NEW WAYS OF LEARNING AT NPP – VALUE DRIVERS AND LESSONS LEARNED FROM VR SIMULATORS (VIRTUAL REALITY), INTERACTIVE 360 DEGREE VIDEO AND OTHER NEW WAYS OF COMPETENCE BUILDING

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1. INTRODUCTION AND BACKGROUND

For Loviisa NPP, using new technologies to improve training results has been a natural continuation for decades of drive to find ways to use digital solutions to improve the safety and operational efficiency of the plant. More specifically it is based on a R&D program run since 2015 to understand what is digitalization and how can it be used to improve the performance of Nuclear Power Plants. As part of the R&D program 36 proof of concepts were implemented to generate natural pull to the development of new technologies and tools. This generated two relevant technology development streams affecting new ways of learning: [1]

- **Interactive 360 degree videos** - Fast and easy way to give the experience of visiting the plant
- **VR – simulators** - Fast, cheap and more flexible control room and field simulator training

This resulted in a series of successful implementations of new tools into practical use. Some of the major milestones achieved related to new ways of learning:

- 2015 first 360 degree videos where captured from hard to reach rooms like steam generator room for training outage personnel
- 2015 the first immersive VR control room simulator PoC was implemented and presented at NPIC seminar USA
- It was followed by three generations of VR control room simulators in 2016, 2017 and 2018 that were used for sub system validation and related control room operator training.
- During 2016-17 the development of numerous 360 degree video applications for training and the rollout of the technology widely to the plant so that plant people can themselves produce just in time type of training material easily
- 2017 first external implementations of the technologies to other nuclear power plants in joint development projects with other nuclear industry stakeholders like NPP owner operators, equipment vendors, national training organisations and simulator vendors.

This paper tries to, in very short, introduce the key technologies and the value drivers that are behind the successful implementation of these training tools and to provide ideas for other NPP when starting to implement this kind of new ways of learning at their plant. Some of the key lessons learned from the successful introduction of new technologies to training:

- Use agile, iterative development methods when introducing new technologies to training
- Involve the end users actively to the development to ensure the solution fits real training objectives, delivers good learning results and is practical to implement
- Start with small examples and pilots so that your own staff get first hand understanding of the opportunities and strengths and weaknesses of the technologies related to training
- Once your organization is experienced and have collected feedback on the learning results, plan for larger implementations involving larger groups of people

New tools should not be intended to try to replace all existing training but they should be used in selected training where they bring training results that cannot be achieved otherwise. Focus on training that is difficult or expensive to implement with other technologies and try to define if there are new trainee groups that you can extend the training to (e.g. extending some plant or task specific training also to external contractors).

2. NEWEST TECHNOLOGIES TO SUPPORT LEARNING

Many of the technologies presented in this paper have existed for a longer time but have not been actively applied to practice at NPP. The fast development of technology during years 2014-2017, especially the wave of commercial products targeted for normal household consumers have opened numerous new opportunity when applied to training and other functions at NPP.

The maturity and suitability of the two novel technologies presented in this paper have been proven through hundreds of applications at functioning nuclear organisations and operating NPP in different countries and different regulators environments.

- **Immersive VR control room and field operator simulators**
- **Interactive 360 degree videos**

Based on these real life operational applications and interviews with a wide range of different nuclear stakeholders, the summary analysis presented in the next chapters has been collected on the applicability of the technologies at NPP. They are based on interviews and feedback from for example: end users of these tools at the NPP, department managers at the NPP, training centre personnel, radiation protection staff, maintenance service contractors working at the NPP, engineering department staff from many different disciplines, project managers for plant modifications, outage planners, equipment vendors having a delivery project at the NPP, decommissioning planners, control room operators, field operators, security manager of NPP and maintenance staff of the NPP.

2.1. New technologies landscape for training

Even though this paper focuses on the two novel technologies mentioned above, there is a full spectrum of new technologies available to support NPP training. The applicability and maturity of these vary and there is a lot of hype around them. To give overview on these technologies and their maturity we have plotted these technologies on a graph (FIG 1) adapted from Gartner hype curve [2] based on Fortum's evaluation on their maturity and applicability for training and other functions at nuclear power plants.

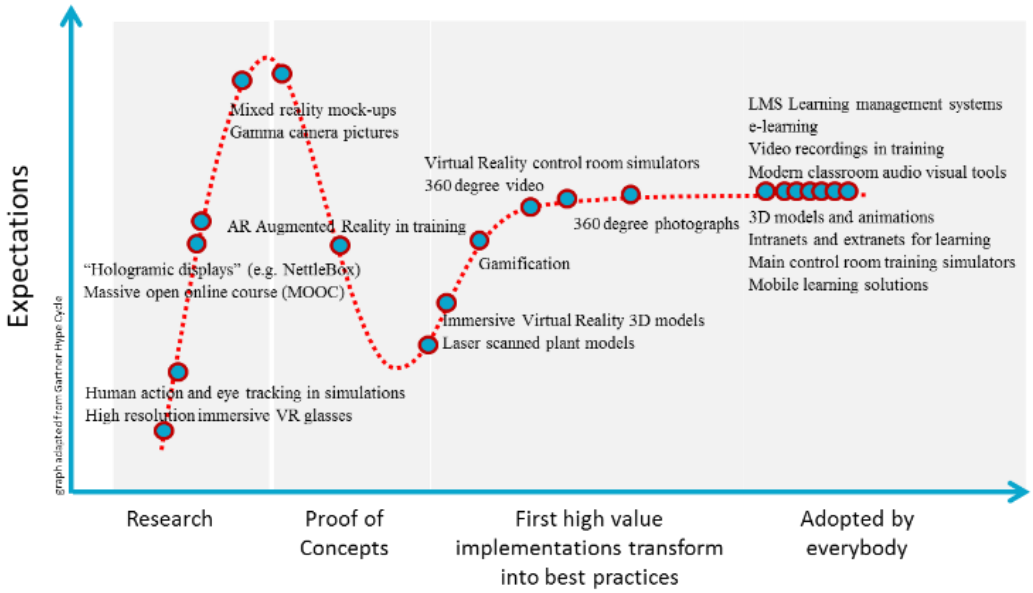

FIG. 1. Different new technologies available to support training. Plotted based on their maturity to take into use at nuclear power plants..

From these technologies the ones in the middle (sectors 2 and 3) are interesting for companies looking for new opportunities to improve their training. The technologies in the sector 3 would be such that are already in common use and the ones in sector 1 such that require strong financial resources to take into practical use.

2.2. Technologies involved in immersive virtual reality control room simulators

To give an understanding of the underlying technologies used in the immersive virtual reality control room simulators, the simulator setup has been divided into the following main parts:

- Traditional process simulator (e.g. Apros process simulator [3])
- 3D model or 360 degree video of the main control room
- Virtual Reality glasses and related headset + hand and other body tracking equipment
- Immersive 360 video for field operator actions

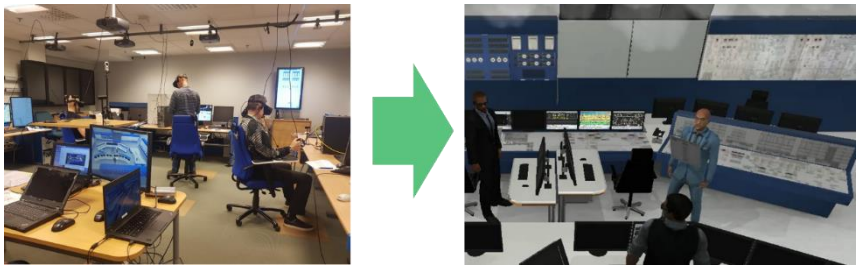

FIG. 2. The NPP control room operators wearing immersive VR glasses in real life (left picture) and in the virtual reality environments (right picture) going through emergency procedures and takin actions.

The traditional process simulator used at the nuclear power plants is still needed as the "brain" of the VR simulator. It acts as the nuclear power plant giving realistic feedback to the control actions that the control room operators and field operators initiate in the virtual reality.

While the process simulator provides the realistic responses of the plant process, the virtual reality environment gives the trainees a realistic experience of working in the control room and at the field.

Typically a 3D model is used for the control room and the experience of operating at the field is done with interactive 360 degree videos.

While the 3D control room and 360 degree videos provide the main environment where trainees move and operate, there are other important features that are used to make the training more realistic and this way further improve the learning results received. Some examples of the most important such features *[4]*:

- several people can work in the virtual reality control room at the same time
- people can talk and communicate with each other in the virtual reality (this enables that people do not need to be in the same physical location)
- the people are presented with avatars showing their hand, finger and head gestures
- operator instructions and procedures are modelled as in real life
- phones, cellular phones and hand held radios have been modelled to demonstrate and train communication and human performance skills
- CCTV cameras can be added to show video material that supports the learning targets

2.3. Technologies involved in interactive 360 degree videos

Recently 360 degree video, in addition to 360 still pictures have become widely used. They have proved to be very useful for training and other purposes at NPP as they give a very realistic experience of visiting the site.

FIG. 3. The left video picture shows the 360 degree video distorted when looking with normal video player and the right figure shows the same video viewed with a 360 degree video viewer program (the video can be looked at any direction by moving the mouse).

While the plain 360 degree video already as such, can be used in training, the real added value comes when new technical solutions are used to bring interactivity and collaboration on top of the videos. This bring more realism to training and improves the learning results achieved. Some of the main features found valuable:

- using tablet computers with easy to use applications to let plant people themselves produce 360 learning material
- presenting the 360 video in an immersive way so trainees van "walk" in the video
- based on geospatial information (plant X, Y, Z coordinates) augment information into the 360 degree video
- connecting the 360 degree to training simulator
- augmenting gamma camera and other type of radiation information to the 360 degree video

3. USE CASES, VALUE DRIVERS AND EXAMPLES OF THE USE OF THE NEW TECHNOLOGIES IN TRAINING IN NPP

During the background study for this paper several successful use cases of the new technologies have been gone through to identify the value drives behind then related to training. This has ended up with a list of the most relevant value drivers at this moment. Examples of the use cases and more detail explanations of the value drivers are given during the seminar presentation or provided on request:

Example use cases covered:	**Most interesting value drives found:**
— Control room simulator training and system validation with immersive Virtual Reality simulators — Plant and technology induction and plant process training with VR — Radiation protection and ALARA training utilizing interactive 360 degree video — Training procedures for field safety walks with 360 degree video — Just in time work safety training at construction sites with tablets	— New value that can be achieved by using existing control room simulators in new ways — The value of immersive and experiential training — Training that is free from time and location constraints — Better learning results from the use of mock-ups — More effective and site specific radiation protection training — Value of collaboration and social interaction with the trainees during training — Opportunities around: just in time learning, on the job learning, self-study — Strengthening the message of the subject matter specialist with cost efficient, realistic and collaborative virtual visits to the plant — Cost efficiency through dramatically lower cost of producing training material — Collecting of data during training to provide valuable feedback to trainees on their performance — Training and motivating the new generation employees

4. SUMMARY AND CONCLUSIONS

The number of successful implementations of VR control room and field worker simulators, as well as the extensive use of interactive 360 degree video for training purposes have proven that the technologies are mature enough to be taken into full use in nuclear industry. They have proven to deliver very fast paybacks.

The keys for success have been starting with small proof of concepts, building internal knowledge of the relevant use cases, involve plant people to the development, deliver fast development iterations to generate "positive buzz and pull" at the NPP, identify change drivers from different departments (especially maintenance, operators, outage planners, radiation protection, training staff and projects & engineering) and use the help of companies that have already implemented training solutions that are in use and focus own effort in change management and identifying the most valuable use cases at your specific plant and environment.

Due to length constraints given, this paper can only present results from extensive work in the form of lists and high level descriptions, more lengthy and detail description of the use cases and value drives are delivered at the seminar and can be requested from the authors. This will support other NPP in getting to full speed in the use of newest technologies to implement new ways of learning and competence building in the nuclear industry.

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