The control room of the future

An interview with Prof. Leon Urbas

The control rooms of process plants are usually as old as the plant itself – 20 years and more are nothing unusual. What's more, as a rule the associated hardware is no longer state of the art. The software too is often no longer up to date. That raises questions. Are the control rooms we have, together with their hardware and software, still capable of dealing with our times? What technologies and standards should one invest in to still be able to control plants safely and efficiently in the future?

We talked about these questions and more with Prof. Dr.-Ing. habil. Leon Urbas, Professor of Process Control Technology and head of the System Process Engineering Task Force at Dresden Technical University.


Prof. Dr.-Ing. habil. Leon Urbas

Prof. Urbas, among the fields you deal with are information models in the process industry, process information and management systems, and middleware in automation technology. Other emphases of your work include methods for user modeling for the prospective design of man-machine interaction, and analyzing, and designing and assessing alarm and support systems. We'd like to find out from you how innovative technologies will affect the operation of control and instrumentation systems in the future – and what will significantly affect everyday work for plant operators.

What should a control room of the future (around 5–10 years from now) look like to take due account of developments like Web-based technologies? What hardware and software, and what communication standards, should plant operators invest in?

When we're talking about the control room of the future, we first have to ask what human work will look like in that room. Who will be contributing what, and where, to make industrial processes safe, secure, and cost-effective?

More flexibility through location-independent task completion

Web-based technologies promise the ability to access the information space of an industrial process plant from any networked location, via any device. These technologies are now mature for use in production, in terms of both efficient engineering and the robustness of their software and hardware. As for the equipment, the control room, as a central space for action and communication in running industrial processes, would not necessarily be tied to a specific location.

Nevertheless, for reasons of efficiency and security, there will still be clearly defined locations where people perform their process management tasks. Where all the relevant information is collected and accessible. Where people work, reflect, and learn – directly at the plant or from simulated scenarios. I call these locations the control rooms of the future, no matter whether they're configured as a remote operation center, an operator training center, or a site, plant or field control room.

If Web-based technologies are properly planned and used for such purposes, they will provide significantly greater flexibility in control rooms than today's client/server systems do. The classic setup with wall projections and workplaces with screens can be supplemented without any additional engineering – with map tables, tablets, smartphones and smart watches.

Activities at other locations can be integrated just as well. It's also conceivable to forward task-related parts of the interaction from the control room to the field, or for the control room to display videos taken by an installer with his helmet camera.

Technical capabilities have expanded considerably. But it's largely unclear what kind of operation helps with a given cooperative activity – and what the best way would be for collaborating in a distributed control room. In one project at the DFG [Deutsche Forschungsgemeinschaft], we have a team of psychologists and engineers studying the best way to support communication between the control room and plant personnel. What we've found is that assumptions we'd obtained from cognition-science theories and accompanying observations at the workplace could either not be confirmed or constantly raised new questions.

What hardware and software and communications standards should plant operators invest in?

As I see it, the question should be: what hardware and software, and what communication standard, will give me the right ability to adapt to the constant and ever-accelerating changes in my market's requirements? What systems will already open up pathways today for the next migration? How can I get away from a CAPEX/OPEX calculation, which is no longer up to date in a wholly digitalized world, to a way of viewing cost over the lifecycle of the process control technology? Granted, these questions are even harder to answer than the one you originally asked. Because they presuppose that users have properly analyzed the long-term requirements for their process control equipment.

If a process control system is going to be upgraded to a new version, that should have as little impact as possible on ongoing operations – and ideally, should be possible without plant downtime. Many companies are hesitating here, and not just for reasons of cost. What do you think are the most important reservations, and what arguments can counter them?

From the user's viewpoint, migrating DCS technology primarily means costs. New process control technology alone won't produce a single gram more of salable chemical products, or even produce them more cost-effectively. Just the contrary! Downtime for the migration itself and for the startup issues that are typical of complex software will adversely affect productivity, at least for a short time. I'd say that before you migrate a DCS concept that's 20 years old, it's indispensable first to analyze the potential of the next generation. Not doing that is the most expensive kind of migration, with the lowest return on investment. The key to a successful migration is a sometimes painful question: where are we not mining our full potential because innovations in process management would be too complicated or too risky with our current system?

Let me illustrate with an example. Imagine that you knew from an analysis of maintenance data that half of your unscheduled downtime over the past two years could have been avoided. In principle, you already had the information you needed to avoid it. But not in practice. Because the data arose in different places. Combining and evaluating them with your system would have been insanely expensive, because of the many uncoordinated proprietary interfaces involved – and because for IT security reasons, you operate your critical subsystems as isolated data islands.

If migration projects are impending, it's worth looking at the investments that would be needed to fully exploit the potential of new functions with the existing system. Risk-based maintenance is only one of many conceivable scenarios. Further examples: a higher level of automation during startups and shutdowns or during changes in loads and products, introducing model-based automation, combining control rooms into a remote operation center, relocating activities from the night shift to the day shift, GMP qualification of new products and processes, integrating your OT into logistics or a supply chain, etc. – all of them applications that require networking previously isolated data inventories.

My experience indicates that if you compare the engineering and investment costs of the old system to the cost of a new system, the comparison often turns out to be disappointing. Even if many new systems promise terrific, innovative functions, when you look at the associated cost there's often no advantage at all. Not uncommonly, these functions will be fully available only at some prospective point – after a waiting period of two to five years. So it's no wonder customers are sometimes not very open to discussing migration.

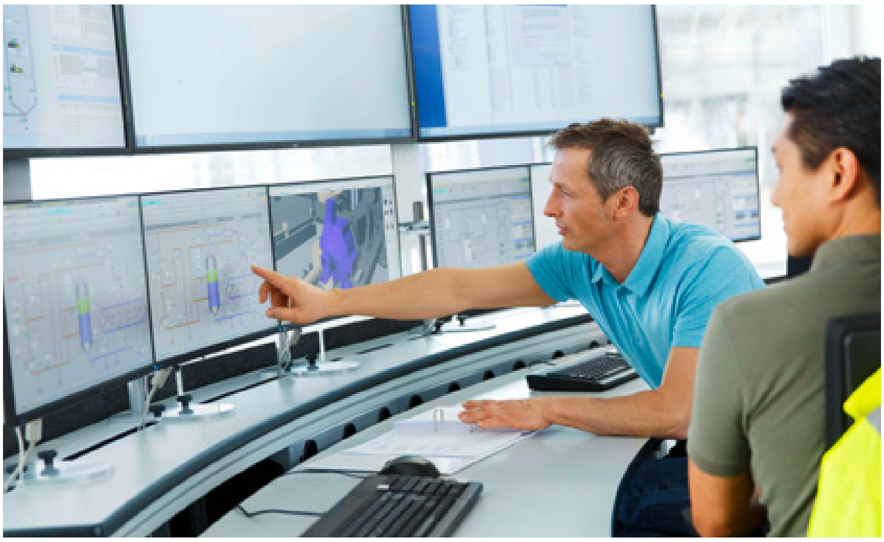
Let's talk about changing conditions – technological, regulatory, or other – and the resulting specific requirements for plant operators. Will these changes be reflected in the design or structure of process control systems?

The basic regulatory requirements for control room and workplace ergonomics have hardly changed in recent years – but they have indeed been adapted to technological developments. For example, the inclusion of flat-panel monitors and standard workplaces into ISO 11064 of 2014. The IT Security Act of 2015 newly added strengthened requirements for the protection of confidentiality and authenticity in the control room – especially when operating critical infrastructures. With the DCS systems installed today, in many cases these requirements can be met only by operating in isolation. Whether we're talking about hardened cores, resilience when it comes to common risks, or the ability to respond to zero-day exploits, here requirements must be met that will further change the architectures of process control systems, and even more notably, of development processes.

The upcoming generations – what are called the "digital natives" – will probably have entirely different expectations for an intuitive use of software solutions and screen designs than the current generation of plant operators. How can that be considered in an automation system and the control room itself?

I can't say whether young people now entering the job market deal more intuitively with software systems – the scientific studies on the subject yield a very inconsistent picture.

But what's not in dispute is that expectations for interactive systems have changed significantly. The gap between positive user experiences with software systems in the private sphere and negative experiences with production systems in the workplace is growing significantly. High expectations in everyday life are established by simple, highly specialized applications with high release volumes and strong competitive pressure and pressure to differentiate. Production systems, on the other hand, are very complex applications with low release volumes. Once they've been bought, they're largely competition-free because of the large initial investment involved. The risks are also unequally distributed – a mistake in dealing with a shopping portal is annoying but can usually be corrected with no economic consequences; on a production system, a small error can have fatal consequences.



Ergonomics at the workplace – a key issue in the control room of the future, too

Intuitive, interactive user interfaces are often immensely important in consumer-oriented software. Are user-centered user interfaces gaining importance in industry as well?

A positive user experience, I think, will get more and more important in production systems too. Our users' expectations have changed substantially. Learning these systems has to be as fast and trouble-free as possible; they have to enable you to immediately read off the system's current status, and impress with their high level of error robustness. What's required is a high-quality, aesthetic design that's quite simply enjoyable to work and interact with.

Obviously, both aesthetics and enjoyment are subject to lightning changes and are strongly affected by individual and cultural factors. The association between technical aesthetics and time is evident from the changes in the interfaces of the leading smartphone and tablet operating systems – a development that then has also quite visibly found its way back into desktop operating systems.

In the meantime, voice control is almost standard equipment in our daily private lives. Do you also foresee this function for controlling industrial plants?

Amazon's Alexa and Google's Duplex are examples of how fascinating interactive results can be achieved by voice with astonishing simplicity – provided the right data are available. That's at least the case for not terribly complex tasks like ordering a purchase, controlling home automation, or playing a piece of music. Many basic technologies of natural voice processing are available to anybody today, and suggest that interacting with natural language is also within reach for other areas.

Augmented and virtual reality will continue to gain in importance in process control technology

Where do you think added value for operation will be found?

There's no doubt that voice control is an advantage anywhere it makes sense to have both hands free – or where an additional, non-visual channel offers added value. But as I see it, there are still some obstacles to overcome for applicability in the process industry. Firs, the noise level in a plant or in a control room staffed by multiple people reduces recognition rate significantly. Second, the contextualization that is essential for chemical plants poses problems. What's more, only a fraction of the vocabulary and grammar of the digital twin that we can generate automatically from the engineering data and written documentation corresponds with the written language in the shift log or with our everyday language.

What challenges or restrictions do you see here at the moment?

Research on machine learning is already addressing these points in great depth under the headings of grey-box and transfer learning. In linguistics, they're doing it in topos construction grammars. For myself, I'm in suspense about how long it will take until voice control can achieve sufficient precision for the industrial context in the low-data, highly segmented, highly regionalized jargon territories of process control – at a reasonable cost-benefit ratio. We're hoping to make a small scholarly contribution to that with our KoMMDia project for dialog-based error diagnostics and correction, which is being funded by the Federal Ministry of Education and Research.

Technologies like virtual, augmented and mixed reality are already relatively widespread in the manufacturing industry, and are also being used in production. Are they also playing a role for the operation of control systems in the process industry, and what do you think are the most promising sample applications?

Very similarly to manufacturing, I think AR technologies will first begin paying off in commissioning and maintenance – i.e., in applications with clearly defined workflows, high volumes, a unique relation with location and product, and large deficits in the quality of status reporting to detailed planning systems. Here we can see applications with great potential. Examples are final inspection of flanges, tracking of delivered equipment, or maintenance of instrumentation – all supported by RFID/AR. These technologies are also promising for documenting visual inspections required by the authorities, for example for fire dampers. They offer considerable potential for savings, especially if the infrastructure for these applications already exists – i.e., the digital twin of the plant with a feedback channel capability integrated into the working processes.

In the control room itself, now I see considerably less demand for AR technologies. I assume that for the foreseeable future as well, process control will take place primarily in a functional information space that can be represented very well in two dimensions. AR applications are being discussed in a variety of exciting research projects – such as controlling plate thickness in rolling mills or simulation-assisted views into packing columns. But if you look closer at the data processing that's relevant to the task, you notice that here too, 3D isn't solely an advantage. For example, determining comparative dimensions of distances and lengths in 3D poses major difficulties – one major reason why after a promising start with 3D technologies, flight control continues to rely on two-dimensional representations.

Something I think is likewise promising, but not yet being used in connection with control rooms: the interactive assessment of high-dimensional state spaces, such as arise with the application of grey-box models. Here I can imagine entirely new approaches for data- and simulation-supported process control. The interface for such a control system might look like a computer game, where you must reach a goal using AI.

To what extent can AI-assisted functions help ease a control room staff's job in controlling a plant?

Let's look a bit closer at the idea of an "AI-assisted function." Up to the 1980s, we in the process industry, especially process engineering, pursued symbolic-logic approaches to AI. In practical use, that ran us up against limitations that were inherent in the principles of the thing. The costs of expanding and maintaining the rule bases of the expert systems grew considerably faster than the benefits. Since the 1990s, the focus has been on data-driven AI approaches, which can deal considerably better with ambiguities, uncertainties and absent data. And they're able to learn high-dimensional models based on extensive observations – by means of computer technologies like GPUs and methods like reinforcement learning and deep learning. The latter two are excellently suited for optimizing recurring processes (reinforcement learning) or for object recognition when a large number of statistically independent data sets are available, and the learning objective is known (deep learning).

In the process industry, we've found in various projects that what mainly gets in our way is the quality and quantity of the process data, which can be deficient from the viewpoint of a specific AI issue. For me, the key question is: what algorithms from the AI universe can we use, at what point in our information space, at a reasonable cost / benefit ratio. And here the cost approach can't be limited to the costs of procuring and installing hardware and software. Because the expenses for engineering the application, the requisite data analysis, integrating additional sensor engineering for model learning or data set characterization, demonstrating the AI's process viability – not to mention for monitoring and maintenance – may be many times higher.

Do you think these functions are more likely to fulfill their potential directly within a plant's process?

When we look at the benefit aspects, we finally get closer to an answer to your question about "where." As I see it, the control room as an application site necessarily presupposes explicability. Because the people responsible for plant security and product quality need to be able to scrutinize the decisions or proposals for using AI.

What skills do operators need for that purpose, and how an AI system needs to be explained – that's a matter of deep research, for example in the interdisciplinary research training group 2323, headed by Prof. Susanna Narciss and myself at the DFG, named "Conducive design of cyber-physical production systems." How it can be achieved methodologically in software for cyber-physical systems is under study, for example, by researchers at Dresden Technical University, the University of the Saarland, and two Max Planck Institutes, in the DFG's Collaborative Research Center/Transregio 248, "Foundations of perspicuous software systems."

A success factor for process control: Efficient interaction between humans and process control technology

Cloud-based services make it possible to increase plant availability or to make the best possible use of equipment lifetime, and to exploit potential for optimization economically – for example if manufacturers can monitor the equipment that's in use by a customer, or plant operators take over that job as a service for the plant owner. How do you view a further opening of process control systems for data exchanges with external partners, and where will developments head over the next few years?

The application cases worked out in the environment of the Namur Open Architecture clearly show the potential for further opening in the process industry. The examples at the Industrial Data Space e.V. association likewise argue for the potential of information partnerships – although the process industry by nature is less heavily represented on this platform, because of the risks associated with releasing data. Another interesting approach is under discussion by the Open Group in the USA, under the leadership of ExxonMobil – the Open Process Automation Framework, as a standard of standards for an open C&I architecture that is most especially also supposed to guarantee migratability of engineering in DCS systems. Finally, Industrie 4.0 is also yielding initial specific results, like the Asset Administration Shell. I think today it's beyond dispute that it makes sense to further open up process control systems to data exchange. Work is proceeding at high speed on approaches to manufacturer-independent solutions.

There's still intensive debate about where the data for further analysis are supposed to be located – on premises, or with an external service provider. Here my thinking has changed considerably in the past few years. In view of the exponential increase in attackers and opportunities for attack, I think the only sensible solution is to relocate data to a professionally operated data and computer center.

Data access from anywhere – without compromising security

Accessing the DCS system by using mobile devices is already an important topic today – especially in engineering, for example for a review or as part of maintenance measures. Do you foresee that operation and data access via tablets will also offer added value for plant operators?

Added value will arise when mobile devices support preparing a shared picture of the situation and significantly simplify communication between the control room and the field. As we see it, the control room is a space for information and action that handles and includes all tasks for process management – from engineering and change engineering, to simulation-based commissioning and operator training, to normal operations and cooperative fault analysis, all the way to installation and optimization.

The key to success is efficient, effective cooperation among people, and in the future certainly also between humans and AI. One design element that is gaining importance here: the process control system's ability to support a spatial migration of activities – between different action locations in the control room, simulation center, switch rooms and the plant. So with the technologies available today, it's primarily tablets that are a major component of a control room. But the list increasingly also includes smartphones, smart watches and data glasses, all of which must fit seamlessly into an overall operating concept.

Let me conclude by coming back to your original question: for me, technologies like HTML5 and tablets are just building blocks. What will be much more important is how we apply these technologies in our future control rooms – with the aim of designing an access to our plants and their digital twins that is easy to learn, self-explanatory, robust, aesthetic, and possibly even as easy as play.

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