BILATERAL COOPERATION ON THE CREATION OF TOKAMAK KTM AND FURTHER MULTILATERAL RESEARCH PROGRAMS

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THE ROUND TABLE "INTERNATIONAL SCIENTIFIC COOPERATION AND ADVANCED RESEARCH INFRASTRUCTURE AS A BASIS FOR INNOVATIVE DEVELOPMENT OF NUCLEAR INDUSTRY"

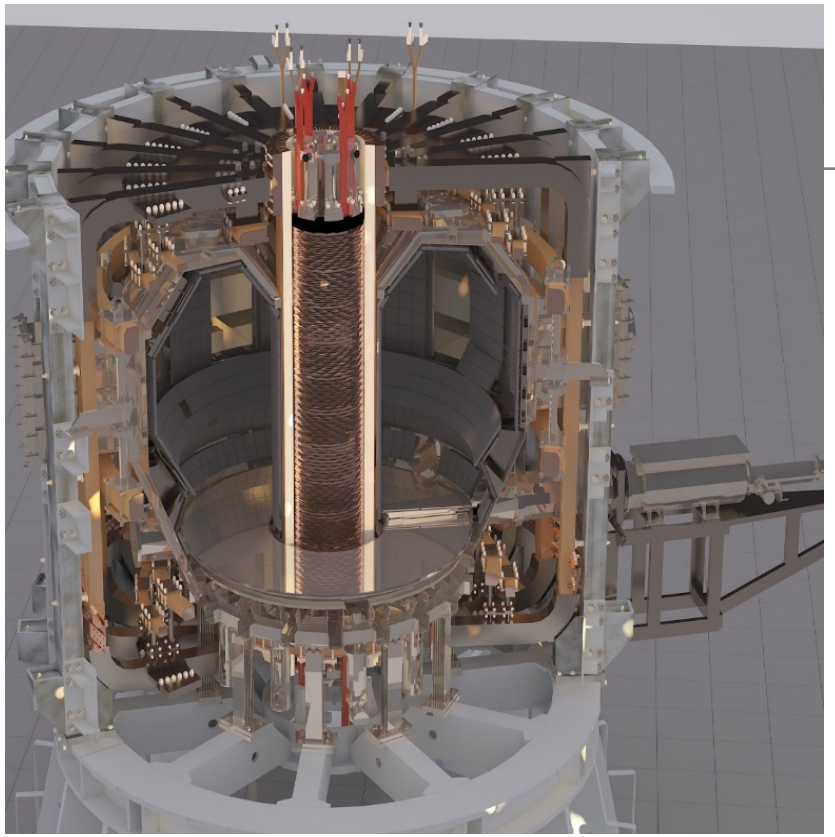
MAY 15, 2018, SOCHI

Meeting N.A. Nazarbayev and E.P. Velikhov. Almaty, 1997

N.A.Nazarbayev and E.P. Velikhov gets acquainted with the KTM mock-up. Almaty, 2001

The creation of the KTM Tokamak was initiated by the President of the Republic of Kazakhstan N.A. Nazarbayev as a result of discussions on the development of science in Kazakhstan with the academician of the Russian Academy of Sciences, E.P. Velikhov during his visit to Kazakhstan. The decision to start the implementation of the investment project was made by the Order of the Prime Minister of the Republic of Kazakhstan dated July 22, 1998, No.143-r.

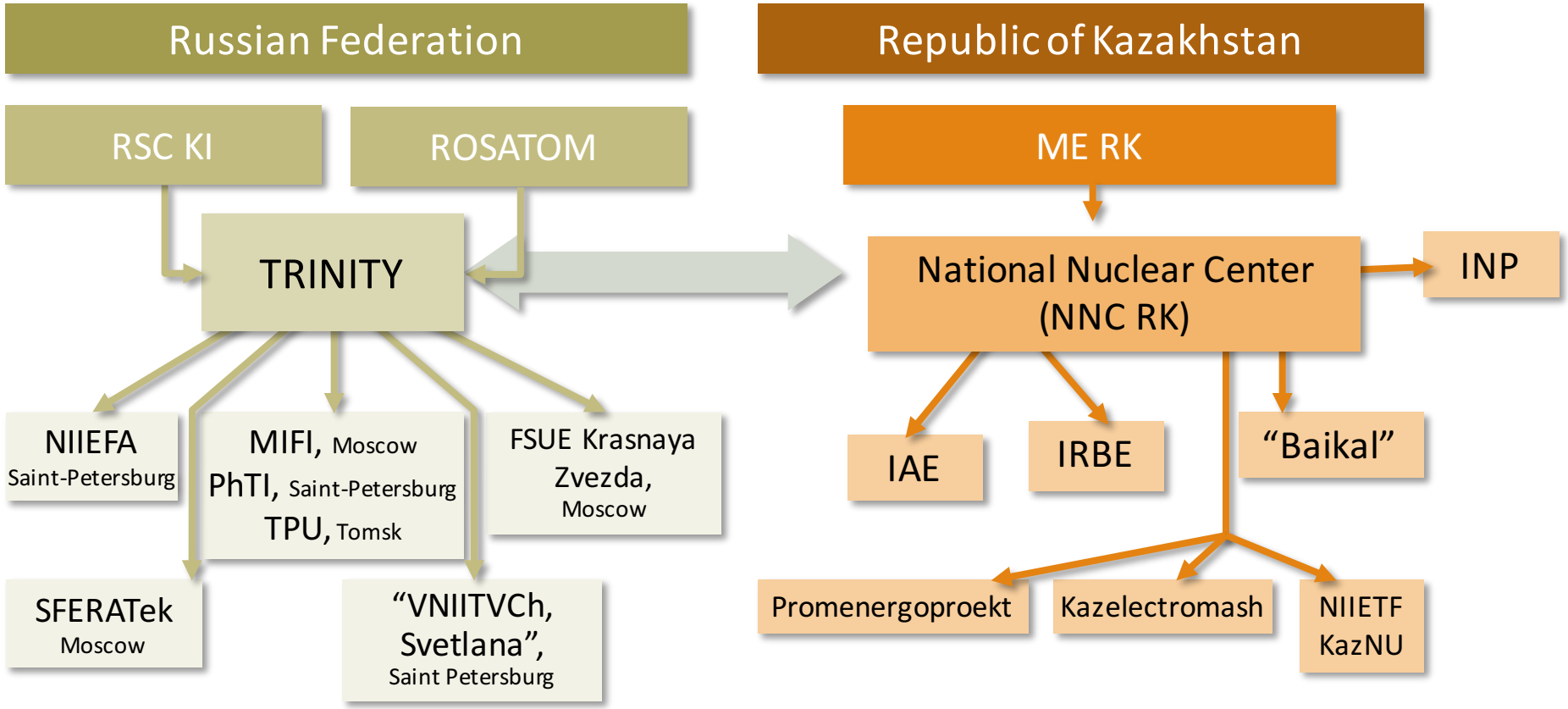
KTM Tokamak Key Parameters



Major Plasma Radius	0.9 m
Minor Plasma Radius	0.45 m
Aspect Ratio **A**	2
Plasma Elongation $\mathbf{K_{95}}$	1.7
Toroidal Magnetic Field on B_{TO} Axis	1 T
Plasma Current	750 kA
Current Impulse	4 – 5 s
Power of ICR Heating	5 – 7 MW
Divertor Heat Load	2 – 20 MW/m^2

KTM – first in the world tokamak, which is intended for the wide range of **material science studies** for development of the materials for working chamber and intra-chamber elements of future fusion reactors.

Work Organization



KTM tokamak project activities are conducted by cooperation of Kazakh and Russian research organizations. The scientific leader of the project is the academician of the Russian Academy of Sciences E.P. Velikhov. This work is included in the "Schedule of tasks assigned by the Joint Statement of the President of the Russian Federation Vladimir Putin and the President of the Republic of Kazakhstan N.Nazarbayev on Cooperation in the Sphere of the Use of Atomic Energy for Peaceful Purposes of January 25, 2006".

KTM Tokamak General View

Existing Big Tokamaks in the World

USA - 3 (DIII-D, NSTX-U, (Alcator C-Mod was closed in 2016)

Russian Federation - 3 (T-10, T-11M, GLOBUS-M, T-15D-under construction)

EU, United Kingdom -1 (JET)

United Kingdom - 1 (MAST)

France - 1 (TOR SUPRA)

Italy - 1 (FTU)

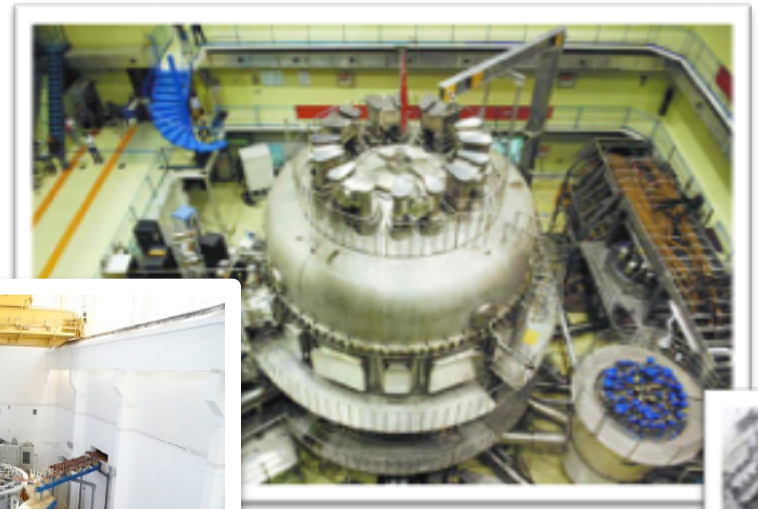
China - 1 (EAST)

South Korea -1 (KSTAR)

Japan - 1 (JT-60M)

Kazakhstan -1 (KTM)

In total, 13 tokamaks.



First Stage of KTM Physical Start-Up. June 9, 2017

The goal of the first stage of the physical start-up was to adjust and test the working capacity of the standard KTM systems. During this stage, the initial phase of the plasma discharge scenario was tested: the formation of the necessary conditions inside KTM vacuum chamber with the organization of the breakdown.

The works were carried out by the specialists of National Nuclear Center of Republic of Kazakhstan, the block of thermonuclear researches of the Research Center "Kurchatov Institute", Efremov research institute and the Troitsk Institute for Innovation and Fusion Research (TRINITI) of the Russian Federation with financial support of GK ROSATOM.

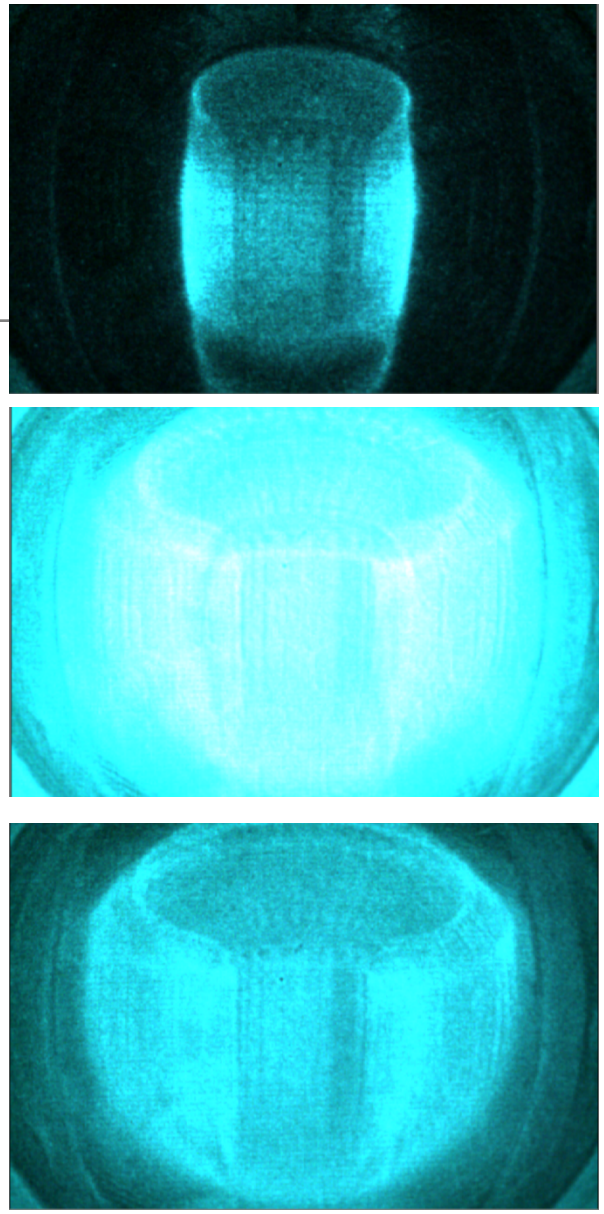
During the first stage of KTM physical start-up, the following plasma discharge parameters were achieved:

- maximum current in the plasma discharge pulse ~ 10 kA;
- plasma discharge pulse time ~ 20 ms;
- toroidal field B_t ~ 0.35 T;

circular cross section of the plasma column.

Hydrogen, helium, and , argon were used as the working medium gases.

The main objectives of the first stage of KTM Tokamak physical start-up had been achieved.



Video images of KTM plasma discharge

Participants of First Stage of KTM Physical Start-Up

National Nuclear Center of RK, Research Center "Kurchatov Institute“, RF

Efremov Research Institute, RF

Troitsk Institute for Innovation and Fusion Research, RF

KTM AT EXPO 2017

Model of Kazakhstani Tokamak for Material science was one of the main exhibits of EXPO 2017, Astana.

EXPO 2017
Future Energy
Astana Kazakhstan

KTM PHYSICAL START-UP

Second stage of KTM physical start-up is scheduled for June, 2018.

During II stage, all the technological systems of KTM facility will be activated and plasma will be obtained under Ohmic mode at reduced parameters.

Main parameters of II stage of KTM physical start-up:

- maximum current in the plasma discharge pulse ~ 60-100 kA;
- plasma discharge pulse time ~ 100ms;
- circular cross section of the plasma column
- toroidal field B_{To} ~ 0.4 – 0.5 T;

Signing the protocol for KTM physical start-up (NNC RK and Kurchatov Institute)

Design parameters of KTM operation (plasma current of 0.75 MA and discharge time of up to 5 s) will be realized in 2018 – 2020 by using the additional RF (ICR)-heating of plasma.

INTERNATIONAL COOPERATION

china eu india japan korea russia usa

ATOM-CIS

- Cooperation in the framework of ATOM-CIS Program, joint working group, joint research program
- Agreement on joint use of KTM complex (26.05.17)
- Joint research program approved by CIS Econ. Counsil (March,2,2018)

Russian Federation

- RK-RF Integrated Work Program (2006,2011)
- Joint Working Group on KTM, Cooperation NNC –Kurchatov Institute,(2010) NNC-Ioffe Institute (2014)

Republic of Belarus

- Cooperation Agreement NNC RK – JIPNR-SOSNY (2013)

Kazakhstan

Japan

- Memorandum of JAEA– NNC Cooperation (2007)
- Coordination Committee
- Trainings of young IAE specialists at JT-60

- Agreement on scientific-technical cooperation **NNC –ITER Organization (2017), work contracts (2018)**

EURATOM

- Intergovernmental Agreement on Fusion between RK-EURATOM (2002)
- Coordination Committee RK-EU (2006)
- ISTC Projects support

Spain

- Memorandum of CIEMAT – NNC Cooperation (2008)
- Trainings of the specialists at stellarator TJ-II

Italy

- Memorandum of ENEA– NNC Cooperation (2010)
- Trainings of the specialists at tokamak FTU

Great Britain

- Joint research by using tokamaks JET, MAST and KTM

AGREEMENT BETWEEN ITER ORGANIZATION AND NNC RK

Within the framework of EXPO-2017 events, the Agreement on scientific and technical cooperation between NNC RK and the ITER Organization was signed on June 11, 2017, in Astana.

Within the framework of the signed Agreement:

The activities has been begun to study the effect of reactor radiation on the characteristics of optical fibers and optical fiber temperature sensors used in the ITER reactor.

NNC RK specialists together with the ITER Organization staff carry out the analytical studies and numerical modeling of the pressure suppression system in the vacuum chamber of the ITER reactor (VVPS) and the process of steam condensation.

The following activities are under discussion: estimation of neutron activation of concrete by using the reactor base of the NNC RK, and reactor irradiation of the in-chamber inductance coil of the ITER reactor.

Potentially, it is possible to use the KTM Tokamak for testing materials and special units for the ITER project.

ACTIVITIES ON KTM PROJECT IN THE FRAMEWORK OF ATOM-CIS COMMISSION

1. Creation of a working group (WG) to develop an intergovernmental Agreement on the joint use of Tokamak KTM and the development of a joint research program. (established in November 2012 by the decision of the ATOM-CIS Commission). Up to date, 6 meetings of the WG have been held.

2. Preparation and signing of an intergovernmental *Agreement on the principles of joint use of the experimental complex based on tokamak KTM.*

3. Development, coordination and financing of the Joint Research Program on tokamak KTM.

Main Participating Organizations

Republic of Kazakhstan - NNC RK, IAE NNC RK, INP RK, NIIETF of KazNU Al-Farabi.

Russian Federation - NRC "Kurchatov Institute", NIIEFA of Efremov, JSC SRC RF TRINITI, JSC Krasnaya Zvezda, Tomsk Polytechnic University, National Research Nuclear University MEPhI, St. Petersburg State University, LLC TomIUS, Ioffe FTI, INP Novosibirsk.

Republic of Belarus - State Scientific Institution “The Joint Institute for Power and Nuclear Research – Sosny, Research Institute for Nuclear Problems of Belarusian State University, LLC "Applied Systems", State Enterprise of Powder Metallurgy.

Intergovernmental Agreement on the Joint Use of Tokamak KTM

The Expert Group of CIS Executive Committee approved the Agreement draft with the comments during the meeting held on February 25, 2016.

The draft Agreement was reviewed at a meeting of the Economic Affairs Committee under the CIS Economic Council in October 2016 and at a meeting of the CIS Economic Council in December 2016.

Six CIS countries (Russia, Kazakhstan, Belarus, Armenia, Kirgizia, and Tajikistan) signed the intergovernmental Agreement on joint use of tokamak KTM (Kazan, RF, May 26, 2017), *which is a basis for* creation of an international laboratory for material testing on the basis of tokamak KTM as an instrument for practical implementation of researches of the participating parties. Notes on the entry into force of this Agreement were received from all the member countries of this Agreement.

The main goal of the Agreement is to create a mechanism for conducting scientific research on the Kazakhstan material science tokamak by the scientists from different CIS countries. This Agreement creates a legal basis for the joint use by CIS specialists of a unique experimental complex on the territory of Kazakhstan.

The **Agreement** defines areas for cooperation, stipulates the appointment of competent authorities and the establishment of an advisory scientific and technical council. The agreement contains the articles on export control and on the protection of intellectual property, as well as on financing issues.

International Cooperation in the framework of ATOM-CIS Commission

Principles of financing

"Financing of joint activities, programs and works carried out on the basis of KTM is carried out at the expense of the funds provided by the national budgets to the relevant ministries, departments, state corporations or other organizations for implementation of research projects on relevant subjects, as well as by attracting the funds of economic entities and funds of extra budgetary sources on a contractual basis ".

Competent authorities of the CIS countries implementing the Agreement.

In accordance with Article 4 of this Agreement - the authorized body for the implementation of the works from the Republic of Kazakhstan is the Ministry of Energy, from the Russian Federation - the State Corporation ROSATOM, and from the Republic of Belarus - the National Academy of Sciences.

International Scientific Research Program for tokamak KTM

For implementation of the intergovernmental agreement on the joint use of the KTM experimental complex dated on May 26, 2017, the Working Group prepared the "**Updated International Scientific Research Program for Tokamak KTM in 2018-2010**", which presents the names of the implementing enterprises from the Republic of Kazakhstan, the Russian Federation and the Republic of Belarus, the schedule and cost of work.

The updated program passed interdepartmental coordination in the member states, was reviewed by the CIS statutory bodies and approved at a meeting of the CIS Economic Council on March 2, 2018 in Moscow.

CONTRIBUTION OF THREE CIS MEMBER-STATES THAT EXPRESSED A PRELIMINARY INTEREST IN PARTICIPATING IN THE JOINT RESEARCH PROGRAM AT KTM WAS ESTIMATED (FOR THREE YEARS):

CIS member-state	Contribution in national currency	Financing source
Republic of Belarus	TBD	Financing will be carried out within the budgetary funds for the corresponding year.
Republic of Kazakhstan	**593,760 mln tenge for 3 years;**	**Financing for the program "Scientific and technical support of experimental research on the Kazakhstan material science tokamak KTM" was allocated under the Target Program of the Ministry of Energy of the Republic of Kazakhstan for 2018-2020.**
Russian Federation	**(35-40 mln rubles per year)**	**FTP "Research and inventions in priority areas of development of the scientific and technological complex of Russia for 2014-2020 ", Ministry of Education and Science of the Russian Federation.** Competition for conducting research and development work on activity 2.1 "Implementation of research in the framework of multilateral and bilateral cooperation"

MAIN ACTIVITY DIRECTIONS AS A PART OF PROGRAM FOR SCIENTIFIC STUDIES AND RESEARCH AT TOKAMAK KTM IN 2018–2020

1. Plasma Physics Studies
2. Research of interactions of first wall and divertor materials with plasma under ohmic heating
3. Material studies of structural and functional materials of fusion facilities
4. Study and realization of innovative lithium technologies
5. The creation and testing of diagnostics for studying the processes of plasma –wall interaction
6. Development of the automation, control and data collection system, experimental verification of calculation codes

COORDINATION OF JOINT RESEARCHES AT TOKAMAK KTM

Coordination of scientific research will be carried out by an international scientific and technical council (IS&TC) from representatives of competent authorities and organizations of the countries participating in a joint research program. In order to implement the Agreement on the joint use of the Tokamak KTM, there will be the trainings of the specialists, exchange of experience, jointly discussions of the works results, joint publications and approbation of research results at international conferences, involvement of other countries in joint research, and attraction of additional investments from interested foreign partners.

All this will be the key to increase the efficiency of financial costs in the research infrastructure of the CIS countries and optimization of research costs.

The coordinated algorithm for joint use of intellectual property object (tokamak KTM and the obtained results) is established in the Agreement on the joint use of KTM tokamak.

A factor, which will impact the success of international scientific cooperation, will be the proper coordination of work with the help of the IS&TC, the promptness and consistency of the work of the competent authorities, the importance and need for state support in implementation of the intergovernmental Agreement.

IMPORTANCE OF JOINT INTERNATIONAL WORK PROGRAM USING KTM TOKAMAK.

The realization of this joint research program at tokamak KTM will help lay the foundations for solving important tasks of modern nuclear power engineering in the CIS countries and potential countries-participants of far abroad , including the development and testing of new structural and functional materials and technical solutions for fusion reactors, the production of artificial nuclear fuel, the closure of the fuel cycle, utilization of nuclear wastes by using hybrid fusion-fission systems, which corresponds to modern innovative approaches to the development of nuclear power engineering by using the achievement of controlled fusion.

In the long term, a positive economic effect in the participating countries will be obtained from the introduction of ready-made technologies based on controlled thermonuclear fusion - an innovative, clean energy with an almost inexhaustible resource.

POTENTIAL PROBLEMS AND RISKS OF INTERNATIONAL SCIENTIFIC PROJECTS

1. Obligation and necessity of a legal basis for any international project - Agreement on the joint use of the facility, monitoring of the implementation of all the arrangements with the help of the collective project management.

2. Distribution of intellectual property during the construction, operation and conduct ion of research (in accordance with the costs contribution???)

3. The possibility of commercialization of the technologies and the results of joint research - may be a potential problem with misallocation of intellectual property rights.

4. Necessity of state support of scientific research at the objects of joint intellectual property.

THANK YOU FOR ATTENTION !