3D VISUALIZATION AND SIMULATION TO ENHANCE NUCLEAR LEARNING

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Abstract

The nuclear power industry is facing a very real challenge that affects its day-to-day activities: a rapidly aging workforce. For New Nuclear Build (NNB) countries, the challenge is even greater, having to develop a completely new workforce with little to no prior experience or exposure to nuclear power. The workforce replacement introduces workers of a new generation with different backgrounds and affinities than its predecessors. Major lifestyle differences between the new and the old generation of workers result, amongst other things, in different learning habits and needs for this new breed of learners. Interactivity, high visual content and quick access to information are now necessary to achieve high level of retention [4], [5].

1. Nuclear industry's HR & teaching challenges

1.1 Aging Workforce

While the nuclear power industry is trying to reinforce its safety and regain the public's support post-Fukushima, it is also faced with a very real challenge that affects its day-to-day activities: a rapidly aging workforce. A 2009 Nuclear Energy Institute survey indicates that 38% of the nuclear utility workforce is eligible to retire by 2014, leaving the US nuclear industry alone with about 21,600 new workers to educate and train [1]. The industry must also take into account the non-retirement workforce attrition which will account for a 10% reduction of the current workforce also by 2014 [2]. In Canada alone, it is estimated that 65% of all power industry workers are over 40 years old and almost 40% are within 5 years of retirement [3]. For New Nuclear Build (NNB) countries such as Vietnam and the UAE, the challenge is even greater, having to develop a completely new workforce with little to no prior experience or exposure to nuclear power.

1.2 New generation, new needs

The workforce replacement introduces workers of a new generation with different backgrounds and affinities than its predecessors. New generation workers entering the industry have been raised with modern digital technology integrated in everyday life. The wide-scale exposure to more and more realistic video games, readily available computers, tablets, smart phones and the internet has shaped the habits and minds of the Y (born 1980-1990) and Z (born 1990 onwards) generations. These generations are considered as "digital natives", people who are "native speakers" of the digital language of computers, video games and the internet and are extremely technology savvy, as opposed to older generations or "digital immigrants" who were not born in the digital world but have adopted many or most aspects of the new technology era [4]. These fundamental lifestyle differences result, amongst other things, in different learning habits and needs for this new breed of learners. Some of these habits can be summarized as [5]:

- They are highly visual learners preferring to process pictures, sounds, and video rather than text.
- They are experiential learners who learn by discovery rather than being “told”. They like to interact with content to explore and draw their own conclusions. Simulations, games, and role playing allow them to learn by “being there” and also to enjoy themselves and have fun.
- They have shorter attention spans, so prefer bite-sized chunks of content.

1.3 Current Nuclear Training Programs

The typical nuclear training program in use around the world is composed of learning technologies and methodologies developed and refined in the 1980s. A typical training program structure consists of:

- **Classroom fundamentals** characterized by text books, lectures and PowerPoint presentations
- **Plant visits** allowing students to see actual power plant equipment
- **Full Scope Simulators** which duplicate control rooms with detailed mathematical modeling of all plant systems

Regardless of the generation being trained, the training profession clearly acknowledges that simulator training is the most effective learning phase of the three methodologies; simulator training allows “Practice by Doing”. The educational community has ranked learning techniques as shown in **Figure 1**, based on their respective retention rates.

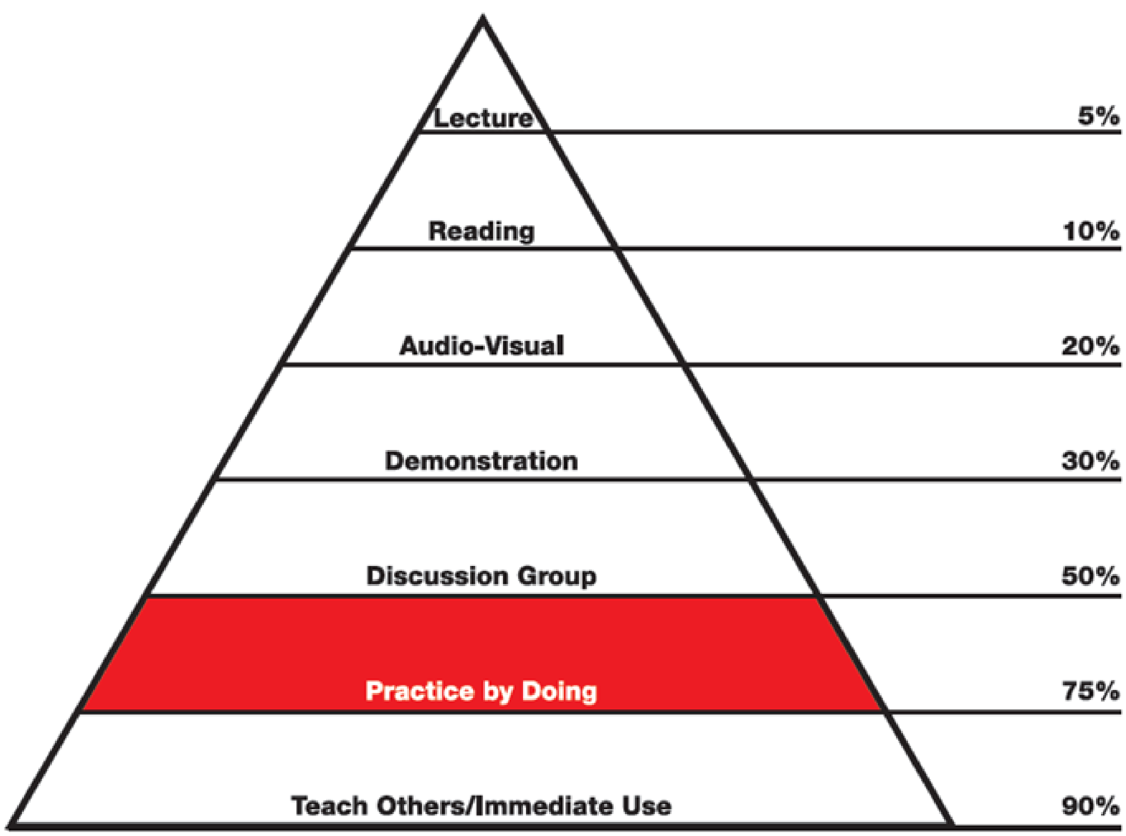

Figure 1: Learning Pyramid [6]

The plant-specific full scope simulator however arrives late in the learning cycle and is largely intended for operator training, because it is dependent on actual plant data/information. Moreover, prior to immersive learning on a full scope operator training simulator, the student must understand the many physical systems, processes and their interactions before training on complex plant procedures can be productive and effective.

On the other hand, early training covered by classroom fundamentals falls in the "Lecture", "Reading" and sometimes the "Audio-Visual" categories of the Learning Pyramid, showing very low retention rates.

L-3 MAPPS has received suggestions from colleges and utilities targeting the training of new students in basic nuclear plant concepts. In their opinion, full scope simulators present too much information and detail when a new student is first mastering fundamental concepts. This is the equivalent of studying about flying in the classroom and then attempting to fly a 777 or an A380 for the first time. In the aviation industry, learning to fly is a gradual process that begins in smaller basic aircraft and flight simulators, with complexity increasing over a period of years.

When teaching programs developed and carried out by "digital immigrants", with methods resulting in fundamentally low retention rate, are combined with the highly different needs of a "digital native" audience, the result is likely to be a low success rate program. Therefore, the much slower and longer training cycle costs more money to the utilities without completely and rapidly fulfilling their need for a new workforce.

It is important to note that the curriculum itself is not the problem: no matter what generation the worker comes from, he must learn how a pump displaces fluids, how a relief valve controls pressure, how a particular system controls the nuclear reaction, etc. The material currently being taught is important and should remain the same. The difference however lies in how the curriculum is presented and how the students interact with it. In order to close the learning gap and effectively teach the new breed of students, the existing curriculum must be enhanced to:

- Create a rich learning environment in which students can interact, discover and feel in control of their learning experience
- Incorporate multimedia elements to complement plain text
- Use the "Practice by Doing" earlier in the conventional training cycle

2. 3D visualization & Simulation to Enhance Learning

To resolve these dilemmas, L-3 MAPPS has devised a solution that addresses all of these issues and provides for the use of "Practice by Doing" earlier in the conventional training cycle. L-3 MAPPS has coupled computer visualization technology with high-fidelity simulation to bring real-time, simulation-driven, animated physical systems allowing immersive, participatory learning in the classroom. With this innovative approach to training, L-3 MAPPS is making it possible to increase student retention rates by making the learning experience that is typically at the top of the learning pyramid much more interactive and efficient.

2.1 3D Visualization

Where full scope simulators are focused on training students in how to operate nuclear plants, the 3D visualization is designed to instruct students in components, systems and fundamental operational behavior. The visualizations are easily reconfigured to address specific learning objectives in a staged approach that build students' knowledge in a systematic manner.

While advanced plant systems knowledge is transferred most effectively with simulation-driven visualization, it is equally valuable for component level or fundamentals training. The student not only can see the physical arrangements and their operating purpose, but can look inside specific components and learn about their inner workings.

The simplest level of 3D visualization is that of basic plant components such as valves, pumps, breakers, etc. as seen in Figure 2.

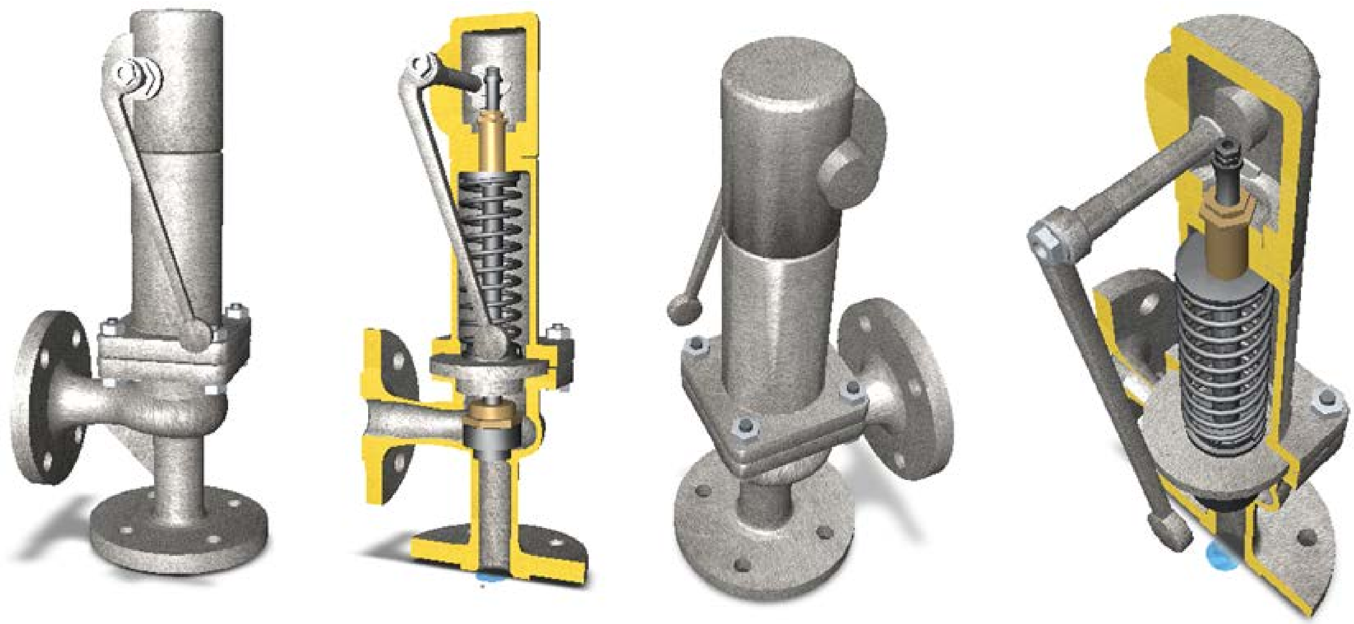

Figure 2: Various Views of a Relief Valve with 3D Visualization

The external casings can be dissolved, rotated and zoomed to display the inner workings of components (Figure 3). Not only are the components identified, but the physical operation is animated, avoiding the difficult task of trying to mentally picture equipment operation from a traditional static 2D presentation (Figure 4).

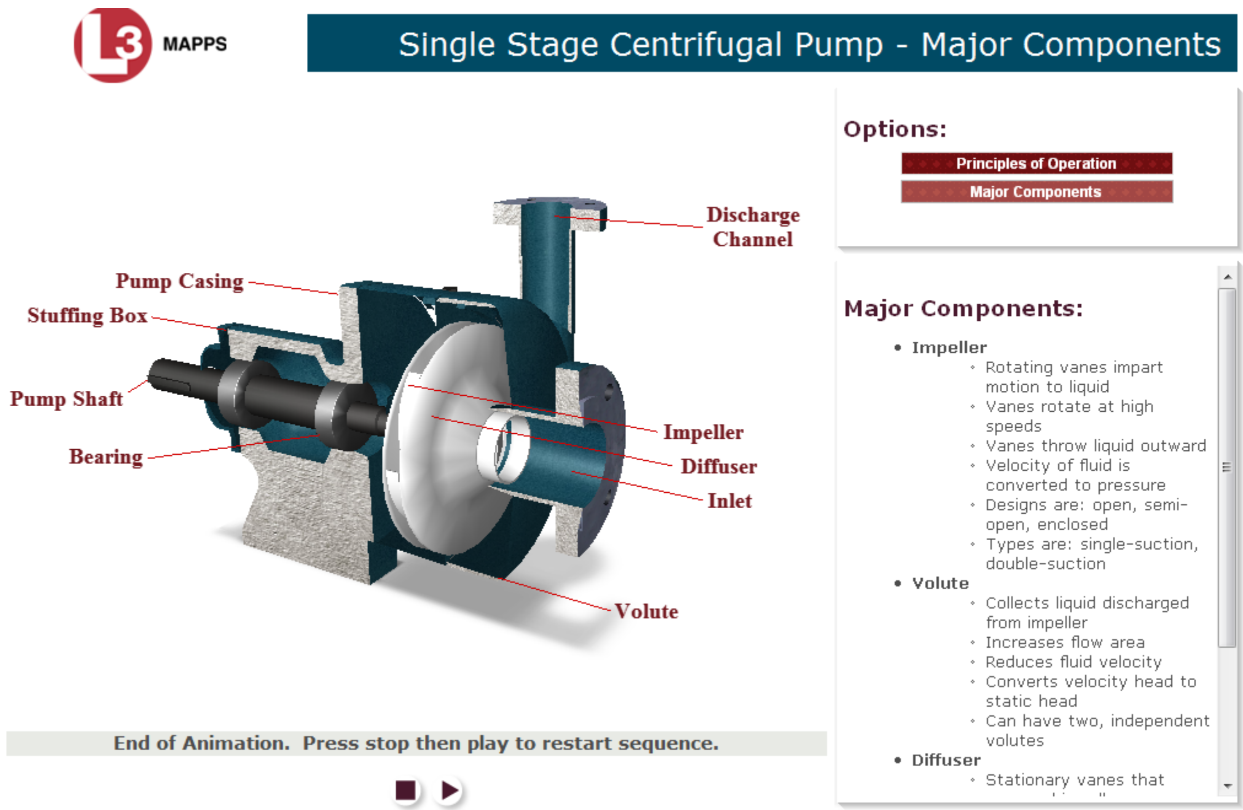

Figure 3: 3D Visualization of Centrifugal Pump Major Components

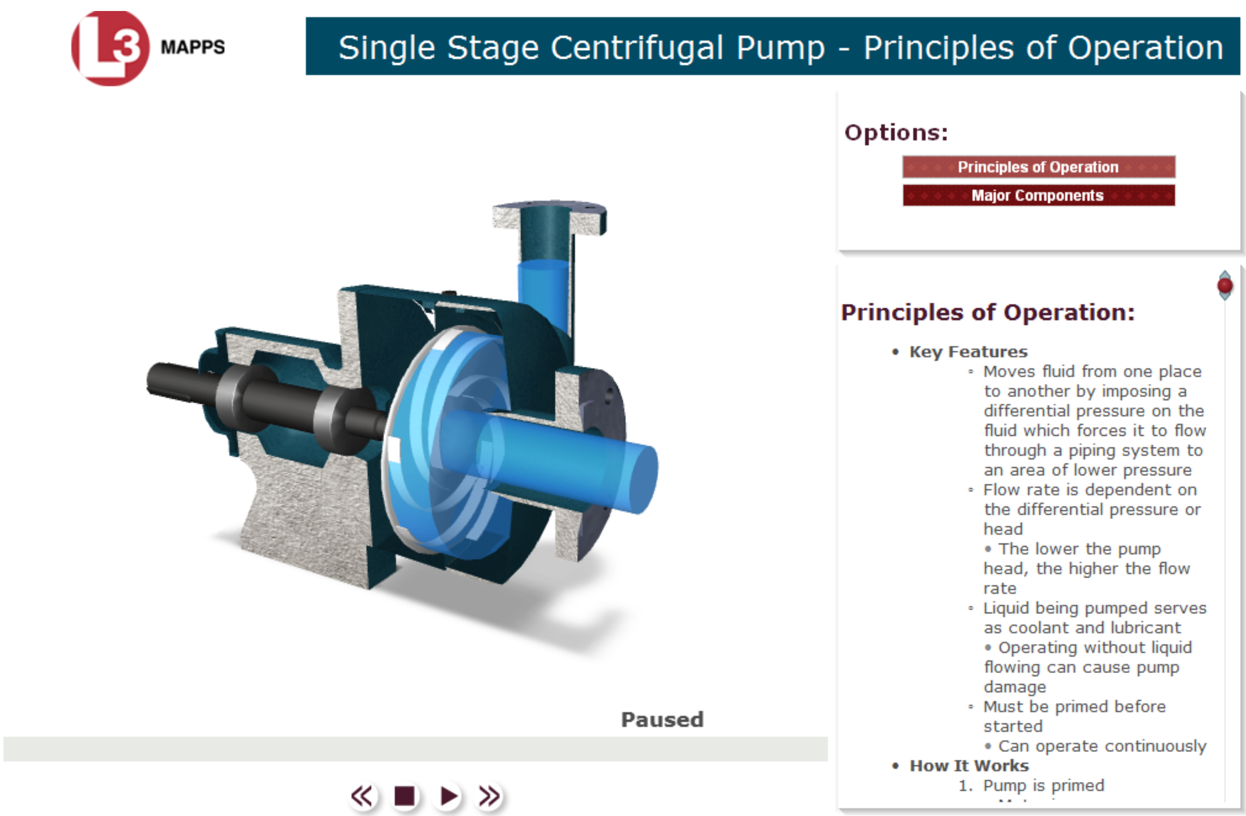

Figure 4: 3D Visualization of Centrifugal Pump Principles of Operation

This 3D visualization differs from ordinary static images or video animations by providing control to the student, who can move, rotate or zoom the 3D model at will. The user can even select a particular component from the 3D model and manipulate it independently. This interactivity allows the student to be empowered and immersed in the learning process.

3D can also be used to visualize major plant components and systems where relative spatial orientation and geometry or internal structure is important. Examples are the relative spatial orientation and geometry of the major NSSS components (Figure 5).

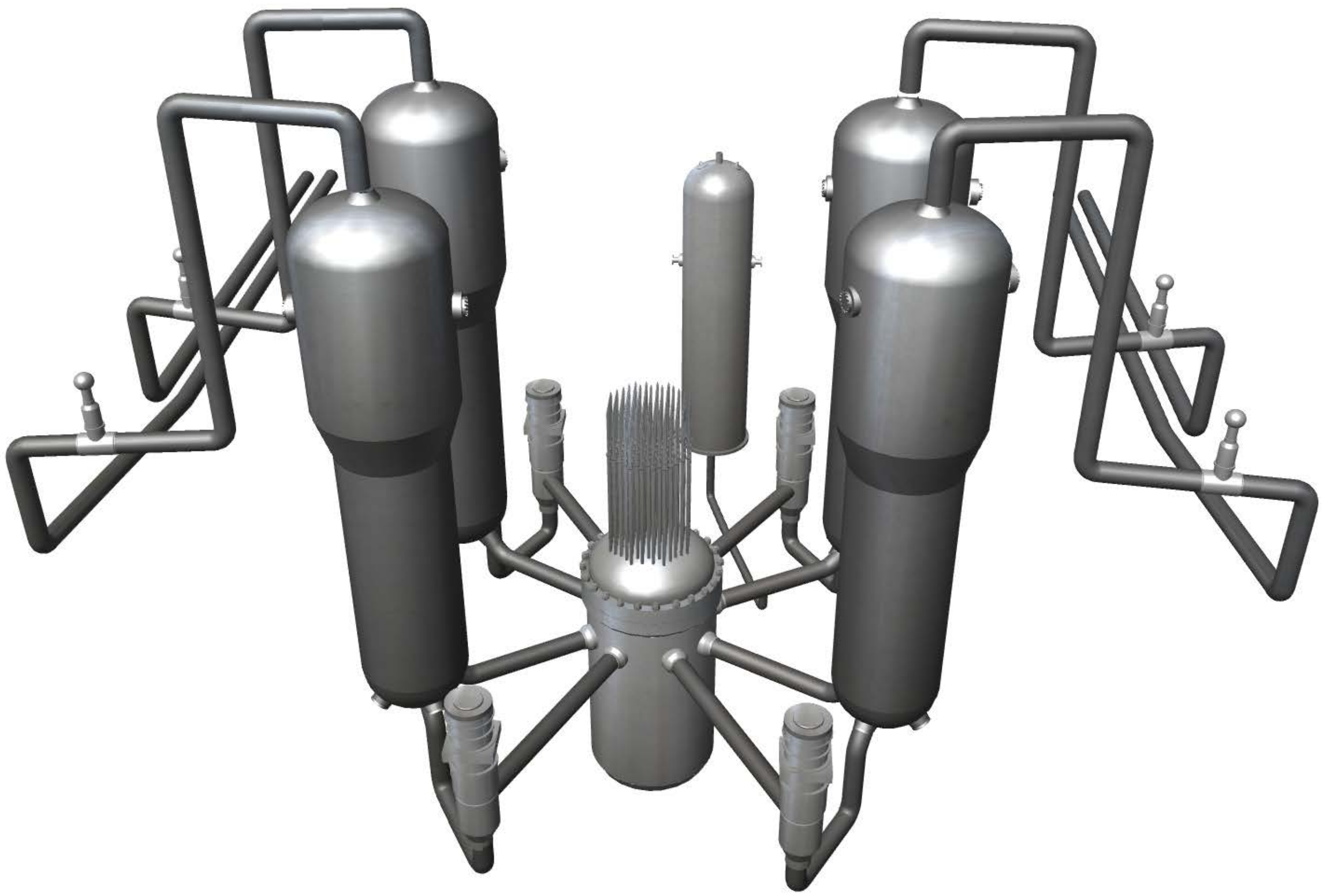

Figure 5: 3D Visualization of a 4-Loop PWR NSSS

3. 3D Visualization & Simulation

After the generic fundamentals phase of the training program, students must learn about complete systems, their physical behavior and interactions with other plant systems. To do so, 3D visualization will provide an unparalleled insight into the physical layout of the system. That visualization alone won't however teach the students how the system works. To do so, the visualization must be enhanced to provide information that will depict and explain the physical behavior of the system itself.

L-3 MAPPS has close to 40 years of proven experience in nuclear power plant simulation. The high fidelity simulation models are extremely detailed calculations which provide a huge amount of information and data on plant systems. The full scope simulation is so detailed and contains so much information that it would overwhelm students with no operations or plant systems knowledge. The simulator driven data can however be used to enhance 3D visualization of plant systems, providing the information that 3D visual models alone lack.

The properties calculated by the simulation models are used to drive the dynamic elements of the 3D models, where different properties are displayed in relation to a working animated component. Physical properties such as temperature, enthalpy, pressure, etc. are displayed as color gradients within the 3D plant components themselves, allowing students to easily visualize and understand thermal-hydraulic processes (Figure 6).

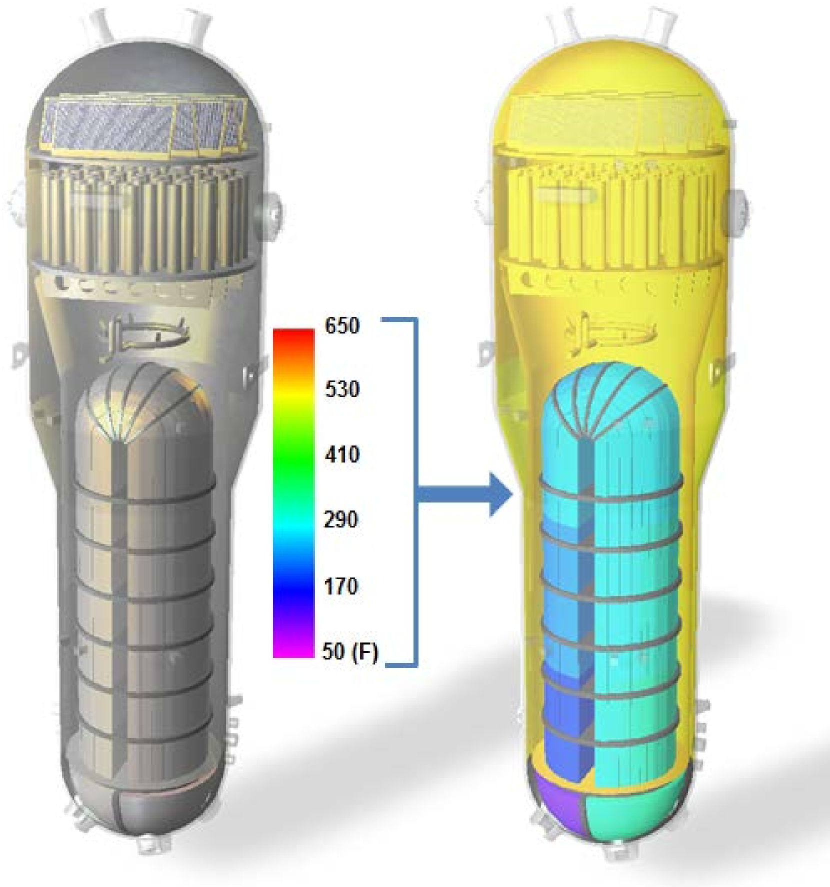

Figure 6: Color Gradients to Display Physical Properties in a Steam Generator

With this overlay of simulation data on 3D models, students can see animated, real-time physical operation versus hearing or reading a description which they would then in turn have to translate into a working model in their mind.

- The simulation can actually be used in two distinct manners, depending on the course objective:
- The simulation can be used to collect data during a particular operation or transient, to be used offline with the 3D models in predefined scenarios
- The simulation can be linked in real-time to the 3D models so that any instructor or operator action is automatically and realistically reflected in the visualization

In the first case, which can be called "offline simulation" visualization, lessons can be created for important plant events. Data is collected from the high fidelity full scope simulation to ensure a realistic response. This data, in conjunction with the 3D models, is then used to run the scenario over and over again. This method would be used when no operator action is required or when the curriculum has not yet reached the system operation training. Lessons or predefined scenarios can then be enhanced with textual descriptions and narrations of particular events of interest to reinforce the learning material and increase retention rates further. Once again, interactivity is important for student retention and with offline simulation, students can control the playback of the lesson as well as interact with the 3D models. These simple controls clearly separate the interactive and engaging lesson from a standard and rigid classroom description.

In the second case, which can be called "real-time simulation" visualization, a bridge is used to communicate the simulation data to the 3D models in real-time (and vice versa). With this bridge in place, malfunctions can be inserted and panels can be operated at will while the visualization models provide instant feedback. This method can be used in a classroom approach by combining the 3D visualization with animated 2D plant system diagrams and real-time plots to better explain complex system behavior (Figure 7).

Figure 7: 3D & 2D Combined with Simulation in a Classroom Environment

This real-time link can also be used in a classroom environment, whether using glasstop virtual panels (Figure 8) or the plant-specific full scope simulator (with its wholly reproduced control room), to provide valuable feedback to the operators being trained, particularly those in initial license training. This key concept emphasizes the importance of system knowledge in daily operations. By combining the "real-time simulation" visualization with standard operator training sessions, which currently is largely procedure-based, the operators are shown the consequences of their actions as they perform them. This allows students to combine their procedural instructions with valuable in-depth system knowledge which will enable them to better interpret and respond to information provided by the control room instrumentation.

Figure 8: 3D Visualization Used in a Glasstop Simulation Environment for Operator Training

4. Conclusion

As the nuclear power industry workforce ages and retires, a new breed of workers needs to be educated and trained. With this audience of highly different habits and needs, the existing methods and tools for teaching become less efficient and maybe even counter-productive. 3D visualization and simulation provide a modern medium that will not only fill the students' need for technology and interactivity in the classroom but also provide rich and valuable information that was hard to convey in the first place. L-3 MAPPS believes that these new tools will help the nuclear power industry to train a knowledgeable workforce more efficiently.

5. References

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