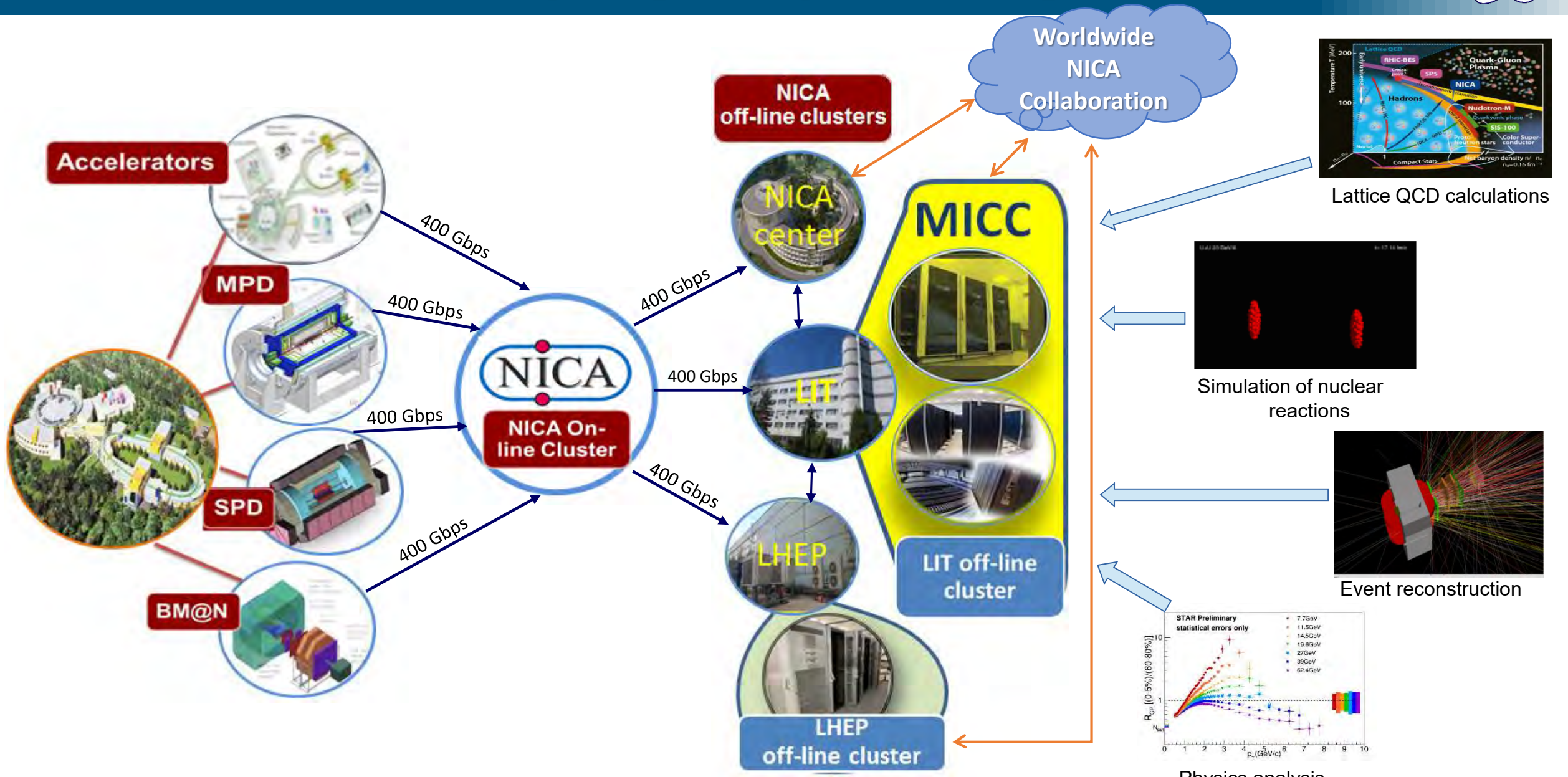


Neural network for data analysis



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.

NICA Computing Concept & Challenges

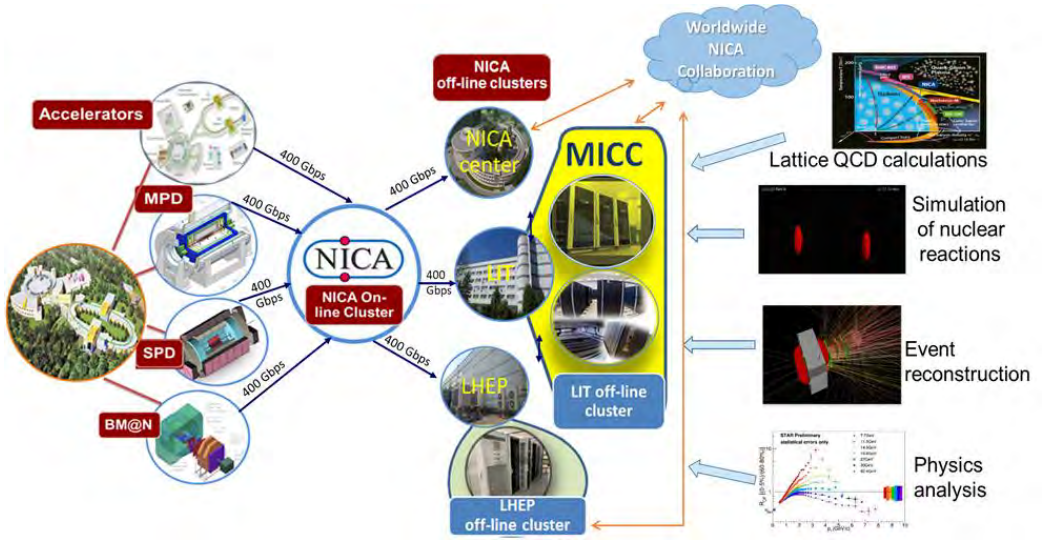


Development of the NICA Information and Computer Complex

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.

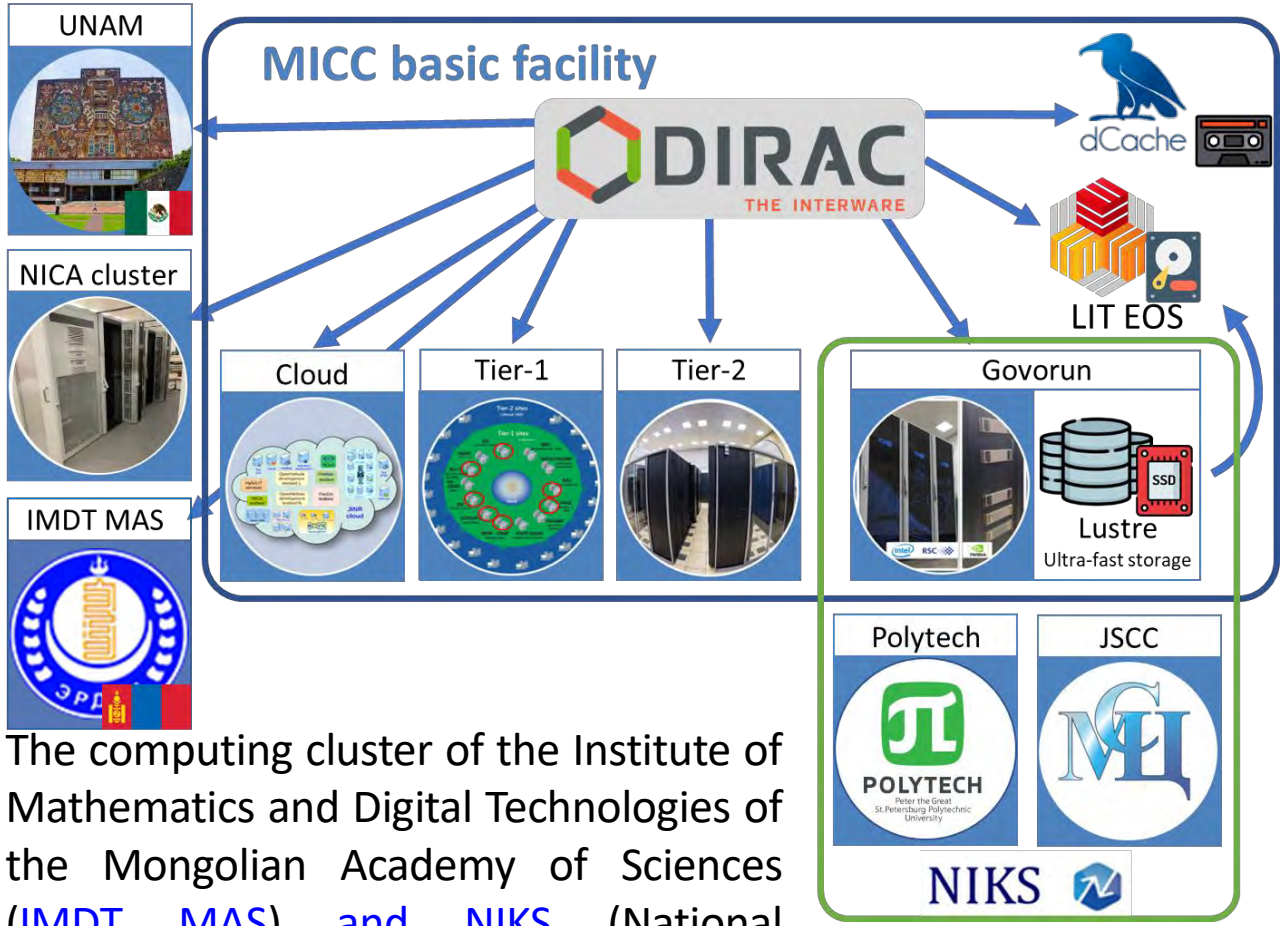
The information and computer unit of the NICA complex embraces:

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**



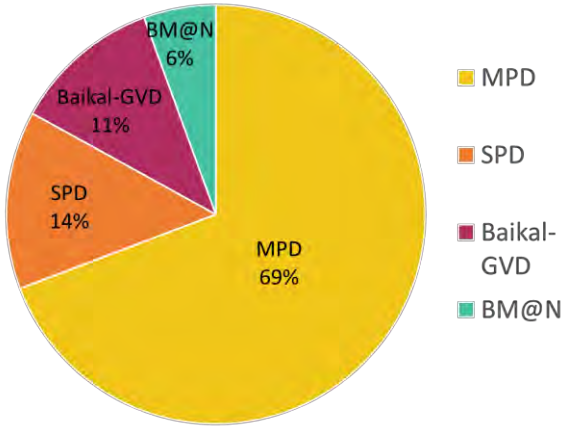
NICA Tier 0,1,2	2024	2025	2026	2027	2028	2029	2030
CPU (PFlops)	2.2	2.6	8.6	8.6	15.6	15.6	15.6
DISK (PB)	17	24	47	75	96	119	142
TAPE (PB)	45	88	170	226	352	444	536
NETWORK (Gbps)	400	400	800	800	800	1000	1000

DIRAC-based distributed heterogeneous environment

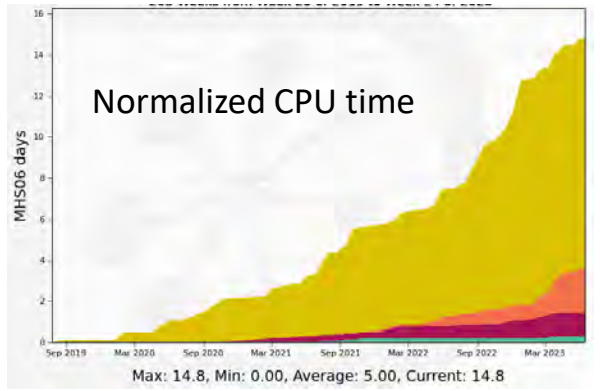


The computing cluster of the Institute of Mathematics and Digital Technologies of the Mongolian Academy of Sciences (IMDT MAS) and NIKS (National Research Computer Network, the Russia's largest research and education network) were integrated into the heterogeneous distributed environment based on the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

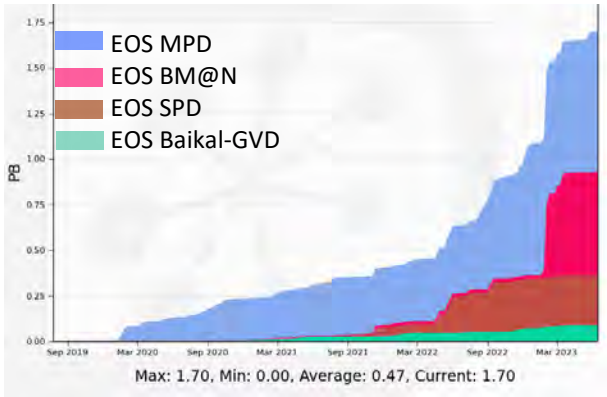
Use of DIRAC platform by experiments in 2019-2022



Total Number of executed jobs



Data processed by experiments

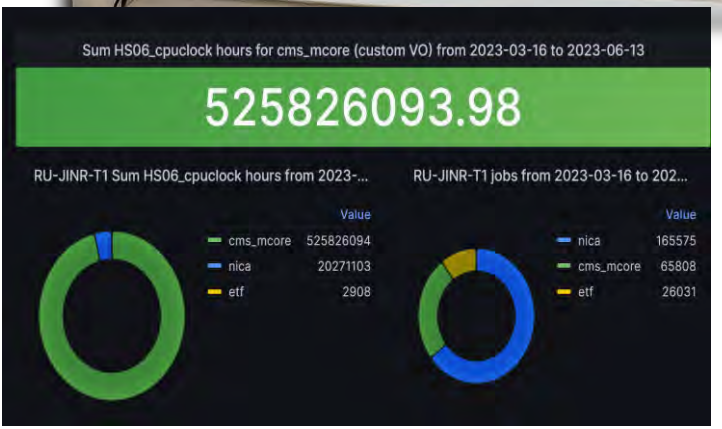


The major user of the distributed platform is the MPD experiment

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

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

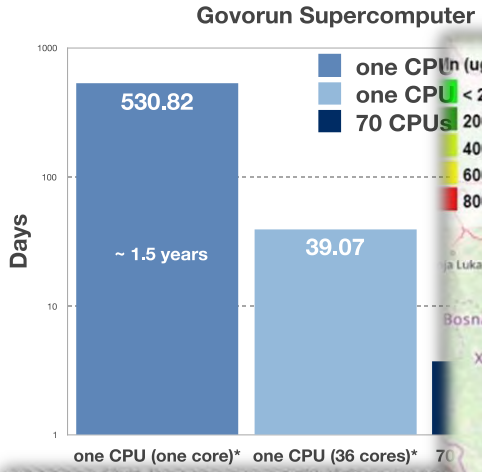
We must to develop intelligent systems that will enable to detect anomalies in time series on the basis of training samples, which will result in the need to create a special analytical system within the monitoring system to automate the process.

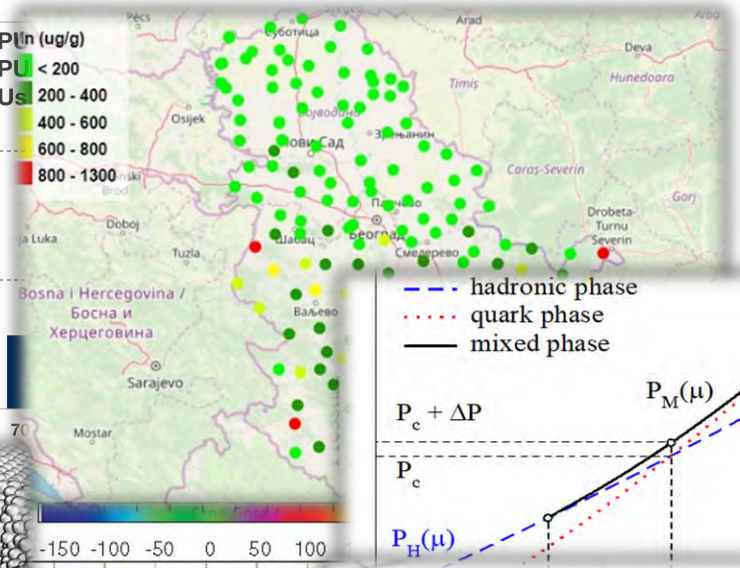
Estimation of the Resources of the MICC Components

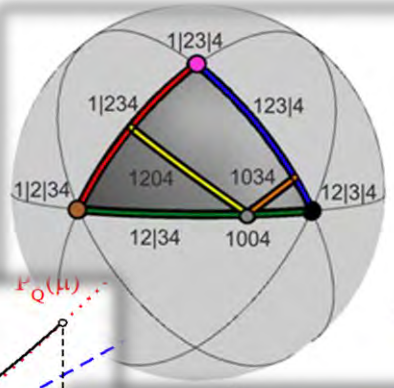
	2024	2025	2026	2027	2028	2029	2030
HybriLIT heterogeneous platform. "Govorun" supercomputer.							
Total number of CPU cores	11000	11000	11000	14000	14000	14000	17000
Total number of GPU accelerators	40	64	64	64	64	88	88
Total volume of the hierarchical data processing and storage system, PB	8	8	14	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

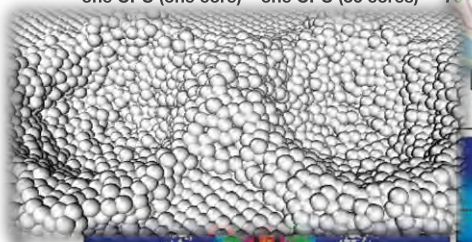
Prices for equipment in 2022-2023 are taking inti account

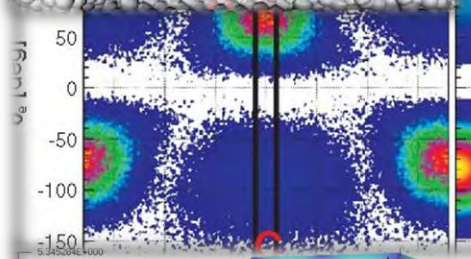
Methods, Algorithms and Software

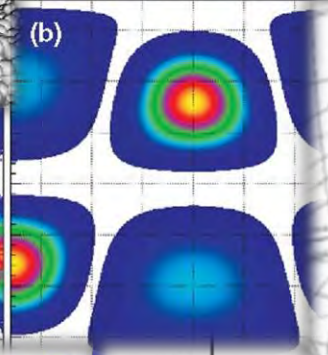


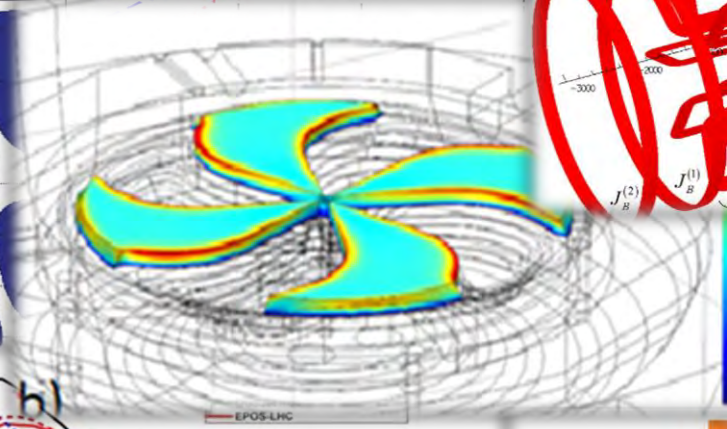


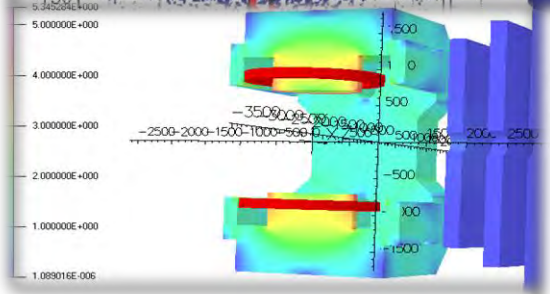


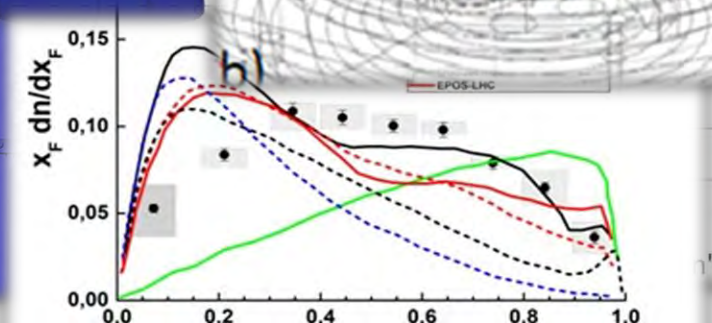


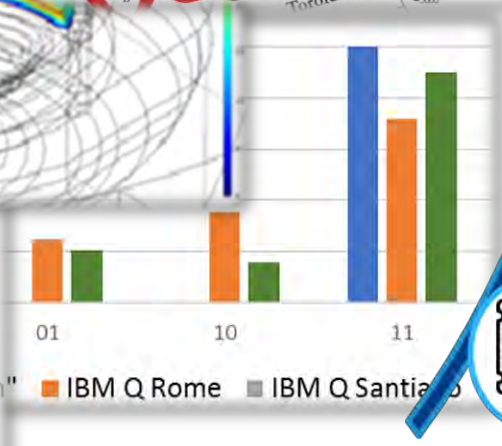






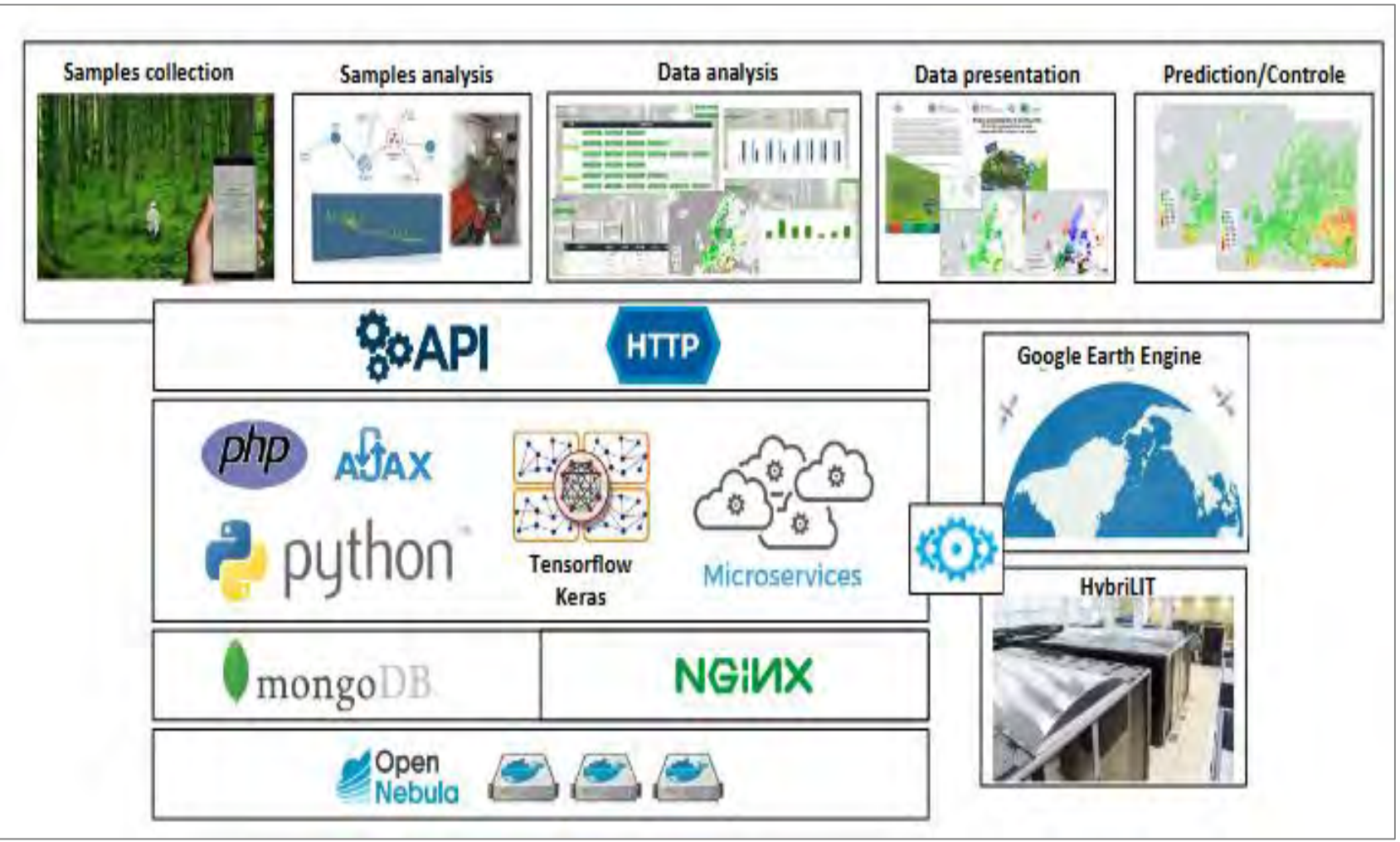






- Numerical modeling of complex physical systems
- Experimental data processing and analysis
- Big Data
- Machine and Deep learning
- AI and robotics
- Computer algebra
- Quantum computing

Intelligent Environmental Monitoring Platform



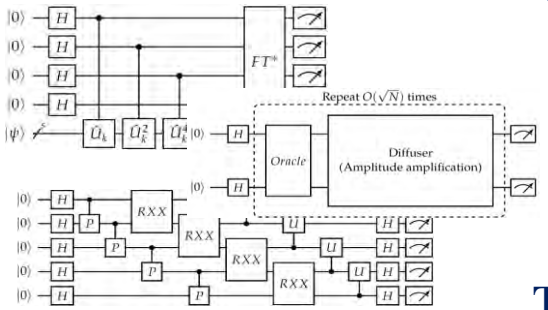
Within the framework of cooperation between MLIT and FLNP, the work on the prediction of air pollution by heavy metals using biomonitoring data, satellite imagery and different technologies of machine and deep learning is in progress. On the MLIT cloud platform, the Data Management System (DMS) of the UNECE ICP Vegetation was created to provide its participants with a modern unified system of collecting, analyzing and processing biological monitoring data.

The studies are carried out using the HybriLIT platform.

Quantum computing and quantum algorithms

Objective: development of quantum algorithms (QAs) to calculate complex atomic and molecular systems, taking into account the limiting capabilities of available computing resources.

Quantum algorithms



Quantum simulators

Qiskit
QuEST
qsim
CUQUANTUM

SC "Govorun"

TASKS

- Form a list of QAs required to solve tasks within the studied physical models
- Select the type of quantum simulator to simulate a classical architecture on computers
- Define resources for the selected quantum-limiting capabilities of available computing simulators (number of qubits and computation time)
- Search for exact solutions to urgent problems of quantum chemistry and study the chemical properties of heavy elements

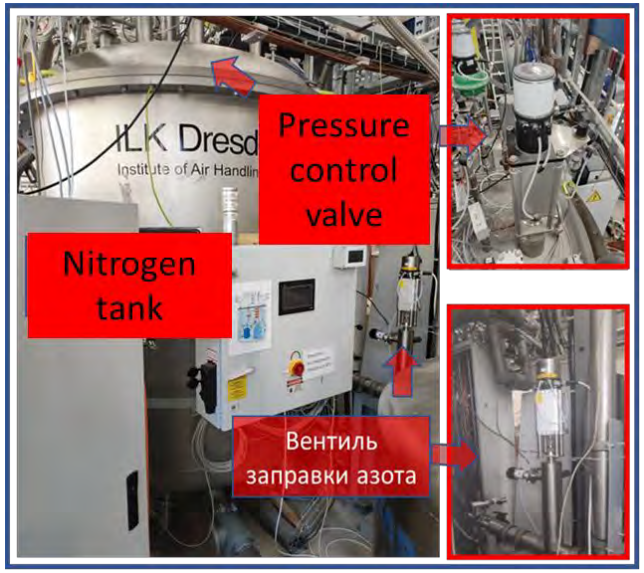
Current result

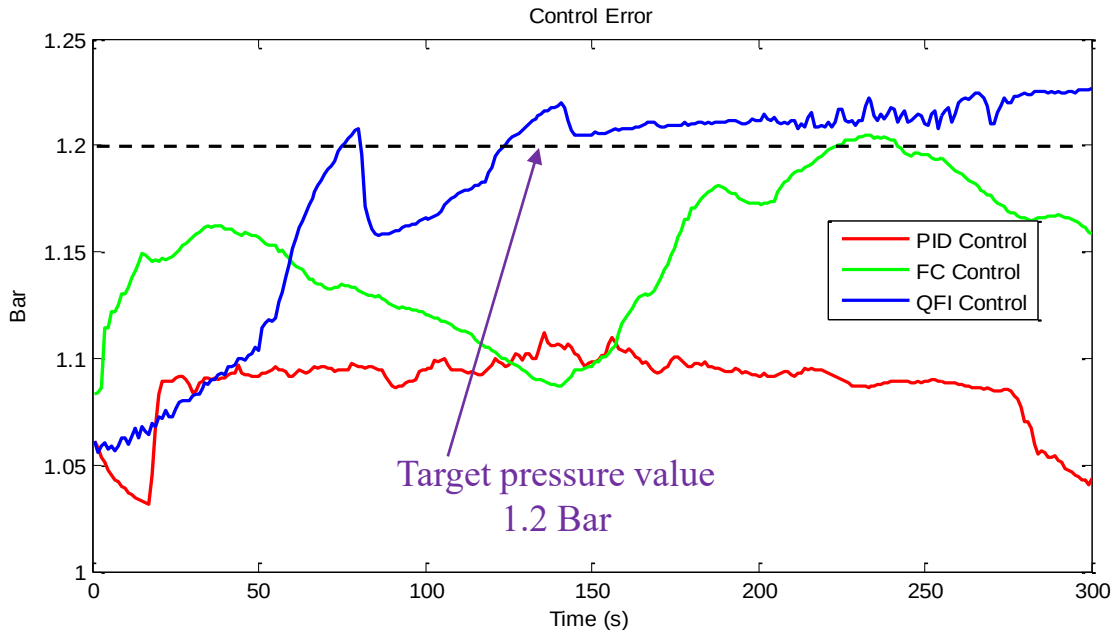
The limiting computing capacities of the "Govorun" supercomputer are revealed on the example of simulating quantum algorithms (quantum Fourier transform, quantum phase estimation, Grover's algorithm, test synthetic algorithm) using a different class of quantum circuits for the following simulators: QuEST, Qiskit, CuQuantum.

According to modern concepts, from 30 to 50 qubits are sufficient for the exact solution of most practically significant problems of quantum chemistry

Quantum intelligent control

Intelligent automatic control system for the nitrogen collector of the satellite helium refrigerator at the site of cryogenic testing of superconducting magnets in the VBLHEP





Control of the process of reaching a predetermined pressure level in cooling mode

- The quantum controller (blue curve) is almost 5 times faster in reaching the target value than the closest controller on soft computing (green curve), while the PID-controller (red curve) does not reach the target value.
- The quantum controller demonstrates low overshoot and accuracy in achieving the control goal compared to other types of controllers.
- Automatic control based on the quantum controller reduces nitrogen consumption by 53%.

The system is used when testing superconducting magnets. At the moment, a similar technological approach is being transferred to control the cooling of the NICA

Activity: Digital ecosystem (Digital JINR)

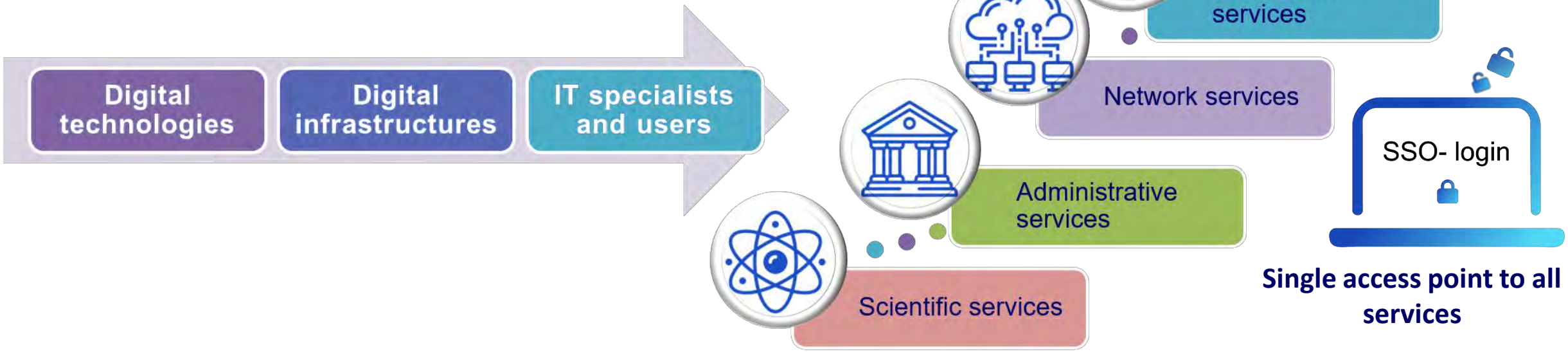
The digital platform "JINR Digital EcoSystem " integrates existing and future services

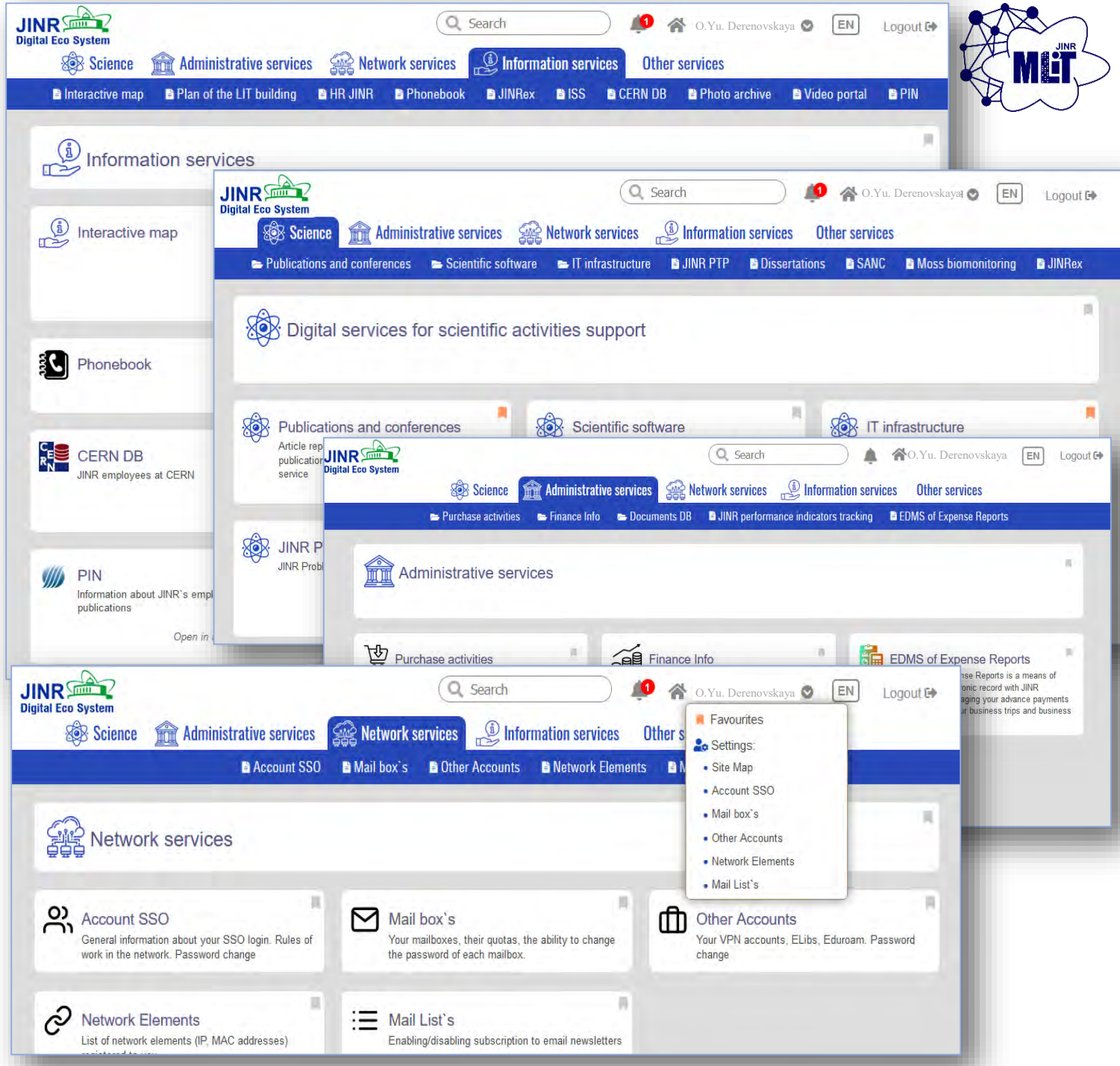
to support
scientific,
administrative and social activities,
maintenance of the engineering and IT infrastructures

to provide
reliable and secure access to various types of data

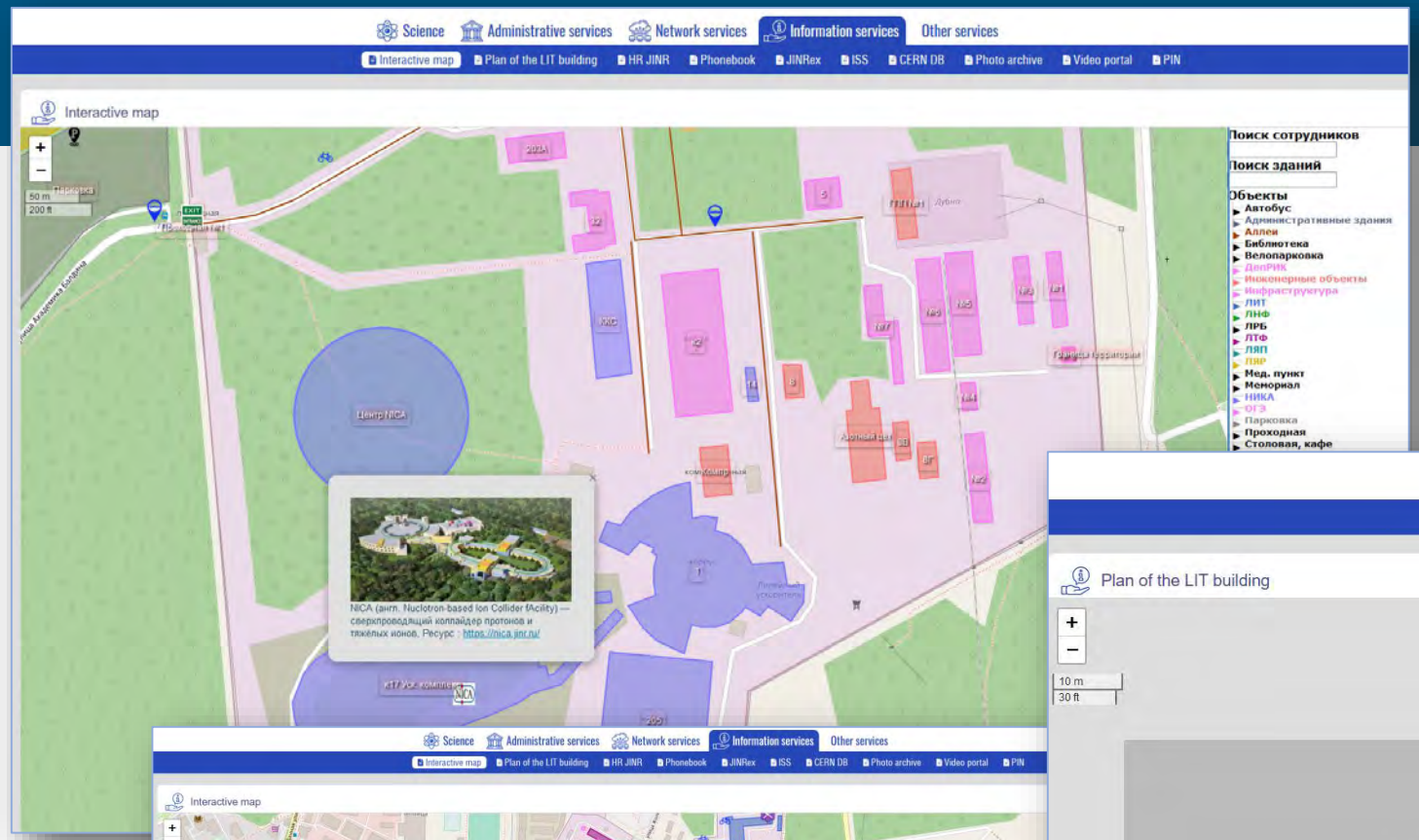
to enable
a comprehensive analysis of information

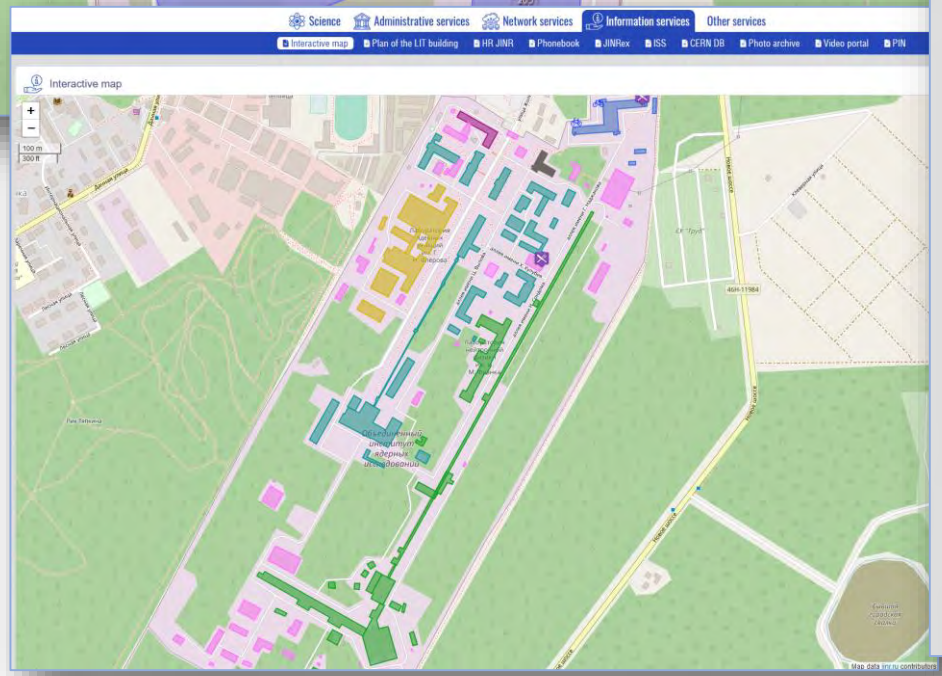
using
modern Big Data technologies and artificial intelligence.

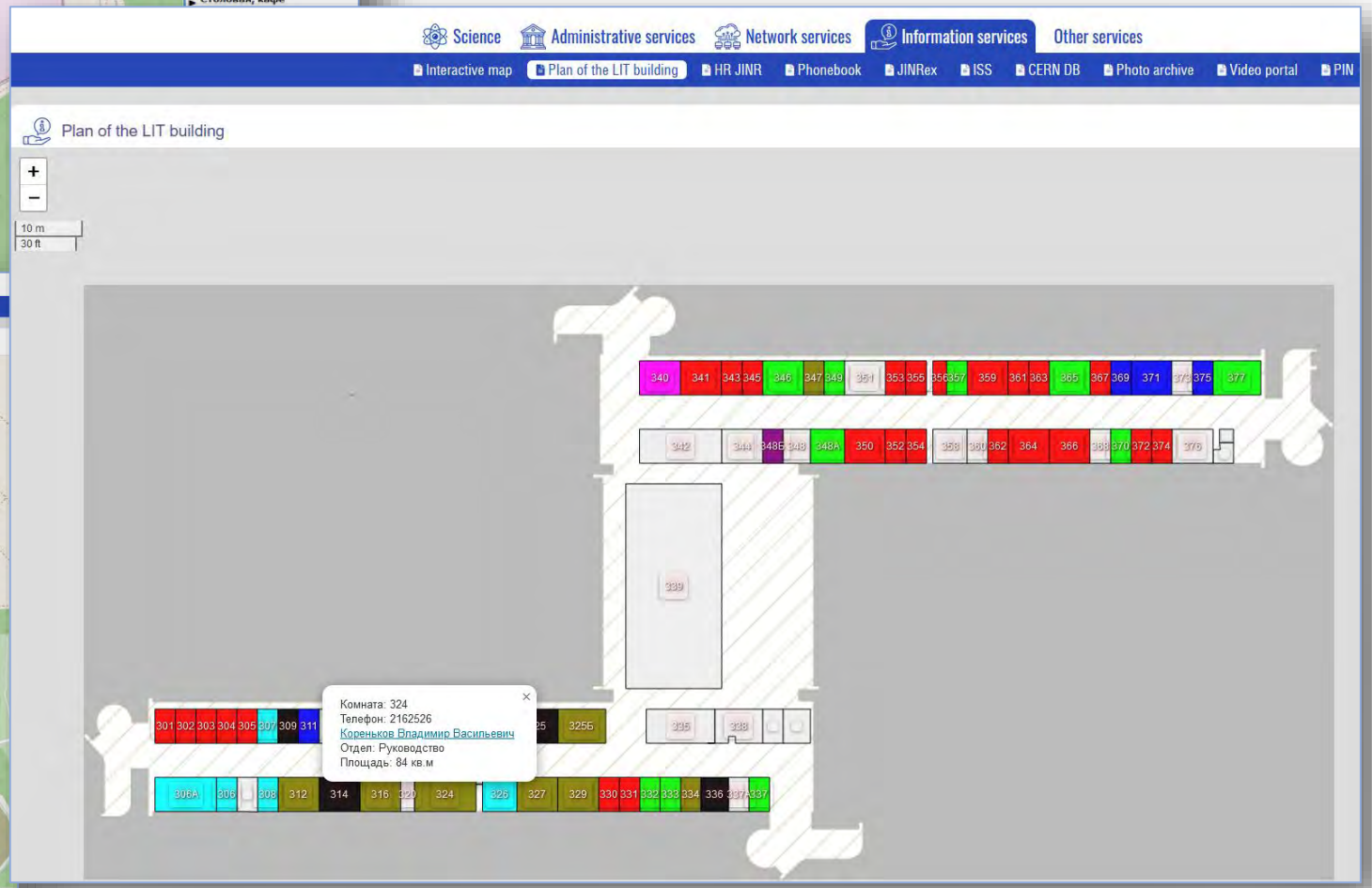




- ✓ Personal account of a JINR employee
- ✓ Notifications in a personal account
- ✓ Responsive interface, customizable by the user
- ✓ Easy access, convenient navigation and search for information on a large-scale network of a wide variety of JINR services

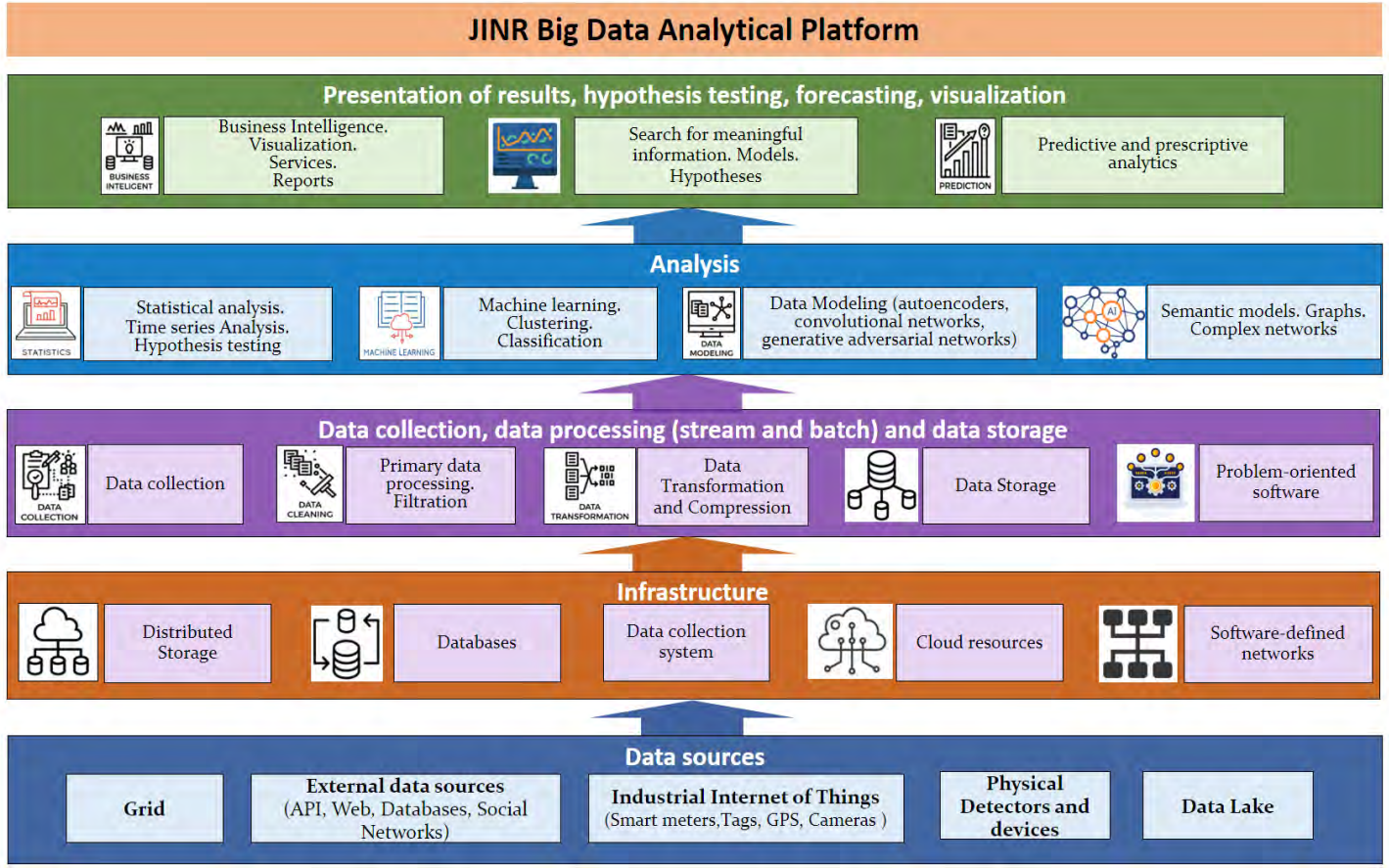






- ✓ Quick and easy search for information, both by services and by employees and buildings on an interactive JINR map

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

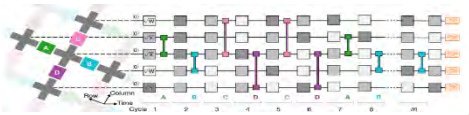
jupyterhub

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

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