The use of simulators for on and off-shore training for control room operators and drillers.

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Despite the good example set by comparable major hazard sectors such as aviation, shipping and nuclear power, the use of simulators has been slow to take off for the on- and offshore major hazard industries. This paper reviews the use and uptake of simulators – based on an HSE review - and includes a case study on the use of simulation for offshore drilling crews reporting on recent work carried out by Maersk Training.

The Maersk work recognises that simulators are becoming more advanced in the oil and gas sector, especially for the wells / drilling sector after the Macondo Well disaster. They still provide a useful platform for developing basic psychomotor skills, but are advancing much further for developing skills for more complex tasks. Maersk Training finds that this training setting can have a real impact on technical and – the equally important non-technical skills (NTS) / Crew Resource Management (CRM) skills.

While this is true of wells / drilling, it is not so clear that the rest of the oil and gas offshore world i.e. production, or the onshore area are also progressing, or that the real need for simulation is consistently or effectively identified or addressed. It is even less clear that, despite some pockets of good practice, that the chemical sector has really taken this up. The reasons for this inconsistency and lack of uptake are explored. Key issues include a failure to recognise key competency areas where only some form of simulation – including simulators – can prepare staff effectively for rarer and more complex non-routine events, or help achieve improved consistency and effectiveness in normal operations. It is argued that the key is simulation, and not necessarily simulators. Though the latter will very likely be necessary for higher hazard and / or more complex processes and operations.

This paper draws both on academic practice, but also case experience with Maersk Training and a range of drilling contractors and operating companies.

Keywords: Simulators, offshore drilling, major hazards, non-technical skills

Introduction

Review of simulator use for the high hazard industries

The stimulus for the original Health and Safety Executive (HSE) review of simulator use (HSE 2001) was the recognition that, under the Control of Major Accident Hazard (COMAH) Regulations 1999 (the EU Seveso 2 Directive as implemented in the UK for the onshore major hazard industries) that a step-change was required in the industry approach to competency in order to allow satisfactory safety report demonstrations to be made. The original review focused on the UK refineries then in operation, but considered other process industries too. The overall industry picture on competence assurance (and competency management systems - CMSs) was poor – patchy, inconsistent and failing to distinguish reliably or clearly between personal safety and major accident hazard competence. The availability and use of simulators to support CMSs varied widely, in refineries and on other COMAH sites, despite lessons from accidents such as the one at 1994 Texaco Refinery (Milford Haven) incident (HSE 1997, p40 para 142), and the widespread use in other high hazard industries such as aviation and nuclear.

The review was partly based on a topic research paper carried out for the HSE's Human and Organisational Factors (HOF) Team (HSE 2000), the team's inspection and assessment experience under the first years of COMAH, and the first author's ongoing research project on onshore control room operator competence. The picture that emerged was mixed and inconsistent. Early safety reports (and this trend continued) rarely referred to the structured use of simulators when demonstrating competence. With a few exceptions there was little in the way of guidance or benchmarks for the regulator or industry. The HSE HOF team also contributed to the subsequent development of HSE inspector training for emergency response, which was based at one UK training provider's emergency response simulator suite developed specifically for the chemical and allied high hazard industries. The simulator review was also jointly updated in 2010 for one of a series of Knowledge Exchange Forums run by the HSE's Health and Safety Laboratories (HSL) for the HOF Team's Continuing Professional Development programme. In this paper it is further updated and includes a substantial offshore oil and gas industry case study, reflecting post-Macondo development and improvement.

Simulators and competency management

Simulation is simply one way of helping to achieve personnel competence (whether for control room staff or for a drilling team), in the context of an overall sound training plan and competence assurance system, though an increasingly important one. Although simulators may originally be developed by companies for process optimisation or design reasons, they can also be developed further to provide an important part of basic, refresher, upset /abnormal conditions and emergency training. For example simulation offers the opportunity to practise rarer but important (including upset and emergency) tasks in a safe and controlled environment, and for the development of diagnostic and decision-making skills consistently across all teams (including e.g. shift teams) and individuals.

Why have simulators?

Simulators can re-create events and conditions on plant, presenting the information in a format similar or identical to that used in the control room itself. Control Room Operators (CROs) can then develop their knowledge of the plant and practise performing specific tasks and procedures either prior to, or as an ongoing aid to, real performance. Specifically simulators can allow:

- Practice of important but (in normal operation) infrequent tasks and those which would be too hazardous to practice 'for real'
- Practice of emergency tasks and scenarios with or without associated stress
- Running of 'what-if' sequences
- Initial training for new recruits
- Trial and error learning, without real consequences
- Repeated practice to learn an assured, second-nature response
- Highlighting of concepts and fundamentals lying behind complex real systems
- Trainers to select a wide range of parameters for training and assessment
- Learning of skill and rule-based levels of control (hard to teach in the classroom)

Simulators are also now increasingly used for such applications as: research & development (process and safety), design and commissioning of new plant and processes, control system changes and upgrades as well as for the training of control room operators and other operations' personnel.

Simulator types and availability

Simulators can be full or part scope (i.e. mimicking the full system or selected parts / variables in it), generic or site-specific (i.e. mimicking common processes or specific site plant), can be remotely or locally situated, and can be developed for training alone but more commonly for many other purposes including design and process optimisation. Simulation has moved on rapidly over the last two decades. It is no longer the preserve of experts or of those companies with the deepest pockets. PC-based dynamic simulations can offer – or can often be adapted to offer - good operator training and practice, can be developed in-house, and are relatively cheap compared to a say a full scope high fidelity process simulator. Design simulators can also be readily adapted for training as an outcome of projects. Of course there is also an increasing range of virtual reality (VR) or 'immersive' simulators – often developed first for gaming or other leisure activities - but these have yet to really penetrate the high hazard industry area.

Generic or Site-Specific Simulation. Generic simulations cover many of the basic plant items and system variables that are common to processes within a particular industry i.e. typical (rather than specific) plant items such as boiler systems, fractionation columns etc. Typical chemical industry variables include temperature, pressure, level and flow though more comprehensive systems include more advanced control system principles. Such simulations provide good experience in controlling realistic variables in a number of different situations on commonly-used plant. They are also usually much cheaper than traditional high-fidelity simulators. Some providers argue that transfer of skills is better from such simulations and better reflects the real-world likelihood of change and modification to systems and jobs. Site-specific simulations can be developed for a particular plant and can be tailored to specific plant requirements. Development costs are substantially lower than high-fidelity simulations

Full of Partial Scope Simulation. Simulations vary in scope from a limited number of variables and specific / typical plant or process items through to full-system modelling including start-up, shut-down, ESD functionality and network capability. Scope should be determined by company/site training needs. Full scope simulations have obvious benefits but are expensive (especially to 'add on' where the benefits of design and commissioning cannot be gained) and are also expensive to maintain - they are sometimes a ready source for obtaining spare parts and may also be a challenge to keep up to date with real system modifications. Partial scope can be very effective for specific issues or in developing and practising general analytical skills. With current technology companies can fairly easily develop their own in-house simulations, especially partial simulations using readily-available software packages. This offers the advantage of being driven by the site's own training needs and programme rather than by market availability.

Remote vs Local Simulation. The scale and costs of computer modelling have traditionally led to simulator facilities being developed centrally or remotely. The advantages of such locations include removal from the normal operating environment and its interruptions / demands, and more independent and consistent training and assessment. With PC-based simulations, however, local siting is possible and more likely. This allows more frequent refresher training (e.g. use during quiet shift periods by individuals or teams), and reduces travel times, accommodation costs etc. for training. Proximity also potentially allows use for a broader range of application such as running 'what if' scenarios.

Training or Multi-Purpose simulators. Flight or driving simulators (including those developed for train drivers) were historically developed specifically for training pilots and drivers to operate particular models of planes or vehicles. While some simulations are still specifically developed for training purposes, the increased application of dynamic simulation has led to an increasing number of multi-purpose simulators. For example, a dynamic simulation may be developed as part of the design process to enable software engineers to check and test the control software but then can be adapted or added to for training purposes (usually in the form of an additional module) and for later process optimisation.

Sites with no simulators. Unfortunately this is not usually an active and informed choice. Such sites in effect rely wholly on the real system and on-shift experience for training, usually with equally unstructured on-the-job training and basic supporting qualifications. This means that opportunities for practising diagnostic and decision-making skills, and upset / abnormal conditions management are limited and inconsistent. For less complex processes or activities, however the appropriate use of *simulation* alone (i.e. without a simulator as such) may be adequate if it is well-designed, thought-through and credible.

Simulator fidelity

The degree of *fidelity* (i.e. how exactly the simulator matches the real system) is variable and also varies with scope. At a higher level these are described as high or low fidelity i.e. how well the simulator mimics (or is similar to) the real system or set-up. High fidelity simulators, purpose-built for large projects and plants, mimic as exactly as possible the control room environment, as well as the actual controls and system. Other forms of fidelity are distinguished (the following is based on (Thomas 2003) such as *physical fidelity* (the realism of the physical layout and design), and *functional fidelity* (how well the simulator mimics the way the real system works). However a key element to successful simulation is that the it has credibility for those being trained and so the term psychological fidelity can be used to capture this – perhaps more easily understood as *task fidelity* i.e. how well the simulator can reproduce the real-world operational task (as opposed to mimicking the system) and how realistic this seems to the trainee. It may be that a ‘Blue Peter’ approach (using cardboard, string and sticky-backed plastic!) may produce greater task fidelity than an all-singing, all-dancing full-scope high fidelity simulator if it feels real to the trainees. Just because high fidelity simulators are available doesn’t mean you necessarily want one.

Another key factor will be the selection and training of those delivering the simulator training. Where training providers are used then they will need to be able to tailor what they have towards the real site context and tasks, and for them to do this the company concerned will need to be able to brief them adequately including providing a well-structured training plan based on a good training needs analysis, an over-arching CMS, and a good range and understanding of likely inputs such as tasks and scenarios. Otherwise providers will be forced to use more generic inputs with a consequent loss of task fidelity and possible training transfer. So the input quality to the simulator or simulation is crucial…

The importance of simulator inputs

A key factor for task fidelity will be the inputs to the simulator – in other words how realistic are the tasks / scenarios selected and developed for training? Many companies do not collect the kind of information necessary to support this realistic input - through reporting and investigation systems, normal auditing, monitoring and review arrangements, and other internal and external learning processes. So for a realistic set of scenarios for a control room operator it would be necessary to have reliably collected a range of well-understood examples of upset or abnormal conditions which have been experienced both in the process concerned and in similar ones elsewhere. These would often be near misses i.e. they occurred but were successfully dealt with. Unless special effort is made to reliably capture and understand these then the input scenarios to simulation will lack range and realism for the operators and may indeed set them up to fail when they later encounter unexpected scenarios. Control Room Operators (CROs) may need support in identifying these events and of course individual operators may experience a very different range of these on-shift depending on chance and experience. Equally if tasks for simulation are selected from safety case / report major accident scenarios then the task fidelity will depend in part on how well the scenario identification and analysis has bene done. Finally it is the nature of complex systems typical of the high hazard and process industries that surprises can still occur. So part of the simulator use will be to prepare operators and others for decision-making in uncertain situations. It is predictable that the unpredictable may occur and this requires going beyond a fixed set of scenarios based on looking backwards at what has already occurred.

Even in aviation the inputs matter – for example the set requirements for regular simulator use may specify the scenarios to be used but these may not reflect current or emerging concerns. Commercial pilots regularly practise an abortive take-off scenario with engine failure but in modern aircraft such failures are now exceedingly rare. That is not an argument for not practising them but there may be other priorities such as more recent air crashes (such as Air France 447 - BEA 2009) where more subtle failures in situation awareness seem to be emerging from more complex recent aircraft cockpit and control designs. Simulator trainers may also skew the training by poor selection of scenarios e.g. if they are basing this mainly on their own experience. This can ‘hardwire’ trainees into a fixed range of responses in an emergency for example, and not necessarily confer flexibility of response where it may be required by non-practised, varying or less predictable events.

Simulators or simulation?

High fidelity (full scope) control room or system simulators still have a role to play in developing competence for more complex processes and should then be a normal part of the development of significant new installations and projects both for commissioning and for e.g. ongoing basic operations, refresher and scenario training. However, simpler simulations can be applied in situations where simulators are either not justified or not (yet) available e.g. exercises such as talk- and walk-through scenario exercises for upset/abnormal conditions’ training (a much-neglected but very important area) and for emergency training. Simulation does not always require a simulator.

Development of simulators

Simulators have been used extensively and successfully for a number of years in aviation, initially for pilots and, as some people may also remember, in the use of the geodesic domes during World |war 2 which housed navigator training simulators. Simulators have been developed in other contexts, for example driving simulators (for vehicles, cranes, trains, ships), robotic simulators (for control of robotic or remotely operated arms) and simulation of control room operation, mainly, in the latter case, in the nuclear industry. Other (non-nuclear) simulation facilities have been developed at some sites such as refineries or other process industry sites but these tend to be more limited in mimicking the control room operator's, control desk and interface rather than a full control room suite.

For most of these applications, developing the simulator has required a sophisticated combination of skills including computer programming, numerical integration and modelling skills. Consequently simulation traditionally remained largely an expert field and a relatively narrow range of applications – but this has changed. Firstly, technological developments mean that simulator realism is improving greatly. Developments in networking technology have also opened up new possibilities for simulator applications. For example teams or groups may actively participate in interactive and large-scale simulations as well as individuals. Secondly, developments such as Object-Oriented Programming and new ways of packaging dynamic simulations have changed the way simulators are built and used. This makes simulation much more readily available across a range of industries and applications, and also as a tool for everyday use by engineers and others rather than just for specialists.

Simulators and non-technical skills' training

Aviation simulator use has been extended to flight crew training (including cabin crew) under the Crew Resource Management (CRM) arrangements developed after a series of air crashes such as at Tenerife Airport in 1977. Two Boeing 747 ('Jumbo') jets collided on the runway while one was attempting take-off resulting in the deaths of 583 people, still the largest single loss recorded in aviation history. Such disasters showed that a focus was needed on non-technical causes. In the case of Tenerife for example there were a number of communication failures between flight crew, and also between flight crew and air traffic control, as well as poor decisions-making, team co-ordination and leadership.

The industry then focused – through CRM - on these non-technical skills (NTS) which underlay what had been broadly (but not usefully or appropriately) termed 'pilot error'. Broadly these are the 'softer' cognitive and social skills that complement technical skills. There are seven core NTS skills (Flin et al 2008, p1); situation awareness (or paying 'attention to the work environment' including the 'shared picture' with others), decision-making, communication, leadership, teamwork, managing stress and coping with fatigue. These skills are, not surprisingly because we are all human after all, the same for non-aviation applications and there is increasing transfer from aviation / CRM to other high hazard industries such as oil and gas and the process industries. The uptake has been slow. For example the HSE first identified the possibility and desirability of doing this for offshore following a series of research projects (see e.g. HSE 2003), but outside emergency response training there is not much evidence of progress to date. The UK Energy Institute produced guidance in 2014 for the energy sector which may help facilitate this change more quickly. Using simulators appropriately can provide a good platform for developing these essential skills for individuals and teams.

Emergency response for on and offshore high hazard industries

Emergency training for the high hazard industries is beginning to follow the off-shore example set for Offshore Installation Managers (OIMs) post-Piper Alpha. Offshore training providers provide simulators to help assess delegates' competency in controlling emergencies. The simulators are generic suites (control room and ancillary offices or other locations) which can be tailored within limits towards the attendees' own control environment. The assessment is against performance standards for selected emergency scenarios set by the Offshore Petroleum Industry Training Organization UK (OPITO). This training has since been extended to emergency team members, supervisors and others, and for example in the OIM courses delegates train with their teams. There is increasing use by onshore high hazard industries such as the chemical and allied with providers offering the onshore equivalent training, to help make their demonstrations of competence under the COMAH regulations.

Key issues in using simulation for training

Many issues should be considered. These include:

- Clearly specifying the minimum skills to be practiced and the levels of competence to be achieved on the simulator
- Identifying the necessary scope and fidelity required. This depends on the training needs – competency training needs may differ from familiarisation ones for example.
- Ensuring that training and assessment is delivered in a sufficiently independent, consistent and credible way i.e. this may need to be delivered separately by persons other than those responsible for day-to-day activities of trainees.
- Identifying negative (i.e. incorrect) routes through the simulation. On more complex systems this can be very time-consuming and expensive with a detailed understanding of the system required though it will improve subsequent learning by broadening trial and error possibilities.

Case Study; Offshore Drilling Simulation

The advancement of simulators in the offshore oil and gas industry

Simulator use is variable across industries, and in some cases the link between simulator use and developing and maintaining competence is not always clear. The increasing availability and use of simulators may in some cases be due to the inherent face validity, i.e. that the training environment looks and feels a lot like the 'day job', something that is increasingly easier to achieve. The drilling industry is one such sector that has seen a growth in simulator use, and these are becoming more sophisticated in what they are able to replicate. They still provide a useful platform for developing basic psychomotor skills, but are also developing much further for building greater depth to knowledge and skills. Of particular interest for this application in the drilling sector is the ability for simulators to replicate plausible abnormal and emergency situations. Inputs from operators also reflect how the real systems would respond. This is of significant importance in the drilling sector due to the dynamics of operations and the potential to drift into an emergency.

With experience spanning several years of high fidelity simulator use, Maersk Training are identifying that the simulator training setting can have a real impact on technical skills and the associated non-technical skills (NTS) / Crew Resource Management (CRM) skills (these terms are generally used interchangeably, though CRM came first). This builds on the existing, but limited information that suggests CRM training can improve safety and / or performance. Examples of papers which provide some evidence of the utility of CRM include Salas et al (2004 & 2006), with other positive findings for more general team training (Salas et al, 2008). Whilst evaluation evidence can be positive, there is also reactive industry data which has highlighted the relevance of NTS deficiency as a contributor to major incidents. One of the most high profile cases in recent times was the Macondo well blowout in the US Gulf of Mexico (BP, 2010), where 'human judgements' were identified as contributory factors. Other large incidents, such as the blowout on a Hercules rig in 2013 (BSEE, 2015) further identify links to human factors and CRM skills.

What is simulation trying to achieve in an offshore drilling context?

It is useful first to consider what the drilling contractor goals are, as the essence of simulator use is to enable these goals to be met more consistently in real operations. At a very high level, key goals are:

- To drill the well as required by the operator and the associated specification
- To do this efficiently with time and other resources
- To manage risks to an acceptable level, with a top priority of always maintaining control of the well (i.e. preventing an uncontrolled hydrocarbon release)

The third point here provides one of the critical reasons why simulation is so beneficial in the drilling sector. It relates to what Patrick (1992) refers to as *'cost and consequences of error'*. The costs of development and operation of simulators can be significantly outweighed the potential costs and consequences of error. A single undetected error for example could theoretically lead to the complete loss of a drilling asset and many lives. Further to this are also additional costs, such as environmental damage, impact on company reputation, and impact on livelihoods.

What are some of the industry challenges?

While the high-level goals of the drilling contractor and drill crew are relatively clear, the day-to-day reality can include a great deal of complexity and uncertainty. It is here that the adaptability of humans can be a key strength, particularly over automation – no designer has 20-20 foresight after all and complex systems can – and do - produce surprises. However, the partial reliance on humans is also an Achilles heel. Some of the challenges managed on a daily basis by drill crew include:

Complexity of operations. Some aspects of drilling technology have advanced with relative speed over the last few decades, using newer equipment and techniques to drill ever more challenging wells. Also the reality of what takes place down-hole is not always completely clear to the drill crew on the surface. Whilst technology provides a fair idea of what is happening, often a degree of interpretation and assumption is also needed. With multiple agents involved in this interpretation and information sharing, there is plenty of room for human fallibility to creep in.

Team interactions. With specialist 3rd parties working alongside the drilling contractor and operating company personnel there can be a significant mix of personalities, cultures and competence. This needs to be 'cracked' quickly to transform a group of initially disparate individuals into a high performing team. This is a requirement if key CRM skills such as communication, decision making, teamwork, leadership and situation awareness are to impact positively on safety and performance.

Risk awareness. The phrase 'chronic unease' (a key characteristic of high reliability organisations (HROs)) is becoming part of modern safety science parlance, and has a strong relationship to the older notion of risk awareness. For drill crews it is not always clear-cut how individual knowledge, experience, and behaviour (action and inaction) will contribute to overall team performance on any given task. For example if a team member fails to spot or share a piece of information, all of the team may proceed blindly, unaware of the potential latent problem in the system. Equally a false positive may be raised, also taking the team down an incorrect pathway. From a system safety perspective, this is certainly not a criticism of individuals or crews, but an inherent problem in the cocktail of system imperfections.

Whilst there is room for improvement in the design of the system, CRM skills, along with other driller competencies can also play a very critical role. The range of core technical and non-technical skills can be brought together in a training format that incorporates high fidelity simulation.

Simulation to support coping with novel / dynamic situations with high consequences

Generic well models can provide useful learning experience, especially with non-technical skills. However, well-specific models are also becoming more common. Both allow advancement of technical and non-technical skills; the well-specific models allow them to be honed with an increasing degree of relevance to the real world, and also ensure they are still applied when pressure increases and timescales are reduced. As an example, the team can practise their skills against the backdrop of:

- Changes in geology and formation pressures that impact on the drilling operation and well control;
- How well the team understand and share data that indicates how the job is progressing, including well control;
- How variations from the planned approach impact on the decision making of individuals and the team as a whole (e.g. conscious decision to deviate from specific procedures); and,
- How the actions and inactions of individual team members can lead to team success, challenges, and failure (e.g. a blowout).

The face validity of this approach is high, as the team are exposed not to a theoretical set of data, but to the feedback and interactions as if they were drilling the real well on the rig. From the authors' perspective, participants see huge value in this compared to traditional classroom training. They recognise that a training model based purely on the classroom setting for well control can be very 'dry' and lead to disengagement. Achieving learning objectives is likely to be lower in a classroom setting, as is the effective transfer of skills to the real work situation.

Maersk Training are also applying such multi-method training, including high fidelity simulation to very specific well challenges, or even the challenges of a particular well phase. This approach could therefore also provide significant benefits in moving from a desk process of 'drilling a well on paper (DWoP)', to partially drilling a well in a simulator (DWiS). The efficiency and safety gains made in such an environment are likely to outweigh the costs of potential human failures that could be made on the real well. Saving just a few hours of downtime, or preventing one safety incident could easily and significantly recover the cost and time of a failure on the job. The potential impact on enhancing organisational reputation is also likely to be high. Becoming more specific in simulated scenarios also has provides a firmer grounding in uptake of competencies. For example Burke, Salas, Wilson-Donnelly and Priest (2004) identify that in CRM training, utilising specific scenarios offers greater training transfer.

Use of simulation also allows individuals and teams to learn from making errors, mistakes, and even violations to company protocols. Allowing individuals to fail safely is simply not an option in the 'real' offshore environment, so this provides a significant advantage for simulation and simulators. Learning from mistakes has not been studied extensively in the drilling industry, but related safety critical domains pick up on the benefit of this type of learning. For example, Ziv, Ben-David, and Ziv (2005) note that there is an expectation that learning from mistakes during simulation can strongly influence future behaviour, particularly in dynamic, high consequence environments:

> *"The basic assumption underlying Simulation Based Medical Education (SBME) is that increased practice in learning from mistakes and in error management in a simulated environment will reduce occurrences of errors in real life and will provide professionals with the correct attitude and skills to cope competently with those mistakes that could not be prevented."*

While this type of learning requires exploration in more detail for application to the drilling industry, it does initially appear to be a valuable learning method for competence development. As Ziv et al (2005) note, such an approach is also likely to influence the attitudes of participants, which is perhaps a more challenging facet of the competence domain to influence during training interventions.

So the environment for learning from failure should be considered when using simulation and simulators but the process of learning in this way can also risk damage to individuals and teams if not handled appropriately. For example, as Tjosvold, Yu & Hui (2004) point out, the team culture and goal allocation is important for maximising learning from mistakes. Where goals were cooperative, teams were better able to learn from mistakes than when goals were competitive.

Evaluation to demonstrate simulator benefits

The scientific evidence to validate the use of high-fidelity simulators in offshore drilling is still lacking, but this most likely does not undermine the efficacy of its application. Work such as Maersk's is after all part of the emerging data on which such research can be based. When running evaluations, there are also a variety of considerations to make on performance impact of individuals, safety and profit etc. Kirkpatrick and Kirkpatrick (2006) provide good detail on methods and considerations for such evaluation. It is also relevant to note that anecdotal evidence is strong. From the Maersk Training case example, participants and instructors using such simulators largely acknowledge significant improvements to technical knowledge and skills, as well as CRM skills. This is also often reflected in positive behaviour change of participants, as well as consistent improvements in participant technical knowledge.

Some of the distal impact can be more challenging to link to an intervention such as training. However, there also appears to be positive impact on business results, although not always in a format that is easy to back up with numerical data. Maersk Drilling for example attribute part of their success and growth with new assets as resulting, in part, from integrated crew training (Personal Communication, Vibeke Sam, 2016). Such training utilises multiple training methods, including high-fidelity simulation. Maersk Drilling also recognise that this high-fidelity training plays a key part in preparing crews for both asset, and operations-specific challenges (Personal Communication, Vibeke Sam, 2016). In the drilling industry demonstration of capability for new assets can be very important for efficiency, as well as safety. Being able to demonstrate capability sooner can enable rigs to begin drilling quicker, which can in turn lead to cost savings of hundreds of thousands of US dollars per day.

There is also some drive to consider simulation and simulators from a regulatory perspective. Guidance documentation for major hazard industries highlight that such methods can be a valuable part of the CMS (e.g. Office of Rail Regulation, 2007).

Method for identifying competencies and learning methods

From the Maersk Training perspective, scenarios and related competency areas for simulation are based on a range of inputs, including:

- Assessment/Certification body input (e.g. International Well Control Forum (IWCF))
- Learning from within and across industry organisations (e.g. incidents)
- Industry guidelines
- Industry case studies

There is potential for even more focus on which specific competencies to target with use of simulator training for the oil and gas industry. This is also an important point for industries less mature in simulation and simulators to consider at an early point in programme development.

Conclusions

To conclude, there are a number of takeaway messages that can be considered for the oil and gas industry, and also in allied high hazard industries such as chemical, particularly when simulation and simulators are being considered.

1. The use of simulators in the drilling sector is proving useful in developing and maintaining competence for safety critical roles. There is likely room for improvement on prioritisation of specific competencies to focus on, for both technical and non-technical skills. There is also likely an opportunity for greater cross-sector sharing and learning on simulator and simulation methods.
2. Some caution is required with simulators and associated evaluation of efficacy. The Maersk Training approach (on which this case study is based), utilises a multiple method training approach, including high-fidelity scenario based simulation. Simulation training provision varies, therefore comparisons are not always easy to make. Some training establishments may, for example, use fewer mixed training methods. When exploring the evaluation of simulation, it is therefore important to take into account the variety of ways in which training bodies use their simulators.
3. Lower fidelity training still has a place in the offshore drilling sector, as with other industries. The case study covered here is testament to how such low fidelity training can be used to build towards higher fidelity training. For industries outside of offshore drilling, consideration should be made as to whether high or low fidelity simulation will be most appropriate. The potential costs of human failure, as discussed by Patrick (1992) is one of the critical considerations in this process.
4. Competency lifespan in the competency management system (CMS) is a consideration that has not necessarily been taken fully into account in the drilling industry. This is an area that could be improved upon, and also a lesson for other industries. For example:
    - What are the specific competency requirements at different phases of drill crew careers (technical and non-technical), and how do these competencies relate to training methods, including simulation and simulators (i.e. what are the best ways to develop competencies), covering normal, abnormal and emergency situations?
    - What are the emerging competency areas, particularly in the context of the industry (e.g. upturns, downturns, selection pool limitations, and ageing workforces) and from both technological and methodological advances?
    - What are the requirements not only for competency development, but also for competency maintenance? i.e. what are the likely frequencies and methods (such as simulation) that should be used e.g. for refresher training and for reassessment?
    - How should competency development relate to competency assessment? Currently there is potential for these two aspects to merge into a single intervention where simulation is applied. There may be significant costs to covering both competence development and assessment in a single intervention.

Wider conclusions

5. The use of simulators should be driven by the overall *CMS requirements* and based on a *structured training plan* derived from a training needs' analysis underpinned by a good understanding and analysis of the hazard and risk profile of the site and processes. It is helpful to think first about what experience or tasks may require *simulation* before moving straight to the use of *simulators*. There may be other – and better – ways of achieving this for some (possibly less complex) processes and tasks. Simulators are only one set of tools in the training box.
6. *Selection of simulators* (or simulation) should be based on the real training needs e.g. for fidelity, scope, multi-purpose, location etc. In selecting for fidelity *task fidelity* (realism for the operational tasks concerned) is paramount for effectiveness and credibility. If training providers are used then they will need adequate briefing on training needs, process context and ideally be able to tailor their provision to make it as site and task specific as possible.
7. The high hazard (e.g. process, chemical, oil and gas) industries still do not show significant uptake of the use of simulators or of *non-technical skills' training* except for emergency response training. There is scope to improve this situation particular with the much cheaper, flexible simulation options now available. While arguably drilling activity is more dynamic than say production work offshore or some onshore processes, there is still more than sufficient read-across to make this worthwhile including savings on costs, incidents and reputation.
8. Simulator use should focus on critical non-technical skills (the 'soft' or cognitive / social skills) – as well as technical skills required. This is a fundamental learning from the aviation sector's experience (and now from the drilling world) but uptake on *non-technical skills training* has to date been low and inconsistent. There is good guidance available to help e.g. Energy Institute 2014).
9. Simulators, no matter how sophisticated, are not going to deliver specified training needs without an *appropriate range and realistic quality of inputs* i.e. the tasks, activities and scenarios used or modelled in them. Organisations need to make sure that they are reliably capturing a full range of for example real upset events (internally and externally) and also structure the simulator training to acknowledge that there may still be system surprises and equip trainees to approach these consistently and with the best chance of success. Currently few companies do this well.

The following table (Table 1) is an initial attempt to populate a chemical and allied industry framework for possible simulator use. If there is sufficient interest then this can be taken forwards in a workshop setting at the next Hazards event. This will allow the input of industry experience and ideas.

Development / Learning Objective	***Proposed environment / style***
Core knowledge and acquisition of principles	Classroom
Learning of a small number of cognitive based, or social skills (e.g. decision making, communication)	Classroom / low fidelity simulation
Practise of small number of skills under time pressure	Low fidelity simulation
Understanding the interaction of multiple dynamic task variables	High fidelity simulation
Application of skills with full team and full performance influencing factors (e.g. time pressure, dynamic situation, social influence)	High fidelity simulation
Practise of skills that are usually rare in occurrence, e.g. abnormal conditions, event escalation, and emergencies.	High fidelity simulation

Table 1: When should simulators be used?

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