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Approach to Remote Participation in the ITER experimental program. Experience from model of Russian Remote Participation Center.

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ITER - global international project

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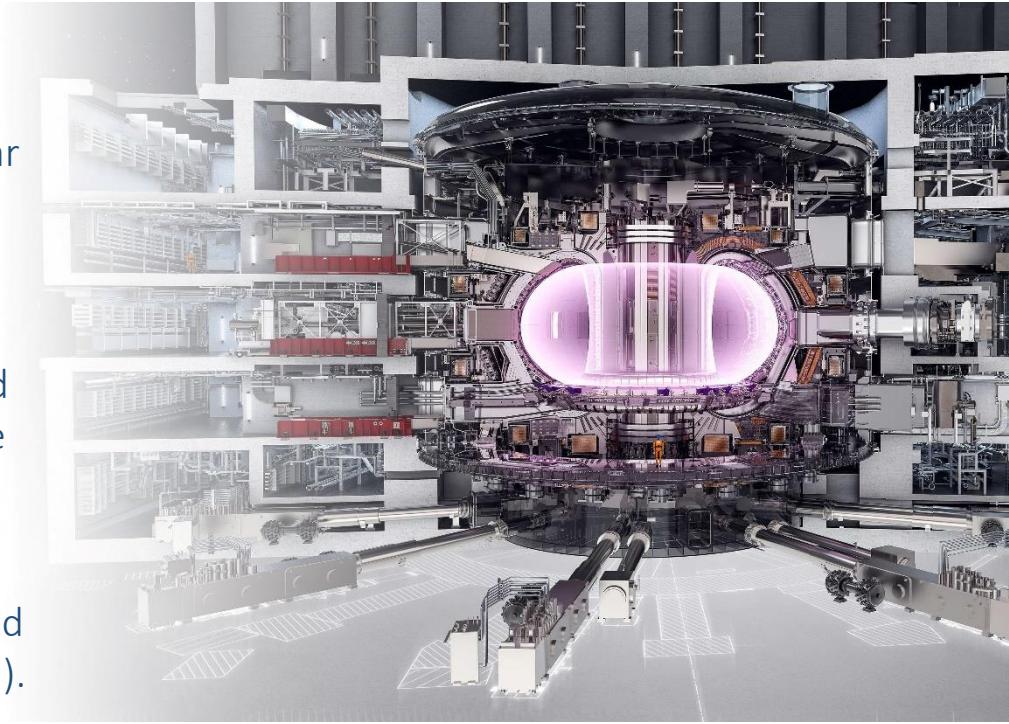
ITER - International Experimental Thermonuclear Reactor - an international project to create an experimental thermonuclear reactor.

ITER TAGET - to demonstrate the possibility of commercial use of a controlled reaction of a thermonuclear reactor and to solve physical and technological problems that may arise along the way.

35 countries participating in the project:
Russia, India, China, USA, South Korea, Japan and EU countries (plus Great Britain and Switzerland).



ITER - physical parameters

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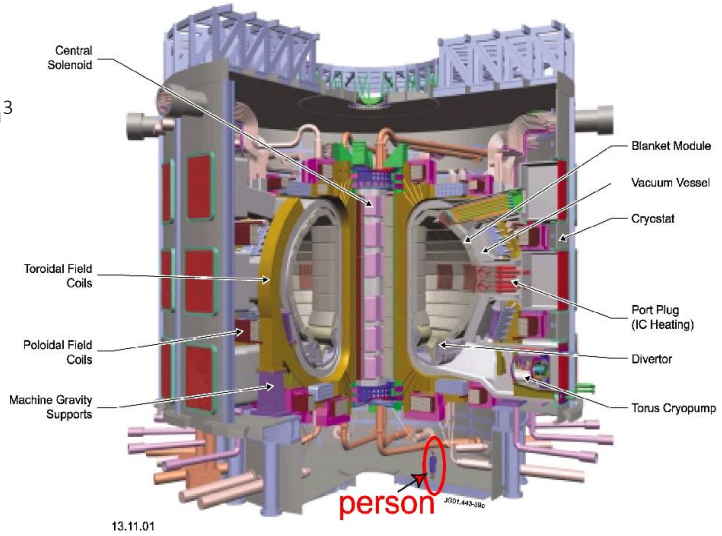
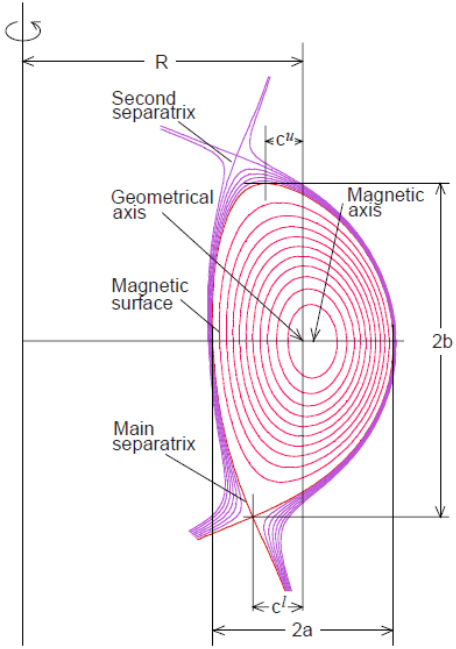
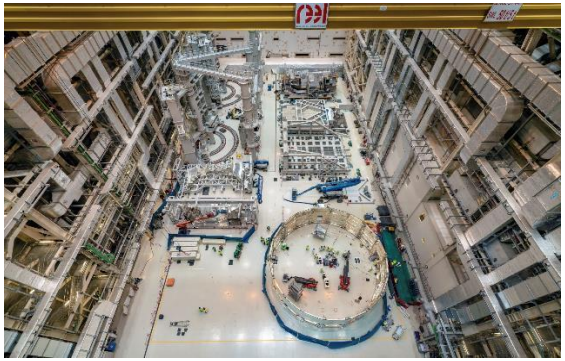
- Fusion power 500 MW
- Plasma temperature – 15 keV
- Working gas – D-T
- Plasma density (Line averaged) – 10^{19} m^3
- Plasma current – 15 MA
- Toroidal field – 5.3 T
- Plasma pulse duration ~ 3000 sec
- Auxiliary heating – 40-90 MW
- Plasma major radius (R) – 6.2 m
- Plasma minor radius (a) – 2.0 m
- Plasma volume – 830 m^3

- 1.5 x 10^{20} neutrons/sec





ITER today – reactor assembly



Data acquisition and control system in ITER

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- The ITER central control system provides interaction for more than 170 subsystems.
- 6 data transmission networks different in their structure.
- 5000 control racks (cabinets).
- Synchronization of systems with an accuracy of 50 ns, including a real-time plasma control system.
- More than 100,000 signals and several million variables.
- The expected total flow of the transmitted data is 20-500 GB / s.
- The possibility of archiving all "raw" data for post-processing is being considered.
- The approbation and development of system elements is carried out in many scientific institutions around the world (see figure).

The future of the ITER project

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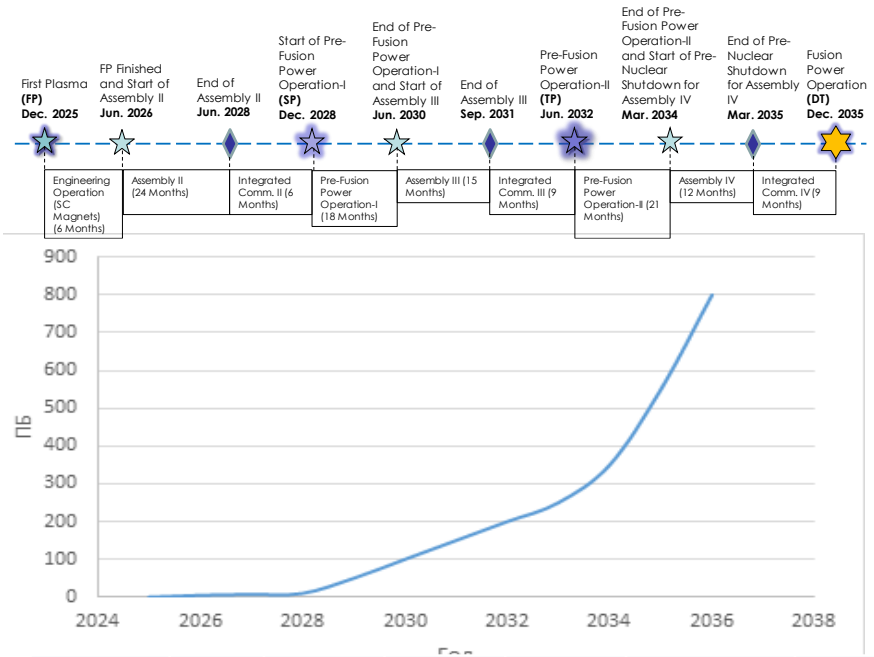
- The ITER scientific program is designed for 30 years.
- The result of the ITER project is the scientific and technical data that it creates during its lifetime.
- It is expected that the total transfer rate of scientific data within ITER will be about 20-500 GB / s, an increase in the volume of the scientific archive 90-2200 TB / day. The amount of experimental data from the ITER project (according to current estimates) will exceed 5000 Petabytes.
- Joint remote participation in an international experiment, including the transfer of the functions of a scientific coordinator from the ITER site to Scientific Centers in the countries participating in the project.



Stage	FP 2025	PFPO-1 2028-30	PFPO-2 2032-34	FPO-1 2036	FPO-2, ...,8	Total
Data (PB)	0.1-1	10-100	100-300	200-500	+500 each	5000

Background and Objectives for RPC

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ITER project has a lot of plasma diagnostics and technological systems Procurement Arrangements with all members. In nearest future (even today) we will need remote functions for commissioning of these PA's, future monitoring in scope of warranty coverage, maintenance support and ITER scientific collaboration.

From 2018 Russian Domestic Agency works on Prototype of Remote Participation Centre that covers these tasks to study and solve problems and borders on this way.

We do this work with ITER IO CODAC team and ITER IT Team. Work done under contract H.4a.241.19.18.1027 with ROSATOM and Task Agreement C45TD15FR with ITER Organization

Technical and scientific tasks to study

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- Modeling of Remote Participation Center
- Interconnection with ITER networks. Security issues in accordance with the requirements of cyber security standards. VPN, firewalls and routing challenges.
- Investigation of the data transfer via existing public networks (reliability, speed accuracy, latency, volume dependence, public networks interconnections problems and etc.)
- Test of ITER remote participation interfaces (Unified Data Access servers, Data Visualization and Analysis tools, etc.). Access to experimental data.
- Exploring the boundaries of participation. What we can and cannot do remotely.
- Participation in ITER main control room activities (remote copy of central screens and diagnostics HMI) and intercommunication.
- Local data processing with integration of existing data processing software (visualization, analysis, etc.) and Local Large-capacity data storage system.

The Remote Participation Center Model room

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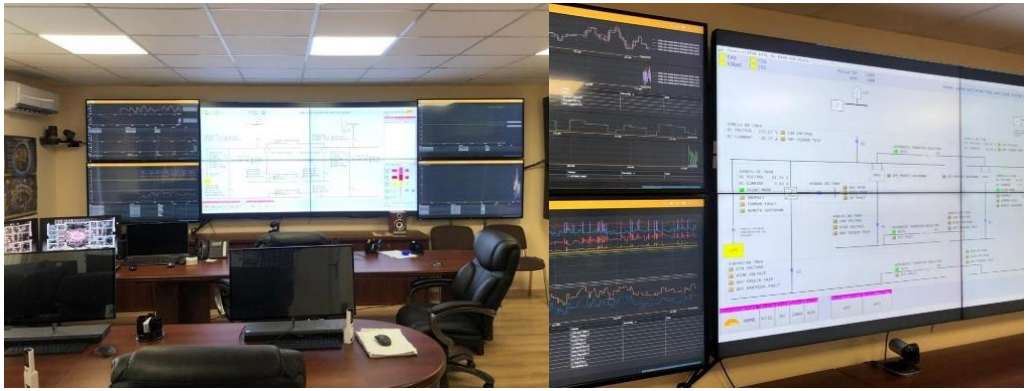
2018 – first approaches.

2019, 2020 – modeling.

TODAY - remote participation.



The Remote Participation Center Model room

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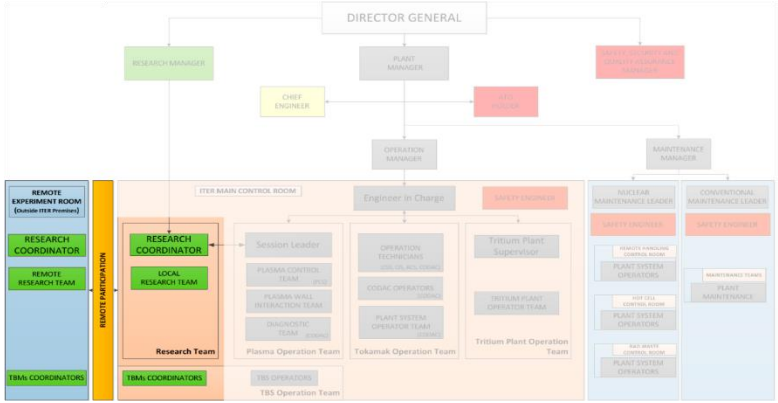
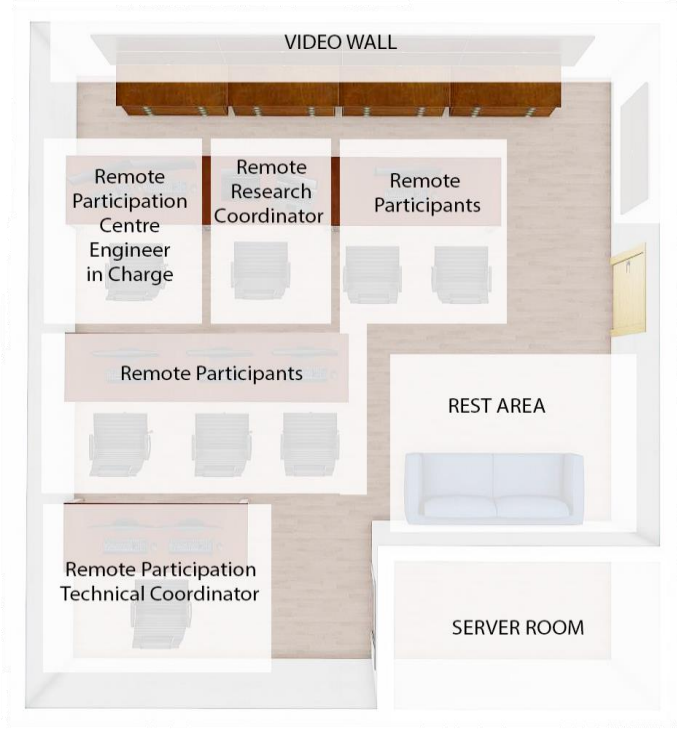
- Room with a total area of about 40 square meters. Including a server room of about 4 square meters.

- 7-8 places in RPC. Three dedicated roles.



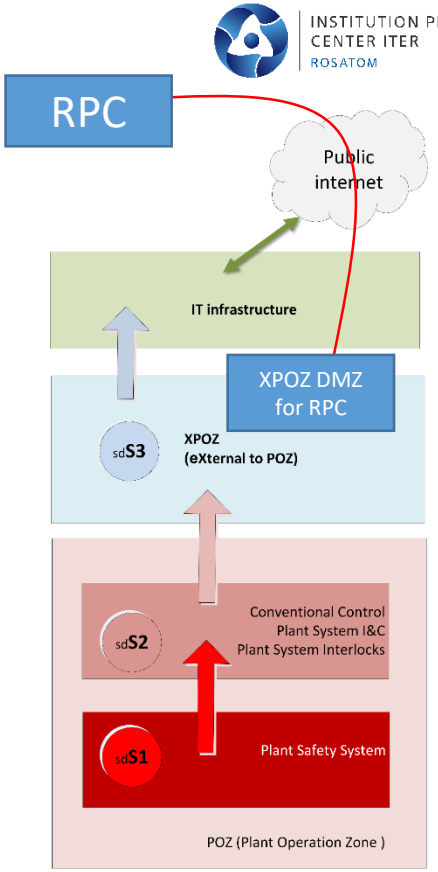


Network zoning in ITER

- ITER infrastructure zoning is assumed in accordance with the requirements of information security and IEC 62645 standard. This standard defines three security degrees (S1, S2 and S3), to which graded security requirements. ITER defined these zones and graded security requirements related to them as follows:

  S1 – Safety systems (POZ)
  S2 – Conventional controls & interlocks (POZ)
  S3 – External to POZ zone (XPOZ)

ITER go further - Anything outside S3 on ITER Site is IT zone. Remote participants moved to XPOZ DMZ zone between IT and S3.



RPC Model public networking

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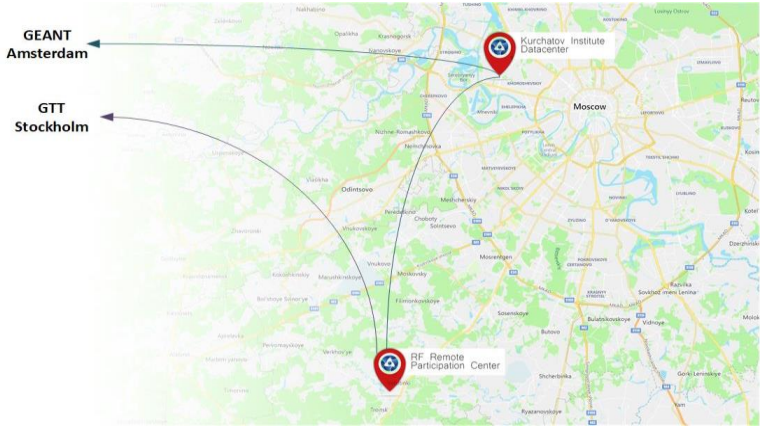
For testing purpose we create 2 separate L3 VPN over 2 separate connections to European Internet.

- via ROSTELECOM from TRINITI (Troitsk) to STOKHOLM GTT TER ONE public internet exchange point.

- via National Research Center «Kurchatov Institute» (Moscow) to GEANT exchange point in AMSTERDAM.

Distance from RF RPC to ITER IO for data travel is more than 3000 kilometers.



From IO to France:

From IO to Russia:

From RPC to Russia:

From RPC to France:

Links latency and hops

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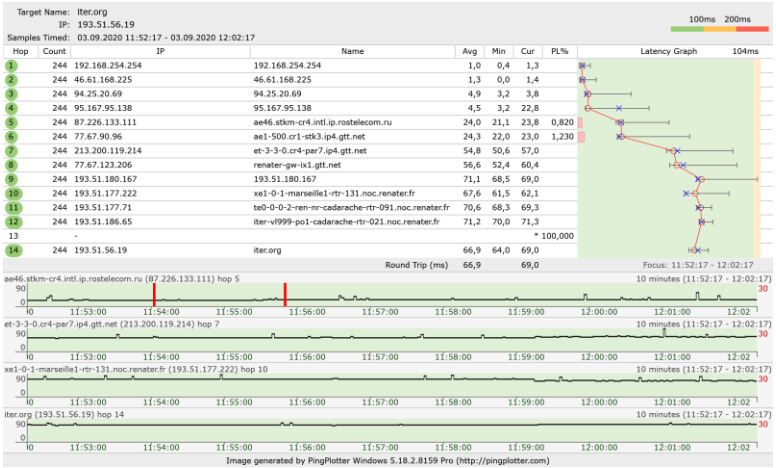
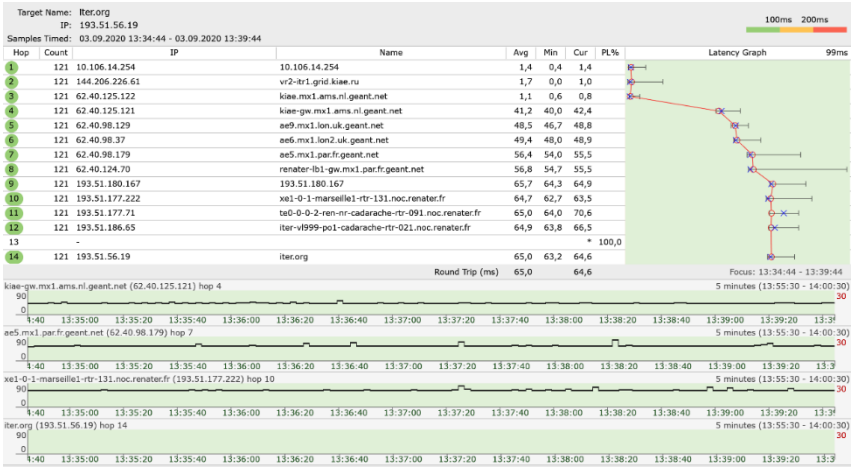
ROSTELECOM from TRINITI to IO - 66.9 ms average



L3 VPN tunnel Latency between host in RPC and edge host in IO 66.4 ms average.

National Research Center «Kurchatov Institute» to IO 65.0 ms average



L3 VPN tunnel Latency between host in RPC and edge host in IO 68.5 ms average.

L3 VPN speed test - single and multi stream

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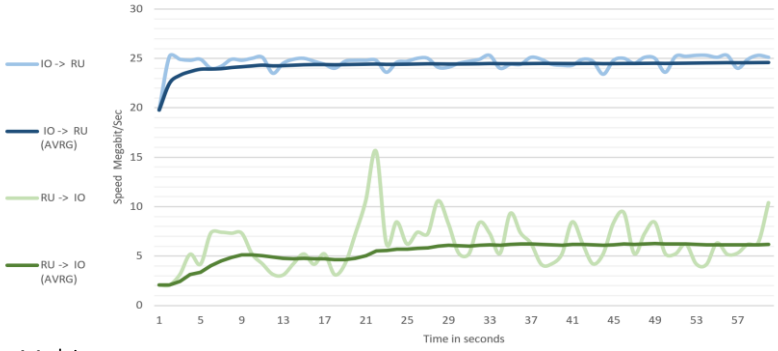
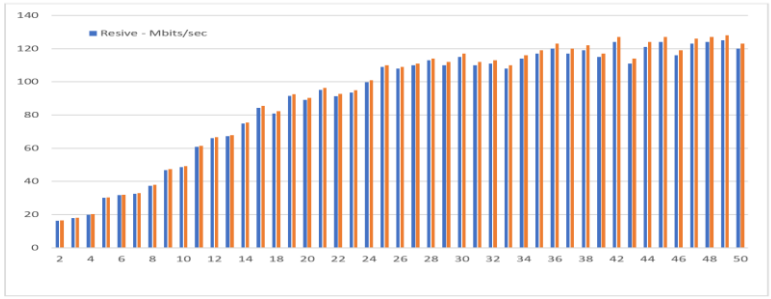
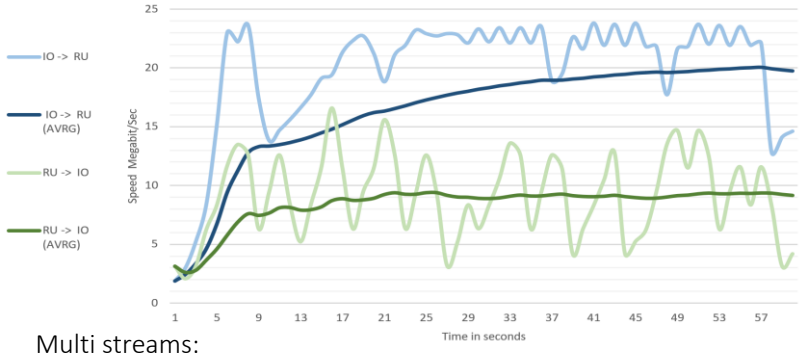
ROSTELECOM from TRINITI (Troitsk) to STOKHOLM GTT TER ONE
Single stream:



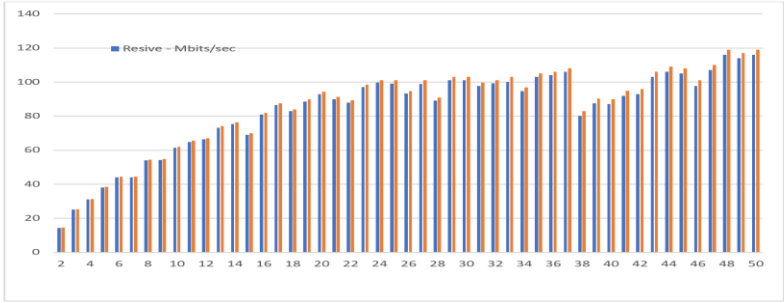
Multi streams:



National Research Center «Kurchatov Institute» (Moscow) to GIANT
Single stream:



Multi streams:



L3 VPN results

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- Latency is not a subject to worry inside L3 VPN.
- In general, the test shows that you we get about 25 stable megabits per second from IO to RPC within one TCP-IP stream.
- More or less stable full channel load approached at 24-28 simultaneous streams.
- Increasing the number of concurrent data streams allows for better performance in a tunnel where regular public(channel) providers are used. At the same time, more channel providers and traffic exchange points on the path of packets show more pronounced the effect. This effect probably in a peculiarities of channel providers bandwidth shaping, which underestimate the speed of one stream in order to prevent channel congestion and provide a more or less uniform bandwidth for all users. We think, dedicated L2-level channels will not be associated with such a feature.

Case of remote operation

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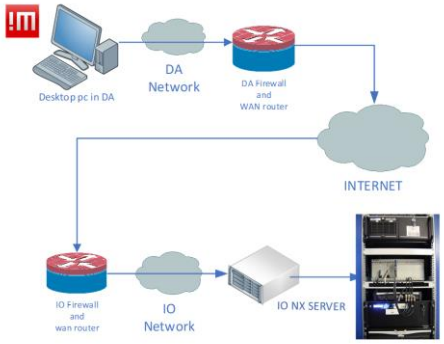
For use case of operation – remote user (operator) observes and controls some system on IO side. We perform test works with "DNFM reference diagnostic" system. The idea: remote user (operator) observes and controls DNFM reference diagnostic system and uses Skype for Business for parallel communication.

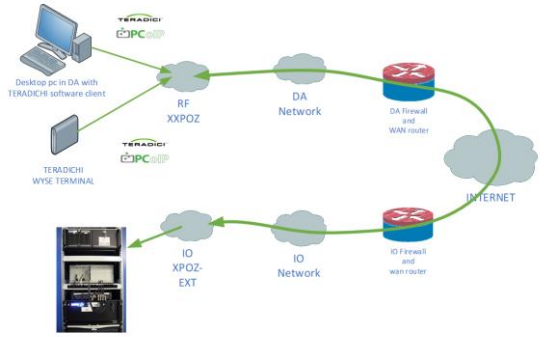
For participation environment, we look for three cases:

A. NX access to DNFM reference diagnostic over public internet using CODAC Development NX-Access.
B. Teradici software client over dedicated network connection.
C. Teradici hardware client over dedicated network connection.

CASE A



CASE B AND C



Remote operation results

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- Both NX and Teradici solution is useable for remote access to DNFM reference diagnostic.
- Teradici hardware client is more usable in Remote Participation Center if we need stationary workstation and Teradici software client is useless because it has no advantages in comparison with NX.
- NX is more flexible solution for remote participation outside the X.XPOZ zone or other dedicated network.
- These tests show also that communication (audio and video) between 2 groups and Screen sharing solution have to be investigated more deeply.

Live participation

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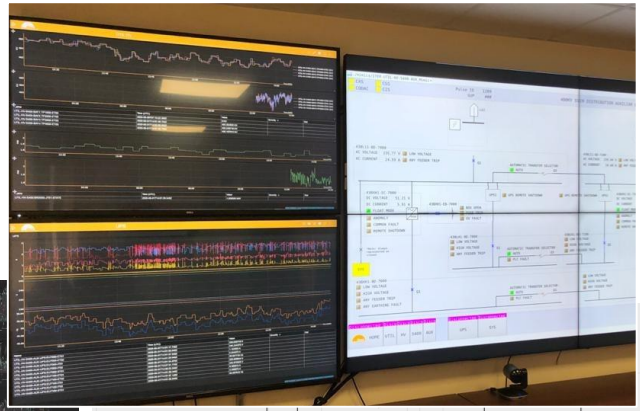
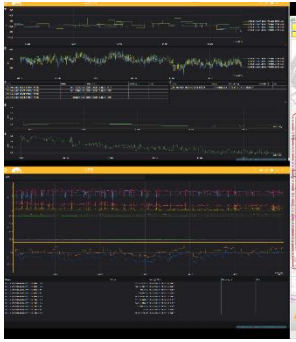
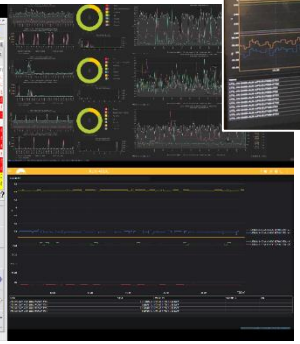
One of the main task of the Remote Participation Center is direct participation during the experiment, together with the main control room, as well as direct participation in various acceptance tests and commissioning. The goal is to provide participants with a fully immersive experience as if they were in the main control room.

Our experiments have shown - most stable and flexible option for demonstrating live data and creating a control room effect is the **EPICS gateway** for mimics and **ITER dashboard** for live data graphics.



In addition, **EPICS gateway** allows you to create, emulate and test your own mimics using ITER live data.





Remote Participation Center today

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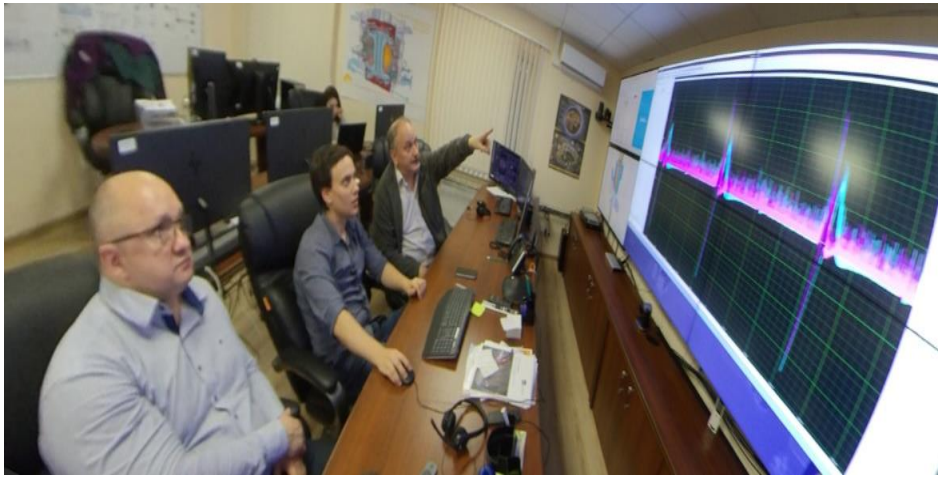
Today RF DA using Model of Remote Participation Center for live experiments. As example - number of successful remote experiments at IBR-2M reactor at Frank Laboratory of Neutron Physics (Dubna, Russia) and Neutron Generator at TRINITI (Troitsk, Russia) for testing some elements of ITER diagnostics. Our experience has shown that this experimental method is convenient. Allows to reduce unnecessary trips to the site of the experiment and at the same time does not reduce the effect of being present at the experimental stand.



Next step - Russian Remote Participation center for ITER

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- Creation time 2023-2024
- Room with a total area of about 140 square meters.
- Server room of about 100 square meters.
- More places for participants in RPC.
- 2 separate WAN - 10 Gigabit each.
- L2 tunnel to ITER.

And more…

Information and communication space for fusion research in the Russian Federation

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- Federal program. Creation time 2021-2024.
- Remote Participation centers in all major Institutions of fusion research in Russia.
- Joint laboratories based on existing and future experimental installations and stands with remote access from all RF Remote Participation centers.
- HPC cluster for data analysis and computing.
- Portal with experimental data, scientific publications, electronic reference books, list of scientific and experimental equipment and other public information.
- Joint planning and conducting remote scientific experiments, support for scientific decision-making, information interaction within the framework of experimental programs on controlled thermonuclear fusion.

Thank you!

OLEG SEMENOV

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