Honeywell | Connected Plant

New Methods for Computer Based Operator Training

White Paper

Executive Summary

The evolution of process and automation technology has made the human contribution to safe, reliable and profitable process operations ever more important. Operators are called upon to perform increasingly skilled and complex tasks, such as intervening during abnormal situations through to appropriate proactive prevention, detection and mitigation activities.

One of the most effective tools to safely and consistently develop and maintain competent operators is computer based training simulators (CBTS). A CBTS comprises a *simulation model* that substitutes for the real industrial process, an *information model* that reproduces the operator's control environment, and a *training model* that provides automated tools for delivering instruction. The first two components are considered mature, so current innovation effort is focused on the training model. Some aspects being addressed are using interventions before simulator training in order to maximize the benefit deriving from the simulator, the provision of timely assessment and feedback during the sessions and the extension of solutions to include field operators and team based training.

Furthermore, to be fully effective, a CBTS must be part of a broad frame approach to operator training that explicitly takes competencies into account. This ensures organizations can most effectively allocate resources, targeting the right interventions to develop the most important competencies in each individual.

"The main benefits of this solution is process safety at the unit. That is, a properly trained personnel is the key to stable operation of the unit."

Sergey Ostrovskii, Tatfnet Oil Company

Drivers of Simulator Training

Across the process industries, operator competency directly impacts safe, reliable and profitable process operations. A well- trained operations team delivers better health, safety and environmental performance, lower cycle times, faster recovery from incidents, fewer off-spec products, and improved morale. Operator training and competency assurance is a key factor in sustained process and business performance improvement.

Developing and maintaining a competent operations team is an important factor in overall business performance. However, developing a competent workforce continues to present new challenges, caused in part by our culture of continuous improvement and the continuous evolution of technology. Advances in the complexity and sophistication of automation systems have placed new demands on human operators, who need to be increasingly knowledgeable and skilled. Automation and safety systems take care of the routine day-to-day activities and the operator's new focus is abnormal situations and non-routine proactive analysis, diagnosis and decision making.

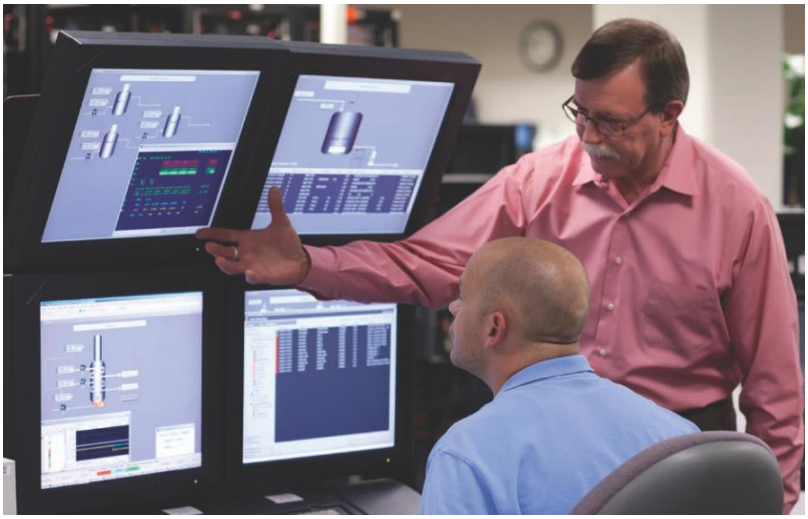
At the same time, there is the problem of workforce attrition. As older workers enter retirement, they take their specialist knowledge and skills with them.

The next generation replacement workforce, who live and learn much differently, must be quickly brought up to speed. New workers also tend to move jobs more frequently, so training new hires is a constant activity.

Overview of Computer Based Training Simulators

To develop operator competencies, companies in the process industries commonly employ some form of computer-based training simulator (CBTS) that lets trainees interact with a representation of the plant and its control and automation systems.

Generally, a tiered approach to instruction is followed. After being educated about the process fundamentals and the main plant variables, operators first use a generic plant simulator that dynamically demonstrates the fundamental process interactions. Then they move on to a high-fidelity customized training simulator that realistically reproduces the process and controls of the real plant. Using this, they can practice procedures such as plant start-up and shut-down, detecting and managing faults, etc. in a variety of conditions. The industry best practice for training delivery is through a combination of instructor-led activities, consolidated with self-training.



CBTS in their present form emerged 40 years ago, coincidental with the adoption of Distributed Control Systems (DCS) technology. They are made up of the following three main components:

- A mathematical **simulation model** to accurately reproduce the real industrial process. The process simulation model consists of a collection of process unit operations modules, high-precision thermodynamic and hydraulic packages and rich databases of physicochemical properties of substances and compounds, and reliable numerical solvers for differential and finite equations. Various vendors offer simulation systems with all the above-mentioned features. Solution will allow customers to unify TotallPlant Solution (TPS)/Total Distributed Control (TDC) solutions with Experion PKS.

- An **information model** that reproduces the operator's information, process control and logic environment. The main Distributed Control System (DCS) vendors introduced the capability of applying system software elements to CBTS as early as the 1990s. Today, re-creating the operator's working environment in this way is a standard feature of all full-scale training solutions. The purpose and intent is to create a realistic and credible control system and operator interface that are practically identical to those found in the workplace.

- A **training model**, that comprises comprehensive and automated tools to provide an instructor all the capabilities to deliver effective competency development and assurance. Typical functions allow instructors to choose and initialize simulation models from a store of previously created initial states, manipulate the training session using pre-configured scenarios or manual interventions and finally to consistently evaluate trainee performance.

Realistic Training Activities

A key factor for an effective CBTS is the *realism* fidelity of the training experience, that is to say, how closely the training activities replicate the real tasks encountered at the process facility. The information provided and the actions required by the trainee must fully duplicate those of the real-word setting, in terms of the list of activities, their volume, sequence, and pace. The simulator must be able to impart, reinforce, and enrich the knowledge and skills required for process control and interactions in various normal, and abnormal situations. In other words, it must reinforce the complete skill-set for effective and safe process control.

Compared to the pre-computer training methods, computer-based simulators have made it possible to sharply increase the fidelity of the training, thanks to the following capabilities:

- Repeatability of initial states of the simulation model. CBTS allow for process states, including those of the control system, to be fully restored.
- Ability to return to any previous state of an industrial process. This also makes it possible to experience and evaluate alternative actions and compare their effects with the basic variant.
- Standardized simulation of process failures and equipment malfunctions (by making interventions during the process in the form of scenarios created in advance).
- Accurate replication or direct connection to real world console operator HMI systems.

Emerging Trends in Training Simulators

Of the three main CBTS components, the simulation and information models can be regarded as most strongly consolidated, whereas the training model offers greatest opportunity for improvement, and is where current efforts are focused. Until now, CBTS have tended to merely implement pre-computer training methods using more recent technology capabilities. They generally overlook foundational interventions that prepare the trainee with basic knowledge and skills prior to engaging with a simulator and do not always support proper assessment. Also, they focus mainly on training console operators and are less suited for training field operators. Recent solutions that address these shortcomings are described the next sections.

Foundation Skills

No matter how realistic the simulator, there is little benefit to trainees attempting full-scale simulation activities before they understand the cause-effect relationships in the plant: its normal and off-normal states, its typical failure modes, and how these are reflected in the process variables. The foundation skills learning provides the necessary base level of process characteristics and operation knowledge to ensure an effective skills and experience development using CBST. It equips operators with the basic knowledge to support fault detection, diagnosis and troubleshooting skills necessary for effectively responses to realistic simulation of normal and abnormal situations.

To meet the need to develop base level process knowledge, simulator vendors have begun to offer systems and technology for developing both basic and specific process operations knowledge. Honeywell's UniSim® Tutor uses a customized knowledge base in a computerized instructor system to take trainees through a series of random exercises that progressively impart basic control, diagnostic and troubleshooting skills. The same exercises are also used for assessment (examinations). Training solutions such as these are very effective in conjunction with a CBTS, but can also be effectively deployed independent of a training simulator.

Fault Detection

The first UniSim Tutor variant is training via fault detection. In this exercise the trainee is presented with process information and asked to determine whether the state is normal or off-normal. The goal is to become familiar with the normal ranges of process parameters while also developing capability to detect deviations, alarm or emergency conditions.

Cause and Effect

UniSim tutor's knowledge base is also used to help trainees understand cause-effect relationships in the plant through two training and knowledge building activities. The first is a 'What-If' scenario (Figure 1) where the trainee must predict the effects of a typical failure. UniSim Tutor generates a random fault and asks the trainee to indicate how various process variables (e.g. flow rates, temperature, pressure, levels, compositions) would change in response to the fault, choosing between: "strongly decreased", "decreased", "did not change", "increased", or "strongly increased".

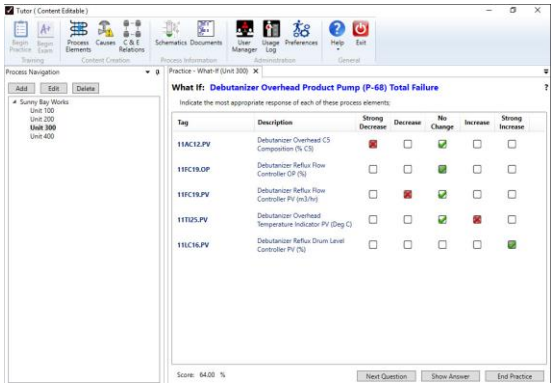


Figure 1. Identifying probable effects of a fault

A second cause-effect activity reverses the previous approach. Rather than predicting the effects of a specified fault, trainees are now presented with one or more (up to three) 'symptoms' and asked to predict what fault will caused those changes and observations. In other words, they are given the effects, and must predict the probable cause.

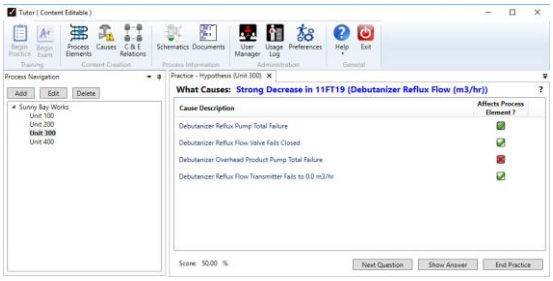


Figure 2. Identifying probable causes of a fault

Troubleshooting

A more sophisticated training activity available in UniSim Tutor is a step-by-step 'game' that closely simulates diagnostic decision making in real-life situations. UniSim Tutor randomly selects a failure, concealed from the trainee, and initially reveals one symptom of that fault. The trainee must identify the correct fault from a list. At each step, the operator can query information about a related process parameter, to help zero in on the correct fault. There are penalties for asking uninformative questions, as well as for selecting the wrong fault. The system gives ongoing feedback about how useful each query was, in terms of reducing uncertainty. The aim of the game is to identify the fault with the highest possible score, that is, with the fewest possible questions.

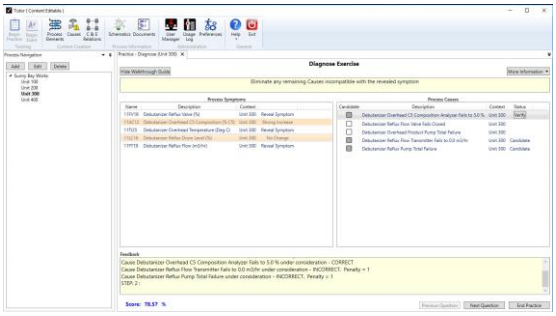


Figure 3. Game like exercises to develop troubleshooting skills

Computer Based Training: Not Just for Console Operators

A recognized shortcoming of existing CBTS solutions is their primary focus on console operator competency development. Rarely are they used to provide a similar realistic training environment for field operators. In their day-to-day work, console operators mainly interact with information on a HMI screen, which a CBTS mimics with high fidelity. Field operators, on the other hand, move about physically within the plant and interact with a wider variety of objects.

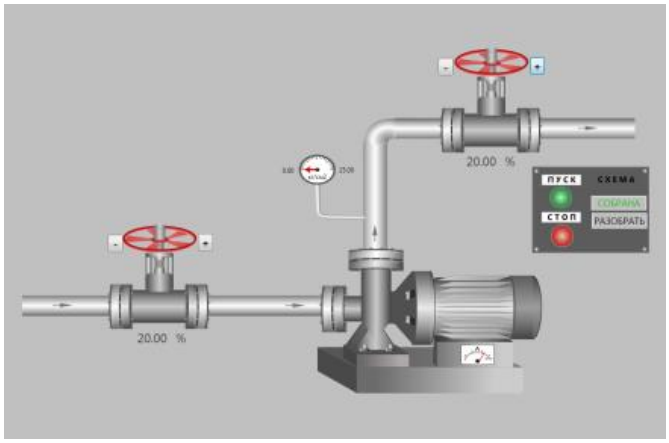


Figure 4. Example of a conventional field operator interface

Panoramic Tours

A cost-effective alternative to unrealistic visualization approaches—or to immersive 3D virtual reality approaches--is 'virtual tours' of the plant based on panoramic digital photographs, annotated with dynamic navigational links, and interactive hot spots. In practice, navigable panoramas create a 3D multi-unit space on the computer screen. The user can virtually move around the plant, and use hot spots to observe process conditions, and to interact with field devices as required.

Honeywell's UniSim Field View provides a credible and realistic field operator simulator based training experience. The UniSim Field View panorama interface is deployed using a series of photographs at various locations within the plant to create an integrated and interactive panorama visualization of the field environment connected to the simulator model.

Figure 5. Raw pictures (top row) and the resultant operator screen (bottom row)

Virtual Reality

Similar to the UniSim Field View experience, an immersive 3D virtual environment also can be used as an effective alternative for field operator CBST. An immersive 3D model involves 'dressing' a topological model created from the design information of the plant. The result is an immersive virtual world in which the user can navigate as a first or third person avatar. Although development of a 3D immersive model is a more expensive there are situations where a 3D model's expense can be justified for example where photographs are not practical (plant is under construction) or where a 3D immersive model provides additional value beyond training. Owing to its cost, 3D immersive virtual reality (VR) is at present used in high-risk domains, such as mining, off-shore processing or subsea maintenance. However, VR does constitute a viable emerging trend in the process industries.

Honeywell's solution offering for simulator training using 3D immersive reality is to partners with vendors that provide the VR technology. Honeywell's UniSim 3D Connect provides the connectivity between the UniSim Operations training simulator and 3D immersive modeling environments to create a credible and realistic field operator CBST environment.

Who are the Judges? The Challenge of Effective Assessment

Modern CBTS still rely upon the input of human instructors in evaluating trainees, and generally provide rich tools to support instructors in such an endeavor. Automated training, event-logging and storage of intermediate states enables instructors to replay all process states and changes that occurred during the training session, and to review specific actions operators took in response. Scores entered in an electronic register at the end of each session can be tallied to assess the training outcome as a whole, to confirm achievement of certain competencies or to issue authorizations to work.

Beyond this, the idea of fully-automated evaluation in CBTS is not new, and has long been attractive to customers. It would eliminate with inherently subjective human contributions, and increase scope of self-training. However, automated trainee scoring is not always possible: In the case of open-ended training sessions, where the operator interacts with the simulation under conditions not specified in advance, automated evaluation is problematic because there are many valid control options. The system risks rejecting certain correct—but formally unobvious—actions of the operator, and this would in turn dent confidence in the automated evaluation.

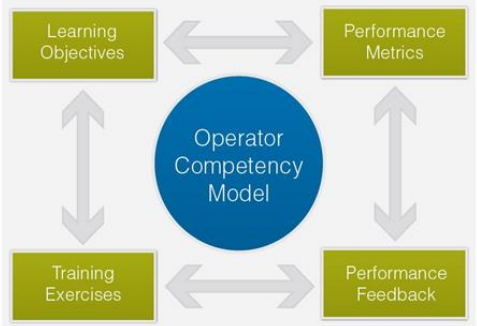


Figure 6. Operator competency model for training program development

That is not to say that automated evaluation is unfeasible in all cases. Present-day CBTS allow two types of automated evaluation:

- Quantitative evaluation of operator actions in transient modes. One of the key pieces of information available to both the trainee and any potential evaluation system in CBST is the process variable measurements. The process variables will always respond in a predictable manner to the actions taken by the trainee. As such, process variable measurements that are important and critical to the training scenarios can be used to create consistent, repeatable automated scoring. The evaluation can be *by deviation* (ability to maintain a process within operating limits), *by objective* (ability to bring a variable to a certain objective value within a specified period of time), or *by trajectory* (ability to maintain a specified ideal trajectory without leaving permissible limits).
- Procedure Checklist. Efforts are currently underway to achieve automated evaluation of actions in pre-set training exercises where the initial conditions are specified, the control constraints and process variables are known, and the operator must achieve a defined final (or intermediate) state. This problem is tractable provided the model quality is high and the required states and constraints are correctly defined. Points can be deducted for failing to complete an action within a specified time, completing actions out of sequence and for executing incorrect actions.

Competency-Based Training Approach

Adopting a CBTS does not, on its own, ensure that an organization maintains a fully competent operations workforce. For this, a CBTS must be deployed within the broader framework of a structured program setting out what specific training activities each worker needs to complete.

These are in turn determined through a 'competency centric' approach that defines the skills, knowledge and behaviors required for each proficiency in a particular job function.

First, the responsibilities of a job function are identified. For example, in the case of console and field operators, two key responsibilities are:

- Operate under normal conditions
- Anticipate and respond to abnormal conditions.

Each responsibility is then broken down into a set of competencies. For example, the responsibility "operate under normal conditions" requires the following competencies:

- Operate unit controls
- Interact with other units
- Execute a shift handover

Next, each competency is linked to a set of associated behaviors, described in terms that can be measured. For example, the competency "operate unit controls" requires a console operator to exhibit the following behaviors:

- Explain unit control schemes
- Manipulate controls without adversely affecting the unit
- Troubleshot control loops
- Explain process chemistry and physics

Finally, each behavior learned by a trainee can be assigned a proficiency, ranging from 'aware', to 'knowledgeable', 'skilled' and 'master', as training progresses.

This competency-based approach provides a structured framework for both training and assessment, to help ensure operators are given the right training against their competency gaps. Honeywell's solution for developing and managing training programs based on an operator competency model is UniSim Curriculum. The UniSim Curriculum competency model is customizable and is focused on skills, knowledge and behavior training designed to deliver important business results.

Cloud Hosted Simulator Training

Despite the established benefits, not everyone can justify a training simulator. The investment required, both in terms of the initial costs and lifecycle commitment, is often tied to a compelling event or a corporate mandate. Even for those who do have a training simulator, access can be somewhat constrained.

Typically, organizations deploy CBTS on a site by site basis. Because operators are site-based, the CBTS needs to be local to the operators. This means each site has dedicated computing infrastructure. Making the CBTS available to offsite resources with similar or adjacent training needs (for example engineers in the central engineering department) is difficult: New infrastructure and licensing is required, and each system requires maintenance by experienced resources.

These factors mean access to a CBTS is generally carefully managed against prioritized needs, precluding more generalized use. A solution to this problem of access is cloud based simulator training.

With a cloud-deployed solution, the majority of the computing resources are centralized--either offshore in a public cloud or at a central facility in a private cloud. The trainee and instructors access the system from local terminals. In addition to a customized CBTS, trainees will have access to a range of other resources available through a web browser: For example, generic training on basic or common unit operations without the need to install and maintain any additional software or hardware components.

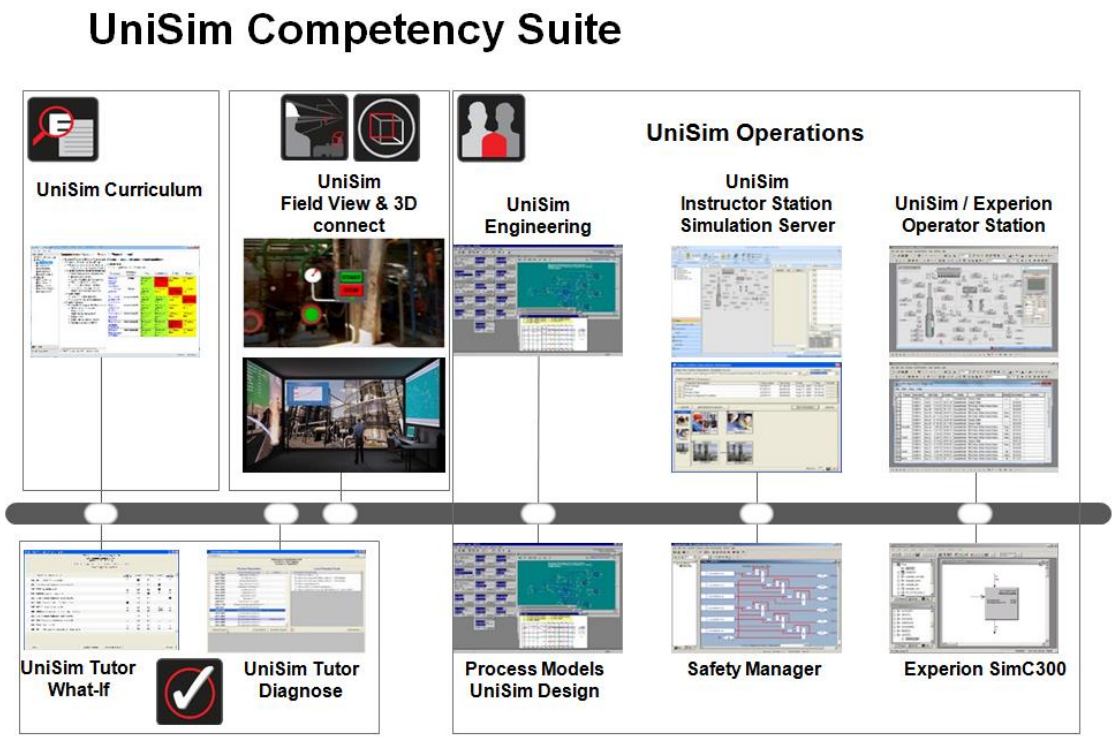
Key benefits of cloud hosted simulator training include:

- Accessibility not constrained by location – where and when needed
- Training to be self-paced and without the need for instructors
- Ability to scale up and scale down as demands dictate – one trainee to hundreds trainees
- Immediate access as required
- The opportunity to leverage economies of scale for wide scale deployment
- A platform to gather and deploy industry best practices and lessons learned
- Relevant and continuously refreshed curriculum
- Engaging, credible, realistic and safe training experiences

UniSim Competency Suite

Honeywell's UniSim® Competency Suite accelerates the time it takes for new operators to gain the experience of a veteran, allowing all staff the opportunity to reach their full potential faster. The suite offers robust solutions to better train plant personnel for safe, incident-free and efficient startups and operations.

- UniSim Operations: Operator Training Simulator (OTS), a dynamic plant simulation system that allows users to accelerate knowledge transfer by consolidating an entire lifetime of experience into a concise process training curriculum; features realistic process, control and safety systems modeling
- UniSim Curriculum: Customizable competency model that aligns and perfects critical requisite skills and behaviors; tracks operator progress; built from Abnormal Situation Management® (ASM®) Consortium research into operator competency to help businesses define, deploy and manage a structured competency program
- UniSim Tutor: Knowledge capture and propagation tool; provides a repository for domain knowledge and experiences; teaches and evaluates "what if" reflexes and diagnostic abilities
- UniSim Field View: Interactive, navigable, panoramic view for realistic field operator training; uses actual facility photographs and extends UniSim Operations simulator training to include your field operators
- UniSim 3D Connect: UniSim Operations simulator integration and connectivity to 3D virtual environment; provides credible and realistic experiences for field operators



For More Information

Learn more about how Honeywell's UniSim Competency Suite can ensure a competent workforce, visit our website www.honeywellprocess.com or contact your Honeywell Account Manager Distributor or System Integrator.

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