Interview with a project manager for the dismantling of core systems at a nuclear power plant (September 16, 2024)
Length: 3:15h

PM:

Could you start by describing your duties and responsibilities at [operator of the nuclear power plant] and your professional background?

Expert:

I started in 2003 with a doctoral thesis at [name of research institution]. That was actually my first contact with nuclear technology. I worked on the development of Generation IV nuclear power plants. At that time, Germany had committed itself to this project with Euratom, within the GIF forum (Generation IV International Forum), to develop the Supercritical Water-Cooled Reactor, a next-generation light water-cooled reactor with supercritical steam conditions. The aim was to use this supercritical steam condition, as had been done in modern coal-fired power plants. Simply for super efficiency, around 50%, because that would have meant that you could build more compactly, that you would have less waste at the end – i.e. fewer spent fuel elements – simply because of the higher efficiency for the same amount of terawatt hours or for the same amount of electricity that you simply generate. There were a whole lot more approaches at that point as to why this was pursued as one of six concepts in this Generation IV. And we were working on the Supercritical Water-Cooled Reactor at [name of a research facility]. It was then called HPLWR, because supercritical and nuclear technology were not something people wanted to have in the same sentence in Germany. But "high performance" was okay. So they said it was the High Performance Light Water Cooled Reactor. After three years of doctoral studies, I moved directly to the power plant. I was actually supposed to take a position at the headquarters in the main administration: control of nuclear power plants, coordination of the fleet. And I said at first: "No, before I know how to coordinate and control such a fleet, I first have to know how such a fleet works." And that's why I decided to go to the power plant. I went to [location of a nuclear power plant] [the expert names the construction line, blocks, and manufacturer] and then started working in the equipment engineering department in 2006. Over time, I took on more and more responsibility for systems and components. I am responsible for systems and components for [the expert lists various systems and components]. I was responsible for quite a few systems. I then also completed shift supervisor training. This was essentially the license to operate the units as part of acquiring specialist knowledge. In addition, in 2011 and 2012, after completing my shift supervisor training, I also had my first contact with WANO [World Association of Nuclear Operators]. I was directly responsible for supporting the WANO team in 2013 in conducting a peer review at the plant, and then I also supervised all further follow-ups and the next peer reviews. I also visited foreign plants in Canada, Sweden, France, Slovenia, Japan, and China several times with WANO to exchange ideas with colleagues as part of peer reviews.

Then came the shutdown of the plants in Germany. [The expert names the shutdown date of the power plant]. Since then, the units have been in post-operational phase or decommissioning. Regarding post-operational phase, I would like to add that as long as the units still have nuclear fuel, a whole lot more systems have to be operated, of course . But there are also other safety objectives. Once all irradiated fuel elements have been removed from the plant, which is actually a pretty big milestone for such a unit or such a plant, then a whole lot of systems can be shut down. Then you can deactivate them, shut them down, and finally dismantle them. And I am now actually the project manager for the dismantling of my "core systems" [the expert names the relevant systems]. That is my task at the moment.

PM:

You've already been around quite a bit.

Expert:

Yes. Indeed, that's true.

PM:

Then let me get started with the technical questions. One of my central working hypotheses is that knowledge, or at least a certain amount of knowledge, is spatially anchored. I'd be happy to show you one or two slides to illustrate how I imagine this. Is this confirmed in practice?

Expert:

What do you mean by spatially anchored? Well, I have a room with lots of file folders, and I find a lot of knowledge in there. That could be one interpretation of spatially anchored, but I'm not sure if that's exactly what you mean.

PM:

I'll just share another slide here. Knowledge can be divided into very different categories. The distinction I'm getting at is the difference between spatial knowledge and process knowledge. In other words, which is more process-oriented and cannot be located spatially. I am primarily concerned with spatial knowledge. Yes, and that could look like we are looking at a technical component. And currently, there are already document management systems where documents are attached. My concept goes one step further in that we provide so-called knowledge elements, where a great deal more immediate information can be entered than can be represented in documents. But of course, the question is, when I create such knowledge elements, where do I attach them? If we look at process knowledge, then they hang in a vacuum. Whereas knowledge that I can assign to a component is spatially anchored at that moment. I also deal with virtual reality and augmented reality. That's mainly about visualization. And of course, it always helps if you can actually locate knowledge spatially. And that's what my question is about. Namely, whether knowledge can actually be well spatially anchored in the context of nuclear power plants.

Expert:

Yes, we can do that. It's true that for every technical component, you naturally have a huge stack of documents. But that's perhaps a leap to the IAEA-TECDOC [1510: Knowledge Management for Nuclear Industry Operating Organizations, 2006] or even to one of your other slides when you look at how this knowledge transfer between the individual phases works. First of all, knowledge changes. Someone who designs a plant has much more know-why than know-how. For me, that's a very important distinction. Do I have know-how or know-why? What we need in decommissioning is actually just know-how when it comes to the component. How do I dismantle the component? Why the component is designed the way it is is completely irrelevant. It was completely different when evaluating events during operation. There, I needed much more know-why—why is the component designed this way?—in order to explain to the expert why it still works, even if I may have noticed one or two things during an inspection. This knowledge suddenly becomes obsolete. When I dismantle a system, the most I need to be able to answer is why do I have to loosen one screw first and then the other? Yes, because there is a spring tensioned there. But I always did that correctly when dismantling this fitting during the overhaul. I simply acquire the know-how of how something is done, but not why it is done. Because the requirement that I have to reassemble it afterwards so that it works again is no longer there. And that is indeed the case. We have databases that contain a lot of information. We have orders, work orders from the past, from which we learn. Of course, there are training courses on individual components, where you look at what is important for the specific task. You also go through it in the briefing when you do a pre-job briefing and perhaps go through it or plan it during disassembly. I have to disassemble all components to a certain extent in order to be able to process them further. So further disassembly steps that may not be done on site, or decontamination steps if I have to clean something, right up to the conclusion that release-relevant measurements are carried out on the parts that I have produced from a component by disassembly. As I said, there is a lot of know-how involved, but less know-why.

What I need to know, what knowledge is relevant, is shifting. And what else do I need now? What is very important for me is, for example, how much mass is in such a fitting? What material is it made of? Because depending on that, it means: "No, we can only get a maximum of 300 kg into a [container] like this, which we use to transport components to our factory, to our technology center, where we can then clean them again and measure them. I think we have a limit of around 300 kg. This also has to do with what the radiological measurement looks like at the end of the process chain. It's calibrated for 300 kg of mass in this [container]. OK, that's a tiny bit of know-why, but no one questions it. 300 kg is set, and of course I also need to know what kind of material it is.

Is it austenitic or ferritic? Can I put it in the dry cleaner or not? I'd be ill-advised to put ferrite in the dry cleaner because the chemicals would eat away at the component in no time, and I'd be wondering where my fitting is, which I actually wanted to dispose of here. With austenite, it's different. I can then assess and consider how long it can stay in there so that only the top layer—i.e., the upper coatings, the crud, the contamination—is removed and when the base material will become visible. So yes, I need to know all that, but then you can plan for it and it actually works wonderfully. We had a management consultant with us, [name of the management consultancy], who really got us up to speed on lean management and lean production and presented us with a concept for designing the production of [the containers], which they called the integrated degradation process.

In my opinion, this is a great thing because it makes dismantling manageable in terms of mass flows. I always know how much I am dismantling, how much I can put in my factory, so that there is no, let's say, congestion anywhere. So that not everyone says, "Oh my God, we're drowning in dismantling mass, we don't know where to put it." No, the process has been thought through and rehearsed with all parties involved. And yes, at each individual stage of the mining process, there is—as they say here—spatially anchored knowledge about how to handle the component and what to do with it. So everyone has what they need to know, how they need to know it.

PM:

Yes, I find that a very interesting distinction you make. Know-how and know-why. With these elements of knowledge—as I indicated—different types of data are conceivable. You could work with text. If I now have the whole thing in VR or even AR, then I can also easily record video or audio. The WANO documents referred to various TECDOCs. That's why I took a look at them. They mentioned lots of other data types. What would you consider to be such small "bites of knowledge"? What data types would be best for recording them on site?

Expert:

It always depends on what kind of plant you have. Take a look at [name of nuclear power plant and construction period]. How many drawings do you think you'll find in CAD? None at all. It's all paper, ink on a huge drawing board. And today I have the luxury of having it scanned. Yes, I have different expectations or different possibilities than if I had a plant that was built in, I don't know, 2000 or 2020, where I have more or less all the pipe routes available in the appropriate resolution in 3D from the CAD system, where I can fly through virtually, track individual pipes, and so on. There is actually, or rather there was, a huge model of [name of nuclear power plant] at [name of research facility]. You could pull it apart and all the pipes up to, I think, DN50 [a diameter of 50 mm] were recreated in plastic to see if they actually fit into the plant as planned in the isometric drawing. Today, in CAD, if anything overlaps, you see a red mark...

PM:

...Yes, clash detection.

Expert:

Yes, exactly. We didn't have that back then. So we built all the pipes and checked whether they actually fit. Of course, the possibilities are completely different today, or rather, the possibilities you have with an old plant or the possibilities you would have today if you were building a new plant. So what can you do about it? What we actually do – we also did this for the 40-meter level at our site – we ran around with Leica, who had laser scanners and cameras with them, and they generated, I think, 600 gigabytes of data and scanned everything in 3D, and we use that in the project to simulate transport or handling processes, for example. To see if it fits? We have the suspension system, we know how long it is, we know how high it is, and so on. Why? The construction drawings we have from the construction period sometimes differ considerably from what we actually find on site in terms of real dimensions.

In that respect, it's a great thing. We also run through the plant with portable scanners, and there is actually a bit of artificial intelligence involved in order to be able to determine how best to proceed in the room based on the data that is then captured with such a scanner. First, remove the pipe, then the other pipe, or: "Hey, find me all the pipes, the 25 DN, 32 DN, whatever they are, because I want to fill a [container] with only these pipes." Just as an example. So you actually use it as a planning aid, because the databases or the data from the past don't contain everything by a long shot. In the past, there were many, many kingdoms. There was the kingdom of fittings, the kingdom of pumps, the kingdom of pipes, and they all had their own databases, which made things pretty difficult for power plants.

There were a lot of special systems and special databases that were not compatible with each other at first. And it's a challenge to get everything on the same page. But then there are gaps. For example, a pipeline does not have an AKZ [plant identification system] at every point in the plant. That means when I go through with a scanner, artificial intelligence, and say, "Oh look, it scanned a sign here too," the artificial intelligence tracks the pipeline and tells me, if I only have one pipe bundle left, "You have the following AKZ in this bundle: [...]" These are really good planning aids, even for the guys who then have to dismantle the system on site, so that they can identify what they are looking at. But we are just getting started with things like this. It's really good, though. So, once I have it digitally, it takes its orderly course, so to speak, through the individual process steps we need until we have actually dismantled such a plant or system. First, I have to submit an application and plan and describe what I'm going to do with it. I then have to include that in the application and send it to the authorities. At some point, it comes back, and maybe I do it myself, or I have to make it available to a company that does it for us under a contract for work. Or we do it ourselves. There's a colorful bouquet of measures that can result from this.

PM:

A lot of the data you've just mentioned is something I would classify as documents. For example, if you have a laser scan, you have your point cloud file. My concept of knowledge elements is that they are more low-threshold. For example, during operation, a plant condition is noticed that is not particularly problematic at the moment, but which could cause difficulties during subsequent dismantling. In this case, one could simply record a short audio clip or video. The whole thing is then archived in my information model and can be retrieved specifically when dismantling takes place. So it's more low-threshold. That's what my question was aimed at. What methods and techniques are most convenient for importing low-threshold knowledge?

Expert:

If I were to build a plant today with the knowledge I now have from decommissioning, I would probably do something like that. We have documented a lot. I was also responsible for operational fatigue monitoring. And that's exactly what we did there. We looked closely at the individual transients, at the degree of fatigue a component had or did not have after such a transient, and whether, according to the regulations, KTA [Nuclear Technology Committee, *Kerntechnischer Ausschuss*], this meant, for example, that an inspection was required. Or we said, "Oh, it's so broken, I have to replace it." It was basically calculated as broken, tested as broken. There was nothing wrong with the component, but the regulations simply said: "You have now reached a fatigue level of X, and I find it difficult to say that I think the component is great." So we replace it with a new one. That's what we did. That's exactly what was documented. Today, we know what causes problems during dismantling. It's precisely the deposits on the inside of the pipes. It's neutron fluences that we may not have looked at. I can't see it if I don't take samples during operation, for example in concrete structures. Then I don't know what fluence I'm actually measuring at that location and at that point. I can calculate, but there are often differences between the calculation and the reality of the measurement. This means that, for example, instead of recording something when I want to dismantle large components such as a reactor pressure vessel or something similar, I would have to regularly hang samples or something similar somewhere outside. With these, I can then say: "OK, and now the fluence is such and such, and that then has, if I extrapolate that or if I now add that to the information from last year..." This was done on a reduced scale, in that small knowledge elements, suspension samples, were also made. But they are in the RDB, it was a kind of advance material sample, where weld material from the primary circuit was irradiated and, because they were a little closer to the core, i.e., to the fuel elements, a slightly higher fluence was seen than the actual material on the outside. The factor was approximately 1.7, so that it was possible to predict how the base material would behave 10 or 15 years in advance. With a program like that. So that's what was done.

The possibility of recording something here is always a bit... Is it an observation, is it a gut feeling, is it a fact? That's always the discussion with WANO—is it a fact or is it an impression that you're actually documenting right now? I have the impression that something is shaking. The fact is, I had a sensor on it and it measured 5.7 G, and normally it's only 1 G. Both statements are the same. But now, which one do you want to work with as an engineer?

PM:

I'd rather work with the one I can prove.

Expert:

Exactly. That means you can collect these knowledge elements, you can do that. The question is always: Do I already know at that point what information will be needed later in mining or in another phase of operation? What do I need to know? That means you have to think very carefully. What do I want to document in these knowledge elements if I were to do something like that? Today I would know, OK, the water samples... Look at what elements are in the water. Look at how deposits form there. Do you have a way to clean your system? Do you have a way to sample it? And then you can ask whether a location is representative? In some cases, we have huge containers, the feed water container is 50 meters long, a lot of feed water has gone in, several degassers, several condensates, and they all have a different load of particles, of crud. And if I now sample the container for dismantling at one point and use that to make statements about the entire container, I will notice: "Oh, that's not right." That means I have to sit down with the process engineering background and think about where in such a container I should put the knowledge element. Yes, in order to be able to capture precisely such operational specifics. On the one hand, clean condensate comes in, on the other hand, dirty condensate comes in.

Later, for dismantling, or whenever... It may also be that if I only replace such a component because I have an extension of the operating life, that is precisely the problem. That I say, "Yes, I have sampled it, there is nothing here." And then I start working on the other side and say, "Listen, it's totally dirty." Then we all scratch our heads and say, we did take samples. In that case, it would actually help to say: OK, look, here is the component with the information, the following went in there. But again: it is known where which condensate flowed in. The fact that there is different crud load in it didn't interest anyone at the plant at first, I think.

We actually looked into this when we were conducting radiolysis gas tests on the feed water tank. This is because the limit values were being reached at different rates during operation. And then we wondered how this could be. We have an extraction system in the tank, the same at all corners and ends, and we adjusted it. And yet the limit value always occurs first at one corner. Then we said, "OK, that's because the water flows into the area, it comes from an area where there was higher gamma radiation. Gamma radiation causes my radiolysis, and then the probability is simply higher at that point that more radiolysis gas will also enter the container at that point." A bit of detective work. But then I can explain what I measured operationally.

PM:

And do you record this knowledge, the induction and deduction, in any form?

Expert:

Yes, of course we recorded it. The system and component managers recorded it because it was discussed with the expert. He asked why the limit value was being reached so early again. Or why did you put this here and that there? And then we investigated and explained precisely these transients or this kind of plant behavior. And then they went to the expert with this, and he said: "OK, dear authorities, the operator understands his plant. He knows what he's doing, he's good, he's not flying blind, he's a strong operator." So that was actually very important. And there, too, they looked at databases—which valve has which switching time, how long has which pump been running, what temperatures have been set? So there were very, very extensive databases with operating data—pressures, temperatures, mass flows, switching times of valves, and how long a valve has been running... Because sometimes we say, "There's a mass flow missing, why is that?" "Yes, the valve has only been running for half as long as usual. So it's stuck halfway." All of that could be pieced together very well with the data we collected on the individual components.

PM:

Did you document it in such a way that you can find it again later?

Expert:

Yes, of course. These were usually incident reports or annual reviews and analysis discussions with the expert, and everything was documented there. We wrote an entire manual for hydrogen in collaboration with the industry because it was such uncharted territory for everyone involved.

PM:

Are there specific use cases where you would say it would be helpful to work with such small, low-threshold pieces of knowledge? You are probably familiar with the SECI model in theoretical knowledge management by Nonaka and Takeuchi, where we have an axis with implicit knowledge and explicit knowledge. And then we have conversion processes: socialization, combination, externalization, and internalization. I'm currently looking to see if I can create a kind of mapping to processes in nuclear technology where knowledge is generated and passed on in some form. I am in the process of making a distinction between what could be represented more with virtual reality or augmented reality. Virtual reality would mean that I don't have to be in the plant itself, I have it from outside. Whereas augmented reality actually supports physical presence on site. And this results in several theoretical use cases. Is there anything that spontaneously comes to mind that you would say has a certain appeal?

Expert:

Both have a definite raison d'être, just as they stand. Virtual reality for the simulation or planning of transport processes, handling processes in confined geometries or in existing building geometries. Yes. Lessons learned sessions. Of course, I can look at what went wrong. Yes, but then I always have to say, "Hey, I actually had it before." So, if I don't have it, I can use it to work through it, sure. And augmented reality is unfortunately where I say it's most difficult. Because to do that, you have to take a whole lot of material into the control area. Putting on glasses like that – what for, actually? For an activity where it doesn't really matter if you do anything. I know augmented reality from [name of a technology company]. There was a science day in [place] at some point, and I had to check some screws on a wind power plant, on a gearbox of a wind turbine. I was given a pair of glasses to wear and sent into a dark room that was the original size, with a little lighting. I don't even know if it wobbled a little. And then I put on the glasses and then external specialists guided me and said, "Now we're going to move further to the left. And there's the screw." "Which screw?" "The one we're marking right now." And then they marked the screw on their platform. Then I saw, "Oh, that one." And then they saw my hand. "Yes, exactly that one." "And now what should I do?" "Ah, that, like this." So, even as a layman, I was able to more or less carry out these tasks because they were able to show me on the tablet what torque to use and what else I needed to pay attention to. Great stuff. But I find it a bit too complex for dismantling. VR is wonderful, of course, but augmented reality? Maybe someday the glasses will be so compact that you can easily take them with you, and every pair of safety glasses will have one of these things in them.

PM:

Well, a lot has changed in technology in the meantime... In research, we also work a lot with smartphones when it comes to augmented reality. Of course, the disadvantage there is that you no longer have at least one hand free. You hold your device up, and then you get augmented information displayed. That could be small pieces of knowledge like that. The appeal is that I receive the information exactly where I am. With VR, it's also together, so to speak, but only virtually.

Expert:

How much time do I have for preparation? Because at the moment, it's like this: The foreman goes with the team on site and says, "Come here, over here, look, you have to take this into account with the fitting, you have to take that into account..." He may have looked at old work orders for the fitting, but he doesn't bother to say, "Oh, I have to hack that into a knowledge element now." Instead, he gives the people on site the information live and directly as part of a pre-job briefing. If we had known that this was the right information for dismantling... Well, then I might have created a knowledge element and then today it would be much easier for me to say: "OK, for the room or for the AKZ, find me the tips and then send them off." And then someone would have actually linked a photo.

Yes. So those are actually points, I think, yes, I'm coming back to this graphic [from IAEA-TECDOC-1510] that you have. What knowledge is there in the areas of construction, commissioning, operation, decommissioning, and so on? It changes. And I would have to know today what I need for dismantling or take into account what I need for dismantling if I want to say to someone who is commissioning the plant: "Listen, you have to pay attention to the following from now on so that we can dismantle the plant properly later on."

PM:

Yes, that may sound a bit contrived, but that would of course be the ideal scenario.

Expert:

Yes, exactly. But again, based on what I know about dismantling today, if I were planning a plant, that's what I would do. I would say, "OK, guys, we have to take this and that into account. Not necessarily dismantling. Just think about performance increases or refurbishment...

PM:

Yes, extending the operating life...

Expert:

...extending the operating life, saying that I have to replace components and to do that I have to carry out decommissioning on a small scale, so to speak. But that's why it's worth [drawing on] this experience from industry, what is important for decommissioning, for decontamination, for such a concept, so that you can start decommissioning later on.

PM:

You are currently very busy with decommissioning and perhaps you see everything very much through "decommissioning glasses."

Expert:

Let's go back to operations. It's the same in operations. If I knew now, at this point... If the commissioning engineer says, "Listen, during commissioning, the valve did something strange during the tests where we had 120% mass flow." And then he says, "OK, we no longer have 120% mass flow. And at some point, I'll increase the power. With a turbine, the rule is: more mass flow, more power. Suddenly, I increase it at some point in the system and suddenly the valve starts to wobble and you say, "Shit, what's going on now?" And then it would be great if someone said, "No, listen, we already had the information from the commissioning. The valve jumps around when you start up at 120% mass flow." So

I don't think that's engineered. Much of the operating experience that went into our simulator came from exactly such experiments. And that's where you mapped the entire plant behavior.

PM:

I'm glad you see it that way, of course. It illustrates the different areas of application and that you shouldn't view them separately—here the operation, there the decommissioning, ...

Expert:

...including operation. You go on site for an inspection or you go on site during operation because you have a leak on a fitting at a screw connection. Imagine you need something like this during an inspection or during operation. You go on site because there is a problem with a fitting. There is radiation on site, there is medium on site, contamination on site, all kinds of things on site. So radiation protection will remind you that this has to be done very quickly and very cleanly. Please don't waste any time on site. And then it's still hot. I think something like this can be a really good tool to make it as easy as possible for the person carrying out the work. You say: "Right, now take the key away and now the yellow key, where we've put the yellow tape around it, and now put it there and turn it here. Then you're done and you can leave." Of course, you can practice this beforehand by building a mock-up. But mock-ups are extremely expensive. And that's exactly where I say, if I can do something with VR or, in this case, augmented reality...I can show something with VR as a film and then say, "Okay, now go to the site, take your cell phone with you, look there, turn it, press it, and do it." I think that would be a really useful thing. I'm still convinced of that.

PM:

OK, great, that's a nice example. I'll definitely take that use case with me.

Expert:

It would be extremely important to take radiation protection aspects into account.

PM:

Let's move on to the area of knowledge management. I was very surprised when I first read through the WANO documents. They appeal to very, very high ideals.

Expert:

Yes. These are criteria for excellence. No plant meets all of them. We mustn't kid ourselves. As soon as they find something that is really good in one plant, they adopt it immediately, and then all the other plants have a problem again.

PM:

Yes, of course, if you only pick the best of everything... But I think it definitely has its justification. Simply to show what the optimum should be.

Expert:

It's the constant pursuit of improvement. As Henry Ford said, "Anyone who stops improving has stopped being good."

PM:

I'm particularly interested in the aspect of error culture. In terms of knowledge management, many supposed errors should be viewed more as lessons learned and consciously shared. This has a lot to do with trust and a culture of error. WANO explicitly says that you should be completely open. But how do you feel about this in practice?

Expert:

It depends on the culture. It's actually country-specific. Depending on which country you go to, you'll find different ways of dealing with mistakes. Take the Nordic countries, Germany, Switzerland. In this region, it's incredibly difficult. People immediately start arguing and justifying themselves. Go to England or Canada. They embrace you and say, "OK, cool, now let's take a look at this—process and procedure, what can we improve and what happened in the first place." Great stuff. And the most extreme thing I've experienced was actually in China, where they said, "OK, explain every single point of the PO&Cs [Performance Objectives and Criteria], because it helps me fulfill my 5- and 10-year plans. Because if I fulfill all of that, then the plant will run safely and stably and we will meet all of our production targets. And tell me where I'm going wrong, because ultimately what I'm doing wrong is preventing me from fulfilling my plan." China, you know. Go to Japan. Very difficult.

PM:

Yes, yes, the loss of face...

Expert:

That's how it is. I can't contradict the silverback. If I tell him now that he was wrong, oh God, oh God, oh God. He'll commit harakiri. No, I don't want that. And you experience this range when you discuss error culture or dealing with errors in such an environment. So, it's incredibly challenging. And there's no one-size-fits-all solution where you can just say, let's do it this way, it works everywhere. It's actually different in every country, you always have to look closely, develop a bit of a feel for how to introduce people to something like this.

The point was always to say: No, the mistake isn't the bad thing. The bad thing is that we don't want to improve as an organization. So, you try to take the mistake away from the individual and ask: What are we doing as an organization? Blame culture was always a thing there. Even at WANO, you actually heard it said once or twice in German plants: "No matter what's broken, the blame gets fixed first." So no matter what's broken, the question of blame is always clarified first. That was so symbolic of how mistakes were sometimes dealt with in the culture.

But there's also the following point: an English plant or a German plant – there may not be such a big difference today – but in the past they were completely different in design. The Germans placed much greater emphasis on automation and automated feed processes and procedures in the emergency and residual heat removal systems. They said: "Once I've programmed the automation correctly and built it to be robust, it won't make any mistakes. And if it does make a mistake, I have a system number two, a system number three, and another diverse fourth system that can also do the job. So what else could happen? Get rid of the mistakes, I don't care. I carry out recurring tests to show that my system works and nothing can go wrong." We had two units and twelve emergency diesel generators at [location of a nuclear power plant]. I was at a plant in France that also had twelve emergency diesel generators. But for six reactors.

In this case, the discussion was always: "Yes, but how do you handle the generators? Do you handle them so much better that you have just as few problems with them?" Maybe they check them much more frequently, or maybe they have much stricter specifications for when they have to change the oil, who knows. So you always had to evaluate everything. If an incident occurred, you always had to look at what caused it.

And of course, the English or French would then look at it and say, "Yes, OK, let's look at the procedures, no problem at all. We did everything according to procedure." Conversely, "Oh, we didn't do it according to procedure. Oh dear, big problem, then we already know what the cause was." Or you say, "No, we did it according to procedure, so we have to improve the procedure." Let me put it this way: In German plants, it was always quick to say, "Now we have to ask why the engineer specified 85 instead of 88 degrees here," for whatever temperature. And he immediately justified himself. Yes, because he says, "No, no, it works. I did the periodic inspection" and so on. So it's completely different, the cultural aspect. But I wouldn't know how to figure something like that out with such a small nudge or element, whatever I want to call it.

PM:

Yes, that's exactly the question: Does such technology fuel negative dynamics or does it simply reinforce every culture where it is already good? Things like that, which are now really ingrained in the culture, are probably very difficult to get rid of. So there are different philosophies to consider.

Expert:

There aren't many industries that have something like WANO. The aircraft industry does it too. Aircraft manufacturers look over each other's shoulders and say, "No, wait a minute, it's better this way." Why? Because a plane crash here has a huge impact on the entire industry. And it's no different with nuclear power plants. An event in Japan and things happen in Germany. This awareness must be discussed again and again. You just have to be creative to make other cultures understand this. And then they also realize... Again: The Chinese or the Japanese also say, "I have a job to do, I want to generate electricity here." "What could possibly happen? Or what's stopping you from generating electricity?" And then you put the cart before the horse and say, "OK, listen, you can't have electricity anymore if this and that..." Direct line to the core. The INPO [Institute of Nuclear Power Operations] used to have these hubs. Have you ever played Monkey Island?

PM:

I haven't played it, but I know a little bit about it.

Expert:

You have to set codes when you get different signals. And a hub like that... They said, "Look now—now the event is running through to the core." They were little toys that we used to work with, to playfully go through something like that with all kinds of people. We used them in Japan, too. It was an American thing, this game hub. So you always have to keep an eye on things. There is no "one" solution at this point.

PM:

China has a collectivist culture. What would help them more in knowledge management? I have the impression that much of what is formulated in theory is formulated from a Western perspective. So there's always the call for us to move away from seeking responsibility in individuals and instead see ourselves as something higher and learn from each other. In your view, is knowledge management not yet sufficiently understood in other cultures? There probably isn't just one global knowledge management concept. On the other hand, you always read about the same concepts.

Expert:

When practicing procedures with augmented reality glasses—especially when operating a plant—I believe that this could also be very successful in China or Japan. After all, radiation is the same everywhere, and the effect of radiation on humans, whether Asian or European, is always the same. In that respect, it helps. Because they have experts or specialists for such work, and they are not a dime a dozen. In that respect, I think that the careful handling of the biological machine, the human being, is also very interesting for the Japanese, Chinese, or whoever. And they have a penchant for cell phones and whatnot...

PM:

Definitely. There is a very strong awareness of technology there.

Expert:

That's how it looks. So I think the barriers to using it would probably be much lower there than they are here.

PM:

Yes, they are more open to technology there.

Expert:

Not only that. Take a look at the average age of Chinese nuclear power plant workers. Where are they going to find an older workforce at the rate they are expanding their fleet? That's one reason why you would say that implementing such approaches would be much easier there. And they themselves know that they don't have the experience yet. I said they snatched the PO&Cs out of our hands because they said, "Wow, this is basically a distillation of 440 nuclear power plants." And I believe – WANO has always estimated – that there are about 20,000 years of operating experience in there. And they're soaking it up. But WANO has relatively few concrete technical details in it. But a manufacturer, operator, or service provider in the nuclear power plant sector, I assume, has a lot of know-how.

PM:

The TECDOC [IAEA-TECDOC-1510: Knowledge Management for Nuclear Industry Operating Organizations, 2006] contains the sentence "Information without ownership is useless."

Expert:

That's right.

PM:

That's along the same lines. Am I perhaps making things easier for people by giving them the opportunity to submit anonymous information? Or should everything be traceable?

Expert:

In this context, ownership is not about who wrote it, but rather that someone says, "OK, this is information that is relevant to me." Such a basic attitude would mean that everyone here at work knows something that I don't know. My point would be to listen and then use it when I need it. And then I have to say, "OK, this is my problem now and I have to see where I can get information about it." And not say, "Team – great, someone else will do it. Here you go – solve the problem and then we'll move on." Ownership would mean, "I'll take care of it."

I may have the information, but what if I say, "So what?" But if I have ownership, I understand that, or at least I want it to be understood that way... When I say, "OK, that's my problem, I have to solve it, or we have to solve it as an organization so that we can improve. And if no one immediately cheers, that's fine. I have to do it." A lot is regulated in terms of who does what. Yes, we have great organizational charts and descriptions of departments and what their activities are. And we have a lot more information. But if a problem arises or is identified somewhere and then there is no one there to say, "Yes, I'll take care of it," and then follow up on it, search for it, and use the information? Then it's all useless. So, information is often there. What is sometimes missing is ownership when you say, "So what?"

PM:

Doesn't ownership mean that you are the originator of this information?

Expert:

That would be more like authorship. That goes in the direction of what we discussed at the beginning. Is that just an impression or a fact? What did you write down? My impression is that it resonates, or 5G instead of 2.5G or something like that. That's why I would also make the distinction between authorship, i.e., that someone is the author of such information and also stands by it, and when someone has entered something and is asked about it, they say, "Oh, right, good thing you brought that up again. That was 0.5G, not 5G." For me, ownership is more like the other thing I just mentioned. But that's also important.

PM:

So I take it that both authorship and ownership should be taken into account. When it comes to information, you should be able to say where it came from and who is looking at it...

Expert:

...QA [quality assurance], exactly. Where it comes from is QA for me. You can also run AI over it, as far as I'm concerned, if you query a position and 200 values have already been collected for a specific fitting, for a specific type of fitting, for a specific operating condition. And suddenly there's a value in there that's 10 times too high. You say, "Listen, either it's really breaking down right now or I have to throw away the measuring device, this is nonsense." So you should actually do that. There were also systems based on that tried to use all the measured values for operational fatigue monitoring to predict where something was about to break down.

PM:

I'm also familiar with this kind of predictive maintenance from the construction industry. It's probably even more prevalent in plant engineering and mechanical engineering. For us, it's a question of when the elevator will get stuck. But in your case, it's a much more sophisticated concept.

Expert:

We had that too, there were approaches, I know them from conventional power plants. [Name of a power plant], I did an internship there when I was still a student. Here we also had providers who tried that... But I think we were already further ahead because we knew much more about components due to the recurring inspections we carried out at regular intervals.

There, too, the intervals at which I inspected a fitting were not set in stone. We looked at it and said, "I'll come back in four years." After four years, we looked at it and said, "Oh, I have a lot of repairs to do here, it's completely broken. I think we'll take another look at it after two years." Then, after two years, they looked at it and said, "Oh, it actually still looks great, let's check it again in three years." And that's how it settled down, so to speak. But then, with 40 years of operating experience with the system and the components, they knew what was good. Another point: Specifications could, of course, be derived from the design: "Listen, these are points where we expect a crack to occur first due to the vibration behavior." This could be incorporated into a VR or AR environment for a shift supervisor.

PM:

Right, maybe what you should pay attention to first when you're standing in front of a particular component.

Expert:

It also has the background... Of course, you can stand there for two hours looking at the fitting. But listen, what would that dose be? What if I could guide you and say, "Listen, if so, then there..."?

PM:

Yes, then we're back to ALARA [As Low As Reasonably Achievable]. You have a responsibility not to expose anyone unnecessarily for long periods of time...

Expert:

...expose. The "achievable" [in ALARA] is always theoretical. "Practically achievable," i.e., how it can be achieved in practice. So ALARPA. With another "P" in it.

PM:

What does knowledge management look like at your site? There are various concepts, for example, that I don't make a big deal out of it, but rather incorporate it into everyday work and, where there are " " meetings where information is exchanged, I put a mask over it from above. There are also other approaches. In TECDOC, I have also seen approaches where you make a big deal out of it and say, "We are now going to have a workshop day and everyone has to stop doing what they normally do for a day, and instead we will all sit down together or everyone will write down their knowledge." What do you think about that?

Expert:

I think that would be fantastic, but it doesn't happen. We don't do that. Of course, we have a learning organization, training, and so on... When I think about how long it took for my colleague to hand over the [two extensive areas of responsibility in the field of monitoring] to me. I sat with him in the office for two years. We exchanged ideas, I accompanied him on the first inspections, and so on. The handover with the systems engineer for [component] was completed in a week – from his point of view. And I was lucky that the people were there, our service provider, who carried out recurring inspections and service during the audits. He took me along and said, "Here, take a look at this and that and everything else. Come with me, we're going to Zwentendorf in Austria to take a look at the plant there. Then we'll crawl around it and I'll explain a few things to you." And I still benefit from that knowledge today. That was a different question, by the way. We got off to a really good start with these projects (dismantling of large components), and one very important aspect is precisely that we started the decommissioning process, the removal of the fuel elements and control elements, with the same mastery and the same team from ongoing operations, and are now beginning to dismantle the core or the reactor pressure vessel internals.

Then there's the issue of brain drain. Yes, of course, take a look at other plants in [region in Germany]. They were shut down in [year], and some of them are still waiting for their decommissioning permits today. Do you think anyone was interested in doing anything there? No. And then they left too. Then someone else took over and took a look. So the brain drain is definitely there in the industry. And as I said, that's a huge advantage for us, that even the system manager like me is still allowed to dismantle the stuff. They said to themselves, "OK, there's actually a nice continuity here. He knows the specifics, he knows where the stellites [nickel-based alloys that are highly activated and highly radioactive due to their nickel content] are hidden in the core."

PM:

But of course, you have to want to do that.

Expert:

Yes, exactly.

PM:

The background to my question is that last year [nuclear power plant operators] invited us to visit [the site of a nuclear power plant]. That was a few days after the shutdown. And they were pretty downhearted there. They said, "We kept everything running here, and now suddenly we're supposed to be the ones to dismantle everything we built and operated." From a management perspective, it may of course be the best thing to do, because then all the know-how is still there. But what I took away from there was that it is very, very difficult to communicate something like this in terms of motivation.

Expert:

It is. Until yesterday, the component was cherished and pampered, and you had to be careful not to damage it during transport. And today, I'm basically pulling it out with a tow truck, and then the scrap collection service comes and takes it away. Well, there you go. That's a question of meaning that you ask yourself. But the question at this point is: I have to dismantle this system with the same responsibility and the same understanding of safety as I had when I operated it. When I remove a component... At that point, I could still say, "Wow, I'm doing this to increase performance." Well, I'm not. I'm actually removing it because I'm breaking it. But that is indeed a point we have also been working on, flipping that switch between the mentality and this focus on occupational safety, which is so important. People say, "OK, it's still not a cookie factory." Well, even a cookie factory has specifications... But we are still special – nuclear is special. We still have post-fission power. We still have radioactivity. We still have protection goals. Our responsibility hasn't gone away just because we've shut down.

It used to be much easier. We set up the plant again to start it up, and then, in the best case scenario, it left us alone for a year. Today, we have so many changes every working day in the plant that we have to constantly reevaluate: What is the situation? What do I find on site? Which, by the way, would be a huge challenge for a VR database or one for augmented reality to keep up to date. Not that someone walks around and says, "No, there's no valve here. What are you trying to explain to me?" Keeping something like that up to date on a daily basis would be a huge challenge. But yes, the mindset is one thing. You have to work on that. But you have to see it as an opportunity. These are new and exciting activities, new challenges. Especially on the shifts. The companies that actually operated the plant, e.g., in [name of a nuclear power plant], which had 1340, 1350 MW up there on the display. It's difficult for them, it was the same for us. The units were the babies of the unit managers. They actually left after the shutdown. They said they couldn't do it.

PM:

Sure, you could say that it's simply about different goals now. Before, it was safe electricity production. And now I'm doing everything I can to ensure that this will be a green field again someday. That's a bit more abstract, of course.

Expert:

Safe dismantling... It's not easy. Yes. And it's also the case that an organization has to reorganize itself for the dismantling of a plant. And in the process, they also lose a lot of knowledge simply because people change jobs and say, "I've basically closed the door on my old life. If no one asks me, that's it." And when you ask people today... It's frightening how quickly you forget. Yes, then I'm back to the point: What chance would I have had to possibly preserve this knowledge?

And then there are events. At some point, components were incorporated into certain structures. And today, they are being rediscovered and everyone is surprised. Oh, now I can't dispose of it as planned. I have to do something else first. And everyone is wondering how this will affect the schedule. "Yes, we won't be any faster." So those are always the questions that are asked immediately. And yes, events like that do happen. So, processing knowledge, but also finding a filter with which I can pass it on to a new organization that is then responsible for dismantling it for ... I think that's where the challenge lies. A plant like this offers thousands of opportunities to collect data.

PM:

You probably have basement rooms full of file folders and then everything digital that goes with it. Now to say, I'm handing this over to a completely different organization so they can familiarize themselves with it...?

Expert:

But yes... I keep coming back to the example. Even in dismantling, if you have accumulated activities in certain parts of the system on site and, for whatever reason, you have decided not to chemically clean the components before taking them apart. And then you can see, "Hey, I always had specifications for operation. If he has to do something quickly, how can I benefit from the fact that he might take it apart quickly and then throw it in the container so that it can be disposed of?" Everyone knows something I don't know, and I have to see when I can use it. I have to listen, I have to read it. You just have to do it from the beginning, I think that's the problem. This "Let's quickly jump on the bandwagon with a plant that might be shut down in five years..."

PM:

Such a concept comes too late, yes. I am aware that what I am thinking up here will no longer help Germany.

Expert:

Exactly. Not in our lifetime.

PM:

Do you have any experience with knowledge risk assessment? We've already talked about personnel. In the best case scenario, you look at the personnel you have, what knowledge they have, and if someone leaves, then it should not be the only person who has a certain knowledge. But what do you do if two or three people leave at once? Do you consider in advance who is the bearer of "critical knowledge"?

Expert:

So, a single point of vulnerability in terms of knowledge... I don't know if even here in [state], we've been guided by the cheerful Rhineland attitude of "It's always worked out fine before." But it's true that a lot depends on individual people. And when they leave, some people are surprised at what that means for the organization. So it's difficult. I don't think we do that, I'm not aware of it. Your follow-up question is how employees are motivated and rewarded for passing on knowledge.

PM:

Yes, exactly.

Expert:

Who should I pass it on to? That would be the first question. Who is the lucky one? That means I would have to go through another transition phase. And that all costs money, such an overlap, and then I have someone sitting there... And that's already in operation? Yes, please, the plant is running. An hour later, I might have earned a hundred thousand euros, depending on the stock market prices. We don't have any of that anymore. In the past, it was the supply mandate, today it's economic constraints, because the reserves are finite, which is why you can no longer set up such models or approaches on a large scale.

PM:

When it comes to the question of how to motivate or reward people for this, money doesn't always have to be involved. Social recognition would also lead to greater job satisfaction, even though everyone has different attitudes toward this, of course. The single point of vulnerability you mentioned earlier is a good example: Is it recognized in any way if someone is the only one with a certain expertise? Or is it simply accepted and no one is really interested in that person?

Expert:

Actually, no one is interested... I think they already looked at who was knowledgeable about what and conducted a survey of interests during the reorganization. Then they made sure to assign people to areas they were interested in, presumably because they were knowledgeable in those areas. And they gave them the opportunity to switch from the operational organization to the decommissioning organization. So it was rewarded when someone said, "Wow, I know the XY system so well, I want to dismantle it now." Or: "I've always enjoyed working on valves, and now I want to dismantle valves too." That's what they did, yes, but of course there were also plenty of people who weren't happy with the position they ended up in, because it didn't work out everywhere. And what they did with those people, well, we'll have to see... I don't have a representative either, I have to say, so I'm also a single point of vulnerability. I do have a deputy for my project at [headquarters of the nuclear power plant operator], but he comes from the lignite sector and says: "I'll bring you endless project management tools from our projects that we've done here with [operator], but nuclear power isn't really my thing." We complement each other perfectly, but the fact is, if I were to imagine that, okay, starting tomorrow, I'm no longer here because of a car accident, then I think some people would initially ask, "Oh, what are we going to do now? Who can take over? And where can I find the information? IT, please unlock [name of expert]'s computer. We need to see what he wrote about it. Maybe we'll find something." It's true that you don't even think about it yourself, like, "I've made provisions for that by...". I didn't do that. Do I need to take a look at myself?

PM:

Yes, that's the question—is it individual responsibility or is it something an organization should provide for?

Expert:

The organization would have to take care of that. Because if I were to prepare that, or had to prepare that, for whom? It has to be tailored to the target audience. So I think if a master craftsman comes, or an engineer, or , some other nutcase, a doctor like me, then the preparation looks different. It's individual. Again, there is no "one size fits all" solution. Another WANO saying: "One man's need is another man's poison." Yes, these are always points where you ask yourself whether you can do it in a week or whether you need two years. You don't know.

PM:

It's always the same: the benefits of preparation and prevention can hardly be quantified, and only when an event has occurred can you see what would have helped in retrospect.

Expert:

Right. I'll jump in with the next statement [from the TECDOC]: "Be careful with trying to prove that KM has a significant impact on business performance." I think it's very difficult to determine knowledge management with metrics. We've discussed this a lot with WANO, because I can't count events that haven't happened. I can't say how often a particular tool has helped me do something better than if I hadn't done such preparation. So yes, it's difficult. It would be interesting to see which metric you would use to determine whether it was a success or not. Because if I do a lot and nothing happens, someone will immediately come along and say, "Listen, we've spent a lot of money on this. We don't have that kind of money. Let's make half as much money. Where will that get us?" And then, at the latest, I ask, "How am I supposed to count that, or how many events are OK for you that happen because suddenly knowledge hasn't been transferred? One per year? Two per year? Five? I don't know." Again, it depends extremely on management, what management wants to show, and the dismantling is mass-controlled in terms of metrics. You tend to ask yourself, "How many masses are there? How much money have we spent? And when is the end date for the dismantling?" But I don't think we have room for a metric that deals with something as exotic as knowledge management.

PM:

Yes, I haven't found one yet either. I've done a lot of research on this, but there's no benchmarking option. Of course, in your case, since you have [two blocks], we could say that [one block] is dismantled with knowledge management and [the other] without. But that's not how it works. It's impossible to work out where something is being used and where it isn't and then separate the two cleanly afterwards.

Expert:

Exactly, I can't say whether a certain event would not have happened if we had trained our colleagues in way X, Y, or Z. There are probably events where you say, "OK, he just didn't know that you have to press green and not red." But we do train people in such basic things, the "know" part of know-how. But as soon as I get into the area where my knowledge covers know-why, it becomes really difficult to describe something like that in a metric. So that's a good question, how to do it. How should it be done? How could it be done?

Sure, if I have a simulator running, I can have 20 people work through the same scenario. Then I can maybe say, "OK, five times the wrong wrench was used and the screw was loosened instead of tightened." And then I have 20 people who I have trained in this area do it again, and maybe it only happens once more. Then I can compare it in the simulation— , but not in the real system, because that's not possible. And then the question is: If I have shown that training is better, then I can assume that the concept of training makes sense. Why do I have to keep confirming that it's still important? Because I'm still working with the same people. Nothing has changed in that respect. So, it's a difficult question from my point of view.

PM:

You mentioned simulators. What should I imagine these to be? Are they like flight simulators?

Expert:

Exactly. You have a full-scope simulator where you go through various scenarios with a complete shift team, where you practice everything. From starting up to shutting down/switching off the plant. And then you have everything you can imagine. With all the failure combinations, which, as far as I'm concerned, are technically impossible. As shift supervisor, you try to push them to their limits. It's like a ship. You only have the systems available in the control room. You can't just go outside and say, "I'll quickly pop out to [a hardware store] and get a few things." That's not an option. You have to make do with what you have and draw the right conclusions and derive the right measures. You can practice this on the simulator because the simulator, starting with the core model, behaves like the reactor core. They also took the burnup simulation from the real plant and so on. So the simulation conditions are exactly the same as they would be in the real plant. Right down to the turbine speed. And that's exactly the point. We used to have the simulator center in Essen, which housed simulators for all nuclear power plants in Germany. A lot of data from the operating settings went into it. Pump performance data and curves, i.e., characteristic curves, were recorded and stored, and then a computer was used to simulate the plant in every operating state. Events, specific component failures, and plant malfunctions could be simulated on the simulator. You could say, "OK, now let's see what the plant does when relay X, Y, or Z breaks down." That's how accurate the simulator was for us. The transients were the same, I could compare the fatigue curves side by side and they matched. It was a huge effort, a lot of money, and a lot of resources, of course. And it was really a 1:1 representation of the control rooms. Exactly the same measurement technology, the same components, the same ceiling paneling, the same carpet, and the shift supervisor said even the same coffee stains on the floor. So the degree of realism, once you've spent 5-6 hours on the simulator, was incredible.

Expert:

At the very beginning, there was a simulator where you could learn the basics and how a nuclear power plant works. But that developed very quickly, and plant-specific simulators were built.

PM:

Is that still the standard? Did that only apply to Germany, or...

Expert:

That is the standard. I've seen it in Russia, I've seen it in Canada, everywhere. It's like a flight simulator. It's a great way to let shifts practice certain tests, such as pump switching. If I have a pump switchover that supplies the feedwater tank and I know that when the feedwater level reaches a certain level, the reactor protection system kicks in and shuts down the plant. Then I want the shift that has to do this next time to have a routine opportunity to practice it. Because the time frames are not tight, and if they say, "Yes, what do I have to press now, and now I've pressed here, boss, now all the pumps are off, what now?" No, I don't want that. I want to generate electricity, so the plant has to remain safely and reliably connected to the grid. So you make sure that the switchover works well, and then you can practice it. That's what we did, for example.

PM:

So when the center was in Essen, did staff always have to be taken out and travel to Essen?

Expert:

That's right, we had six shifts and one of them was always on the simulator. So you really have to take that into account. That's eight simulator weeks or so per year for each shift up there. For shift supervisor training, I spent 14 weeks on the simulator over two years, and you really go through everything.

PM:

How well can communication be simulated there?

Expert:

Communication between the shift members on the simulator is clear, of course. I have the whole shift team there and can talk to them, shout at them, snap at them, whatever, just like in the control room up here. And then the simulator instructor—who knows what's going on—usually has one or more phones, and I have the real phone numbers at the front. Then, as shift supervisor, if I say, "Oh, I'm going to call the radiation protection team or the transport team because I need X, Y, or Z," I dial the number and the instructor at the back sees which number I've dialed and then he plays his role in a role-play scenario. It's great, the level of realism was really good. The colleagues from the simulator were also here often enough and talked to the respective colleagues to incorporate a few witty remarks so that you know: "Oh God, the person on the phone doesn't care if there's a meltdown. He's on his coffee break now, so I don't need to call." So the simulator was a great thing. Really good.

We actually did simulation exercises on the large board (tabletop): What happens if... And we also did exercises like this at the power plant, with the whole team. We often did exercises, for example once a year, which the shift team ran on the simulator. Then they had a connection to a control room here, and the simulator data was projected onto an information system here, and all the operational units here at the site that were involved in crisis management, whether it was the workshops, the fire department, radiation protection, whoever, saw this data. Terrible things happened on the simulator, and our organization had to pretend that it was happening here at the site, and then it started: sending a measurement technology vehicle to XY, taking a soil sample, coming back, and the others had to haul some parts on site. It went so far that the fire department actually hauled pumps up the stairwell because they said there was no power and the elevator wasn't working either: "Now see how you can get that 75 kg pump up the stairs." We practiced regularly to this degree of realism.

PM:

The blocks [of your nuclear power plant] were shut down – as you said – [at a certain point in time]. Looking back, how do you assess the preparations for decommissioning in terms of knowledge management? Were you able to quickly find everything you needed to know? Were there areas where knowledge may have been available but was lost and data had to be collected again?

Expert:

Everything. Well, there are areas where we were very well informed. Of course, I know almost everything about my components, or so I imagine. But of course... A colleague from [location of another nuclear power plant] once said, "It's dark before the dawn." So, once I start, I'm sure I'll find some surprises. One example would be the activation of [certain components], where we did calculations, where samples were also taken, and everyone was sure that we wouldn't find anything. And then you take the component apart, measure it, and say, "Oh fuck, there's something there." That was an example of "It's dark before the dawn." You have to learn that. In the other block, I know this from the outset, so there won't be any surprises. But of course there are areas where people said, "I don't need that anymore, or I can cut back on staff there, and they're all so old anyway, I'll just send them into some kind of partial retirement and they'll be gone." And someone is celebrating because they say, "Look here, this is our [downward] staffing curve, we have to show it to the board, and, and, and." And none of those who left took their work with them. It was left behind somewhere. I think a lot of detailed knowledge, a lot of little things, have been lost. When you suddenly find some component somewhere and you say: "Oh, where did that come from, what is it?" "Oh, wait a minute, we repaired components sometime many moons ago... in 2014 or so." "Oh, okay, ten years ago. Who knew that?" "Oh, he knew, but he retired last year."

Yes, those are the kinds of things. But the knowledge was there. It was recorded that there was something in the database. But if the person who maintains the database doesn't take ownership and say, "Uh, by the way, there's something else here," then it was there, but not in the right place.

PM:

I once read a sentence in an IAEA document that said that knowledge about the availability of explicit knowledge is already implicit knowledge. That's along the same lines.

Expert:

Right.

PM:

Can you give any other examples where implicit knowledge was no longer there, but would have been welcome? In line with your example just now, where there were components that no one had anticipated.

Expert:

What other examples do we have? Yes, actually, we took a lot of samples in [a certain area]. There were measurements, but colleagues retired and actually deleted their files at the end. I don't know why. A lot of data describing how chemical phenomena occur in the plant... Whether it's Crud [Chalk River, Unknown Deposit], i.e., any deposits, how that's related. Or how certain cleaning measures were carried out in the past. In fact, a lot of knowledge has simply been lost that could perhaps have been better preserved if it had been said, OK, there is an obligation to store this information in a central system. But because every expert maintains their own structures... In our project, we are also trying to record everything on a standardized project drive and not store anything on private drives or anything like that, so that if something happens, everyone says: "Look here, this is the folder, this is the structure, you're looking for a quote, addendum, PÄM [project change notification, *Projektänderungsmeldung*] – it's all in here." There are quite a few examples where something like this has been lost – without being able to be too specific.

Fittings too – I have a cabinet here for parts for [cleaning activities]. We did a chemical cleaning, in a system, [details on the time and type of cleaning]. I have all the fitting inserts that are required for this here. And I would like to have a second set, because I want to do things in parallel in the future, in the blocks. Yes, do you think anyone will find the VPU (preliminary test document, *Vorprüfunterlage*) that was used to manufacture it? The component is there. Everyone says, "Wow, awesome component, great. Let's build another one." "Yeah, how are you going to build it, you don't have a VPU?" "Oops, problem." So those are examples. And someone definitely knew that. Or maybe the folder is still somewhere. That's the example, yes. That's implicit knowledge. Someone just needs to know that this specific knowledge is there.

But those are actually points, yes. Krško was my favorite plant in that regard at the time. They actually maintained a database like that on the intranet. You could type in an AKZ or a plant identification from their system—it's a Westinghouse plant. And it was amazing what information they could retrieve about a component. From photos to recurring tests, to the last inspection and an invoice and external personnel who worked on the component. So everything was so ingeniously tagged and searchable in such a database. Gigantic. But again: I come from a world with many kingdoms, and these kingdoms have not always spoken kindly to each other. It was always a bit like, "We're better than the rest." Those are examples from the past. WANO uses the term "silo mentality" and says that the silos need to be broken down.

PM:

A silo is, to put it bluntly, ultimately like a kind of trash can, except that the data is not deleted. The main thing is to upload it somehow...

Expert:

...and there is no exchange with the other pillars, silos. I would say that issues like this are a permanent work in progress.

PM:

To what extent are external personnel involved in processes where knowledge and documentation play a role? The examples you have just listed primarily concern employees who belong to the operator. Would it be fair to say that external personnel, who are also frequently employed in power plants, contribute significantly to the accumulation of knowledge, or is that too hypothetical?

Expert:

No, that's not hypothetical. We actually did some knowledge transfer once. At some point, we noticed that the developers of the control element drives were leaving [the service provider]. They were all quitting. And then for a while it wasn't clear who would take over everything and who could do it. So we had them write a training manual as their last official act, in which they explained to us in detail how to perform recurring inspections of such a drive, how to repair it, and how to install and remove it. In retrospect, I have to say that there was far too little know-why in it, but pretty much all the know-how you need for these processes. With a detailed list: Which wrench I need – offset and shortened to 10 centimeters so you can turn it around.... So really an incredible amount. And, of course, this document was created entirely by external personnel, who then also trained us, i.e., the master craftsmen and me as the person responsible for the system, so that I would be prepared, so to speak, for events that might not even exist at the time or might not have occurred yet.

It was similar in the simulator. Sure, it was simulator personnel, essentially external personnel, but they prepared everything for us, conducted the training, and were also trained in teaching methods. So not only were they gifted technicians who understood the system extremely well, but they also knew how to convey that knowledge. So we had that covered as well. And when it comes to pure documentation, we actually have a number of external companies that create technical drawings for us, manage these drawings for us, maintain the archive... Yes, these are often external companies. Or external personnel, temporary staff.

PM:

With regard to the knowledge elements in my concept, you could work with access rights so that certain organizations can only see a specific area. There could be a kind of central data storage, but individual organizations would only have access to certain things. Since the information is centralized, it could be accessed in its entirety by the parent organization. Of course, security aspects must be taken into account, i.e., how far do I allow an external company into my systems? One could, of course, consider concepts of encapsulation and access protection and benefit from the fact that they are working with virtually the same system, but cannot view all data.

I think this works very well with access rights. We also use tools like this, file sharing or something similar, where you have set up sharepoints in exactly the same way. But the thing is, if I put everything somewhere and give everyone full rights, I have to be prepared for stupid questions. Because there will probably be people who look at things and then make up their own minds and say, "No, that can't be right, because... That's stupid, explain it to me." So: How much work am I creating for myself by putting all my data online? How much time will it take me to explain it to others who are just playing around out of interest and say, "Oh, what kind of graph is that? It doesn't fit at all. And now I'm going to overlay last year's temperature graph... No, I don't understand that at all." So, there is a chance, yes, that you say, "OK, we have an outside view of the data and they look at it..." This predictive maintenance concept would have been nothing more than me opening my databases and letting his algorithm run over them, and then he tells me that something is going to break tomorrow. Yes, it's a chance, but in my opinion, you have to weigh it up carefully.

A few weeks ago, I conducted an expert interview with the head of a department at a large executive company that is also involved in decommissioning. We talked about tenders. As a rule, documents are published in advance, or when things become more concrete, you can also request them. He said that in many areas, it would make sense to have not only plans, but also the implicit knowledge to go with them. That way, you would know what you are getting into and not just see what is on a plan—which could contain anything. Implicit knowledge might help you to better assess what you can actually expect on site.

Expert:

The language of the engineer is still the drawing. If I have a good design drawing, I think I can deduce quite a lot from it. But the fact is that we often received drawings from manufacturers that allowed us to understand the function, but with which we could never have replicated the component because they contained proprietary knowledge and they said: "I don't want you to have that knowledge, because if a competitor goes to the archive and says he needs it, he won't be asked for justification and he'll get the folder, copy it, and then build a control rod drive to replace ours. And we wonder why we're running out of orders." Says [our service provider]. So in that respect, it's a point that although you've gained a lot of knowledge in the form of drawings, not everything may have been correct in terms of dimensions. So yes, that would be implicit knowledge, where you say: "OK, here's the drawing, but please note that..." "Yes, that's a functional principle, it looks great here, but you can't manufacture it that way." It's very time-consuming. If I want everything to be made to measure, I would usually have to go through the recurring tests, where I did a dimensional accuracy test and so on. So then I have to put together a huge package. And that's probably what my colleague means, too.

PM:

Exactly, putting together a kind of package so that you think ahead and make it a little nicer for the contractor.

Expert:

But that's a huge effort. And from my point of view, the tender is developing. We have this [name and description of a dismantling project with large components]. The tender took over two years. We started with a fairly high-level plan and said, "Listen, how long will it take, roughly?" And it went so far that I converted all the design drawings I had for [one component] into a 3D CAD model so that cutting and packaging plans could be created entirely on the basis of this 3D model. All suppliers received this model. And then they were allowed to get started with it. And at the end, we said, "Aha, look, this one needs 20 KCs [Konrad containers, a type of container suitable for final storage] and that one needs 15 KCs. 15 KCs is more attractive for us, because a KC also costs money if we have to buy fewer of them. Great." So those were definitely things. Everyone also received the same activation calculation as a basis. Not that one person says, "Wow, I've packed brand-new steel here," and another says, "No, I had to take the activities for the KC into account here. That's why there are only 10 kilos in here, because it emits so much radiation." But that took time. We wanted to see what concepts were on offer first. There were things that [the expert describes an unusual construction approach to dismantling a component]. Very adventurous things, where we said to ourselves that it would have been unfair to the company if we had provided them with details at this stage. They would have invested an incredible amount of time in planning...

PM:

...Of course, you could see it that way...

Expert:

...and in the end, nothing comes of it. They would say, "Listen, we've spent hundreds of hours evaluating your drawings, and in the end, you say 'Yes, thank you' – nothing but expenses." That's why we structured it that way. The better a company's bid was, the deeper we went into the details. And in the end, because the dates/milestones in this schedule were very, very important for our dismantling process, we said: "OK, and we have to get the whole thing done by day X in [one block] and by day Y in [another block]. Now show us that your planning makes that possible." And then we delved into individual handling steps in MS Project, 1Plan, Primavera, or whatever else the provider used. For example, [certain components], where they said, "OK, and for [this component] with this geometry, we need five minutes to dismantle it." And then we developed a feel for how good the time planning was for the person who wrote the tender or for the provider. But as I said, that was at a later stage in the tender process. We didn't start with that.

PM:

Yes, I understand your reasoning.

Expert:

Of course, I could give him all that information right from the start, but then he'd probably want to know, "How should I break it down for you?" And then I could plan it myself and do it all myself. Now all I need is the machinery. In fact, there are now individual systems in our company where we take exactly this step and say: "Listen, we've explained so much to you now, we know exactly what we want, you just need to provide us with the machinery. Now we only need you for the special machine construction." That's a big feature of the project, that we say: OK, these are all machines that we don't have ourselves, that we can't just build ourselves or simply put in the corner. A large band saw, for example. You use it to cut pipes into small pieces, you put it somewhere in the machine room and then it cheerfully saws away. But I'm always underwater dismantling reactor pressure vessels and core components at depths of up to 30 meters, where I need cameras. That's special machine construction, and we have no way of building that. So it's clear that we need a service provider for that.

PM:

In the construction industry, we exaggerate by saying that claim management is the only way for a contractor to make money. So it's a matter of making the cheapest possible offer and then, in the course of claim management, saying, "Yes, we didn't know that, so unfortunately we have to make it a little more expensive." Is that also the case in measurement technology?

Expert:

Yes. There are projects like that. Claims went back and forth. "Justify PÄM X, Y, and Z, justification is not accepted, this and that is still missing..." And then someone said, "Hey, what is PÄM? Take a look in the directory. Oh, you have so many emails about 500 euros." Crazy. I say, that's impossible, they don't need a project anymore. Resources are limited, which means the claim manager then asks the project engineers: "Tell me, how was that, how is that?" Do they think that one of the engineers is still working on the project at that moment? It's a vicious circle, you can forget it. That's why there are actually other ambitions in construction projects, and we learn from that. So not time and material—that would be another option, where you simply bill according to time and effort. A fixed-price model is what most people offer cheaply and then come in via claims, and the middle ground, in my view, is a target price model.

It's moving in the direction of open book. It's quite complex because you define a 100 percent value – that's the target achievement cost – and you commit to it together with the provider. And then when new information comes to light – "it's gloomy before the shovel" – you say, "OK, you, dear service provider, should have known that. Then the 100 percent value remains the same, but you spend a little more money. We pay you for that because, at the end of the day, we want the plant to be dismantled. But please, you won't get a 10% margin on top of what we pay you for having to do this extra work now.

Now there's only 9% or 8%." It's a curve that you apply over a period of time. This requires a lot of transparency from everyone involved. And yes, at that point, you're basically just in the archive looking at drawings together when it comes to determining a 100% value. But in my opinion, that's very, very good. Why? Of course, a company can always exercise its right to refuse performance in a contract for work and say, "Stop, that's not defined that way. We need a request from you first, then we'll give you a quote, and so on." As a project manager, that's no good to me at all, because then all my deadlines go out the window.

The first step was to say that we would include a clause stating that you cannot exercise your right to refuse performance. Then, as a first step, we thought we would simply give the project managers some play money. They have a budget that project managers can access immediately if a company says, "We've identified this and that, and if you don't give us €1,000 for engineering now, we don't know how to proceed." Then we said, "OK, here you go, here's the €1,000, and let's move on. We'll then discuss how to deal with the PÄM." But that has its limits. A PÄM budget or play money like that is limited. You can't say, "OK, now you have a million-dollar contract here and you'll get the same amount again as play money." That's not possible. No board of directors would go along with that. And that's why we approached the supplier or service provider with the lessons learned from the project and said that we would convert it into a target price model contract. We have had very good experiences in the construction industry with two construction projects in the company. Especially with regard to material price developments now with Ukraine or inflation, they didn't have any of that in there. They said, "Well, if I build one more thing here, I'll be insolvent and the construction site will come to a standstill." Yes, and then they said, "OK, then listen, we'll do a target price model. If you need to hire additional staff, then include us in the negotiations. Maybe we have a different, more favorable contract, or maybe we have another supplier who can support you." So, in my opinion, there are many ways to improve with a target price model like this. And as I said, we are currently working on it.

PM:

Yes, I think that's good. You also have to think about the next generation: Probably only a very small percentage of people are enthusiastic about tough claim management. There are people who really enjoy that kind of thing. But many who start their engineering studies want to have a good working atmosphere and not be unnecessarily involved in something like that.

Expert:

Right. To stay focused on working towards solutions, a target price model like this is really good. As we said, we want to avoid claims.

PM:

Let's stick with claim management: What role does the availability and exchange of explicit and implicit knowledge play? Is it about the "misinterpretation" of documents or also about implicit knowledge that the client had but did not pass on to the contractor and then thinks afterwards: "Well, maybe I should have passed that on..."

Expert:

We had the example with [certain components] that were suddenly activated. Everyone was surprised. A lot of research, measurements, and work had been done, and there was simply no indication of this. And then, in the end, the measurement technology said, "Yes, there is something there" when it came to the real material. In retrospect, you have to straighten out the models again and say: "Now I've been calculating until the model shows what I actually measured, and lo and behold, add a 'fiddly factor' and suddenly it fits." Of course, no one had specified that beforehand. Yes, that was a surprise. I don't know which category I would put that in. What we also had – same construction site, same component – was a steel structure inside [a certain component]. You couldn't see it from the outside. We had drawings from [the manufacturer] that looked great and corresponded roughly to what we actually saw upstairs. And then they made a cut and said, "We need much, much longer and the drill bit is getting hot, there's a lot more steel in there – fear factor." It was only documented somewhere that they threw all kinds of things into the steel on the construction site. It held up fine, everything was fine, but it was different from what was originally planned. Implicitly, one of the old builders certainly knew that. But I bet there was no chance of getting hold of that knowledge. No one would have said, "Listen, there's a bicycle frame in there and I don't know how many bottle caps." Definitely not explicitly. But I also have an example for explicitly.

I said: From the outside, it looks like it was planned. Then we looked at it and passed the drawings on to [a service provider] and [another service provider]. And then we came across a shaft. And I said, that can't be right. So right in the middle of the [component] there's a massive wave and lead sheathing, what's going on here? And then we looked at the drawings here and said to ourselves: "No, we don't see that on our drawings, which we have here officially." Then we spoke to an old civil engineer and he said: "Wait a minute, which company is this from? [Name of the service provider] – is that [from branch A] or [from branch B]?" "Yes, the last drawing here was done by [branch A]." "There was a change during the construction period and the archivist at the time didn't trust [the staff at branch A]. For him, only what came from [branch B] was important, and he entered that into our system, but not what [branch A] sent. Yes, they used to have playgrounds like that, where someone would say, "I don't trust them." So, you can find examples for everything. Explicit knowledge that it's simply not there , or you find the surprise, and implicitly you also find examples. That has a lot to do with trust, the transfer of implicit knowledge in tenders.

Again: if, as a project manager, I want to complete my project within the time and budget constraints, I have to pass on as much as possible. We've had bad experiences with "OK, here's a key, I'll be back in six months and then the component will be gone." So if that works out without any claims, then I don't know. So, those are the points... That's why I pass on as much as I know or know is not documented.

PM:

Then I'll move on to the next section, IT. As mentioned earlier in the TECDOC discussion, do you have an IT strategy specifically for knowledge management?

Expert:

No. I have to laugh about that. Knowledge management, IT strategy... I can't say "yes" to any of that. Although, we do have an IT strategy. So, that works. That's great. But we don't have knowledge management directly integrated into IT. I said I knew about it from Krško. They had a really cool database system and everyone had to enter their data into it, there was no way around it. I thought that was great. I learned about it in 2014. But we never managed to do it because at some point it becomes so much work to transfer databases that you say, "Oh my God, if one column slips, we'll never find the data again." So we always shied away from the effort involved. So, something like that exists, yes, but not with us. But I think it makes perfect sense.

PM:

What elements do you think a KM strategy in IT should include? You mentioned the example where things can be traced back to a single component. Could it also be process knowledge? What should ideally be part of such a strategy?

Expert:

Okay, now I'm back as the shift supervisor. I think in terms of system diagrams. When I have a system diagram, I have the entirety of all AKZs in this system in front of me. If I now want to know how many fittings of type X, Y, or Z are in this system and I select an AKZ, then I would expect the software to be able to tell me exactly that. So what information should I not include? How do you determine which information is not necessary? It's like my spice rack at home. I have everything in there and I don't say, "No, I never need black pepper. Curry either, no, I'll get rid of that too." At some point, I'll need it. I know where everything is and can put it together appropriately so that I can react. That's why—it's very difficult, and I don't think it will get any easier if you now go into creating such a database with the knowledge you acquire during decommissioning.

So now I know exactly what I need to operate a plant in order to prove it, according to KTA, and you haven't seen it. Now when I think about what else I need for the dismantling of such a component? You have to think far ahead when considering what goes into such a database and why. The "why" is also important. Because if someone says, " , we buy pepper every year, it expires every time. Why is pepper so damn important in this place? We're not buying pepper anymore." And then at some point someone comes along and says, "Every 15 years we make this pepper recipe here, so we need pepper. Where is it?" No pepper there. That's why you have to think incredibly far ahead so you don't shoot yourself in the foot somehow.

PM:

Since you say there is no formalized IT strategy for your area, how is it organized overall? Does knowledge management take place digitally, analogously, or informally, i.e., in conversations with each other?

Expert:

Databases and how to use them are taught in face-to-face conversations. Then there's incoming and outgoing mail, i.e., expert systems where you can search for information. At AKZ-level, someone used to take the trouble to record operating resource cards or enter type plates, and then you can search for tons of information there. So it's already there, but we don't have everything in one place.

PM:

Would that be desirable, or would you say it's actually possible to do without it?

Expert:

I think we've now come to terms with the fact that we can do without it for dismantling. I mean, we're now walking around with the laser scanner and scanning everything, and then the AI tells us a little bit. If I had to dismantle another plant later on and I said, "OK, you know, the guys in the factory at the back are really good at cleaning fittings of type X, Y, or Z, and in terms of materials, they're all the same, and we've found a smelter that will buy them from us." Then it would be cool to be able to press a button on a system that says, "Here you have components that are exactly the same in terms of material, and here and here you have components... But the cloud is getting smaller because the following components are contaminated as hell and the following ones aren't contaminated at all..." I need all the data again for the dismantling. Yes, of course it would be great to be able to form clusters or clouds or whatever you want to call them, because you can certainly get a lot out of them.

PM:

In construction informatics, we work a lot with artificial intelligence and machine learning. Large language models are a big trend right now, of course. You know them from ChatGPT. If you have your database, you could build a kind of chatbot on top of it by "feeding" your large language model. Then you can ask exactly those kinds of questions and hopefully get good answers.

Expert:

That's the ideal scenario. It's a question of the database, which must of course be absolutely correct, otherwise I'll be in big trouble.

PM:

With conventional large language models, we allow for a little bit of hallucination. In a field like nuclear technology, where safety is paramount, this can of course be problematic. Furthermore, reproducibility is difficult with large language models. If you ask the same question twice, you get two different answers. But I understand that this is the direction your thoughts are going in. So, a kind of internal knowledge catalog.

Expert:

Probably because I'm so old, I still think in terms of databases and keywords. And then someone just has to be clever enough to say, "Wait a minute, we're looking for 'spindle material' as a keyword, and then it specifies the material." Then they have to say, "OK, I can only find spindle material in fittings, so I'll hide pipes and containers. Then add the material and there you go, here's your list." And then I say, "Yes, cool, 115 pieces, fantastic, dear smelting company, I have the following on offer." I'm surprised when someone says that's a classic use case for ChatGPT or whoever. "Hey Siri, find me all the fittings." No, that's a database query! Enter the material number and yes. In the past, the material data sheets from the different smelting companies, from different [list of various steel producers], whoever, all looked different. Maybe artificial intelligence is helpful in data collection. You say, "So you're telling me these are material data sheets. Take a look at them." And then I say, "OK, that looks the same, and here I have another X5, Cr20, didn't you see that, it's another one..." I think AI is capable of recognizing material compositions like that. Or even if they're in a table and the AI then says, "The V2A you're looking for is actually here in the other document, it's the V1.4541. It's the same thing. You were only looking for 1.4541, but I'll still give you where it says V2A, because it's the same." So I think artificial intelligence would be more helpful in data collection, in order to implement quality as well...

PM:

...Yes, I think that's exactly the consideration. Do you want quality in the raw data or in the evaluated data?

Expert:

If the raw data is incorrect, it doesn't really matter how good the evaluation of the raw data is. Because the error I have in there will always be propagated. There should be no errors in the raw data. It has to be correct.

PM:

That's where the question arises, if I don't want any error tolerance: Is that all the more reason for a human to do it, or for AI to try its hand at it?

Expert:

Who makes more mistakes? And who is faster? At the very beginning, we had the discussion between the American and English concepts, where humans do everything, switch and rule. The German comes along and says, "No, I have an automatic system, a control system that is seven times faster than humans and makes fewer mistakes under stress." Well, then maybe I'm the typical German who says, "I want the automatic system in there early on, it makes fewer mistakes and is faster than humans." But I don't know if the classic engineer at that point... So , when we scanned 40 meters above, a real engineer actually sat down and said, "OK, and that's a concrete bar, I can grab it and it's gone." And then the model panicked and said, "Help, there's a black hole under the beam if you remove it." Then we had to tell [the model], "No, look, there's a smooth surface again and that's another beam." And we did the whole thing four times, and again and again the model said, "Black hole, model error." Until we said, "Now all the bars are gone and there's finally the floor." But floor is floor. Our model doesn't know that there might be a bar supporting a ton of weight or that there's just an opening that's been sealed with fireproof mortar, so I'd better not put anything on it. So that's the next step when I start with something like this, i.e., actually creating a digital twin from the construction technology. What do I include, and then I need qualitative data again. I think a human being with common sense always has to look over it again.

PM:

There are now also ethical considerations where it is said: "Even if AI is good in a certain area, precisely because it is critical infrastructure, perhaps it should not be used there. Because if something goes wrong, a human being should be able to fix it." In case of doubt, AI cannot fix itself. It can do a good job of mapping business as usual, but when it really comes down to manually detecting errors in an AI algorithm in a worst-case scenario, it becomes difficult. I think this consideration is important. And yes, you don't have this problem with traditional databases with keywords and heuristics. But if I move away from that and just imagine a large data silo, then you could also let AI loose on it. Everything has its advantages and disadvantages.

Expert:

For me, the question is always how much I trust AI, i.e., how much freedom I give it. How do I set the guidelines? And I have to set them, I have to think about it. I don't think I would let a truly free AI model loose on it. Then I might suddenly have three systems where there were only two before, because the AI has rearranged the system components and thinks it's much more intelligent that way...

PM:

In construction informatics, we work a lot with BIM, Building Information Modeling. You said that you have already used it for tenders by creating 3D models. How much do you actually take advantage of the fact that you not only have 3D geometry, but can also attach semantic information? This is an important feature of BIM.

Expert:

As far as I know, not at all for the components we have for dismantling. It takes place separately. We have a component. I know that it has the following dimensions in the reactor, and then I put some model over it. This then tells me: "OK, I saw this and that fluence at this point." And then something magical happens, someone says: "OK, the material has captured this many neutrons, so it is now activated to this extent and has a certain dose rate." Then someone comes along, superimposes color schemes and says: "OK, now I have to cut it like this, then I can pack it well and then I have optimally filled a KC." I have volume, weight, and activity, which I am allowed to pack in, and our goal is, of course, to always make maximum use of two out of three criteria. This is actually a manual process. You could certainly run AI over it. I would probably have to map this fluence better in this 3D model. Maybe I need to specify exactly which KC types I have available, because otherwise my degrees of freedom are arbitrarily high again. Then it has a great solution, but because I only need one type once, it is much, much more expensive to purchase than if I had somehow used the other type twice or five times. Then it's a question again: How do I optimize, which parameters can I specify? These are again the guidelines that I set.

PM:

Of course, there are possible combinations of BIM with AI. But even if you take BIM on its own, it's already different from a CAD drawing. Our professor always says that a line on paper is not intelligent. But a digital line in a section or in a view in BIM is intelligent because it knows that it belongs to a wall and that this wall has a specific stored material, a certain density, and so on. So there is already knowledge in there.

Expert:

OK, that's in the model, of course. So the different steel keys, the steel numbers are of course stored in the construction drawing we have there. We took all the information from the construction drawing, the melting certificates, or simply the documentation.

PM:

You just mentioned the digital twin. Do you have that for parts of your plants or even for the whole thing?

Expert:

I think there was a project where they considered implementing something like that, and that's where the examples came from, where they said for a factory layout: "OK, great, here's the space with the following machines. Here I have a model of the machine, I'll put it there." And then it turned out that someone said, "OK, you can't put the five-ton saw in the corner." "Why? Look, it works, I can move it here, can't I?" "No, there's a hole there and it's only sealed with fireproof mortar, which isn't load-bearing. But it's been painted over." So he went through it, scanned everything, and the scanner didn't distinguish between fireproof mortar and other materials. So someone has to check again which drawings I have of the room area. "What kind of effort is that? I don't have them digitally, now I have to read paper..." I think that's quite a lot of work for these old systems.

PM:

Yes, as-built models like that are complex. My thoughts are along those lines because my concept is very much based on geometry, i.e., the visual aspect. I can then attach documents or even knowledge elements to it. Ideally, I have a digital twin as a basis. When new power plants are planned and built, BIM or another 3D-based methodology is already used for planning purposes. Then I would already have this geometric representation. I just have to make sure that it is actually passed on to the energy supplier...

Expert:

...and that only one model is maintained. If I then have a fork like this: "... and now we've only changed which walls have been painted red..." – oh no.

PM:

Yes, exactly, those are the difficulties. I do have a model from the outset, but of course I have to make sure that it is updated over decades of use.

Expert:

Exactly, discipline and data integrity. And that's one of the points where I say you have different kingdoms. One kingdom says, "I'm only interested in recording which walls are painted red." I think that's another cultural issue.

PM:

In addition to BIM, there is also the so-called PIM, the Plant Information Model, specifically for nuclear power plants. There is also a kind of theoretical concept from the IAEA that is only three or four years old. It's called the Knowledge-Centric Plant Information Model. It also appears in my concept. Are you familiar with this concept? Have you heard of it before?

Expert:

Describe it, tell us what it is. Maybe we've had it.

PM:

It's a kind of jack-of-all-trades. People say that BIM is good for geometry, but ultimately everything else that's important—control systems, accounting, etc.—requires me to create a higher-level system. That would be the PIM, the Plant Information Model. And Knowledge-Centric Plant Information Model would mean that I feed this model with knowledge rather than data. Knowledge then means that I don't enter documents, but – ideally – that these are broken down into their knowledge elements. Knowledge-centric would mean that I only have very small units, which I can analyze much more easily afterwards. This is where semantic web technologies come into play, for example. For example, I could rely on ontologies instead of relational databases. So it should offer more flexibility, but in my opinion – and this is why I am asking you – it is still a theoretical concept that has never really been put into practice. Everyone I have asked so far whether they are familiar with this model, which is really being promoted by the IAEA, has said that they are not actually familiar with it at all.

Expert:

No, I don't know it either. But that may also have something to do with the fact that we were shut down [several years ago].

PM:

It is also more relevant to operation than to decommissioning. Let's move on to the identification systems. You have mentioned AKZ several times now. How detailed is the system? You also said that there are individual pipes that do not have their own number...

Expert:

Yes, they always have their own number, it's just not written on them everywhere. It's on certain points where they are suspended. So it's just the labeling that hasn't been applied so generously. Of course, a fitting is a spatially limited lump or a component in the room, so naturally there's a sign on it. But a pipe like this runs between two fittings, and maybe there's only a label on one fitting or in between to indicate which pipe it is. However, we don't organize the dismantling by system, but by room area. That's actually a point where you say, "OK, now cut everything out of the room." And suddenly I can no longer trace a pipe.

PM:

Because it continues on one side, but I've already cut out the part with the label?

Expert:

Exactly. And that's where laser scanning comes in, this artificial intelligence, where you say, "Look, find me all the DN32 pipes here." And then it marks them for me. And then I can plan for this section of pipe only. So that helps me. When I look at it with artificial intelligence, I say, "I just scanned that area, there was a sign on it, and that's now the pipe here in the bundle." Because we simply assume that there are no pipe crossings in the wall opening. So we have that, we're great. We have AKZ signs galore, so all the components can be found. That's good.

PM:

How are the components labeled? Just with the number...?

Expert:

It's a combination. We have a block assignment. Then there's a two-letter combination for the system. YC, for example, would be the reactor pressure vessel. Then comes YC01, because there's a strand behind it. I only have one reactor pressure vessel, so 01. Then comes a B, as in vessel in this case, and again a number, 001. And then I have described the vessel properly, I can do the same for valves. Then I don't just have a 0 at the end, but maybe also a 2, a 4, a 6. Or 1, 2, 3 – depending on whether it's redundancy or diversity, it doesn't matter. And so, when I can read these numbers, I can find my way around pretty well. Whether I'm in the high-pressure path of a system or in the low-pressure path, suction side, pressure side... I can tell everything from these numbers. So there's a really good structure behind it.

PM:

How do you go about identifying them? Do you carry around a kind of manual and look up the numbers when you read them on the pipe?

Expert:

Technical expertise.

PM:

So you know which number belongs to which area?

Expert:

Yes, you learn that at some point. When you read a system circuit diagram and then go through it, you know: "Ah, here I am on the pressure side of the high-pressure pump, then I'm in the 24 path, ..." You learn that at some point. But it's also systematic, so once you understand it, you can apply it to other systems. It's not as if the manufacturer just threw the numbers together at random.

PM:

Can these numbers also change? For example, when components are replaced or upgrades are made?

Expert:

No, because the system ultimately explains the function at that point. The high-pressure pump will always be a high-pressure pump. And the high-pressure path is therefore always the high-pressure path. That's why the number is the same. But what can change is that there are other numbers behind it, the operating codes. The system goes even further. And based on the numbers, I could probably say, "OK, the motor has already been replaced twice." But honestly, as a shift supervisor, I didn't care. I knew where my pump was, and if it failed, I didn't care whether it had been inspected twice or three times, or who had inspected it. I don't have time for that on the simulator. I have to make sure the core is cooled, then I switch on another pump. The technical department takes care of the details later. And they'll definitely let me know what happened.

PM:

Is some kind of digitalization already taking place around the AKZ? Other industries also work with such clear classifications. But they are no longer visible. In an Amazon warehouse, codes such as QR codes or barcodes are used on a large scale. No one reads them anymore, only machines. I have seen that there are also hybrid approaches in nuclear facilities, for example, where a QR code is displayed next to each alphanumeric code that a human can read. During maintenance, for example, I could use this code to enter or retrieve certain information.

Expert:

It's not standard practice. I'm not sure if there were stickers like this at certain measuring points for the shift supervisors, because they basically just scanned the measuring point, typed in the value, and moved on to the next measuring point. That definitely happened during the shift. Otherwise, we also scanned the signs when scanning with the pipe scanners. We also captured them at 40 meters, and I was horrified that with a Leica scanner, you suddenly have the AKZ sign in front of you like a 3D scan and can see the exact number. For us, in our project, that was way too much information. We filtered all that out because at some point it became unmanageable. For the colleagues who are tackling the dismantling here with artificial intelligence, this is exactly the information they need to have missed the pipeline one day. They say, "OK, we've scanned it in 3D from the sign. Let's hope there weren't any spelling mistakes on the sign." And I think that's what they did, yes.

PM:

That's exactly what I'm thinking. So, I use the AKZ as a connection between the physical and virtual worlds. That way, I can reference what I have in real life and attach documents and these elements of knowledge to it.

Expert:

Exactly, yes. So that's possible, and as I said, I was thrilled to see how the resolution is there and you could still scan further in.

PM:

Back to labeling systems in general: I'm familiar with AKZ, but I also stumbled across RDS-PP during my research. It seems to be a kind of successor system.

Expert:

I'm not familiar with that abbreviation. I know AKZ, I know KKS. But the numbering was often specified by the power plant manufacturer, yes. It's just a different language.

PM:

Yes, the principle is probably the same. Everything is clear and it reflects the system reference.

Expert:

Yes, exactly.

PM:

The TECDOC presented the individual phases from design to decommissioning. You can probably say a lot about the area of decommissioning now, perhaps a little bit about the transition from operations to decommissioning. Let's go through the individual phases and you tell me what comes to mind spontaneously, what knowledge is conveyed and where the bottlenecks are in each case. More specifically: Where is there a risk of knowledge being lost and is it perhaps different types of knowledge?

Expert:

Yes, that's right. Because the type of knowledge that is relevant simply changes in the different phases. For example, I once talked to Professor Michael Corradini at ETH Zurich about why boiling water reactors are operated at approx. 69 bar. Why not 85 bar? Why not 62 bar? Why this value? And he was able to explain it. He said that experiments had been carried out and that under certain conditions in the core, the distance from something to meltdown was greatest at 70 bar. I can't remember the connection anymore. But I think it's really important to know. And it bothered me that I never found out again. I read books—Thermal Hydraulics of a Boiling Water Reactor—and told myself that it must be in there somewhere. I couldn't find it. And that information is definitely lost . So, that must have been something from the research and development phase. Moving on to design, i.e., conceptual design and detailed design: that's where it was constructed, and from then on it was decided that all boiling water reactors would operate at 70 bar. Approximately 1000 PSI. And in my view, that also has a lot to do with how much know-why has been lost and how much know-how I still have. And, as I said, that has a lot to do with the question of what I actually still have to do. What knowledge is relevant? We did well. When the first shift supervisors joined us, we took some on from the manufacturer. So, that means we had a lot of shift supervisors from [name of manufacturer] at the beginning. And they trained our people and took over. So, that was a good thing. There are certainly approaches everywhere to avoid losing knowledge. But even there, a classic commissioning engineer also made sure that the component was running and the customer was happy. But why did it work so well – it didn't fail, it runs stably – so what? The only thing that mattered was how I got there. Why did it work this time? Irrelevant for now. "Robust component, doesn't break down easily, fits." I do believe that there is something in many areas, but I couldn't say where most of it is lost. But I can see that There is a great danger that a lot will be lost between operations and decommissioning because the organization changes so dramatically and suddenly focuses on completely different things than in the operations phase. I believe that's where most of the knowledge is lost. Somewhere you said 60 years of operation, right? At some point, I won't be able to find anyone who was actively involved in the concept phase or detailed design.

PM:

The IAEA always says that it takes 100 years or more from the planning stage to the greenfield site. That's two or three generations.

Expert:

Yes, that's right. At the beginning, I have to ask myself what of the knowledge I have put into the construction or development of the plant is still important for achieving this target state of "greenfield site." This holistic view.

PM:

My impression is that this line of thinking is also neglected in the new reactor types. I was at this conference in Prague [International Conference on Nuclear Engineering 2024] and there were also various exhibitors, many from China, who presented new reactor designs. They did a nice job with 3D and BIM. I asked them, "Do you also think about decommissioning when you design?" They said, "No, we've never decommissioned a reactor in China, we don't know how to do it. But you in Germany know how." That's exactly what surprised me—I mean, it's kind of good for business when I sell a reactor and say, "Okay, and I'll give you the basics so you can decommission it properly later." But apparently, at least for this one company, it wasn't even worth thinking about. I was really surprised.

Expert:

No, you don't have to think about dismantling; refurbishment is already mentioned somewhere here [in the illustration]. It's not as if I do refurbishment shortly before decommissioning. Actually, I do refurbishment and then operations and maintenance should come again. That means for this point, you have to say, "And we've thought about how you can replace components to extend the service life and increase performance." This aspect is important if you want to attract the Chinese. "Yes, you haven't dismantled it yet, but it will happen at some point. In the meantime, you may have a few major defects. And if I can show you that you can easily remove a valve because it's described that way and that you can get back online as quickly as possible..." That's how you can attract them. At least, that's what I believe. In Fuqing, I took a look at the Hualong One, the Chinese pressurized water reactor.

It's a great model, all in 3D, with holograms you can look at, and then the component rotates in space – it's really fascinating. But back then, in 2018, I hadn't actually thought about decommissioning on that scale. We were on the road with WANO, and the focus was on how we could optimize peer review content. They did a lot with WANO. The WANO teams were coming and going at the six blocks they had there, and at some point they realized: "Wait a minute, we haven't even finished implementing one measure yet. And now we have a new recommendation from the next team." I said, "Yes, I know what you mean. When I was a student in Karlsruhe, I signed up for something at a student exhibition and suddenly I had a subscription to Men's Health magazine. And then every month I got this thing called 'Six-pack in six weeks' and after four weeks the next great plan came along." And that was exactly the situation. If I had followed the plan for six weeks, I would have had a great stomach, but then four weeks later the next issue of Men's Health came out with an even better plan. So, folks, that's exactly the situation, and we thought about it with WANO, how we could coordinate things better and how we could see what's really relevant and then coordinate the teams so that there's continuity. Because there are always different teams coming from WANO.

So the perspective is different. One adds more pepper, the other more curry. And everyone asks, "Which recipe is it?" And then, to satisfy the same hunger, you say, "OK, listen up, you two team leaders: coordinate with each other, because the recipe is still the same for satisfying hunger." That's why I didn't pay attention to the dismantling.

PM:

The situation in China is special. At the conference, I would estimate that two-thirds of the attendees were Chinese. And ten years ago... I looked at the publications, but you had to search hard to find Chinese authors. So much has happened. With all the research and expertise that has been accumulated in such a short time, it is difficult to achieve consistency now that everything is moving forward there.

Expert:

My professor from [German university town] confirmed this to me. He said: "When we were active, from around 2000/2003 to 2006, the Chinese came to us and had us confirm that what they had found or measured was correct." He said that it was roughly comparable from the institute's point of view. He was over there in 2015 or so, and he said: "Suddenly they had two buildings as big as ours, and because the second building was already half full, they built a third one next to it." And in 2018, he was here again and said, "They're not coming anymore to find out if their research is correct. Instead, they're asking what else they can do to make even more progress in this direction." So it's no longer "Please confirm what we've found," but "We're done everywhere, and we're already looking at what else we could do beyond that." He said that the pace at which the is working is incredible. And now I hear that two-thirds of them are participating in some kind of event – it's crazy.

PM:

This International Conference on Nuclear Engineering was traditionally organized on an equal footing by the Americans, the Japanese, and the Chinese, at least that's how it seemed to me. The Europeans were a bit carried along by the Americans. But as I said, two-thirds Chinese—that was a very interesting experience.

Expert:

Yes, I believe so.

PM:

Then there was the quote here [in the IAEA-TECDOC] about system engineers. That they are actually the ones who should be driving this whole issue of knowledge management and information transfer. Who are they, in terms of job profiles, who are most likely to have knowledge management on their radar?

Expert:

Actually, I think it should be an HR issue. Managers together with HR. They should know who is leaving next or who is changing, whatever. And how do I replace that colleague, and how do I get the new colleague who comes in up to the standard I would like them to be at? I think we already talked about this briefly earlier when I said that I haven't created a plan for what I will make available to someone if I change or if I am changed, whatever. So I would say that the systems engineer doesn't do justice to this in practice. Why? He has much more fun thinking within his system than dealing with such issues. But what is true in the quote is that the systems engineer does not necessarily know all the components inside and out. Because he says, "OK, I have a system, I have to fulfill the function. The shift supervisor says so. The pump has to run, the water has to go in, and I know what I have to do in the system to make it work."

And then the component engineer comes along and says, "Wait a minute, we have to do this and that with the valve, pay attention to this with the pump, and that with the pipeline." [Quoted] "But rather, they know where to find..." – Exactly, they need to know where to find it, or who the relevant component engineer is who can then provide them with this detailed information. That's right. So, yes, in my opinion, the system engineers live up to the claim made in the quote. We used to do this very well, saying that we had taken on many engineers from the shifts. Shift work is not tolerable for everyone for any length of time. Then there were engineers or shift supervisors with engineering training, and we said, "No, he can't handle the shift anymore for health reasons, we need something in day service." But with the understanding that he brought with him from the block, we then made them system engineers.

Great thing. He knew the plant, he knew the system from operating hours, he had watched the system in operation for hours. He knew the connections and they took him on and that was a really good thing. They were able to take a step back and look at the big picture: "OK, I understand how everything works here, I know the impact of my system, and I also know exactly how this system works." So that was also a very good approach that we used to take here. Of course, none of that is relevant in decommissioning. But for a plant that is in operation, ask yourself: Where do the system engineers who bring this kind of systems thinking come from? You can get them from the shift. That would be one point at this stage.

And in order to promote cooperation between a system engineer and the shift, there was a rolling system for the shifts—as I said, we had lots of shifts, six per block—so there were always shifts responsible for the system, and they swapped over. That means that for a year, shift 1 was responsible for the reactor pressure vessel and then also provided intensive support during the inspection. Then shift 2, then shift 3, and so on. So it was a rolling system to ensure that as many people as possible were involved. No operational blindness. I was always the same system engineer, but the people asking the questions changed. And then you learned something new every now and then and got questions you hadn't heard before.

PM:

Yes, it makes sense that everyone really saw everything.

Expert:

Exactly. And again, at some point, one of the shift workers came along and became a system engineer somewhere else, but he had seen the system at least once before. And through the shift supervisor training, he also had an idea of the systems as a whole and how they had to work together. So, from my point of view, that was very important.

PM:

Then we have the question of whether feedback on the current knowledge management practices is actually being sought from employees. This naturally raises the question of how involved they are. There will probably be a lot of wishful thinking involved. But how much can individual employees really influence this large-scale knowledge management system?

Expert:

When they leave, they can delete their directory.

PM:

Yes, well, influence it in a negative sense.

Expert:

That's an extreme. He can hold shift training sessions. For example, I did shift training for my project [name and description of a large-scale mining project]. What are we planning there? What do we want to do there? Because they have their cameras up there and they're watching, you can do that, of course... Of course, we have online training options, but that's more in the soft skills corner. What can I do to be a good project manager, what communication tools are available, how do I persuade people, and what do I know? So, this whole colorful bouquet of soft skills and social skills. These hard skills, i.e., technical expertise... Of course, there used to be an entire training department for this, which trained the shifts, including in the systems. There was great documentation on the simulator for each individual system, which explained how it worked. But otherwise, as a systems engineer? Daily work with the system was always where you learned or, perhaps, questioned yourself. What am I actually seeing here? Curiosity was always important. But I think that's the case everywhere.

PM:

Let's move on to the point [from the IAEA-TECDOC] with the list of knowledge capture techniques. A whole range of possibilities are mentioned here. For example, there are onboarding and offboarding interviews. Offboarding involves attempting to gather all the knowledge before someone leaves. This can be done, for example, through a guided interview. It should involve someone who knows the technical side of things, but also someone who has an overview of the big picture. But the interviews should take place separately if possible, because people don't like sitting across from two people. And of course, this can only be done on a voluntary basis. You can't say to someone who wants to leave anyway, "Now sit down here and we'll grill you" – to put it bluntly.

Expert:

They have to want to do it and allow it, yes.

PM:

What is your practice? Earlier, we talked about brain drain and attempts to prevent it. Which techniques, for example, of those mentioned here, do you use?

Expert:

That's a really interesting question. Because when we encountered this situation, where we surprisingly found these components, we asked ourselves how we could have prevented it. I think an audit should be carried out or something similar to check whether all aspects have been considered during organizational changes and that they have been or will be handed over. That no blind spots have been created by reorganization. That suddenly entire regions can no longer be mapped because the colleague is no longer there. That's a good question. We don't have an answer to that yet. Onboarding—as I just said—I've read about it, I've heard about it, we've done it. But offboarding... I saw a checklist somewhere about what people have to do when they leave the company. But that's more of a checklist about handing in keys, email accounts, and so on.

PM:

But that's a rather restrictive way of thinking and not optimistic about what someone is willing to share.

Expert:

No. These are simply things they have to hand in, otherwise we won't let them leave, period. Nowhere does it say that they also have to hand over their knowledge. So that's actually a good question. But I don't have an answer to it. Onboarding, yes. Offboarding... If you have any information on that or if you come up with something, then I think that would be a great thing where I say, "Look, folks. Before we send people away, you have to do something like this. Then we won't have any gaps anymore."

PM:

WANO has said that there should be procedures for all employees to report concerns or problems related to human performance, facilities, or organization.

Expert:

Voluntary reports, suggestion boxes, whatever you want to call them. Yes, there are places where you can write things down completely anonymously. And then it ends up somewhere in the organization where someone says, "Oh, that could be something for the kitchen, that could be something for radiation protection." And then they can deal with it. But there is also a suggestion system where you can make improvements, so to speak. If you know specifically, "We need to do this and that here, then we'll save 100 euros per year." Then it is also rewarded with a bonus. So that exists too; there are many methods or tools. But again, it has to be the right fit, and how does management cultivate something like that? If you start branding people who have lots of ideas and then get paid for them as "rip-off artists" and tell them, "You get a salary here, it's your job to make things better here. You see your salary as an attendance bonus and want to earn money through suggestions for improvement" – that's not possible. So, you have to look again at how to deal with something like that, to prevent such uncontrolled growth in that area. There are people who have an incredible number of ideas and then employ an organization to evaluate these improvements, and they are quickly offended. And when it comes to occupational safety issues, they might submit the same idea again via the safety engineer and put it to him... So it's exhausting, it does exist, yes. But there are also some really good things. There are some great studies by Toyota, I think.

They evaluated the average value of such improvements and somehow had 600,000 improvement suggestions per year. And then they said, "Yes, dear people, that's [too much]." And then they said, "No, we calculated the average value of such a thing, and even if it was only worth a certain amount of dollars, we ultimately achieved so many millions of dollars in improvements for the company. Please give us one reason why that shouldn't make sense." You just have to set it up right, make it meaningful. You also need resources that can process it, i.e., evaluate it and implement what comes out of it. And another problem is that it's sometimes unpleasant for the person who did certain things when someone slams them with a suggestion for improvement and says, "But it's better this way."

PM:

Sure, that hurts.

Expert:

Yes, that hurts. Now we're back to culture again: What does the German do? He justifies his actions, why he can't do it that way. He often doesn't see the value behind it and tells himself that he has to implement it now so that the company is in a better position. Instead: "I'm right." And that's another cultural thing internationally. You could say that in other countries, they don't see it that way, but say to themselves, "Great, this is helping me to improve." The Chinese and the British, or whoever, to give my examples, take a completely different view. And the other extreme, as I said, are the Germans, Swiss, Swedes, and Japanese. And somewhere in between is the rest of the world.

PM:

What are some examples of concerns or problems that are described there? Is it really related to nuclear technology, or is it more about general human interaction?

Expert:

It depends. What we have a lot of is occupational safety. Occupational safety is very important to us. I say this deliberately because the condition of the plant changes almost daily. If you see something somewhere, you write it down or report it if you can't solve it any other way. Then there are – I think – points where processes are perhaps nonsensical. Where you say: "OK, the following process could be simpler. We could omit that step, it's no longer necessary. It used to be important in the company, but now nobody cares about the stamp anymore." And we still have a lot of processes, and then you still find some that can be optimized. But human interaction? A coffee machine here, or an ice cream machine there? No, there are certainly things like that, but...

PM:

... or conflicts in cooperation, or when responsibilities are not clearly defined and this results in disputes.

Expert:

I used to be in that circle, so I always had to evaluate things like that in the past. But I never noticed back then that we wrote about interpersonal or interhuman relationships.

PM:

All right. We've gone through all my questions.

Expert:

Then you'll have to evaluate it now. Exciting topic.

PM:

Yes, thank you very much. It was a very interesting conversation. I really appreciate how much time you took for this.