

$$\Delta^*\Psi + r'^2 p'_\Psi + FF'_\Psi = 0$$

NRC "Kurchatov Institute" Fusion Research Centre

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Dep. Head



TOKAMAK T-15MD:

***experience of scientific and
technical project realization in
RUSSIA***

Stage one: Physicists decided



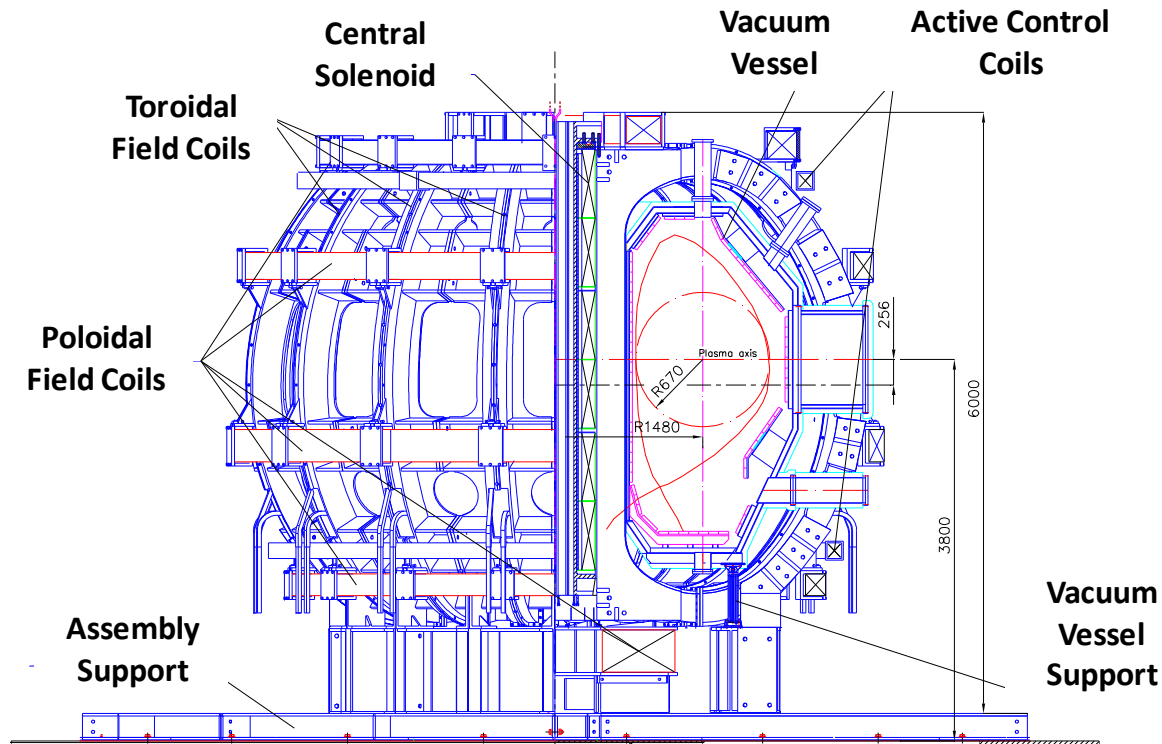
**What tokamak is
needed?**

- ☐ Compact or medium size (Aspect ratio ~ 2 or ~ 3)
- ☐ Divertor configuration: one null or two nulls
- ☐ Magnet system: superconducting or conventional
- ☐ Plasma current value
- ☐ Toroidal field value
- ☐ Auxiliary plasma power heating: gyrotrons, neutral beam injectors, LH current drive system and etc

Finally: $A \approx 2$, $I_p = 2$ MA, $B_t = 2$ T, SN & DL

Stage two: Conception Design of Tokamak

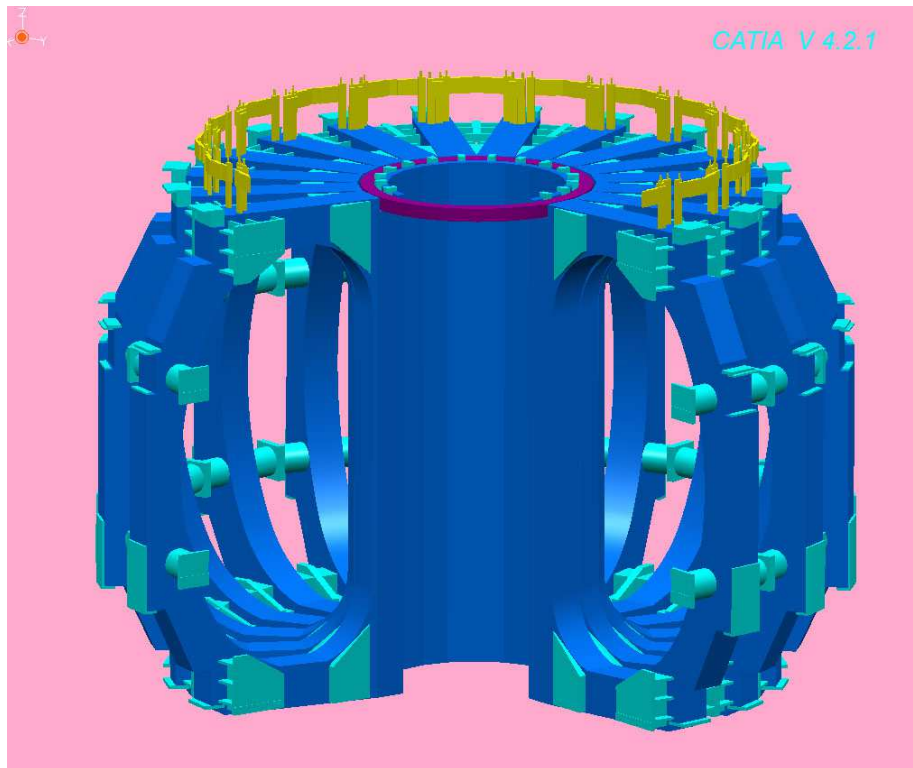
Chief designer – NIEFA (St.- Peterburg)



Parameter	Value
Plasma current, MA	2
Aspect ratio, A	2.2
Major radius R_0 , m	1.48
Minor radius a, m	0.67
Elongation k_{95}	1.7-1.9
Triangularity δ_{95}	0.3-0.4
Toroidal field on plasma axis $B_{t Ro}$, T	2.0
Pulse duration $\Delta t_{\text{plateau}}$, s	5-10
Auxiliary power heating P_{AUX} , MW	10-15
Plasma density n_e , 10^{14} cm^{-3}	1.0
Magnetic flux $\Delta \Psi_{\text{cs}}$, Wb	6
Plasma configuration	SN, DN

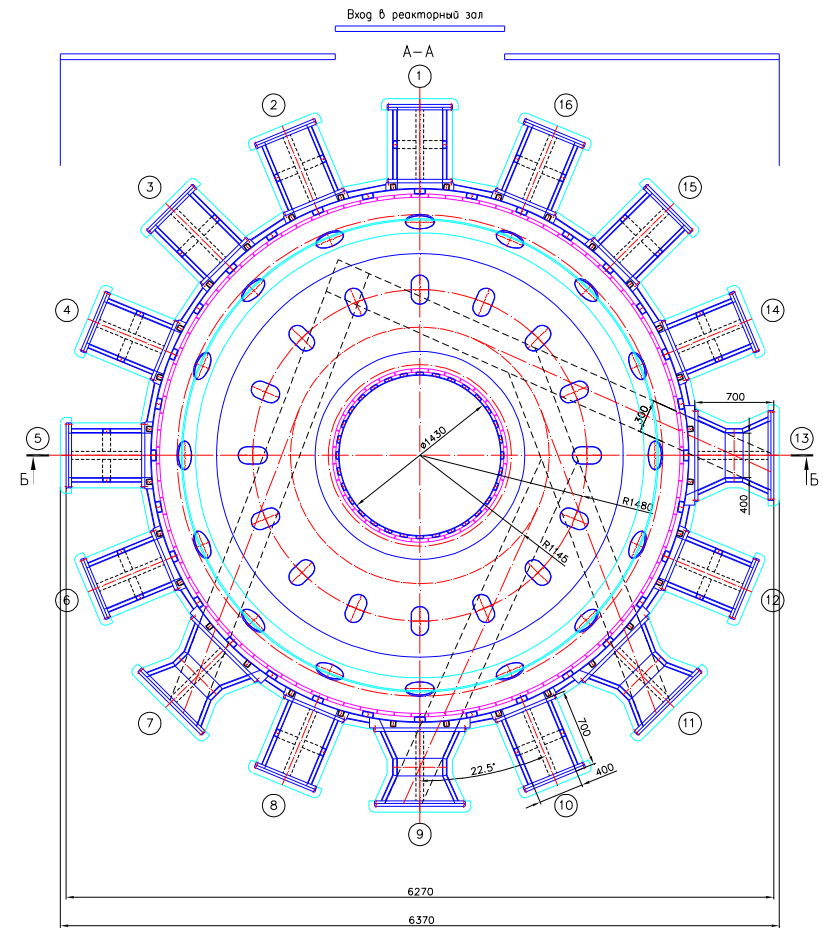
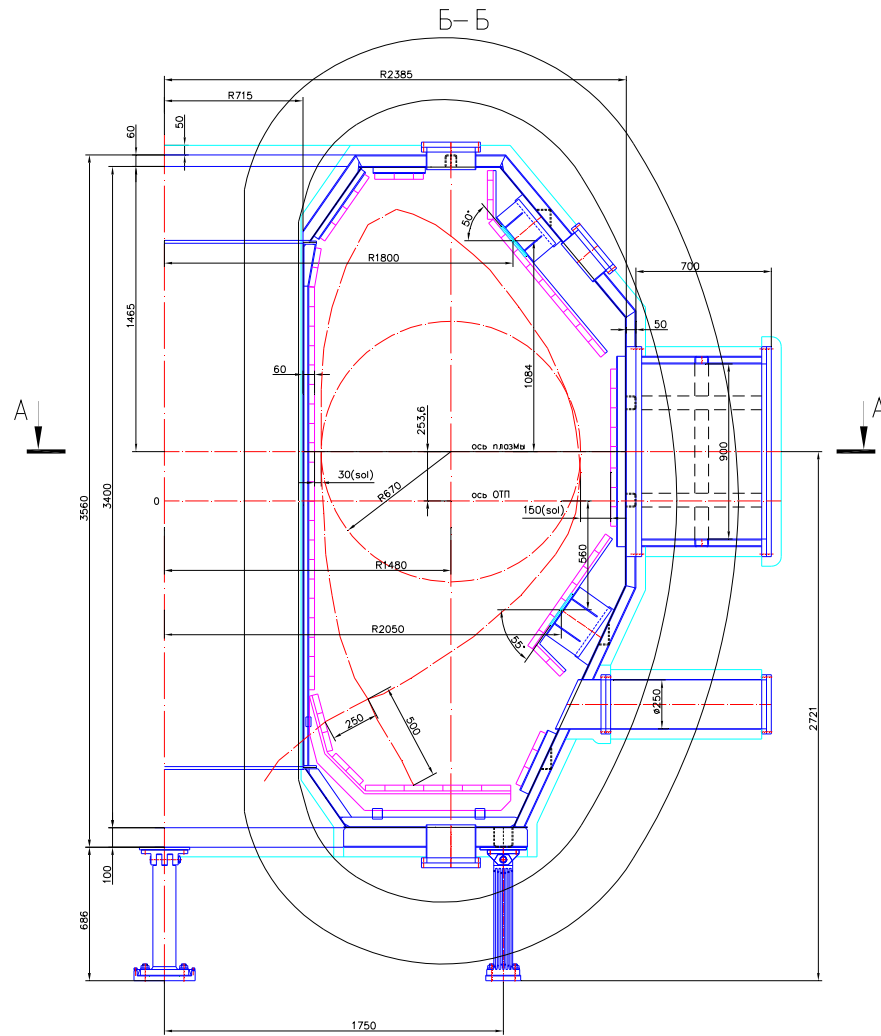
Toroidal magnet system

(conventional)

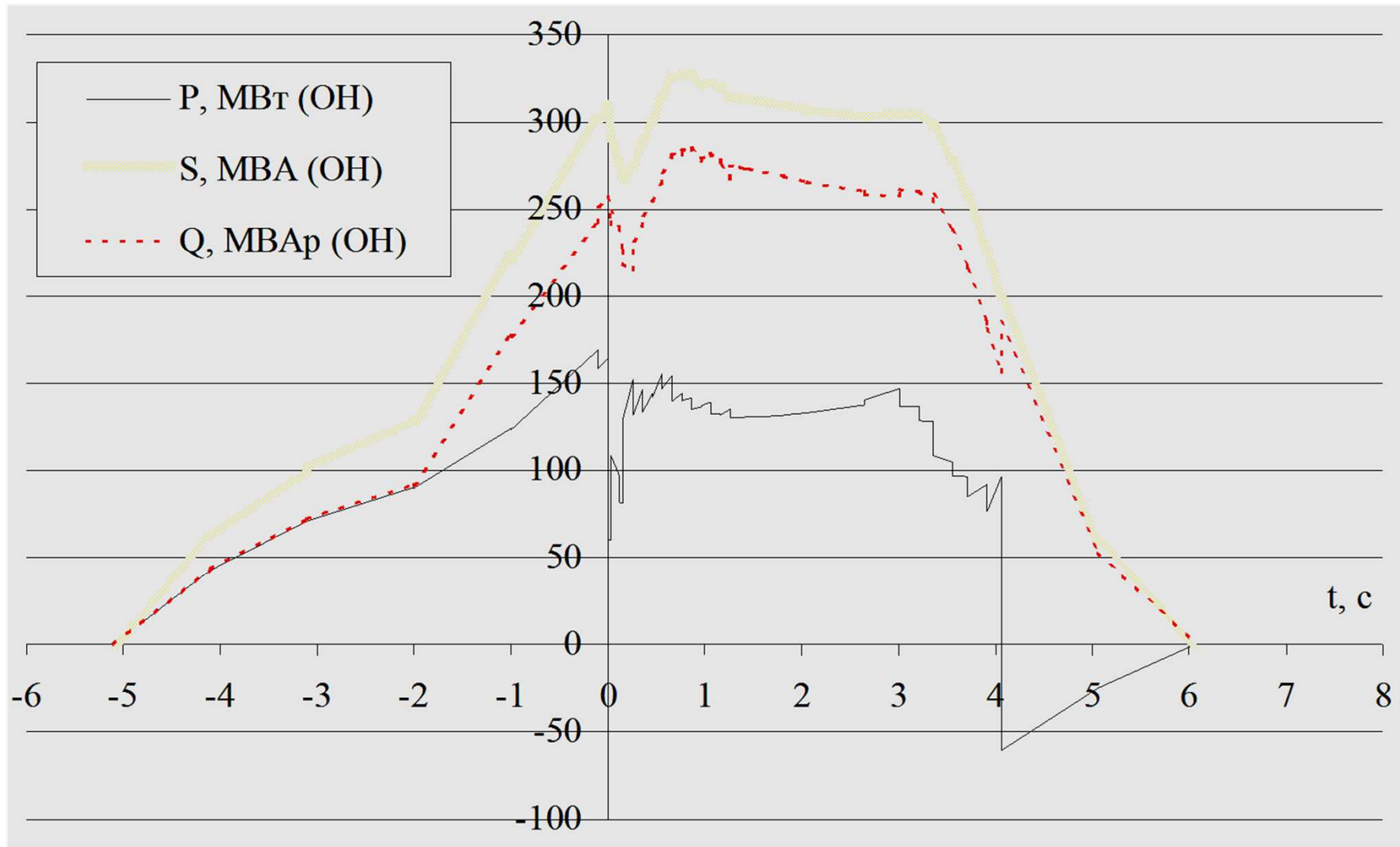


Parameter	Value
Number of coils	16
Number of turns in coil	50
Value of toroidal field, T	2.0
Current plateau duration no less, s	10.0
Pause between pulses no more, s	900
Coils cooling	water
Coil overheating no more, grad.	50
Field ripple at plasma outboard, %	0.78

Vacuum vessel



Consumption of impulsive electrical power ~ 300 MVA

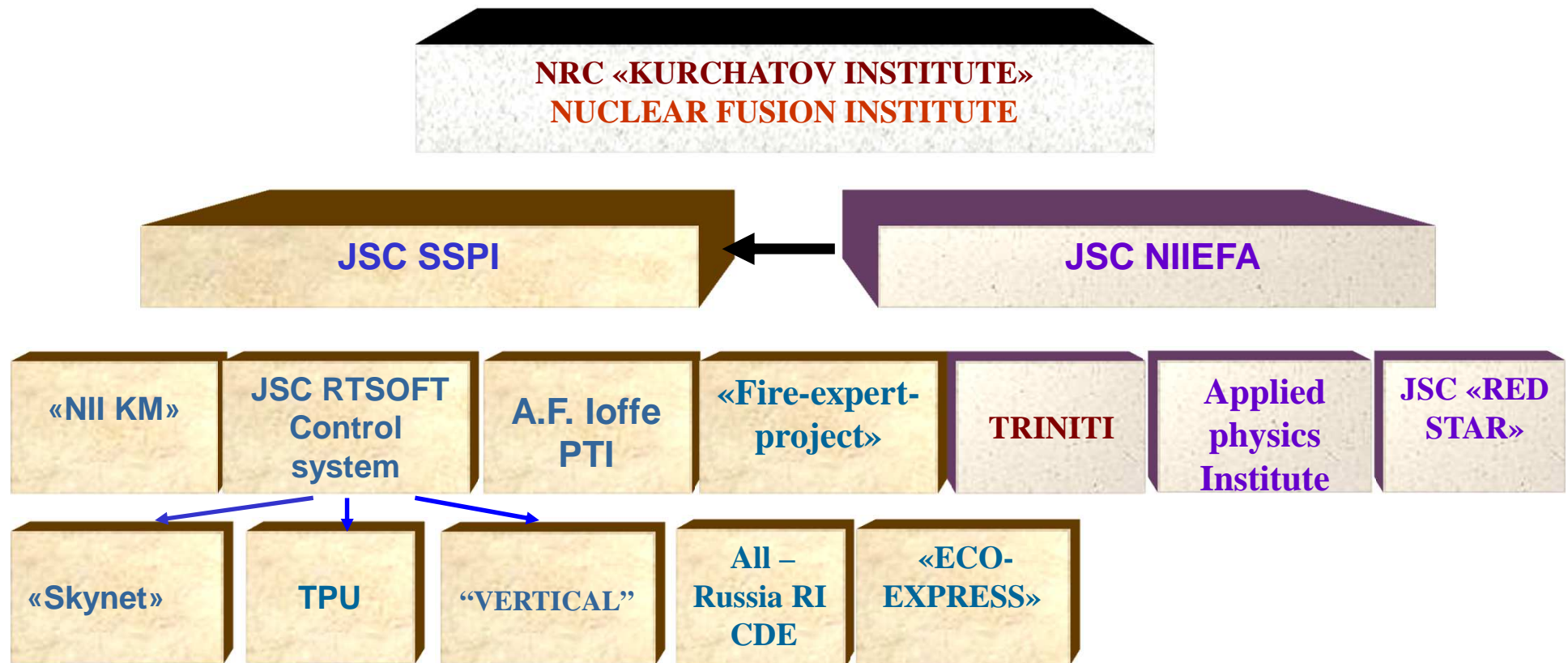


Stage three: Preparation of requirements specifications

General Project Organization – State Specialized Project Institute (belong to State Corporation “ROSATOM”)

Volume 1 - General explanatory note	Volume 2- Engineering systems
1. Input data and guidelines	1. Electrical part
2. Appointment, composition, characteristic of the complex	1.1 Input data and guidelines
3. Layout solutions, transportation and technology transactions	1.2 Power supply system of the complex
4. Engineering systems	1.3 Power supply of electromagnetic system
5. Mode of operation. States	1.4 Power supply of injection heating system
6. Major decisions on technical security, occupational safety and health	1.5 Power supply of HF- plasma heating system
7. Waste	2. Automated control system
8. List of equipment	3. Radiation control
9. Cost characteristics of complex	4. Ventilation and heating
10. Operating condition of engineering systems and the requirements for their modernization	5. Water supply and sewerage
11. Requirements for the physical protection of the complex	6. Communication and signaling
12. Engineering and technical measures of civil defense and emergency prevention	7. Fire extinguishing and fire alarm
	8. Heat points
	9. Engineering systems and the requirements for their modernization

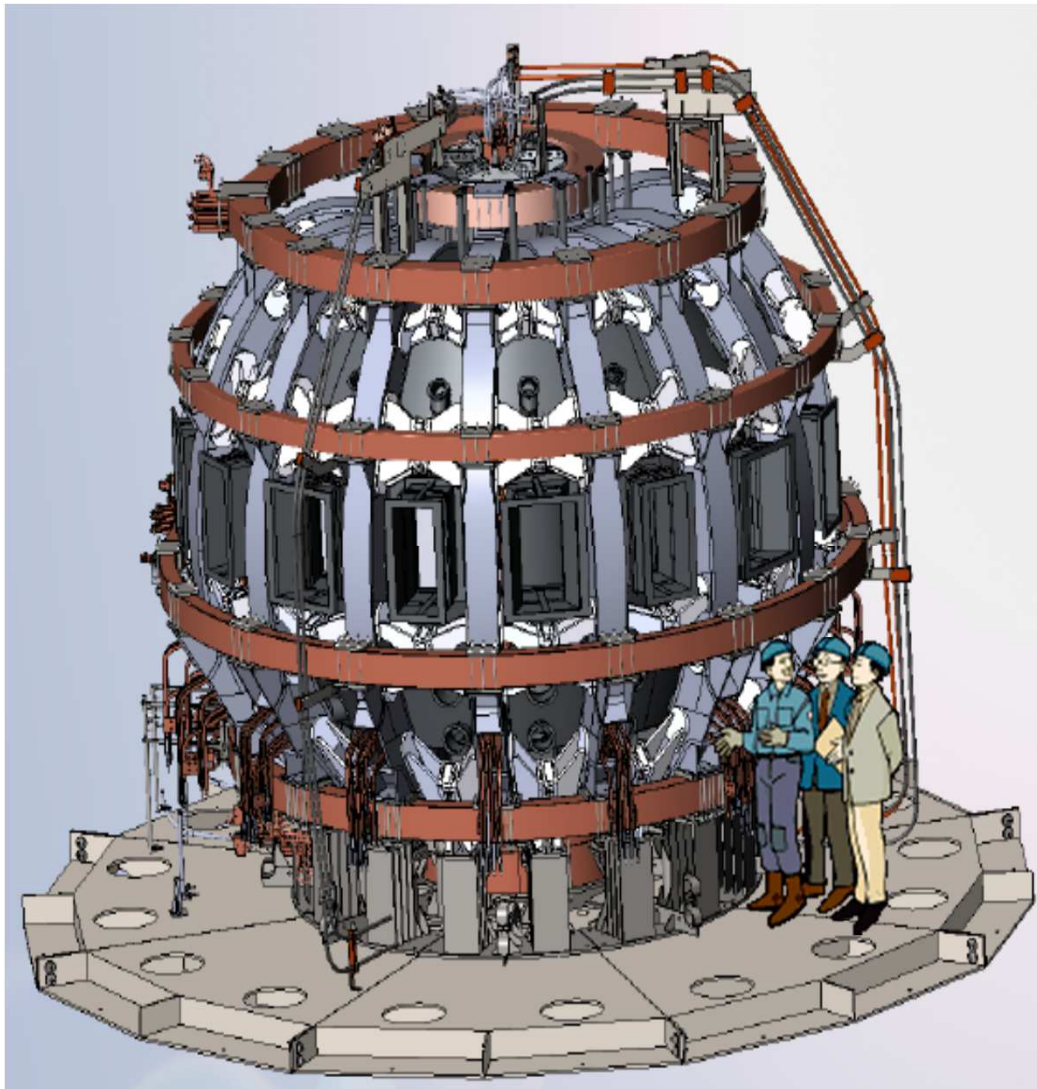
Stage four A: PROJECT of Technical Reconstruction of TOKAMAK T-15 (T-15MD)



14 organizations took part in T-15MD project

38 volumes of the project has been released

Stage four B: Detail Design of Tokamak T-15MD



Major radius of torus R , m	1.48
Aspect ratio	2.2
Plasma current I_p , MA	2.0
Elongation, k	1.9
Plasma configuration	SN, DN
Discharge pulse duration, s	10
Toroidal magnetic field at plasma axis, T	2
Magnetic flux swing in central solenoid, Wb	6
Neutral beam injection power, MW	6
ECR heating power, MW	7
ICR heating power, MW	6
LH heating power, MW	4

Stage five: Assignment for the development of the project

“Technical reconstruction of experimental fusion installation T-15”

AGREED

Директор

РНИЦ «Курчатовский институт»

член - корреспондент РАН


М.В. Ковалев
« 29 » 2007 г.



APPROVE

Заместитель руководителя федерального
агентства по науке и инновациям


М.А. Камболов
« 29 » 2007 г.



ЗАДАНИЕ

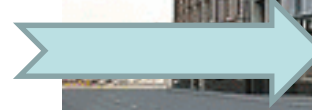
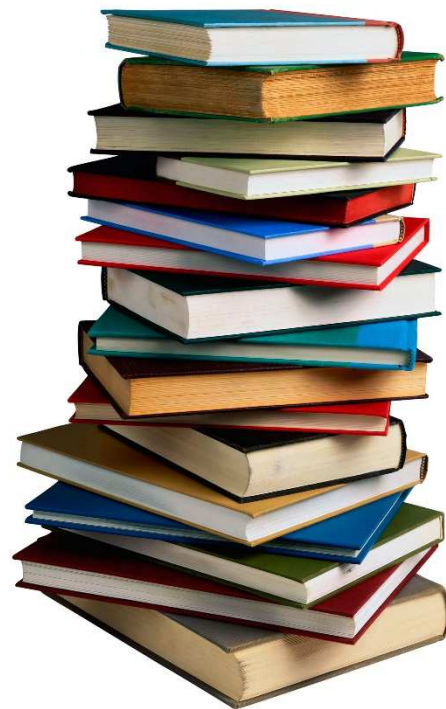
На разработку проекта

«Техническое перевооружение экспериментальной термоядерной установки Т-15»

This is document in which the basic data and requirements are indicated:

Information about the site and planning constraints. Special geological conditions. Construction type. The appointment item, production capacity. Specify the queue allocation of construction and commissioning stages, their composition. The timing of design. **Construction start and end dates (2010-2020). Source of funding – Federal Budget.** Category complexity. Stages of design. **The developer of the project documentation - SSPI-General project organization, Efremov Inst.- Chief Designer,** developer of the magnet system and vacuum vessel for tokamak T-15MD, **Nuclear fusion Institute -supervisor**, operator. **Main technical and economic indicators - The estimated cost of capital costs is 6.9 billion rubles (~230 M\$).** Urban solutions, master plan, territory improvement, planting. Architectural and planning solutions. Engineering systems of buildings and structures. Mode of operation. Environmental protection. Engineering civil defence activities. Prevention of emergencies.

Stage six: Approval of the project in the Home State **Expertise of Russia**



~ 6 months later

THE POSITIVE DECISION!!!

APPROVED PROJECT COST - is 6.3 billion rubles

~ Five years have passed from the beginning of the project

Stage seven: Implementation of the project (2011-2020)



The Government has adopted (2010)

The Federal Target Programme “Nuclear energy-technologies of new generation for period 2010 - 2015 and to the prospect until 2020 year”

FTP «Nuclear energy-technologies of new generation for period 2010 - 2015 and to the prospect until 2020 year»

Project «Technical reconstruction of experimental fusion installation tokamak T-15»

**In 2010 the project has been allocated 5927,1 MRub.
(~200 M\$)**

TOTAL	2011-2016	2011	2012	2013	2014	2015	2016	2017-2020
5905,42	2915,79	313,9	677,4	628,9	457,6	421,94	416,05	2989,63
5927,1 (2010)	2949,75	283,9	377,4	368,9	557,6	677,45	684,5	2977,35

2011-2016 y.y. – 2915,79 MRub.

Stage eight: Development of working documentation, construction of the tokamak, equipment procurement, constructing-and-mounting work

The procedure of execution of works the same in all cases:

8.1 Preparation of requirements specifications

8.2 Commercial listings (no less 3)  average cost of work execution

8.3 Accommodation on the government site of procurement tender documentation

8.4 Determining the winner of the contest (or auction) and the execution of the contract

TOROIDAL MAGNET SYSTEM



One of 16 coils at the plant in Bryansk

Central Solenoid



Poloidal Field Coils

PF1



PF4



HFC



PF2



PF5



PF3



PF6



Vacuum Vessel





Placement of HF coils inside toroidal winding

PREASSEMBLY OF MAGNET SYSTEM



STATUS of ENGINEERING SYSTEMS

Vacuum Pumping System



STATUS of ENGINEERING SYSTEMS

WATER COOLING SYSTEM



Information and Control System

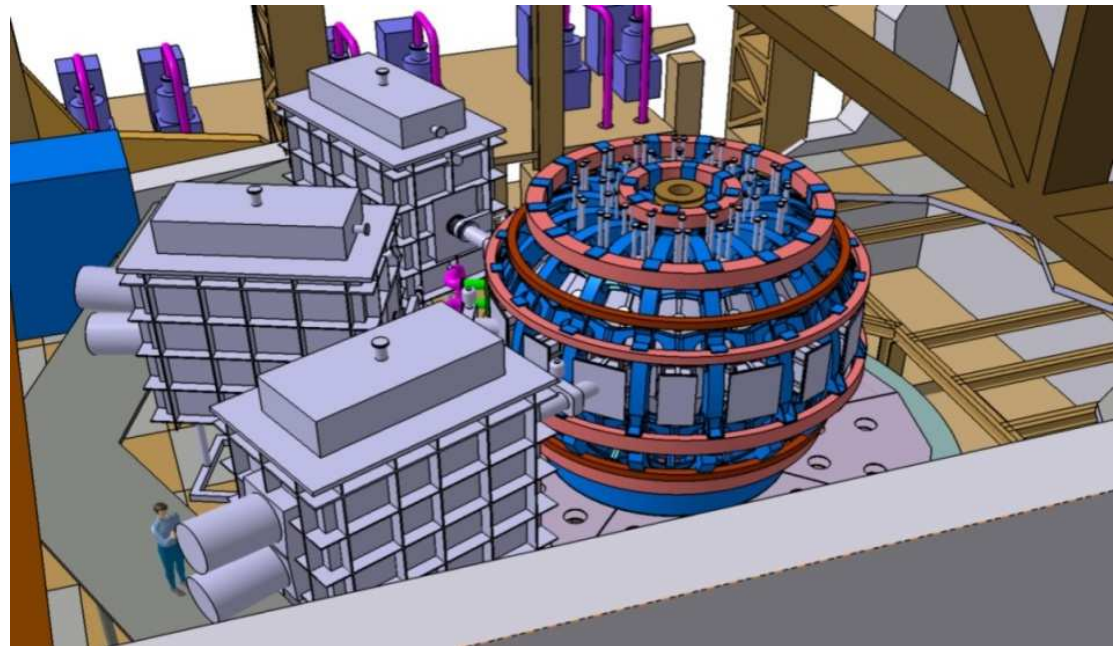
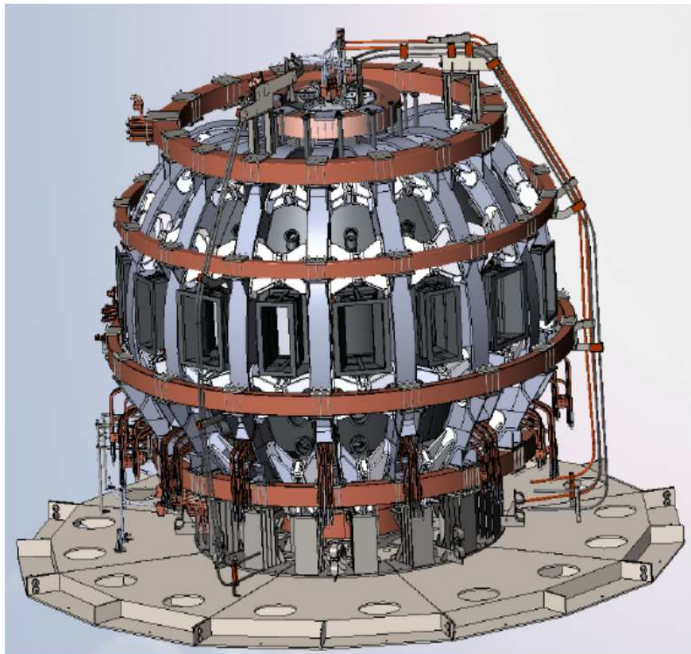


T-15MD Data Center



PLANS

- The time schedule is the following:
- 2017-2018 - assembling of T-15MD and adjustment of engineering equipment;
- 2019 – connection of engineering systems to T-15MD;
- 2019- Physical start-up. 2020-2021- Introduction of aux. heating systems



It took fifteen years for the realization of the project

**Thank you very much
for your attention**