

## Information Technology

### Development of the computing infrastructure

The aim of the further development of the JINR computing infrastructure is to provide performance of a whole range of competitive research activities at the world's level at JINR and cooperating centres worldwide both within the JINR programme for scientific research and development, in particular the NICA megaproject, and within the priority research tasks that are performed in cooperation with leading research centres such as CERN, FAIR, BNL, etc.

For the Laboratory of Information Technology, one of the major objectives in the Seven-year plan is the creation of a unified information environment integrating a number of various technological solutions, concepts and techniques. Such environment should integrate supercomputer (heterogeneous), grid- and cloud-complexes and systems in order to grant optimal approaches for solving various types of scientific and applied tasks. The necessary requirements to such an environment are scalability, interoperability, and adaptability to new technical solutions.

#### Expected results:

1. Creation of a JINR Multifunctional Information and Computing Complex (MICC) of a global level for the development of advanced information technology;
2. Development of a territorially distributed research environment to provide the use of the Complex capacities by the JINR and cooperating centres worldwide including joint international projects;
3. Research in the field of intensive operations with mass data in the distributed systems (Big Data), development of corresponding tools and methods of visualization, including 3D;
4. Scientific studies in the field of integrating base, cloud, grid and high-performance computing technologies with the purpose of their optimal use within the MICC;
5. Research on issues of optimizing the processes of using the existing capacities, in particular supercomputers, for data processing in distributed environment;
6. Introduction and development of a methodology of a short-term/medium term/long-term forecast of the MICC development;
7. Research in the field of integration of heterogeneous computing resources and data sources into a unified distributed computing system;
8. Creation of a software technological complex providing introduction of cloud technologies for organization of research by distributed user groups, introduction of intellectual methods of new generation grid-cloud structures management;
9. Research in the field of the global monitoring of the distributed computing systems;
10. Development of new parallel applications, cross-platform and multi-algorithm software complexes in a heterogeneous computing environment that allow one to expand a spectrum of computationally intensive solved fundamental scientific problems.
11. Development of a unified analytical system for managing MICC resources and data streams to increase the efficiency of using computing resources and storage resources and simplify the process of processing data from new experiments.
12. Development of a hyper-converged platform, including the “Govorun” supercomputer as a satellite project in the general infrastructure project of MICC, in terms of increasing computing resources and in terms of developing services deployed on the platform, determined by the needs of users, including the needs of the NICA megaproject and the neutrino program, for significant acceleration of ongoing research based on the paradigm of heterogeneous computing.
13. Creation of a multilevel data storage (“data lake”) of JINR to provide a constantly expanding resource for long-term information storage, the volume and speed of which is balanced with the corresponding information flows.

One of the main components of the Multifunctional Information and Computing Centre providing access to the resources and opportunity of work with Big Data is the network infrastructure.

For this infrastructure and its telecommunication data links to correspond to the requirements on reliability and availability of the complex for the JINR and cooperating centres worldwide using the resources of the complex to perform their investigations, the obligatory double reservation of all the connections and reliable 100 Gbps and more telecommunication channels are required.

A major task of the Seven-year plan will be further extension of the engineering infrastructure of the MICC connected with the start-up of the NICA accelerator complex and conduct of its experiments.

One of the most demanded and ambitious tasks, which should be implemented within the framework of the seven-year development plan of JINR, is the development of the JINR corporative information system for collective use and management of the information produced by JINR laboratories and departments to establishing of the general information space, improvement of information provision and decision-making process support. JINR plans to develop a digital model of an international research center, a replicable information platform that allows automating and digitizing administrative processes to ensure the maximum efficiency of the main activities of a scientific centre.

### **Mathematical support of studies conducted at JINR**

The solution of problems in computational physics and mathematics, encompassing a wide spectrum of research underway at JINR, requires the development of new mathematical methods and approaches, the creation of algorithms and software for numerical and symbolic-numerical simulations with the help of the newest computer hardware with multi-core architecture, coprocessors and graphic accelerators. Such computational systems provide the way towards significant speed-up of mathematical calculations by selecting the paralleling technology which takes into account the specificity of the problem under solution. The adaptation to the heterogeneous architectures of previously developed software and the creation of new applications based on modern parallelization techniques making the best use of the opportunities provided by the available computing resources are of particular importance. A separate task is the development of software platforms and environments for designing parallel applications and development of services that will significantly simplify the user work on such computing complexes.

#### **Expected results:**

1. Software development and realization of mathematical support of experiments conducted at the JINR basic facilities and in frames of international collaborations at the largest installations worldwide, including introduction of high-speed methods, algorithms and software for parallel processing and analysis of experimental data on heterogeneous and distributed computer complexes;
2. Development of numerical methods, algorithms and software complexes for modelling complex physical systems, including interactions inside a hot and dense nuclear matter, physico-chemical processes in materials exposed to heavy ions, evolution of localized nanostructures in the open dissipative systems, properties of atoms in magnetic optical traps, electromagnetic response of nanoparticles and optical properties of nanomaterials, evolution of quantum systems in external fields, astrophysical studies;
3. Development of methods and algorithms of computer algebra for simulation and research of quantum computations and information processes, low-dimensional nanostructures in external fields, discrete quantum systems with nontrivial symmetries.
4. Development of mathematical, algorithmic and program methods of description of tangled (entanglement of) conditions of qubit systems as a basic resource of quantum informatics.
5. Development of symbol-numerical methods, algorithms and software complexes for the analysis of low-dimensional compound quantum systems in molecular, atomic and nuclear physics.
6. Development of algorithms based on recurrent and convolutional neural networks for ML/DL problems and big data analysis, which are primarily intended to accelerate the recognition of multiple tracks in particle physics experiments, including for the NICA megaproject and the needs of neutrino experiments.

**Plan for the development of the Multifunctional Information and Computing Complex**

	2017	2018	2019	2020	2021	2022	2023
<b>Tier1-CMS and NICA data storage</b>							
Performance upgrade: CPU kHS06	67.2	83.2	160.0	200.0	240.0	300.0	350.0
Disk storage upgrade (TB)	5 070	6 100	8 000	8 800	10 800	13 100	16 100
Mass memory upgrade (TB)	20 000	20 000	20 000	25 000	30 000	35 000	42 000
<b>Tier2 and computer resources with a storage system for local users</b>							
Performance upgrade: CPU kHS06	59.2	75.2	96.0	110.0	130.0	150.0	170.0
Upgrade of disk storage (TB)	2 970	3 400	5 000	5 500	6 000	6 500	7 000
<b>Heterogeneous cluster for parallel computations</b>							
Performance (Tflops)	180	240	300	360	420	480	540
Upgrade of disk storage (TB)	55	60	60	65	70	75	80
<b>Cloud infrastructure</b>							
Cores	630	1 000	1 500	2 250	3 500	5 000	7 500
RAM (GB)	1 280	2 000	3 000	4 500	7 000	10 000	15 000
Disk servers (TB)	40	80	160	320	640	1 200	2 500
<b>External telecommunication data links and JINR local area network</b>							
Data link bandwidth (Gbps)	100						

**Financing schedule (k\$)**

<b>Name of works</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>	<b>2023</b>
<b>Section I</b>							
Phased modernization of the climate control system, fire extinguishing system and uninterruptible power supplies (UPS)	404.3	794.9	1454.7	697.8	666.3	521.2	507.3
Gradual increase in computing resources	653.0	1 603.2	690.0	1 578.0	839.4	907.8	870.4
Phased expansion of the storage system on disk servers	433.2	1 593.3	119.9	1 365.1	1 177.6	1 199.2	1 399.3
Robotic Tape Storage Gradual Capacity Expansion	263.8	0.0	0.0	0.0	0.0	0.0	0.0
Step-by-step build-up of local network infrastructure	377.6	0.0	0.0	0.0	0.0	0.0	0.0
Extending computing resources and disk arrays of a heterogeneous cluster (HybriLIT platform)	41.7	116.9	48.4	151.6	150.0	361.3	412.5
Supercomputer “Govorun”	2 495.0	194.6	2 537.6	0.0	0.0	0.0	0.0
Cloud infrastructure development	172.1	0.0	0.0	176.3	110.0	110.5	110.5
Diesel generator set (DGS)	440.4	412.2	0.0	0.0	0.0	0.0	0.0
Replacement of transformers	327.3	0.0	0.0	0.0	0.0	0.0	0.0
<b>Total for Section I</b>	<b>5 608.4</b>	<b>4 715.1</b>	<b>4 850.6</b>	<b>3 968.8</b>	<b>2 943.3</b>	<b>3 100.0</b>	<b>3 300.0</b>
<b>Section II</b>							
Step-by-step build-up of local network infrastructure	0.0	1 272.7	682.5	390.3	25.7	0.0	0.0
Robotic tape storage incremental capacity expansion	0.0	0.0	1320.0	0.0	145.5	148.3	149.7
Consumables, equipment and specialized licensed software	281.0	230.7	192.5	43.1	220.1	121.2	120.3
Replacement of critical and obsolete equipment	301.7	294.4	965.7	139.2	0.0	88.0	280.1
Equipment for the central core of the network infrastructure	282.9	193.2	201.5	0.0	234.4	122.3	330.2
Modernization of equipment for external communication channels and transition to 100 Gbps	180.0	340.2	260.1	52.7	0.0	200.0	0.0
Diesel generator set (DGS)	0.0	0.0	18.2	87.0	20.0	20.2	19.7
Modernization of the 2nd and 4th floors	0.0	0.0	0.0	0.0	12.7	0.0	0.0
<b>Total for Section II</b>	<b>1 045.6</b>	<b>2 331.2</b>	<b>3 640.5</b>	<b>712.3</b>	<b>658.4</b>	<b>700.0</b>	<b>900.0</b>
<b>Total</b>	<b>6 654.0</b>	<b>7 046.3</b>	<b>8 491.1</b>	<b>4 681.1</b>	<b>3 601.7</b>	<b>3 800.0</b>	<b>4 200.0</b>
Licensed software	233.6	228.0	203.8	201.1	200.0	150.0	250.0