Progress with Remote Participation Tools in ITER Control System

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Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization

iter
china eu india japan korea russia usa

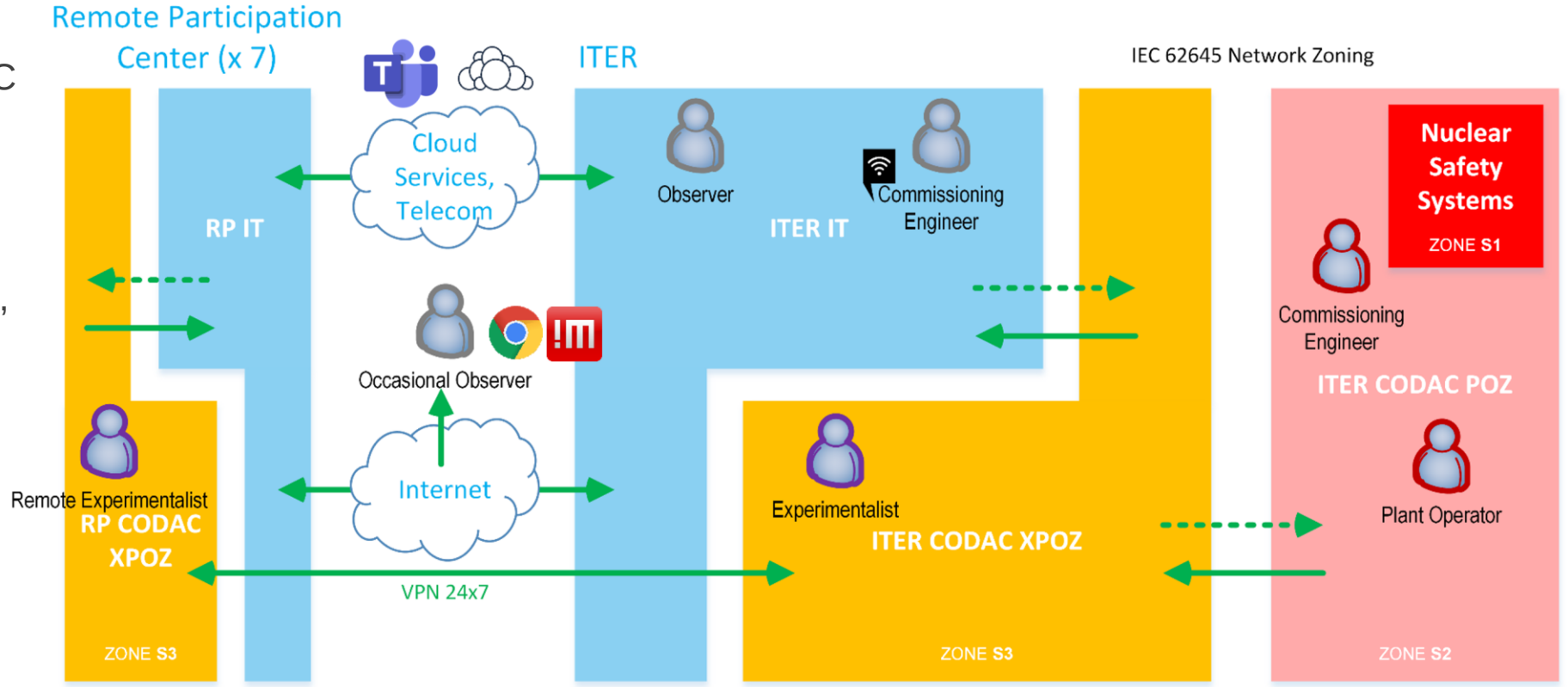
ITER CONTROLS AT A GLANCE

- Control system team formed from the onset of the ITER Organization in 2007. Circa **50 staff** as of today.
- Split in **independent tiers**: conventional controls (CODAC), machine protection, occupational and nuclear safety. Control technology between tiers varies as well (intentionally).
- The ITER Organization team is responsible for **central controls** + **integration** of local controls delivered "in-kind" (~170 subsystems).
- To assist with and steer I&C development, a "**CODAC Core System**" software suite is released yearly since 2010. EPICS (epics-controls.org) is used as a backbone. From 2016, "**CODAC Operational Applications**" are also released and gain momentum.
- Plant services have been integrated or under integration: electricity, building facilities, cooling water, cryogenics, occupational safety. Many others are being readied in the labs around the world. As of today, circa **950.000 process variables** out of projected 5.000.000 are online.
- Unprecedented international collaboration on plant system manufacturing prompts for **remote follow-up** needs during commissioning and operation.

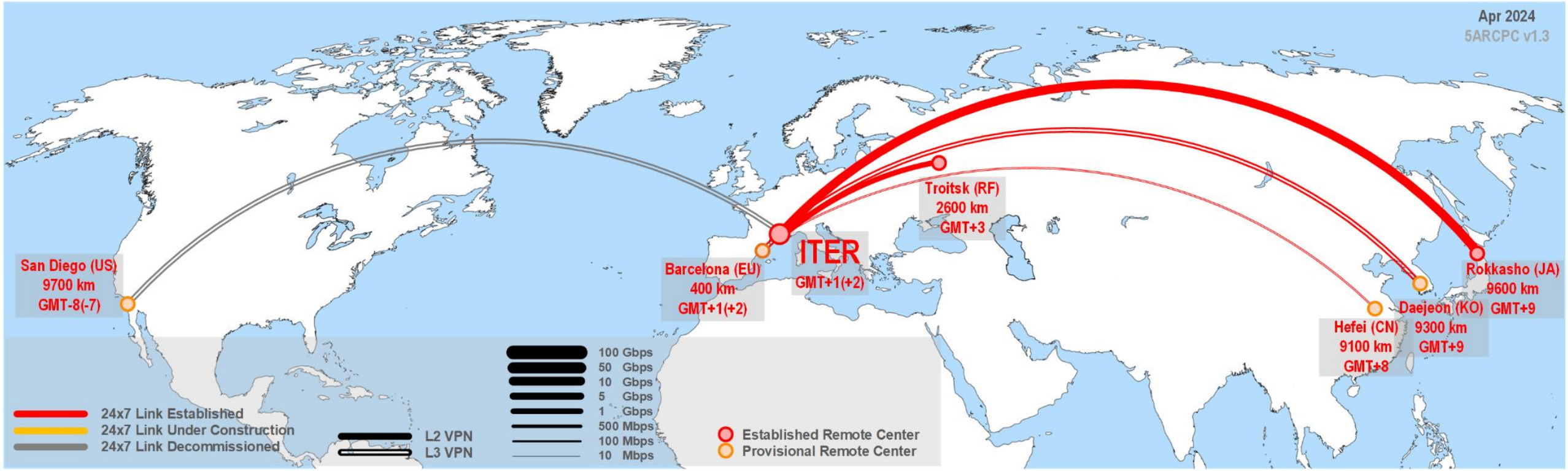
CLASSES OF USERS

1) **Plant Operators**: access from plant network (POZ, IEC 62645 S2) using control system (CODAC) tools
2) **Experimentalists**: access from experiment preparation and analysis network (XPOZ, S3) using CODAC tools in read-only mode
3) **Occasional Users**: access from office network / internet (S4) using web / remote desktop tools

Network zone extension to a remote site is done using a VPN (zones S1 / S2 require on-site presence)



ITER REMOTE PARTICIPATION CENTERS (RPC) AS OF TODAY



- **Japan**, **Russia**: national program / financing / leading organization defined. Connection and deployment done
- **EU**, **South Korea**, **China**: temporary / model centers (T-RPC) deployed. National programs under development
- **USA**: T-RPC done under contract 2020-2021; on hold as of today pending internal resource planning in the US
- **India**: to be decided

ESTABLISHED REMOTE CENTERS

Established RPCs (Rokkasho, Troitsk) are operation-ready facilities

Rokkasho, Japan; 9600 km; GMT+9

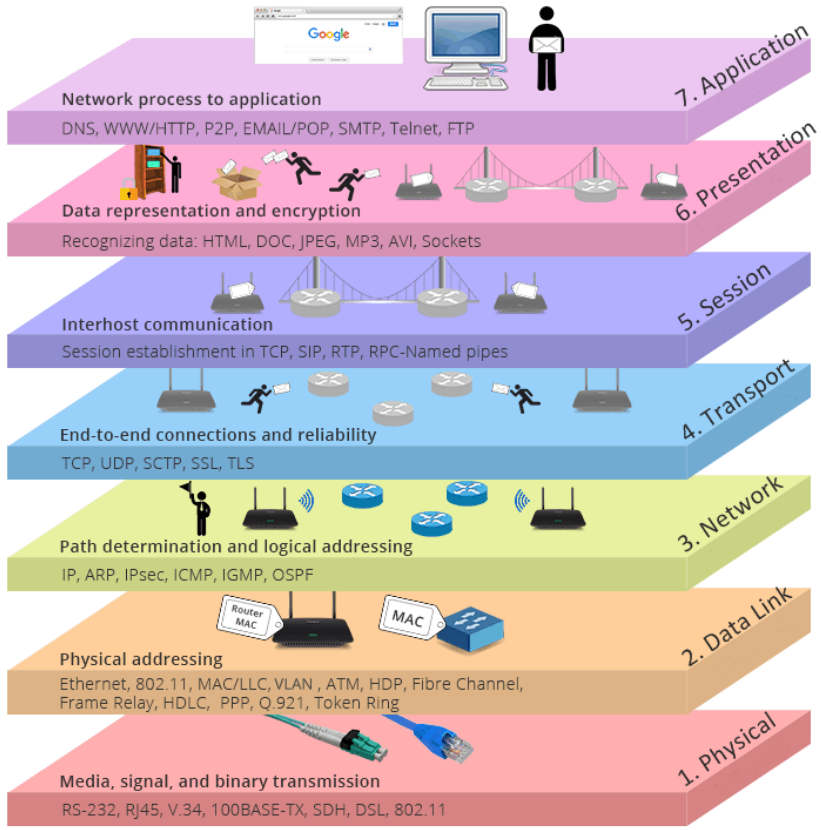
Troitsk, Russia; 2600 km; GMT+2/3

Temporary RPCs are virtualization hosts plus one–two CODAC terminals in laboratory environment

Daejeon, S.Korea; 9300 km; GMT+9

Image credits: QST, Project Center ITER, KFE

TYPES OF CONNECTION



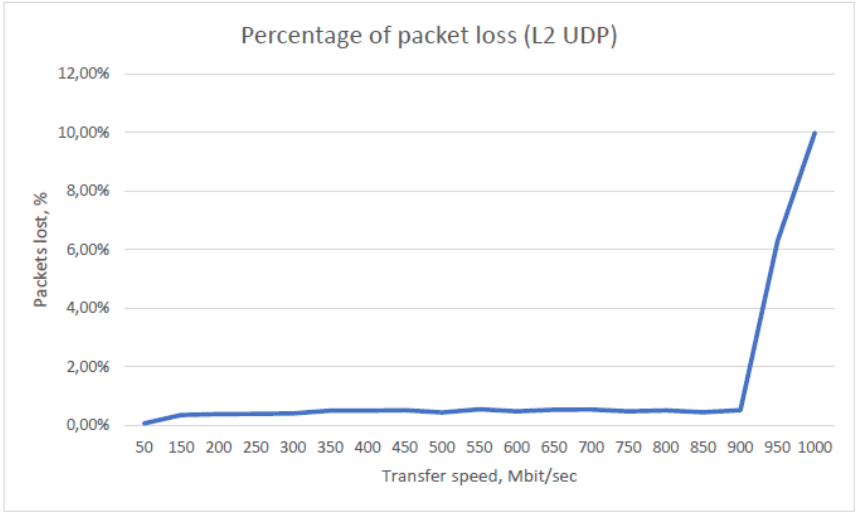
OSI model. Image credit: fs.com

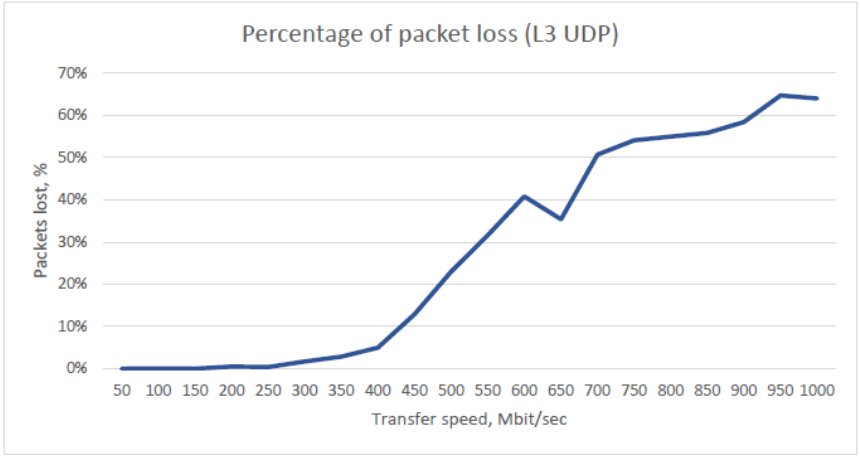
🡐 **L7**: Occasional users:
HTTPS / HLS / SSH / NX

🡐 **L3 VPN**: RPC users

🡐 **L2 VPN**: RPC data sync

Inside a VPN could be any type of control system traffic (EPICS, real-time network, data streams, …)





- L3 VPNs are easy to set up
- L2 VPNs are preferred for bulk data transfers

MARSEILLE CONNECTION

ITER is located in a rural area with conventional business network availability (tens of Gbps).

Works have been done in 2022-2023 to lay **dedicated redundant fiber** optics to Marseille area (80 km from ITER). As a result, ITER has got 2 x 400 Gbps connectivity readily available.

Marseille is an international network hub with research networks and cloud providers already present with hundreds of Gbps capacity.

In 2024 we plan to move ITER remote experiment center in Rokkasho, Japan to **100 Gbps** connection end-to-end (9600 km from ITER).

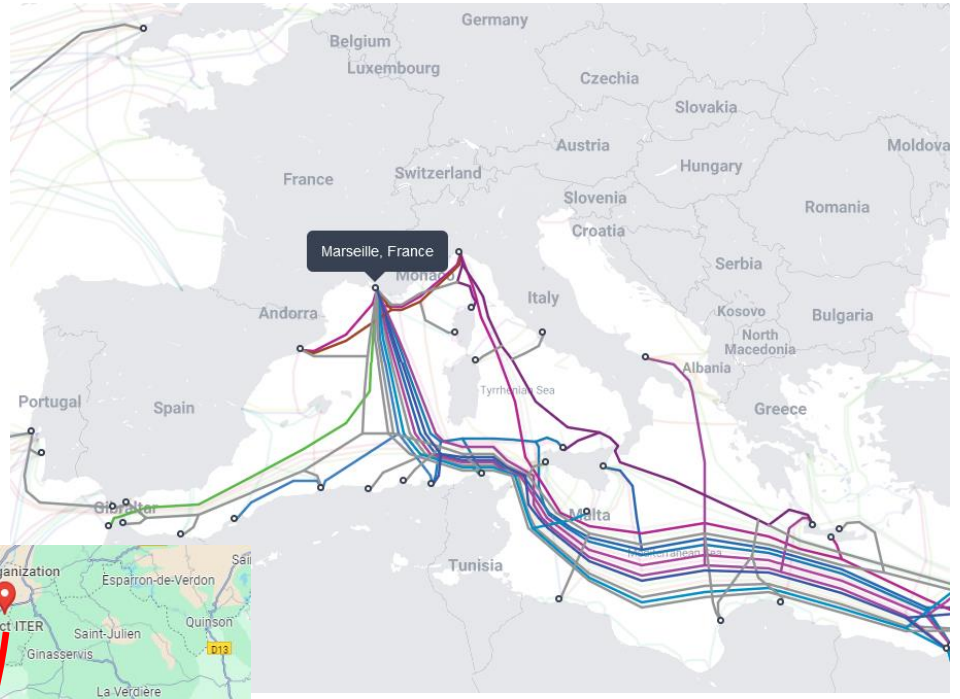
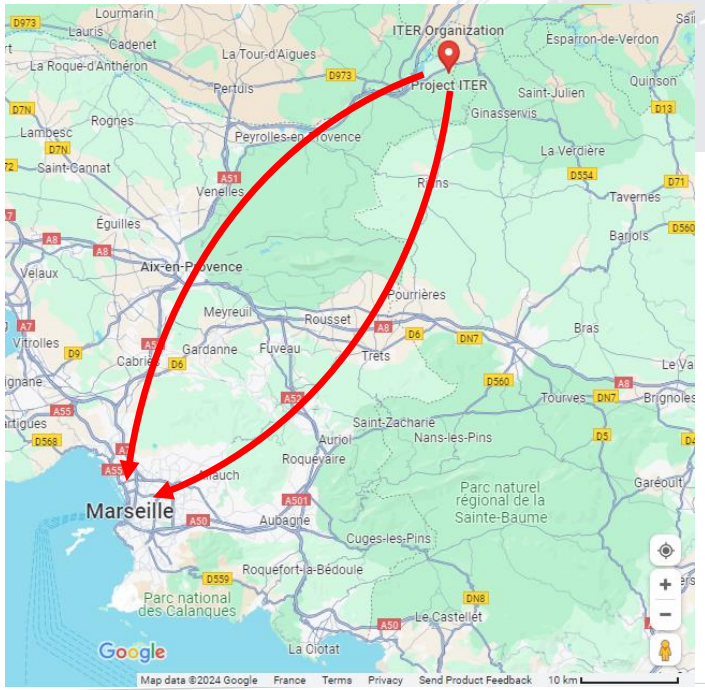


Image credit: submarinecablemap.com

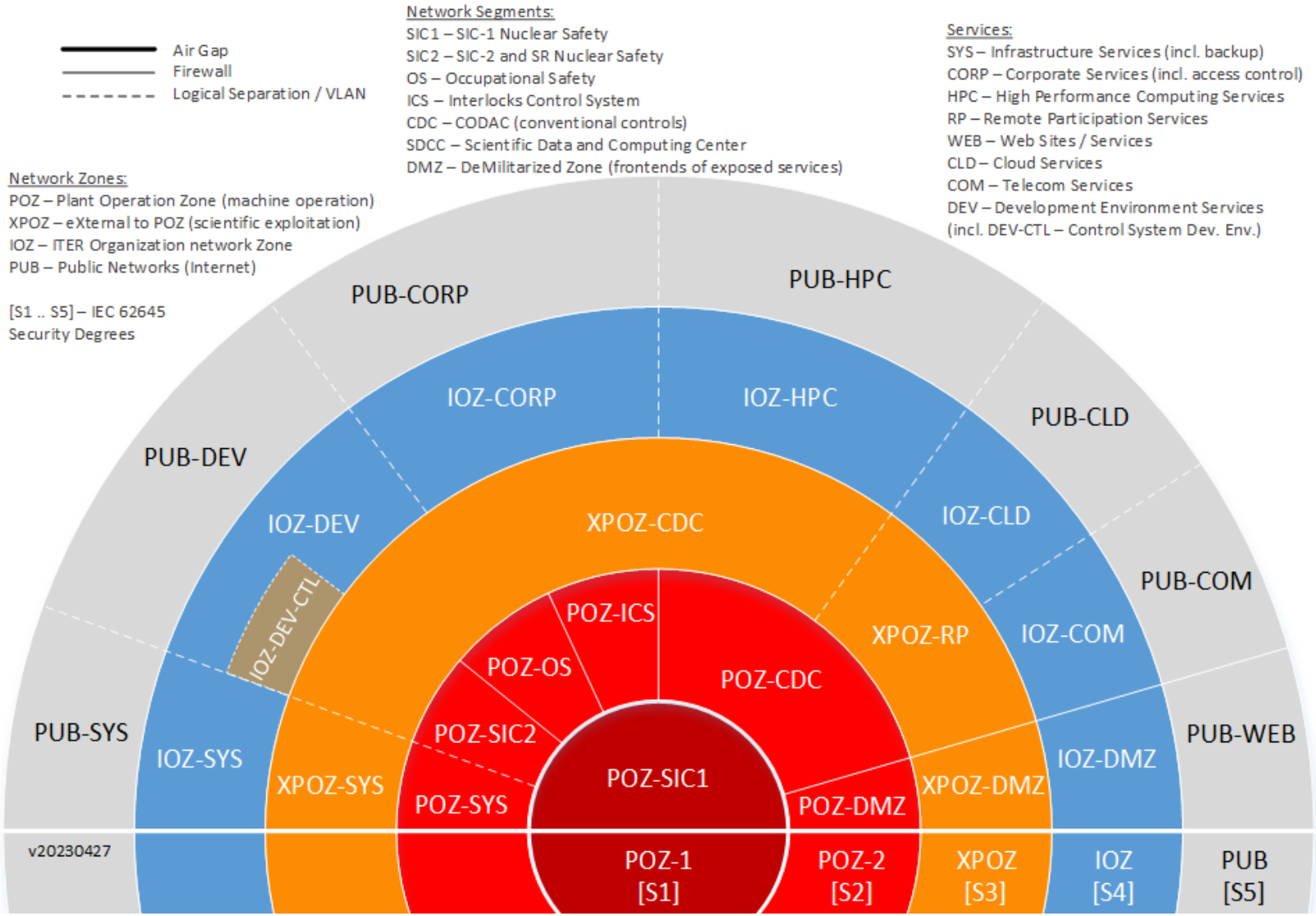


NETWORK ZONING: DEFENCE IN DEPTH

Significant work has been put into **network segregation** according to IAEA guidelines and industrial standards. Role-based access control has been put in place. Operators work under personal accounts; no shared accounts.

During active commissioning it is hard to strike balance between needs for quick turnaround on changes vs strict computer security. Remote connections are controlled.

The implementation is being periodically audited by an external computer security auditor (latest one in 2024).

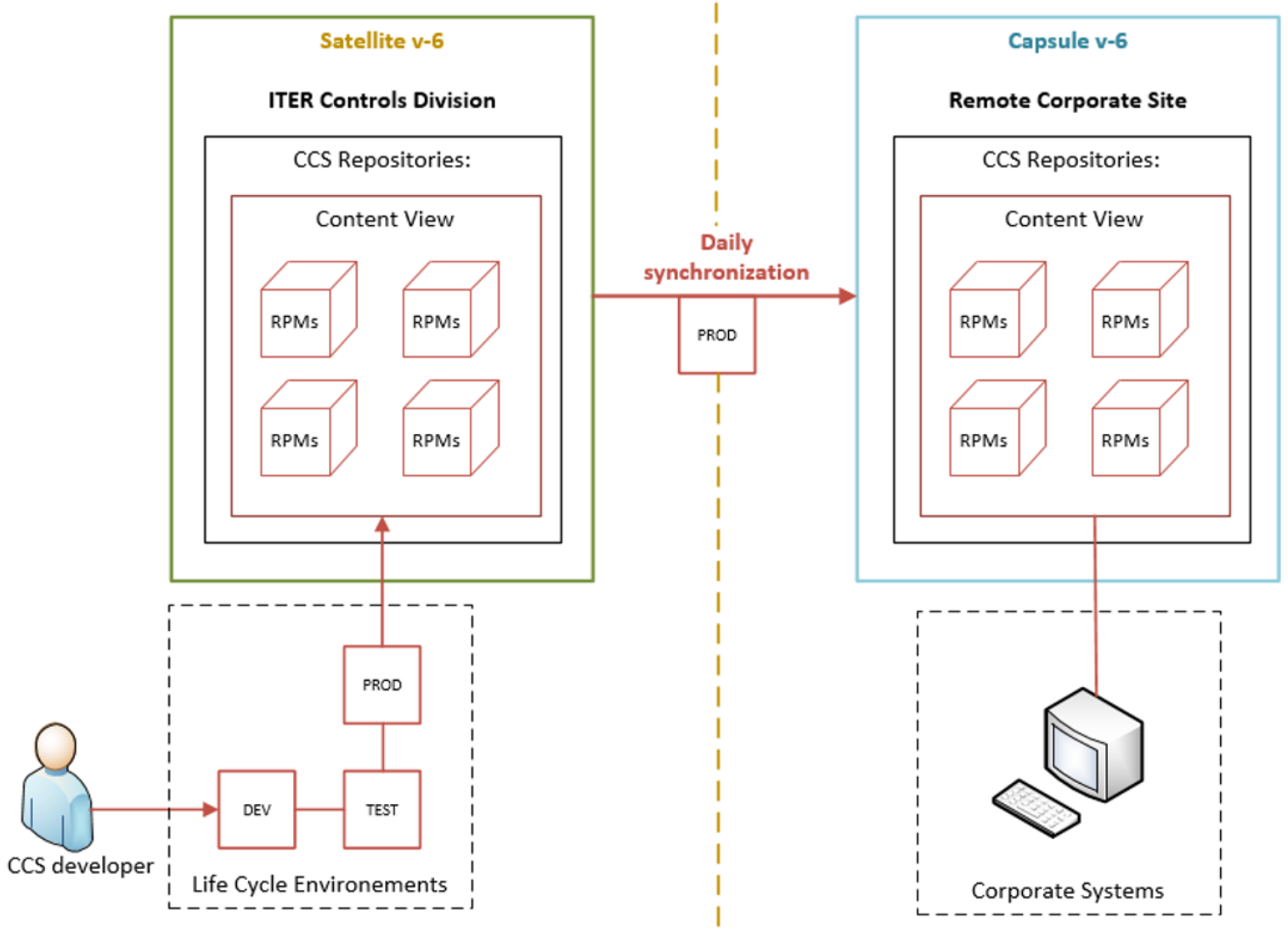


STANDARDIZED DEPLOYMENT

All changes are tracked in software version control systems and in action tickets. All files on production systems are made part of Linux RPM packages deployed via central repository; no stray files lying around.

All third-party repositories are mirrored and peer-reviewed by ITER. No public repository is used to install a production server or controller.

Because remote centers are connected via VPN, we extend our deployment infrastructure to them using standard Red Hat Enterprise Linux technology and deploy them using the same methods as at ITER.



COMMUNICATION KIT FOR CODAC TERMINALS

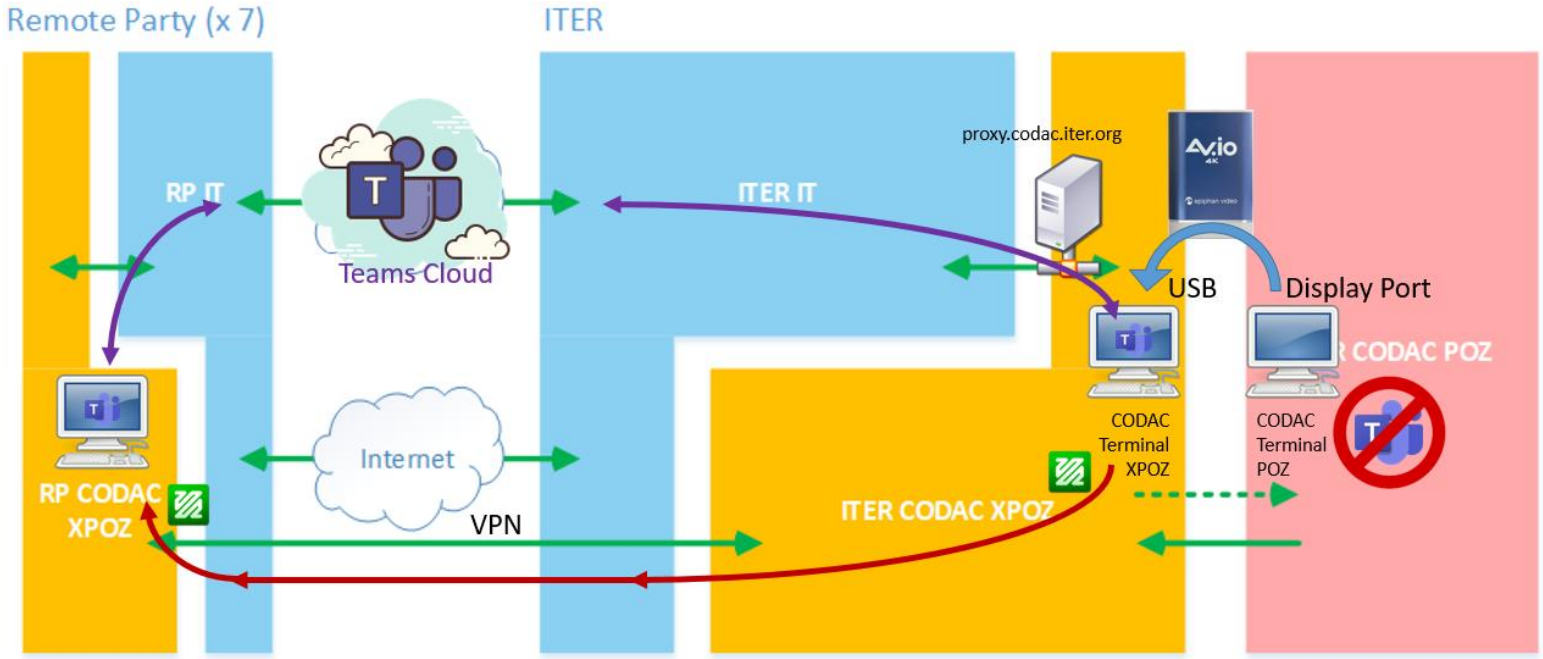
A standard CODAC terminal is located in a plant network (POZ) – not suitable for communication with external world.

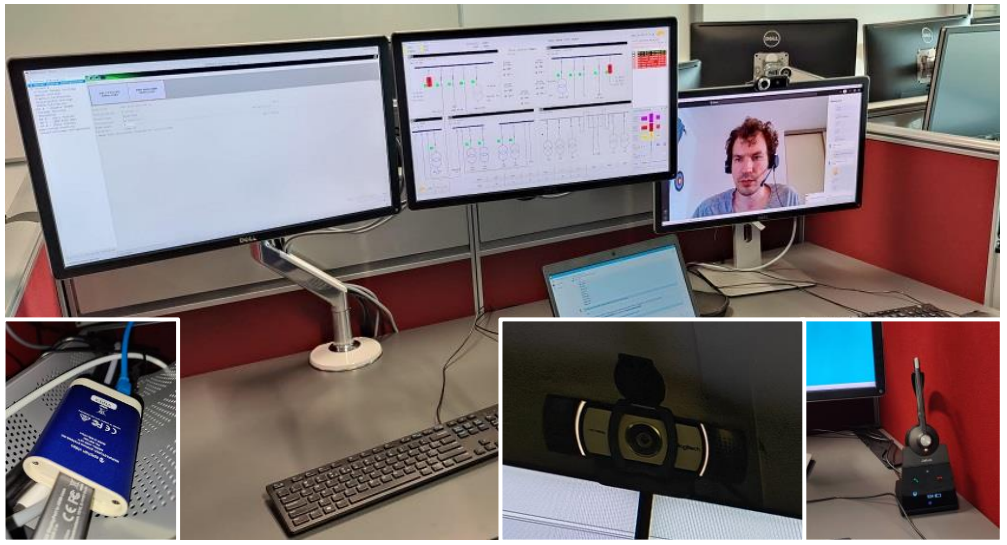
Options exist to propagate control system traffic to external networks (XPOZ) and deploy read-only terminals.

Such terminals could then be equipped with a “communication kit”:

1) a long range single ear DECT headset
2) a full-HD wide angle web cam
3) a video grabber to stream the controlling terminal’s screen cast beyond plant network

+ software: Microsoft Teams for Linux; video clients.





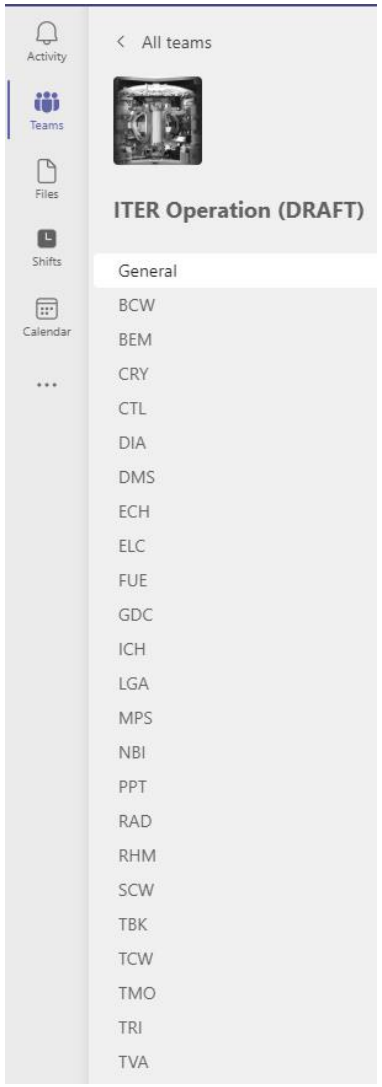
MICROSOFT TEAMS FOR CONTROLS

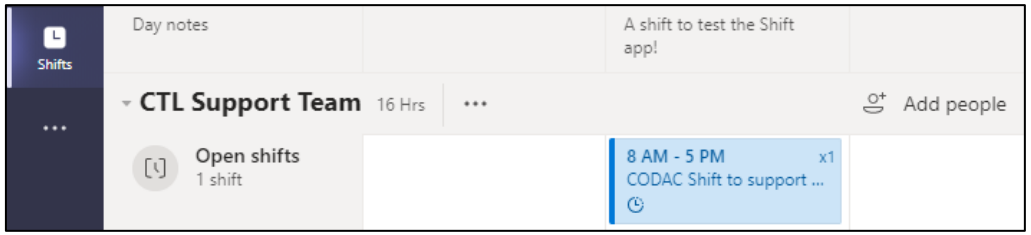
ITER switched to MS Teams for office communication. Teams have many out-of-the-box **features** which could be of use to support plant operation:

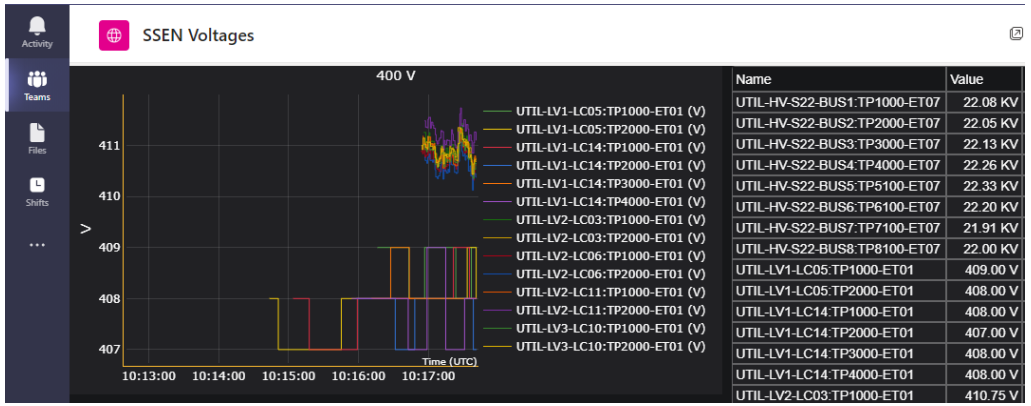
- Communication channels per plant systems
- Display of web-based data visualization directly in Teams app
- Built-in Shifts support
- Aids with project / resources planning
- Sketch boards
- File sharing, collaborative editing
- Live subtitles and transcripts – very useful in ITER context

… but also **drawbacks**:

- Cloud-based, meaning uncontrolled availability
- No fast switching between calls or support for parallel calls
- No support for 4k video
- Cumbersome integration of users from other organizations





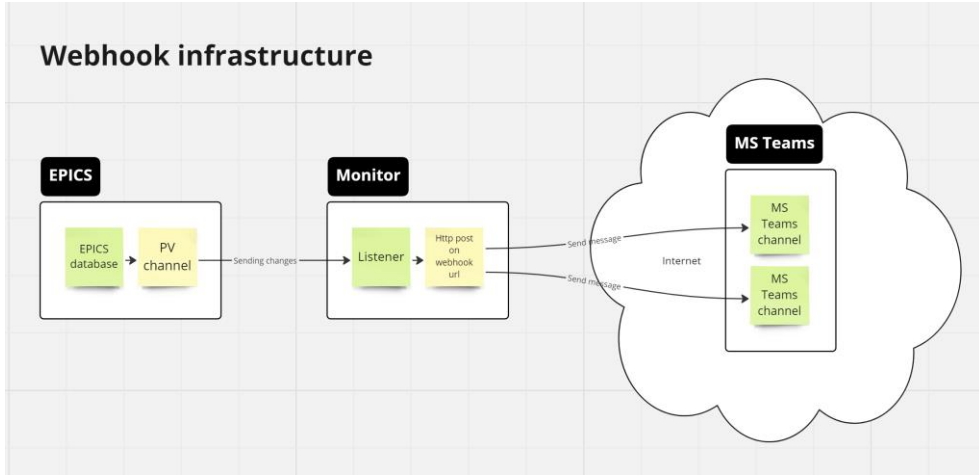


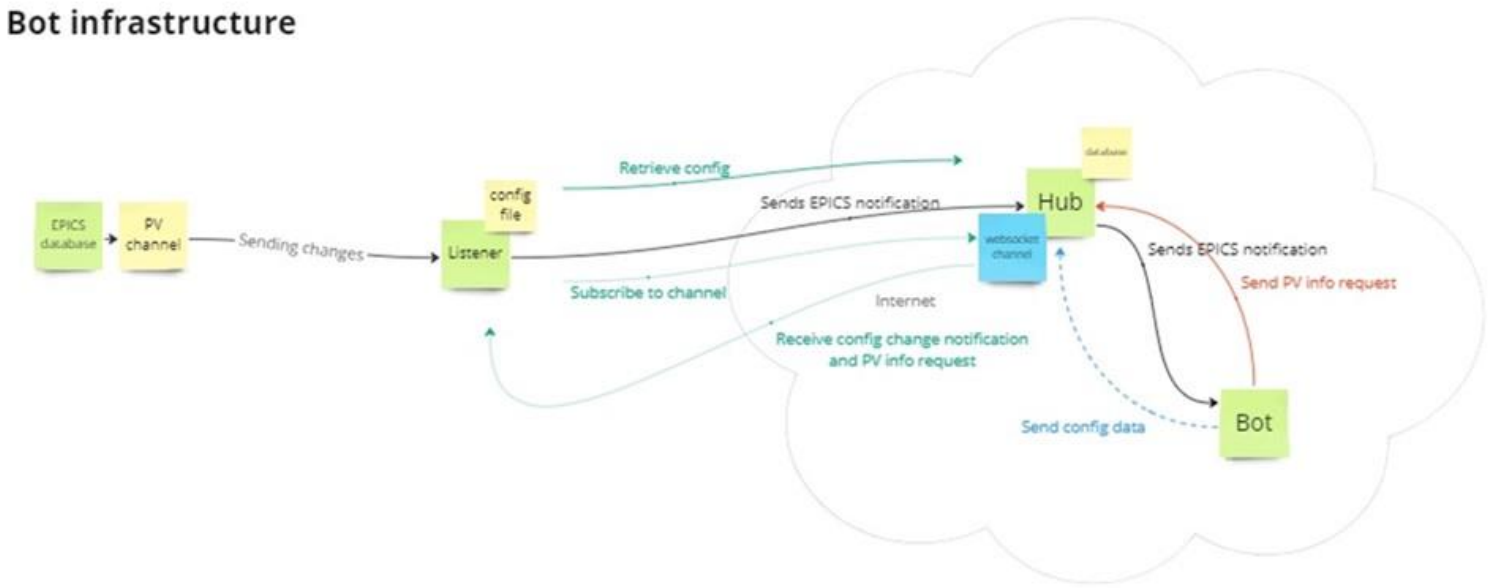
CONTROL SYSTEM ALERTS IN MS TEAMS

An on-call team may have interest in receiving significant control system events as messages in Teams. At least three different possibilities exist:

1) Each channel has an associated **email** in Azure, so email-based alerts could be relayed to channels
2) Calling a **web hook** in Azure to post a message (a typical IoT approach)
3) Deploying a **bot** application in Azure. Bots could offer more features, such as dynamic subscription

We made a prototype bot application posting EPICS alarms into Teams.





EPICS DIODE

EPICS traditionally uses "**EPICS gateways**" to structure a large control system network. This bi-directional software was not designed for exporting live traffic across network zone boundary. A 2020 security audit highlighted it as a risk.

In response, ITER has developed an "**EPICS diode**" — a software which converts bi-directional EPICS TCP/IP traffic into a unidirectional UDP stream and then back to the original protocol, at expense of some features.

A standard industrial **hardware diode** could then be inserted in the middle to further reinforce the security, if needed.

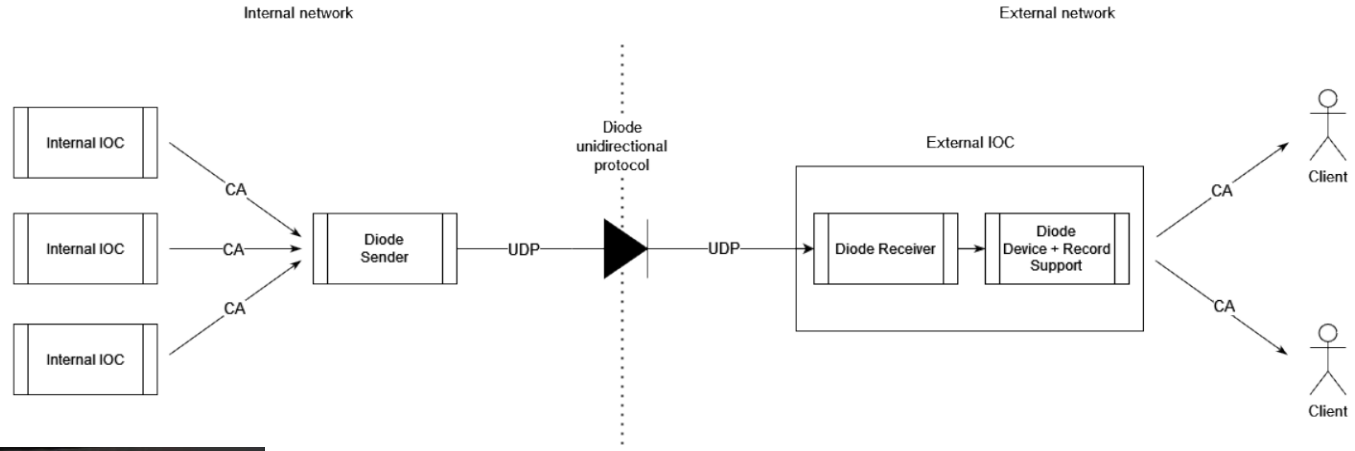
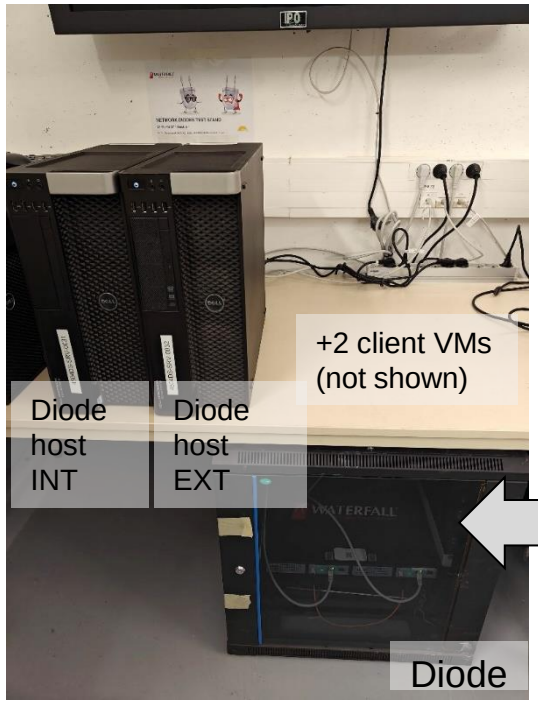


Figure 1 EPICS Diode basic architecture

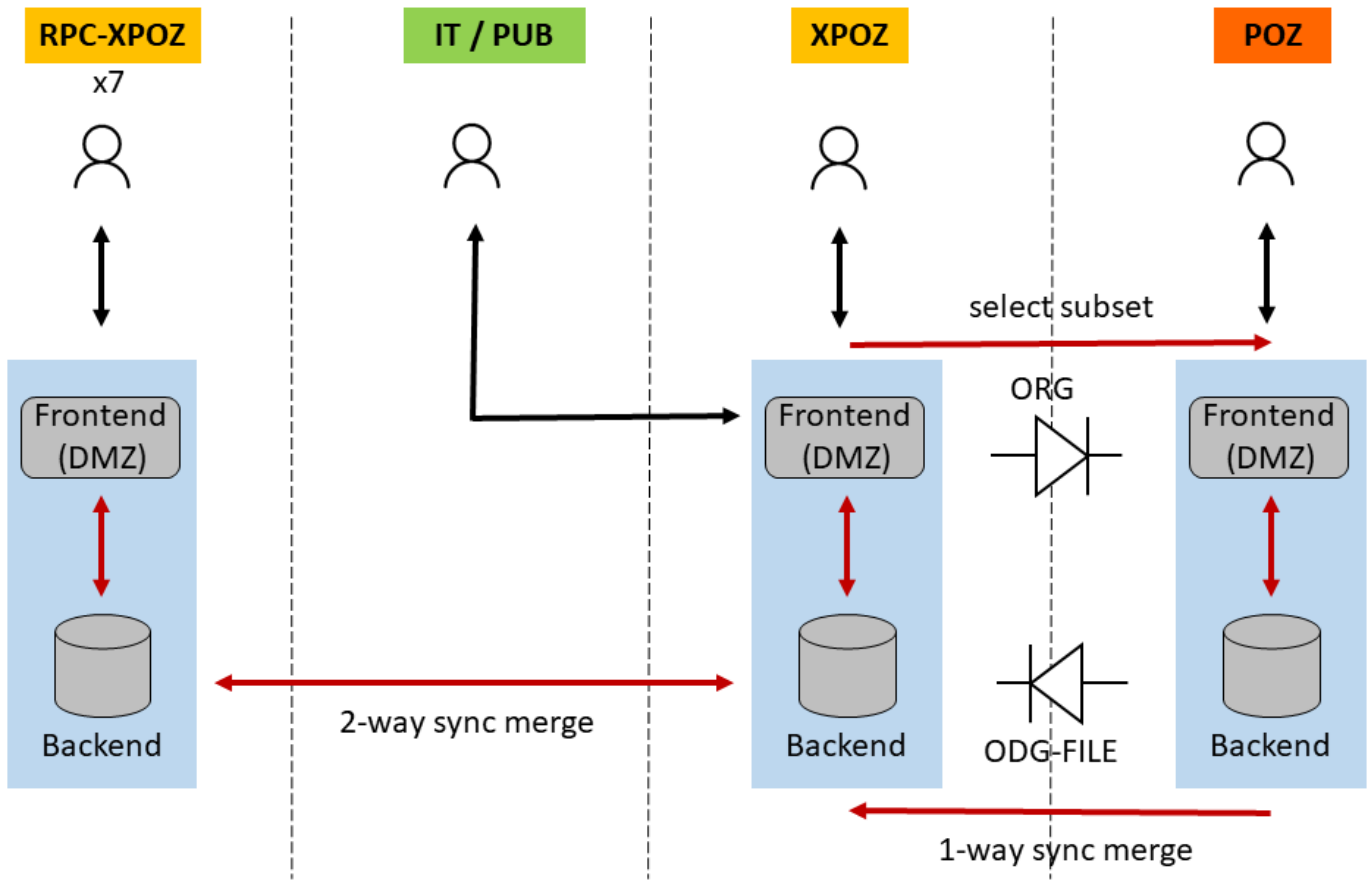


“CONFIDE” – CONTROLLED FILE DELIVERY AND EXCHANGE

Even if all software and configuration are packaged in RPMs, a flow of files (screenshots, snippets, manuals, notes, …) between operations is needed for efficient cooperation.

The idea is to replace email, “scp”, USB stick, etc file traffic in a controlled network and to reduce chaotic use of shared folders. It could be seen as a “Dropbox for operators”. The actions behind the scene are access control, access logging, antivirus checking, automatic expiration, etc.

We developed a prototype software based on an open-source version of ownCloud Infinite Scale. ownCloud’s federated infrastructure fits well with the concept of distributed remote centers. Currently the server part is done, and clients need more work.



VIDEO DISTRIBUTION SERVICE

There are identified needs for video processing in a fusion experiment:

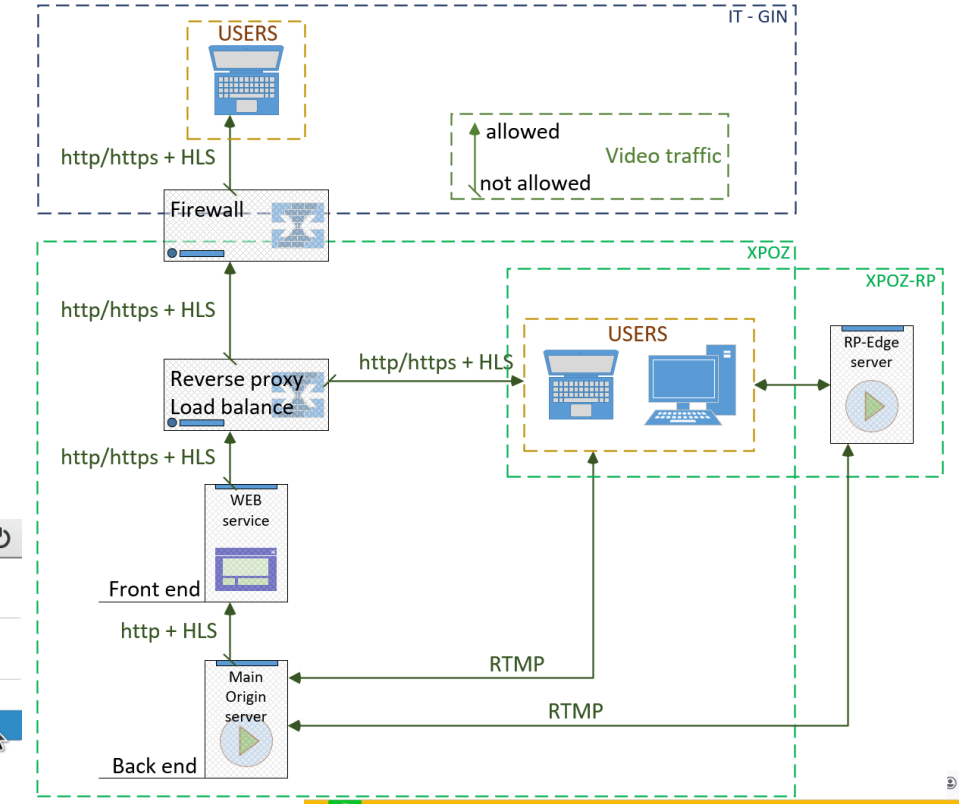
1) Images from **scientific instruments** like diagnostic cameras → handled with a high-performance archiver

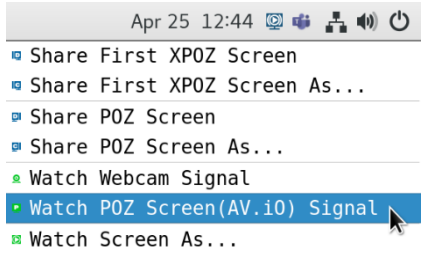
2) Images from various **process / people surveillance** cameras. Because cameras become increasingly widespread, the demand for this has grown up significantly

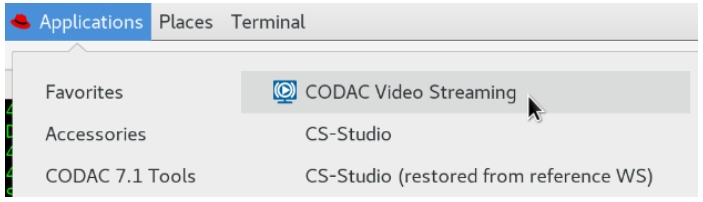
3) Communication needs: calls, screen sharing, video wall composition, …

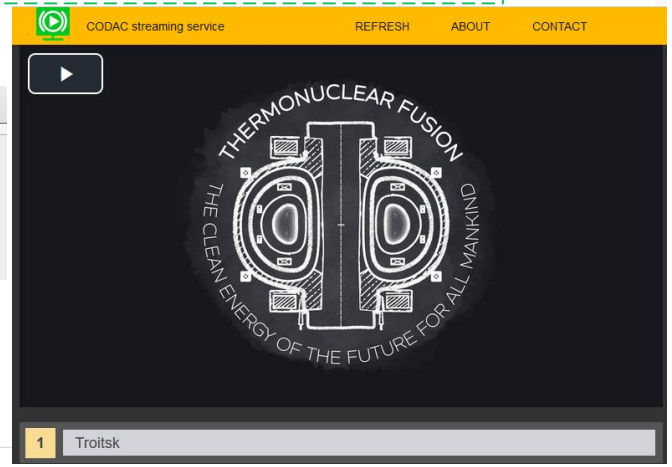
We looked into ##2–3. Unfortunately, MS Teams deliver full-HD resolution max, and with adaptive (=poor) frame rate. While this is OK for calls, for 4k @ 30 Hz (CODAC standard) it is not sufficient. So we deployed our own **video distribution service**, based on SRS (github.com/ossrs/srs, server) and FFmpeg (ffmpeg.org, client).

The service is fully deployed in XPOZ (external network) where users are; plant processes – if any – connect through hardwired connections (HDMI / DisplayPort).









MOBILE TERMINALS

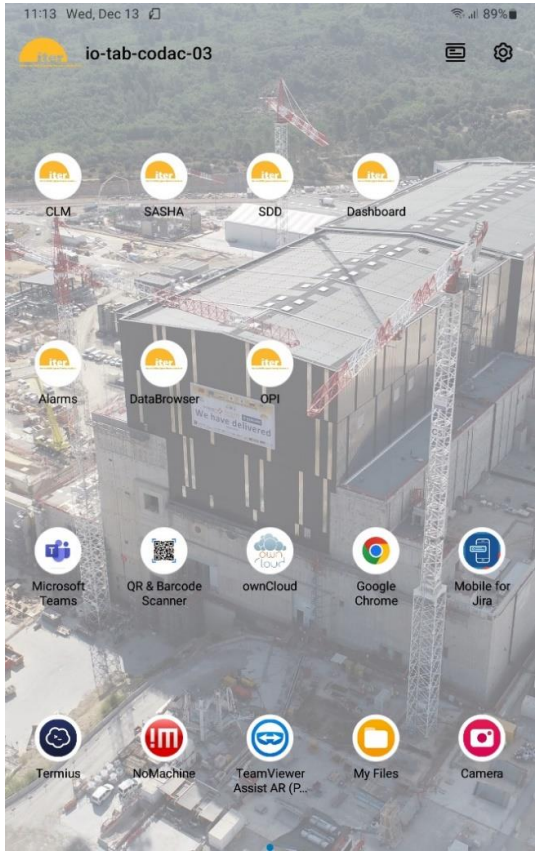
Many people want to use wearables (smart phones, tablets, …) to look at live control system data. Because these devices connect via Wi-Fi or 4/5G, they are always considered as remote (an “occasional user” case).

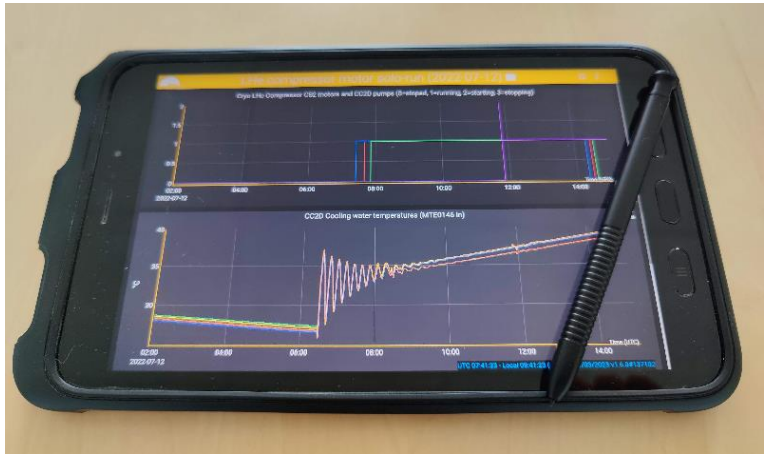
We made a dedicated profile for tablets, pre-loaded with applications relevant in CODAC context (mostly web).

We also experimented with augmented-reality (AR) look-through glasses. These could be useful in two scenarios:

1) As a hands-free headset when talking to a control room or remote expert (see next slide)
2) Similar to tablets, web applications could be run on glasses to visualize portions of live data. QR codes could be used for quick access

More advanced uses are possible but require dedicated programming in mobile environment.





B04 450504-CU-0004 monitoring

Name	Value	Time (UTC)
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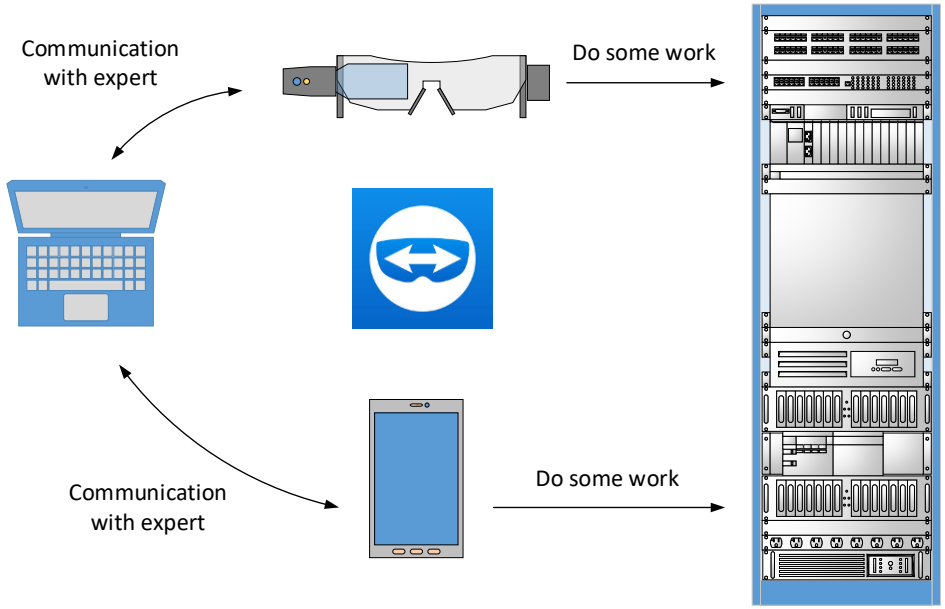
D1-I9-SYSM-4504-UC:PSH0001-HTH-CY1	Close	2022-06-08T12:14:24.105Z
D1-I9-SYSM-4504-UC:PSH0001-HTH-CY2	Close	2022-06-08T12:14:24.105Z
D1-I9-SYSM-4504-UC:PSH0001-HTH-FAN	On	2022-06-08T12:14:24.105Z
D1-I9-SYSM-4504-UC:PSH0001-HTH-TT	23.144531	2022-06-09T08:19:37.322Z

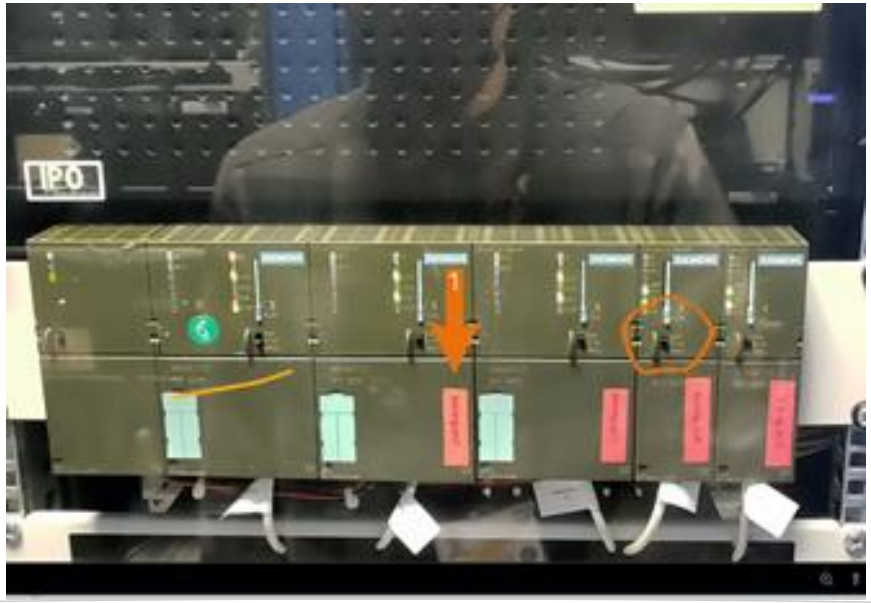
REMOTE ASSISTANCE

Augmented reality moves remote assistance to a whole new level. A remote expert could intervene online and do additional things apart from communication:

- Point a technician to particular items of interest (knobs, indicators, wires, …) – both live or on a frozen picture
- Send information like schematics to the technician's screen
- Remotely take high quality photos or videos, record sessions
- Even operate some peripherals like a light

We used "TeamViewer Assist AR" software. It works well both with tablets and with smart glasses.





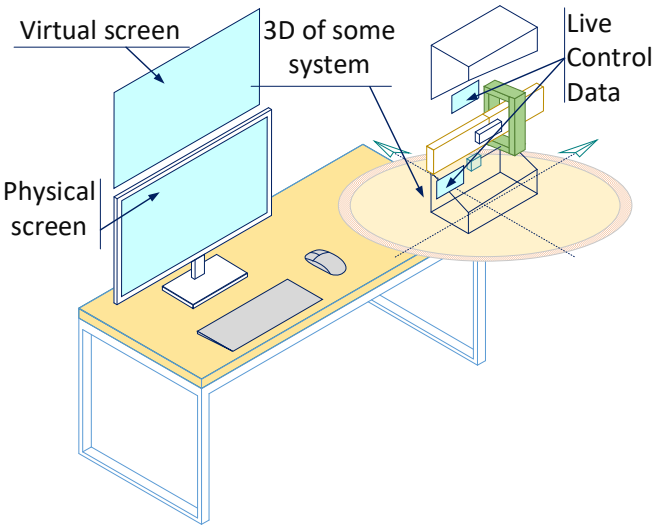
HYBRID WORKSTATION

Going one step further, one could imagine animating some 3D or virtual reality (VR) scene with live control system data. This could be used in combination with a traditional computer terminal, or the entire terminal could become virtual.

We do not plan implementing controls using this way – just observation, but the technology is capable of making controls too.

In this example positions and loads of heavy-duty cranes in the ITER assembly hall are sent to a remote center (2600 km) and used to animate a 3D model of the hall using Unreal Engine software.

Propagation delay is ≤1 second.



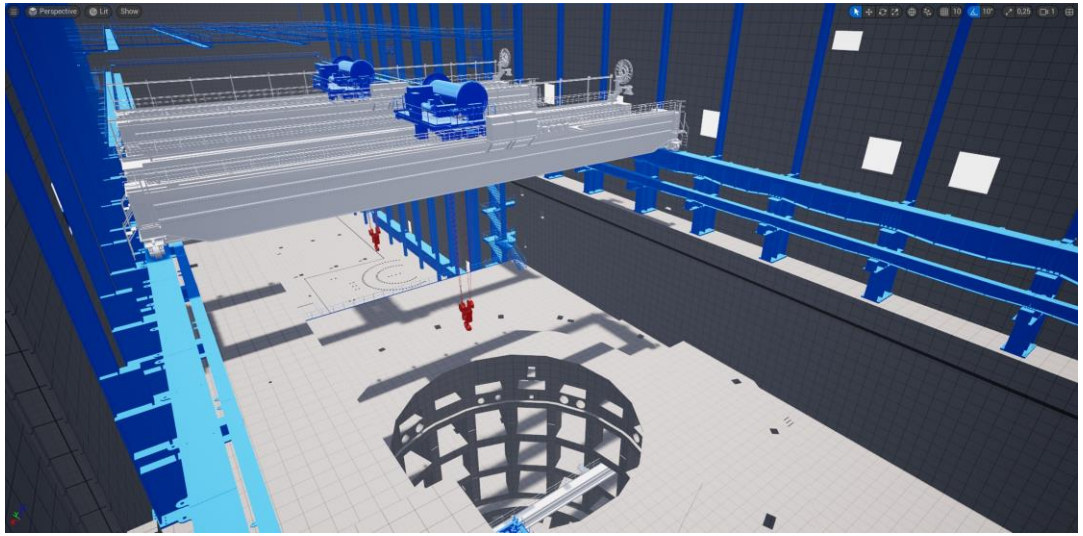


Image credits: Project Center ITER

CONCLUSIONS

- Remote participation is taken into account in the design of the ITER control system
- Attention is given to computer security; all designs are peer-reviewed and implementations audited
- ITER members are gearing up for remote commissioning with six out of seven centers connected with various degree of readiness
- ITER Organization made investments into high performance connectivity to cover mid-term needs
- Read-only extension of a control network via VPNs allows reusing a full set of CODAC tools and operator experience at remote sites
- Human communication tools are tailored to bridge office use and control system use
- 3D / AR / VR-enabled tools seem to gain popularity in operation scenarios

Thank you!

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china eu india japan korea russia usa