Report för projekt “Treatment of Fission Waste Radioactivity by Means of Fusion Neutrons “
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Summary of the project

The project was a small part of the collaboration with Baltic Infrastructure for Research, Technology and Innovation (BIRTI) activity. Within the framework of this project spherical tokamak with parameters major radius 0,5m, minor radius 0.3 m, toroidal fiel 1.5 T and current 1.5 MA, heating power 6 MW and output of neutrons 2 MW is being designed and constructed in collaboration with other partners supporting the Salaspils Fusion Neutron Source (SFNS). There is the plan to upgrade this device employing superconductive technology developed at ITER. The secondary goal is to assist European Spallation Source project in Lund preparing for Latvian heavy involvement in this project. Kurchatov Institute has plans to built its own neutron source and also to build hybrid fission – fusion reactor in Sosnovy Bor..
Two hybrid devices Multi Functional Experimental Reactor MFER and Spent Fuel Burner SFB with participation of the project are planned in China .

Enclosure 2

Report of the Project

The state of the physics and technology of superpower neutron sources was considered in detail in the framework of this project, aimed at comparing the highest possible neutron yields in fission and fusion reactors and accelerator sources based on spallation reactions. Problems of creating low and moderate power sources were analyzed within the framework of the project as well. Volumetric neutron sources based on s tokamaks and intended for testing structural materials to be used in fusion reactors were analyzed. The problem of a tokamak operating as a neutron source for solving nuclear technology tasks has been studied extensively throughout the world. . Conferences and meetings attended by the project leader have demonstrated great interest in the elaboration of high power neutron sources and their implementation in science and technology.

The result is that the tokamak-based neutron sources can, in principle, provide intensities higher than 10^{18} neutrons/s. It has been calculated that an intensity of 10^{20} neutrons/s will be achieved in ITER at a pulse duration of 3000 s of neutron sources produced under DT operation. Applications of tokamaks as neutron sources have been addressed within the framework of the project on the conceptual and design level with regard to scientific research; material studies and the development of nuclear technologies for fusion reactors including tritium reproduction. The first steps in implementing the DT reaction at a megawatt power level in tokamaks were made in TFTR] and JET tokamaks.

Our analysis has shown that the contemporary level of tokamak technologies meets the technical requirements for creating a superpowerful research source of 14 MeV neutrons with an intensity of $(0.2–1) \times 10^{19}$ neutrons/s for the case of the DT reaction or 2.5 MeV neutrons with an intensity of 3×10^{17} neutrons/s for the case of the DD reaction.

Significant progress has been made addressing the treatment of fission waste radioactivity by means of fusion neutrons. The main thrust is constructing the most powerful fusion reactor ITER in France. ITER is completely unique, and a large number of its constituent parts will be first-of-a-kind. Although other large tokamaks have been built around the world, not one of them resembles the tokamak that will be assembled in Saint Paul-lez-Durance, France in terms of scale and complexity.

ITER Members are involved broadly in the in-kind procurement for ITER, sharing responsibility for the fabrication of components and systems.

Participating in ITER also means reinforcing the scientific, technological and industrial base in fusion back at home in Sweden.

Adding to the complexity of ITER is a unique procurement program that divides the fabrication of the machine's components and systems among the seven ITER Members (China, the 28 members of the European Union plus Switzerland,

India, Japan, Korea, Russia and the United States).
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If the ITER Project was "only" about building and operating the largest tokamak in the world, things would be simpler. But ITER is more than that. From the beginning, the project was designed with the idea that the Members, through their participation, would each advance their own scientific, technological and industrial base in fusion, and in this way prepare for the next-step machine, a demonstration fusion reactor acting as a source of large high energy neutrons with fluences in excess of 10^{19}neutrons/second .
As a result, the ITER Members are involved broadly in procuring components and systems (referred to as "in-kind" procurement).
The fabrication of the ITER vacuum vessel sectors has been divided between Europe (7 sectors) and Korea (2 sectors)
the central solenoid is a collaboration between the United States and Japan
Divertor manufacturing and testing is divided between Europe, Russia and Japan;
India and the United States are sharing responsibility for ITER's cooling water systems
The blanket system aimed at the close cycle of producing tritium will be produced by China, Europe, Korea, Russia and the United States
Finally, six ITER Members (all except India) are involved with the production of ITER magnets.

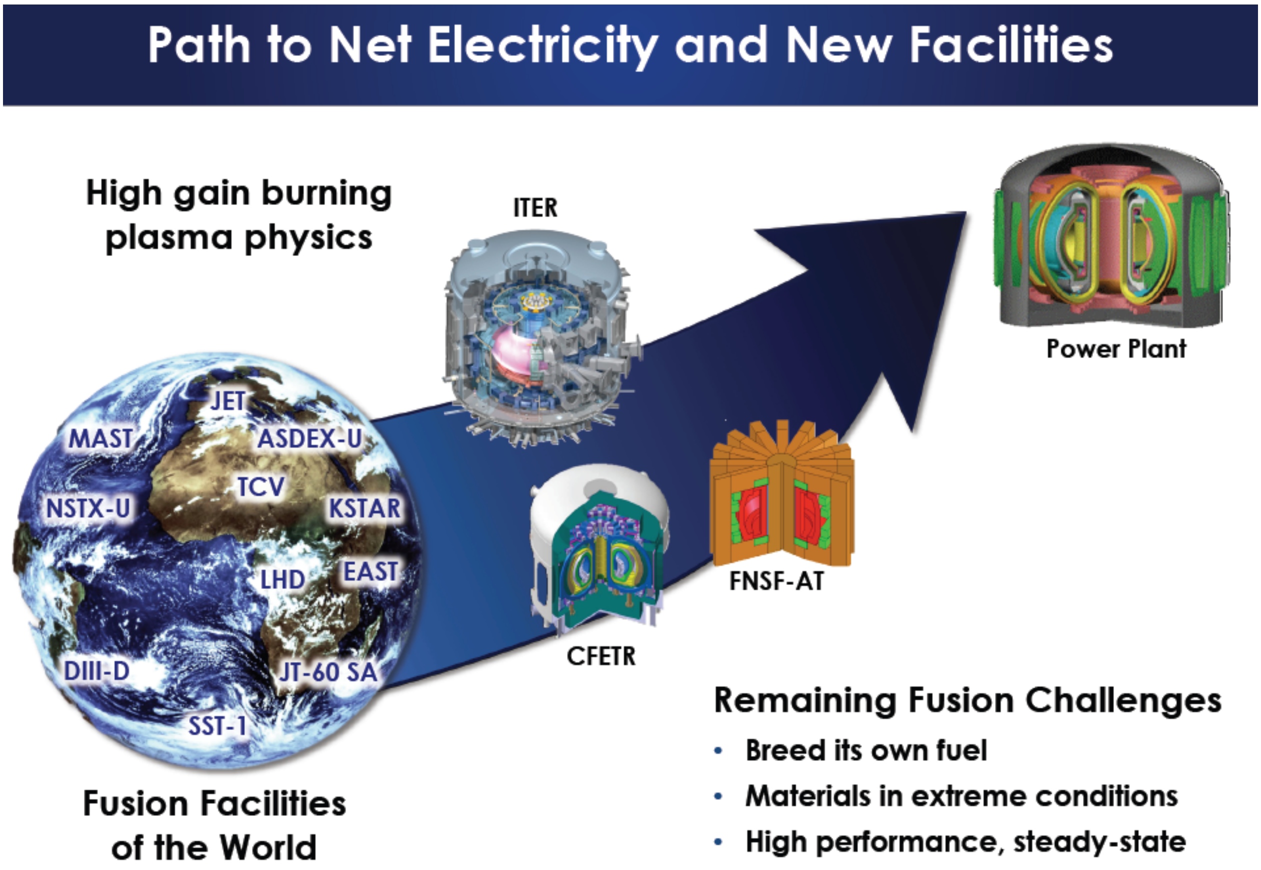
Finalized in early 2013, the distribution of in-kind fabrication tasks was based both on the interests and the technical and industrial capacities of each of the Members.
China, India, Japan, Korea, Russia and the United States have each agreed to cover 9.1% of ITER construction (nine-tenths of this contribution will be supplied in kind to ITER, and only one-tenth in cash).
Europe, host to the ITER Project, participates at the level of 45%, including a share of ITER components and systems as well as nearly all the buildings of the scientific facility.
For its greater investment, Europe also reaps the lion's share of economic benefits (EUR 4 billion in contracts have been awarded for ITER on European territory since 2007).

To manage all of these in-kind contributions, the ITER Organization—which coordinates the project—has already signed nearly 100 Procurements Arrangements with the ITER Domestic Agencies (one Domestic Agency has been established in each ITER Member). These agencies, in turn, contract out to industry for the fabrication of the component according to the very specific conditions laid out in the Procurement Arrangement documents. Since the beginning of the process, more than 1,800 contracts for design or fabrication have been

Parameters of the ITER device under construction are listed below.
- Dimensions 80*110*60ht m (-16m underground, weight 350,000tons)
- 493 Seismic Isolation Pit completed on 18 April 2012
- Main B2 slab completed (~14, 000m3 concrete) on 27 August 2014
- Started erection of walls in October 2014

The project contributed to the management, design and physics basis of ITER

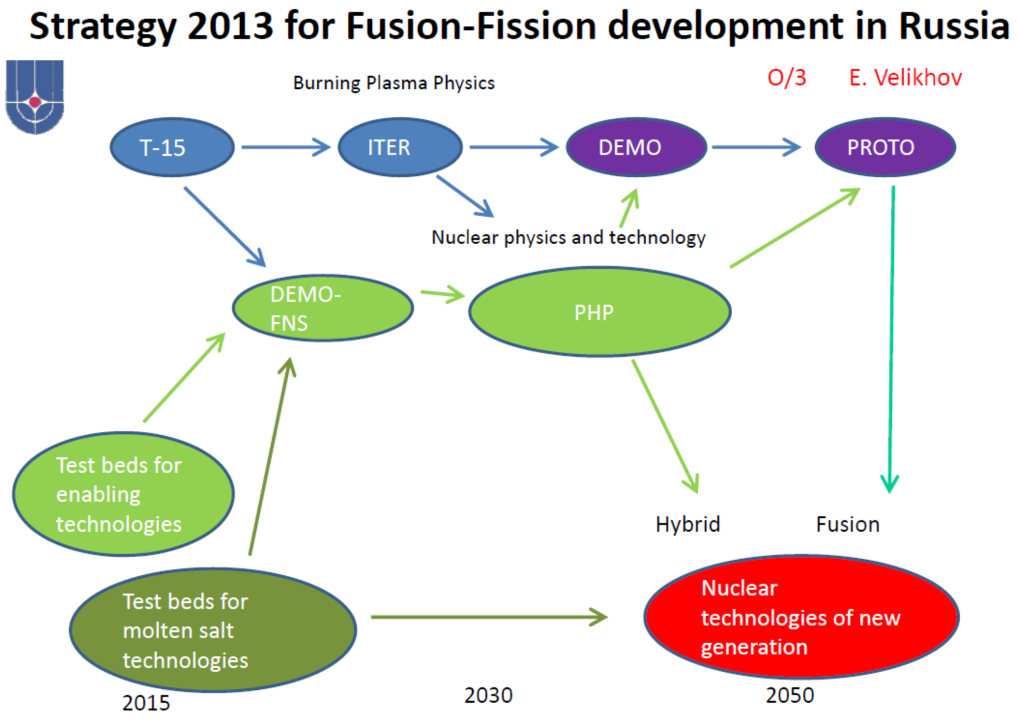
The approach adopted by the USA in implementing the Neutron Source Based on Fusion Neutrons is illustrated below



Path to Net Electricity and New Facilities

Remaining Fusion Challenges
- Breed its own fuel
- Materials in extreme conditions
- High performance, steady-state

The Long Term Plans of Configuration Studies for an Spherical Tokamak -Based Fusion Nuclear Science Facility
Carried out in Russia is shown below



Strategy 2013 for Fusion-Fission development in Russia

O/3 E. Velikhov

Burning Plasma Physics

T-15 → ITER → DEMO → PROTO

Nuclear physics and technology

DEMO-FNS → PHP

Test beds for enabling technologies

Test beds for molten salt technologies

Hybrid

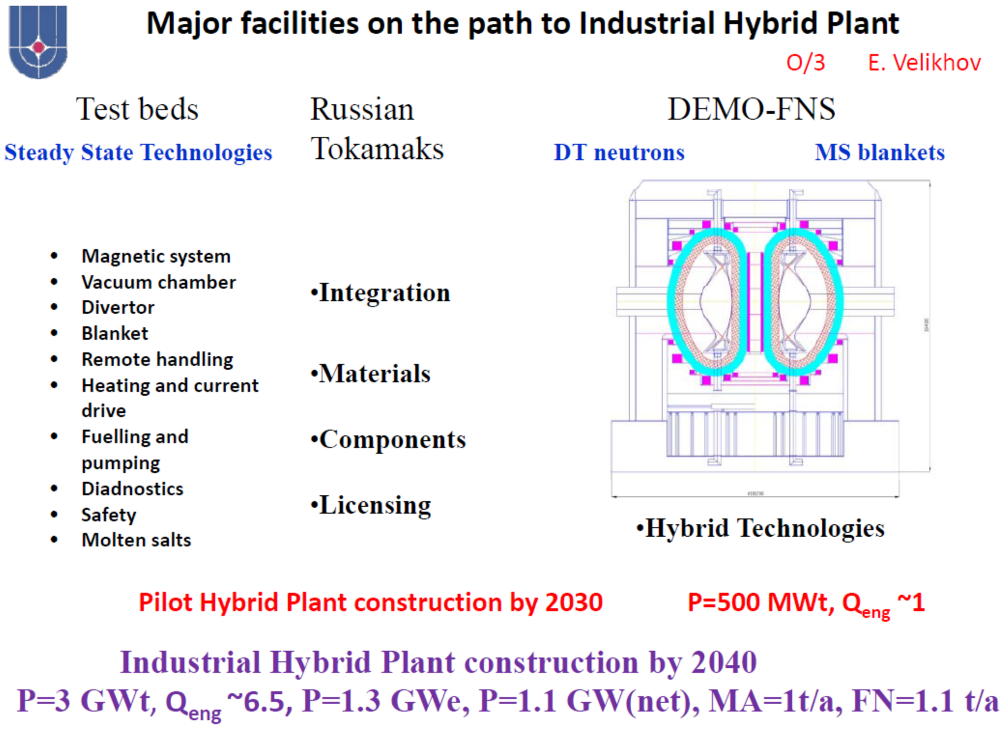
Fusion

Nuclear technologies of new generation

2015

2030

2050



Major facilities on the path to Industrial Hybrid Plant

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Test beds	Russian Tokamaks	DEMO-FNS
Steady State Technologies		**DT neutrons** **MS blankets**

- **Magnetic system**
- **Vacuum chamber**
- **Divertor**
- **Blanket**
- **Remote handling**
- **Heating and current drive**
- **Fuelling and pumping**
- **Diadnostics**
- **Safety**
- **Molten salts**

•Integration

•Materials

•Components

•Licensing

•Hybrid Technologies

Pilot Hybrid Plant construction by 2030 **P=500 MWt, Q_{eng} ~1**

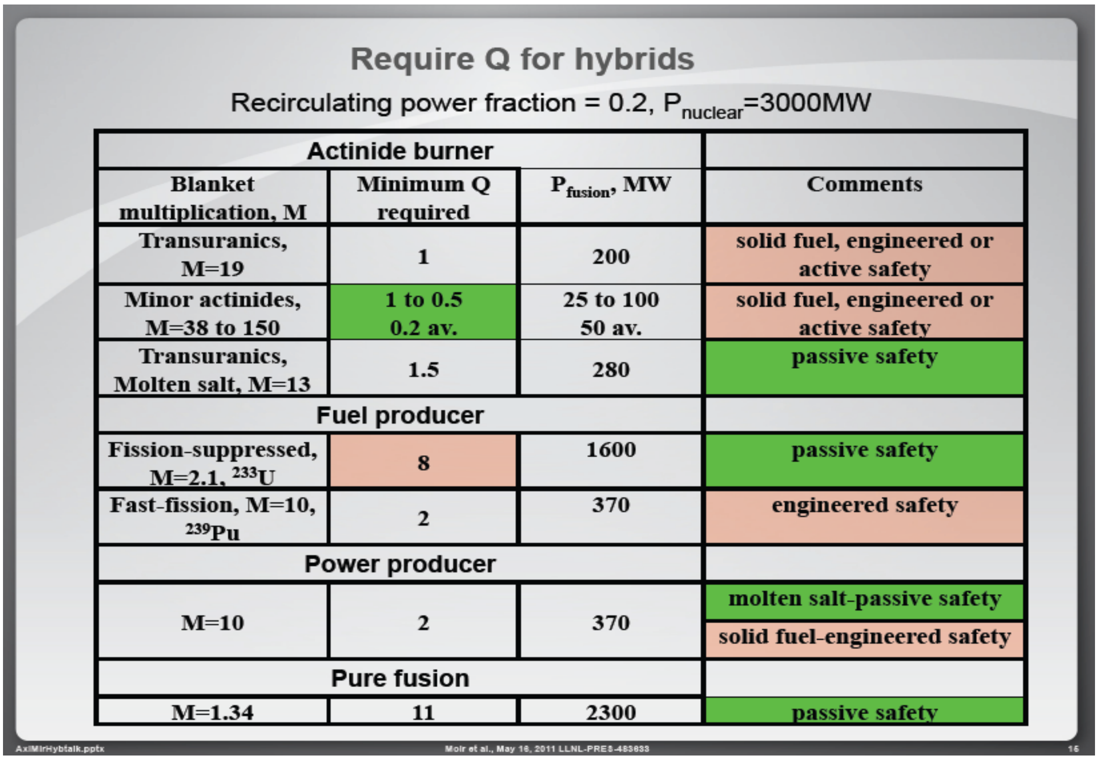
Industrial Hybrid Plant construction by 2040

P=3 GWt, Q_{eng} ~6.5, P=1.3 GWe, P=1.1 GW(net), MA=1t/a, FN=1.1 t/a

The outline for the industrial Hybrid Plant to be constructed is shown above.

Enclosure 2

The Q parameter showing the ration of the nuclear gain versus the injected power and the safety requirements are shown below.



Require Q for hybrids

Recirculating power fraction = 0.2, $P_{nuclear}$=3000MW

Actinide burner			
Blanket multiplication, M	Minimum Q required	P_{fusion}, MW	Comments
Transuranics, M=19	1	200	solid fuel, engineered or active safety
Minor actinides, M=38 to 150	1 to 0.5 0.2 av.	25 to 100 50 av.	solid fuel, engineered or active safety
Transuranics, Molten salt, M=13	1.5	280	passive safety
Fuel producer			
Fission-suppressed, M=2.1, ^{233}U	8	1600	passive safety
Fast-fission, M=10, ^{239}Pu	2	370	engineered safety
Power producer			
M=10	2	370	molten salt-passive safety solid fuel-engineered safety
Pure fusion			
M=1.34	11	2300	passive safety

AxiMirHybtalk.pptx Moir et al., May 16, 2011 LLNL-PRES-483633 16

Major issues addressed within the framework of the project are given below

Double Null divertor with long external leg and Vshaped corner is accepted.

Beryllium tiles with liquid lithium is used for edge plasma control.

Maximal heat flux density of 5-9 MW/m2 is evaluated by B2SOLPS5.2 and the Semianalytical Hybrid Model (SHM) codes for configuration with small plasma-separatrix gap.

Neon puff facility in vicinity of strike point is foreseen for detachment.

Mock-up of the water-cooled first wall element of DEMO-FNS with beryllium tiles was successfully tested.

No tiles lost the mechanical and thermal contacts at both 5 MW/m^2 (sustained 1000 cycles) and at 10.5 MW/m^2 (sustained 100 cycles).

Michael Tendler

Enclosure 2