Industrial plants contain many potential hazards. Toxic materials are handled with high temperatures and/or pressures. The equipment often requires large amounts of energy. Properly training plant staff is of paramount importance to ensure safe and sustainable plant operations and is one of the most critical elements in process safety management standards such as OSHA 29 CFR1910 119 (2000), BOEMRE (30 CFR Part 250 Subpart S, 2011), Center for Chemical Process Safety CCPS (2007), and others.

Because plant workers can come into contact with a wide variety of substances and have to work with many different pieces of equipment, training in the real environment has to be handled with extreme care. The main cause of process industry accidents today is still human error.

In addition to ensuring in depth but safe training, owner/operators must tackle another large challenge; the current generation of facility workers is ageing and approaching the end of their working careers while...
a younger generation of new employees enters the plant's workforce. With this, the need for and volume of staff training and knowledge transfer is rapidly increasing. Furthermore, as in any learning environment, the approach and methods used for training have to be adapted to the audience to ensure good learning results. The younger generation of plant staff belongs to the computer savvy gaming generation. Why not leverage their knowledge of computers and gaming for training simulation in the industrial plant environment? A simulated training environment also addresses the issues of safe training and high volumes of training. One could say that an operator training system is to a plant operator what a flight simulator is to a pilot. The introduction of 3D simulation using 3D models or laser scans has raised the game several levels.

Highly realistic experience
Increasingly 3D based training simulation solutions provide a highly immersive and interactive training experience for industrial plants. These real time, high fidelity simulation solutions, provide a wide range of simulation, training and engineering solutions to the power generation, oil and gas, chemical and manufacturing industries can be used by plant instructors, operators, engineers, maintenance staff, inspectors and planners.

These tools are continually improving their features and the best ones in the market currently offer 3D representation of the full plant that is fully interactive, freely navigable, realistic and physics aware. The 3D representation of the plant can either be based on a 3D model or a laser scan complemented by high definition photographs. They include powerful, user friendly features and functionality to visualise plant operation and create scenarios to immerse trainees in a highly realistic training experience. This enables companies to optimise and manage staff training and certification and plan and simulate numerous production support tasks in a risk free environment before the trainees need to be exposed to plant hazards that may occur while physically performing the task.

The more realism in training scenarios the more effective the training. According to Paul A. Roman, Royal Canadian Army, the 'Serious Gaming' (SG) approach with simulated training solutions has led to significantly improved training results in terms of time spent, final scores, and costs (Table 1).

Creating the training field
How does it work? A 3D CAD model or a set of photorealistic laser scans are imported to set up the 3D/virtual representation of the facility that needs to be covered for training. Once a 3D model is imported, the model is immediately physics aware, meaning that equipment, facility structures, and human characters interact with each other as they do in the real world. To increase realism, various effects, such as materials, particles or light/shadows can be applied. Equipment and instrumentation can be mapped to drawing, P&IDs, operations and maintenance procedures, or inspection and emergency response procedures.

Users can also create and add photorealistic, custom made equipment into the 3D/virtual representation, including welding machines, locks, switches, transmitters, scaffolding, etc. These custom made and placed objects immediately become part of the facility and are available to use in the configuration of training scenarios. Best in class solutions also include a fully configurable dynamic animation system and particle effects system, including steam, fire, foam, water, bubble or sparks.

3D models of hoists and cranes can be configured based on design criteria to allow the trainee to activate standard hoists/cranes that are present in a 3D model to simulate the removal or insertion of equipment or perform site layout planning for outages, etc. If high detail mechanical 3D models of equipment are available, then these can be included to provide assembly/disassembly scenarios.

The trainee is represented in the software by a realistic looking human character (avatar) that is fully controllable by the user to be dressed with appropriate personal protective equipment (PPE), crawl/crouch/walk/jump/run around the plant and perform actions in a physically realistic way.

Administrators can assign access levels to users in terms of the content and functionality available. This prevents unauthorised users from making configuration changes. It also ensures that a trainee only has access to relevant training content.

Building a set of scenarios
One of the most advanced 3D training simulation solutions, Samahnzi 3D PACT, offered through Intergraph, provides a user friendly way to develop procedures in a Microsoft® Excel® type interface. No programming or scripting is required to compile or execute procedures.
For each procedure, the user simply lists the objectives of the procedure and the steps/actions required to achieve each objective. Through 3D PACT’s unique ‘Challenge’ engine, the procedure instantly becomes an interactive, dynamic scenario.

The different activities within a training scenario can consist of one of a combination of, among others:

- Define reusable multiple choice questions; animate
- Define detailed informative or instructional messages that
- Update third party interface values bidirectionally (typically simulation software).
- Define triggers for particle effects and physics driven effects, as well as actions by other workers on the facility to assist or interfere with the trainee’s objectives.
- Define and interact with other workers in the facility.
- Exert and visualise damage to the trainee as well as other workers as a result of incorrect actions.
- Define required PPE to be worn to perform an action; configure tasks to be executed in parallel, as well as unforeseen events to occur at any stage while a trainee executes a procedure, to test decision making and reaction under pressure ability.
- Define detailed informative or instructional messages that depend on whether the scenario is run in ‘tutorial’ or ‘test’ mode.
- Define reusable multiple choice questions; animate equipment based on trainee actions and/or the third party simulation interface.
- Perform a crane operation to move equipment, or simply an action to move equipment manually to a designated area or define time limits for reacting and completing an objective in a certain time.

Training modules may be configured to include dynamic animations (i.e., colouring components based on process parameter values) and particle effects (i.e., fire, water/steam/foam flow, smoke) running standalone or coupled to a third party simulation engine to provide trainees with an in depth view and insight into process dynamics under normal and abnormal operating conditions.

The software can integrate with any third party simulation system via object linking and embedding for process control (OPC) or a proprietary interface to drive dynamic animations and particle effects and offers a quick compilation and testing of new operating, maintenance, inspection and emergency procedures for new build facilities.

3D PACT allows much quicker and more accessible navigation around a 3D plant compared with walking around the physical plant. For plants that are laser scanned and have Leica TruViews, the user can easily navigate between camera locations, zoom in and out, and also create custom groups of camera references to make large facilities with many camera locations more manageable and more easily navigable.

The execution interface includes test or tutorial modes and a full online trainee management and reporting (TMR) system. Instructors and subject matter experts (SMEs) can create training programs (by grouping relevant procedures together), assign training programs to trainees, and track trainees’ progress and performance via the web. The system can be integrated with legacy learning management systems (LMS) if required.

Among the multiple and broad application areas, two can be highlighted here: Inspection and condition monitoring training and planning, and emergency response training. Performing planning and preparation for inspections from a desk not only saves time, but it also offers a risk free environment for workers to practice and gain confidence to perform inspections and condition monitoring tests. Through a remote database connection, employees can further monitor real time plant status and operational data and gather visual feedback of equipment status while on the road and away from the facility. Lock out/tag out scenarios test trainee’s competence on knowing the precise location of isolation points and correct sequencing of isolation operations. The technology can also be operated offline on tablet PCs to provide mobile guidance on the plant floor.

Furthermore, when it comes to emergency response training, simulation of real life situations becomes essential, not only because addressing dangerous hazards properly and timely saves plant assets and operation, but also because it primarily and fundamentally saves lives. The software helps companies create awareness for potential threats or unsafe situations, including workers making dangerous actions or performing work in an unsafe manner. In addition, companies can evaluate whether emergency response personnel know which equipment to use and which procedures and routes to follow during emergencies.

In the 3D simulated environment, trainees can easily visit areas of the plant that may be physically or logistically difficult to access (due to heat, noise, poor access/egress, etc). This allows them to visit frequently and become familiar with these areas that they may have otherwise avoided. 3D training simulation solutions allow instructors and supervisors to train and evaluate staff more efficiently and effectively than ever before, and empower them to quickly determine staff proficiency and identify skills that need to be improved.

### Conclusion

Simulation training has become vital for preventing incidents and accidents in many industry sectors, and plant operators are not foreign to this trend. Simulation training also improves process control, resulting in higher throughput and quality with less downtime. Maintenance is reduced because equipment is operated closer to specifications. Costly errors and incidents can be minimised or eliminated with the right training plan and equipment, of which process simulation is a key and cost-effective component. Most importantly, trainees experience an enjoyable, highly immersive, and engaging training experience resulting in faster and better training results, all at lower cost.

### Notes

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**Table 1. Impact of serious gaming on training**

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<th>Amount of SG</th>
<th>No SG</th>
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<tr>
<td>Final scores</td>
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<td>100%</td>
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<td>Costs/field exams</td>
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<td>4</td>
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