Guidance on human and organisational factors aspects of implementing new technologies

energy institute

GUIDANCE ON HUMAN AND ORGANISATIONAL FACTORS ASPECTS OF IMPLEMENTING NEW TECHNOLOGIES

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FOREWORD

The introduction of new technology into an organisation is not a novel problem; however, what may be novel is the low cost and maturity (as well as their everyday use in the non-work environment) of such an array of technologies that have the potential to significantly alter the way organisations operate. Whilst, arguably, the energy industry has been slower to introduce new technology than other sectors, it is likely that the next five to 10 years will see more and more usage of technologies such as unmanned aerial vehicles (UAVs), touch screen tablets, tracking devices and electronic permit-to-work systems. Whilst these (and other) technologies are not necessarily 'new', in the context of this publication they should be considered new if they are new to the reader's workplace.

Unfortunately, too often technology is introduced into an organisation simply because it is available. This can lead to a number of problems affecting the use/misuse and uptake of the technology and, ultimately, whether its perceived benefits are ever realised. A consideration of human and organisational factors (HOF) is key to overcoming these problems in order to ensure the successful design, introduction, and use of new technology.

This publication is aimed at organisations who want to introduce a new technology to the organisation. It aims to prompt the reader to think about HOF issues that might need to be considered when introducing new technology, and to direct them towards relevant processes and tools which may assist in the management of these issues. The processes and tools themselves are not covered in detail as these may require the input of specialists to use effectively.

Whilst some mention of specific technologies is made, this publication primarily provides a generic set of questions and accompanying guidance to help organisations plan for the introduction of *any* new technology. The questions focus on understanding whether the technology will:

1. be beneficial;
2. affect the level of risk, and
3. be accepted by the workforce.

Guidance is also summarised in easy-to-use check-sheets (Annex C), and examples and case studies are provided throughout.

The EI welcomes feedback on its publications. Feedback or suggested revisions should be submitted to:

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1 INTRODUCTION

1.1 OVERVIEW

The aim of this publication is to provide guidance on the introduction of new technology into an organisation, and more specifically, the management of HOF issues which have the potential to influence the success of its introduction.

1.2 SCOPE

The focus of this publication is on new technology in the energy industry. However, examples from other sectors have been included where appropriate (notably the medical sector where there is a lot of published research). For the purposes of this publication, new technology is any technology that is new to a workplace, regardless of whether it has been used in other situations. For example, an electronic shift handover system may have been used in other workplaces, or even at other sites within a company, but if it is novel to a site, then it would be new for the purposes of this publication[1].

Whilst some discussion of new and future technologies has been included (section 2), the aim of this publication is not to try to predict which new technologies will become widespread over the next few years. Instead, the focus is on providing generic guidance for managing the introduction of *any* technology novel to a workplace.

The main emphasis in this publication is new technology proposed for introduction by organisations. That is, not technology which has been adopted by individuals in their personal life with the potential to affect their work (e.g. personal tablet computers or smartphones brought into the workplace), although this issue is discussed briefly in section 2.

1.3 STRUCTURE OF THIS PUBLICATION

The structure of this publication is centred on three questions, to be asked of any proposed new technology. These are:

1. Will the technology be beneficial?
2. Will the technology affect our level of risk?
3. Will the technology be accepted?

Each question is discussed in turn, and supported by illustrative case studies to show how failure (or success) to consider these issues may undermine (or support, where they have been anticipated) the introduction of new technology. The case studies and examples are either drawn from literature, or, where no citation is given, from discussions with organisations when researching for this publication.

To help ensure all the issues raised in this publication are considered by an organisation contemplating the introduction of a piece of new technology, check-sheets are included in Annex C.

1 Of course, if a technology has been previously used in other workplaces, then there will be important lessons that the implementing team will be able to draw upon.

Tools and processes that may assist with the identification and management of HOF issues are listed in the check-sheets. Annex D includes links to relevant resources and further reading (full references can be found in Annex A).

1.4 USE OF THIS PUBLICATION

The aims of this publication are to prompt the reader to think about HOF issues that might need to be considered when introducing new technology, and to direct them towards relevant processes and tools which may assist in the management of these issues.

Whilst some practical guidance is given, there is insufficient space in this publication to provide detailed information on these tools and processes. Moreover, it is probable that some of the HOF issues will require the input of HOF specialists to properly analyse and address. For example, if the new technology will significantly affect the nature of a safety-critical task, such as a proposal to control a process from a remote location, this will have significant HOF implications (e.g. changes to how information is acquired, and opportunities for better information presentation provided by new interfaces, will potentially affect an operator's situation awareness).

The principal issues raised in this publication are summarised in check-sheets in Annex C. These are designed to be short enough that they could be used as a prompt for issues to consider in small scale projects, or as the basis for planning more significant pieces of work. The amount of time spent considering these issues should be proportionate to the degree of change or novelty arising from the new technology, and the criticality of the related tasks (e.g. in terms of process safety).

Finally, whilst this publication is presented as a checklist of important issues, the introduction of a new technology should be an iterative process, with opportunities taken at every stage in the selection or development of a technology to review the likelihood of success.

2 NEW TECHNOLOGY THEMES

2.1 TECHNOLOGY THAT MAY SOON BE SEEN IN THE ENERGY SECTOR

Whilst this publication does not attempt to predict the new technologies that will be adopted by the energy sector over the next few years, when contemplating some of the issues set out in section 3, it is useful to consider some possible future technologies. This helps to focus attention on important HOF issues and how they might be managed.

As previously discussed, for the purposes of this publication, new technology is any technology that is novel to a workplace. Therefore, a technology may have existed for many years before it is applied in a work setting, but, if it is novel to its users, it will be considered to be new for the purposes of this publication. This section discusses some technologies that have been recently adopted by the sector, or that might be adopted in the future, the opportunities they present, and the HOF issues that may result and require management[2].

2.1.1 Touchscreen technology in tablets

One example of a technology that has been available for some time, but has yet to be widely used in the energy sector, at least in field environments, is touchscreen technology in the form of tablet computers. One use for this technology might be to access up-to-date procedures at point of use, potentially in different formats than have traditionally been used due to the limitations of printed documents. For example, they could include access to interactive elements, such as checklists, or be connected to measuring devices (such as gas detectors) to ensure that correct readings have been achieved before a task can proceed. They could also provide access to short reference videos to illustrate how task steps should be performed, and provide a record of task performance. In addition to technical concerns, such as the management of sources of ignition (from electronic components, etc.), relevant HOF issues might include ergonomics (e.g. the visibility of the screen in different lighting conditions, the ability to input data when wearing gloves, the robustness of the device), and usability issues related to the presentation of information. As a comparison, many early web pages were simply the equivalent of printed paper documents, before it was realised that the new medium required different forms of presentation. Similarly, it is probable that considerable development effort will be needed for the presentation of procedural information on tablets in a field environment, to maximise the potential value of the technology and minimise the scope for failure.

2.1.2 Remote control of processes

It has been possible for some time to control processes remotely. However, as technology develops further (e.g. improved teleconferencing facilities), and pressures on staffing costs escalate, its appeal in areas such as offshore oil and gas installations is likely to increase. As well as reducing the costs associated with locating and maintaining staff in difficult to reach work environments, remote operation offers the opportunity for individuals to monitor and control several different installations. However, there are a significant number of related HOF issues that may act as barriers to its success (see Anderson and Johnsen, 2006). For example, the task as performed offshore is likely to feel very different when controlled from

2 Some of the examples discussed here are taken from the Health and Safety Executive (HSE) website concerned with so-called horizon scanning (HSE website), and considered in the context of the energy industry.

onshore. From a training perspective, if experienced offshore workers are used initially in the remote roles, they will be able to lean on their prior experience of working offshore when interpreting the data with which they are being presented. However, this may not be as easy for subsequent generations of controllers. Some changes, and their impact, may be more difficult to anticipate. For example, informal communication of important information, which will happen without much conscious effort offshore, may be difficult to replicate when controllers are in geographically distant locations. Workload will be a key consideration, particularly if individuals are required to monitor and manage different processes, as there may be periods of relative calm, followed by periods of extremely high workload.

2.1.3 Drones

Drones, or UAVs, are a form of technology that, as costs have reduced, has moved from primarily military applications to a wide range of proposed civilian uses, including deliveries, monitoring traffic accidents, searching for missing people, traffic management, and construction (Techworld website). In the energy sector, there is the obvious potential for their use in the inspection of hard to reach structures, without the need for temporary forms of access such as scaffolding. The rapid adoption of this technology has meant that existing regulatory frameworks have been challenged with, for example, legal questions being raised about rights to fly over individuals' property. In the US, the rules regarding commercial drone use have recently been significantly relaxed (BBC website, *Drone industry delight at new US rules*). In addition to regulatory issues, there are likely to be ergonomics issues related to the control of the devices, and, if they are used in the context of inspection, questions of fidelity. For example, a drone equipped with a camera should be able to provide sufficient information to determine whether maintenance is required.

2.1.4 Automation

The automation of industrial processes has taken place for many years. However, developments in technology continue to offer opportunities for new forms of automation. This is particularly important in process control, where control room operators can find themselves monitoring processes controlled primarily by computers.

The risks associated with these developments have been known about and discussed for many years (see Bainbridge, 1983). The greater the degree of automation, the less practised the operator will be when they are required to intervene. Unfortunately, this is likely to be when there is a problem, and when risk may be higher than in normal operation. Without day-to-day interaction with a system, the operators' understanding of the process, and their ability to develop solutions to unusual problems, will be reduced. Moreover, unless the allocation of function between operator and technology is properly considered, then there is the danger of the operator being left with the most difficult and hardest to automate tasks. These issues can be compounded by the tendency of technology to fail abruptly (compared to the tendency for people's performance to decline steadily before failing). Finally, from an operator's perspective, an important source of job satisfaction arises from exercising the skills used when interacting with the systems they control. If the system is largely automated, this satisfaction may be reduced.

As the technology and software related to automation become more complex, the ability of sites to manage and understand the systems that control their processes is likely to be reduced. During the research for this publication, the authors became aware of issues related to manufacturers' software updates that had negatively affected operational processes and controls, such as the removal of over-speed protection on a gas turbine, changes to alarms, and a system being unintentionally reset to factory settings. The transparency of these systems is also an issue. One organisation wanted to use their management of change processes to manage alterations to software, but found that they did not have the necessary internal competence to do this.

2.1.5 Pervasive technology

The idea of embedding interconnected technology in everyday devices, sometimes referred to as the 'internet of things' (IOT), has been talked about since the first internet-connected toaster was presented at a conference in 1990 (Living Internet website). In the energy sector, there are numerous potential applications. There are existing examples of the use of sensors (e.g. vibration, acoustic, level, position) interconnected to a plant's control and monitoring systems, and analysed by software for the purposes of asset management (Control Engineering website). Many of the sensors can be operated without batteries and are wireless. This means that readings that previously had to be collected during operator rounds, potentially in hard to access areas, can now be collected and analysed automatically. This has obvious potential benefits in terms of obtaining a consistent picture of plant performance. It can also reduce the probability of measurement errors, and of operators being unable to take measurements during rounds due to competing priorities. One refinery using wireless acoustic transmitters to monitor gas flow to flare stacks reported a reduction in hydrocarbon losses by $3 million annually, due to detection of faulty valves (*ibid*).

On the downside, these changes may mean that operators spend less time on plant rounds, which apart from the primary objective of taking measurements, also provides opportunities for spotting and responding to issues which sensors alone may not identify (e.g. valves left out of position, small leaks). In addition, there may be HOF issues related to the presentation and analysis of data captured by these devices. For example, given that control rooms often already suffer from information overload in the form of alarm floods, adding additional asset management alarms will introduce an extra layer of complexity which may increase mental workload.

There are also potential issues related to complexity and security. One organisation reported that the interconnected nature of the technology, particularly when linked to automation, can make it difficult to understand what data are being collected, and how this is related to actions being performed by systems. From a security perspective, if these systems are connected to the same networks, then there is the possibility of sabotage from viruses, inadvertently introduced by employees using their own networked devices (e.g. smartwatches, laptops).

2.1.6 Rapid manufacturing

At some point in the future, rapid manufacturing (also referred to as 3-D printing, or direct digital manufacturing) may become widely used in the energy industry. The ability to create small items such as gaskets from scratch, without waiting for supplies to arrive, could be very useful. Related HOF issues might include failures arising from selecting incorrect templates, or potentially, a temptation to improvise a solution, when it might be better to wait for a specific part. The management of the technology should therefore involve the development of clear rules about when it should be used. In addition, new forms of quality management systems may need to be developed. Currently, when a component is purchased from a manufacturer, they are responsible for ensuring that it meets the necessary quality standards. However, if a component is produced at site, there will be questions relating to ensuring that the manufactured item is of the required quality.

2.2 PERSONAL TECHNOLOGY

This publication focuses on technology that organisations plan to introduce. However, there is also the possibility of personal technology being brought to the workplace by individuals. This issue is likely to increase in importance as smartphones and small wearable devices become more widely adopted by the public.

In addition to the security issues (e.g. viruses, hacking etc.) there may also be direct safety implications. For example, individuals working in a remote location on work that involved long periods of waiting, punctuated by occasional bursts of safety-critical activity, were making widespread use of smartphones to pass the time, even though they were forbidden by the organisation. An apparent example of the potential dangers of this practice was the head-on rail crash in Bad Aibling, Germany in February 2016, which killed 11 people. It was reported that a rail dispatcher, responsible for the two trains that collided, was playing a game on his mobile phone for an extended period of time prior to the crash (Guardian, 12 April 2016).

Whilst the potential role of smartphones as a distraction from safety-critical tasks may be relatively easy to anticipate, other forms of personal technology may have more subtle effects on behaviour. For example, wearable personal fitness devices, which monitor an individual's activity level, may mean that individuals are less keen to sit at a control room monitor for lengthy periods of time, with the potential to reduce the time that a process is being actively monitored.

Organisations may seek to capitalise on the widespread personal use of portable devices. For example, some organisations are actively promoting the adoption of such technology, seeing it as a way to increase the overall fitness levels of their workforce. This in turn has prompted questions about privacy issues, with concerns raised about the potential for companies to sell on data to marketing firms (BBC website, *Do you want your company to know how fit you are?*).

3 MANAGING HUMAN AND ORGANISATIONAL FACTORS ISSUES IN THE IMPLEMENTATION OF NEW TECHNOLOGY

The examples discussed in section 2 are just a small sample of the types of technologies that might be adopted by the energy sector in the coming years. They vary widely in terms of their purpose and utility. However, they all have the potential to significantly affect the way that work is carried out. It is this aspect, and how these changes can be managed to give the best chance of a given technology succeeding, that is the focus of this publication.

An important prerequisite for success is awareness of the potential impact of HOF issues on the introduction of new technology. Without this if, for example, an organisation assumes that a technology will seamlessly replace an older technology, or that any issues with the usability of the technology will be worked out over time by the workforce, then there is a high probability that the technology will fail, or at the very least fail to realise its potential.

Sections 4, 5 and 6 pose a series of questions that any organisation contemplating the introduction of a new technology should ask. Thinking about these questions should leave an organisation better placed to successfully manage the adoption of a given technology.

4 WILL IT BE BENEFICIAL?

Before deciding on the introduction of new technology, it should be clear what benefits the technology brings: this might be because it solves a problem (e.g. the use of drone technology to inspect difficult to access equipment), or because it will improve performance. This is important, as otherwise there is the danger of the technology being introduced simply because it is available (i.e. the introduction of the technology itself becomes the goal, rather than bringing a specific benefit).

4.1 HAVE THE ANTICIPATED BENEFITS BEEN CLEARLY IDENTIFIED?

This question should be self-evident, but there have been many cases of a technology being introduced because it is available, rather than because it solves a problem or will improve performance. Without a clear statement of the expected benefits, the risks of poor choices, such as over-investment, are increased. Moreover, a common trap is for the implementation of the technology to become the overall goal (e.g. 'we must get this electronic permit system working'), rather than achieving the benefits promised by the technology (e.g. 'we need to get the safety and reliability improvements that the permit technology can provide').

There is evidence of this in healthcare, where technology choices have sometimes been led by a physician's personal enthusiasms, or as a result of local competition between hospitals (e.g. for the best medical imaging technology), rather than because of any clearly identified benefits (Coye and Kell, 2006). Even where the benefits of the technology appear clear-cut, specifying the expected benefits will help to clarify what the organisation hopes to achieve by its introduction.

The benefits of new technology might fall into one of several categories (Eason, 1988):

1. cost reduction (e.g. as a result of staff savings);
2. improved productivity (e.g. increased throughput);
3. improved support (e.g. support for decision making);
4. organisational enhancement (e.g. making new forms of business, or safer ways of working, possible), and
5. enhanced operator job satisfaction and fulfilment (Jordan, 2002).

Although this has rarely been explicitly identified as a significant potential benefit for introducing new technology, the potential for demotivating staff to the point that they perform their work less efficiently (e.g. because of boredom), is a significant risk when introducing new technology.

Certain benefits, for example increased throughput, will be much easier to measure than others, such as improved organisational communication and safety improvements. In healthcare, for example, return-on-investment (ROI) analyses are easier for new computed tomography (CT) scanners, where the acquisition costs and expected throughput are easy to establish and compare with current systems, compared to so-called 'disruptive technologies'. Examples include surgical robots or computerised order entry systems which have the potential to significantly affect the way in which work is carried out (Coye and Kell, 2006). Furthermore, some technologies will take longer to achieve their full potential than others. If the aim is to reduce costs, then whether this has been achieved can be established quite quickly, but other types of benefits may only be measurable once the workforce has had sufficient time to work with the technology, and has acquired the necessary experience and training to utilise it effectively.

Box 1: Automated systems

The benefits of the introduction of automation can be particularly difficult to evaluate. In many cases the claims made by designers may not match the users' experience (Woods, 2015). For example, a designer might claim that the technology can be simply substituted for an existing technology and provide better results, but in reality it transforms the way things are done and the roles of people. It might be expected that automation will free up resources by offloading work, or focusing attention on the correct responses. However, the end-users' experience might be that it creates new types of cognitive work at inconvenient times, or creates more pieces of information to track. Furthermore, it might be claimed that less training is required, whereas in fact new forms of training may be needed, which require additional resources to develop and implement. Vendors may not be keen to advertise these issues, or may not even be aware that they could arise in a specific context. When introducing a new technology, not only should the possibilities that the technology affords be understood, but also what will be different about work when it is in place (see sections 5 and 6). In other words, organisations should avoid the trap of the introduction of the technology becoming the goal, rather than achieving the anticipated benefits which prompted its introduction in the first place.

Even where anticipated benefits have been specified, they may prove difficult to achieve. For example, some benefits may be in conflict with each other. One benefit of an information technology (IT) system might be that it will assist in decision-making for a specific role. However if, at the same time, the opportunity is taken to reduce administrative support for this role because the technology makes this possible, then the benefits may cancel each other out (Eason, 1988).

4.2 HAVE THE POTENTIAL COSTS BEEN CONSIDERED?

The potential costs associated with the new technology should also be identified. These will include costs that are relatively easy to estimate, such as the capital costs and training, and others that are more difficult, such as disruption to other activities and user frustration.

Some outcomes, which the organisation sees as beneficial, may be costs to other stakeholders. For example, a new automated control system may improve throughput, but consequently make the job less engaging for the operator. These types of costs have the potential to undermine the success of the technology, if they affect the willingness of the users to accept it (these issues are discussed in more detail in section 6).

If the technology has a significant impact on the way work is performed, this may have a knock-on effect for the organisation. For example, if a decision is taken to introduce remote operation of an offshore platform, this will change the role of the operator significantly, with potential implications for career progression, salaries, and organisational structures. This does not necessarily mean that the technology should not be adopted, just that the organisation should be aware of the implications and develop plans to manage the transition.

Box 2: Police body-mounted cameras

A United States police force undertook a trial of body-mounted cameras (Katz et al., 2014). The technology was expensive, costing around US $500,000, but evidence from other police forces had suggested the technology reduced complaints and increased arrest rates. However, rank and file police officers had expressed reservations that the technology could be used against them, or that it may remove some of their discretion when considering how to process offenders. For example, officers may feel obliged to arrest or detain those committing minor offences, where previously they would administer cautions or warnings.

As anticipated, the trial of body cameras did correspond with a drop in police complaints, an increase in convictions (including domestic violence), and quicker convictions. However, the aforementioned reservations regarding the technology persisted, and other problems included increased time spent on administration, long download times for video data and challenges imposed on the courts service to prosecute using video evidence.

This trial meant that the police force had a clear understanding of the potential benefits and costs of the technology before implementing it. Even though there was evidence of the value of the technology elsewhere, they took the time to establish how it would work in their setting. Because of these insights they were in a position to mitigate potential costs and address user reservations.

5 WILL THE TECHNOLOGY AFFECT THE LEVEL OF SAFETY/ SECURITY RISK?

The proposed technology might bring with it the possibility of exposure to certain hazards (e.g. electricity, rapidly moving objects, radiation, sharp edges), which should be subject to standard risk management processes, and the application of appropriate control measures. However, the way the technology is used will influence the potential for the hazards to be realised. For example, having identified radiation as a hazard in an X-ray machine, standard risk management interventions will result in the addition of screening to protect the user from the source of radiation. However, understanding the tasks the user needs to perform with the machine may identify additional scenarios where the control measures may fail or be circumvented by the user in order to achieve wider task goals.

For this reason, the hazards associated with user interactions with the technology should be considered as part of the risk management process. One area where this process has been well defined is in the field of medical device design – where the term 'use-related hazards' has been applied to these interactions (Food and Drug Administration [FDA], *Applying human factors and usability engineering to medical devices*).

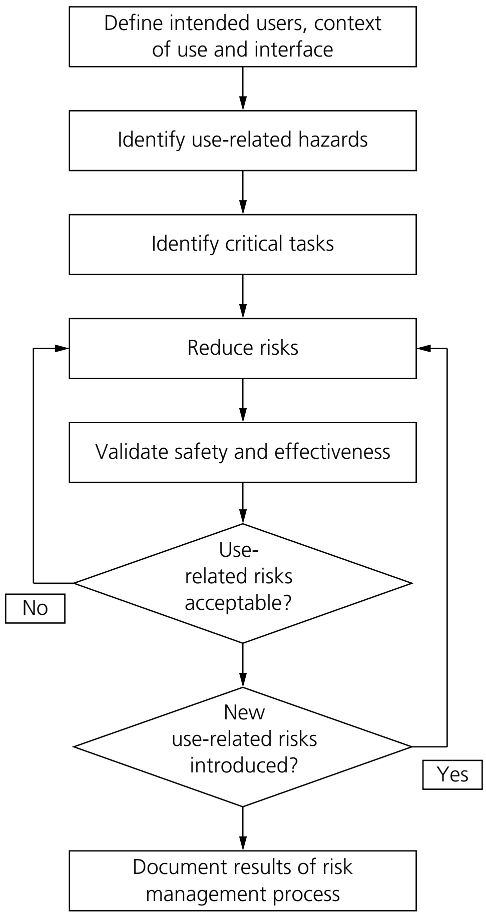

Figure 1: Use-related hazards in risk management
(adapted from FDA, *Applying human factors and usability engineering to medical devices*)

Figure 1 illustrates some of the key aspects of assessing use-related hazards, which are discussed further in this section.

A company contemplating the introduction of new technology will either be involved in the design of the technology or will be buying it from an external supplier. If they are involved in the design process, they will clearly have more influence over the process outlined in Figure 1. However, even if they are not involved, the context of use for the technology they are purchasing should still be considered. Many of the questions set out in this section may equally be asked of a technology vendor.

5.1 HAVE THE POTENTIAL USERS OF THE TECHNOLOGY, AND THEIR CHARACTERISTICS, BEEN IDENTIFIED?

The success of any new technology will depend on it being accepted and usable, which involves the identification of potential users of the technology (e.g. process operators, engineers, instrument technicians), and an analysis of their characteristics.

Depending on the nature of the technology, relevant factors to consider may include:

- physical, cognitive and sensory capabilities;
- experience levels, knowledge, and behaviours;
- variability within the user group (e.g. in terms of abilities and other attributes) which the technology must accommodate, and
- change of some characteristics, such as physical size (see box 3), over time.

Without an understanding of user characteristics there may be a mismatch between the functionality of the technology and the ability of the user to effectively and safely interact with it. For example, one company introduced a new piece of software for writing procedures, but found that their experienced team of mechanical technicians struggled to use it, as they had had limited exposure to this type of technology during their careers. By contrast, the operating team were generally younger, had more experience of working with software, and were more comfortable using it.

Failure to consider these issues might therefore result in:

- a gap between the functionality of the technology and the ability of someone to use it;
- resistance among sections of the user population to adopt the technology;
- increased probability of user errors;
- increased stress within sections of the user population when using a new technology, and
- increased burden of training, mentoring and assessment.

Box 3: Failure to identify user characteristics

An extreme example of the importance of establishing user characteristics was the fatal crash of Air Midwest Flight 481 in 2003 (National Transportation Safety Board [NTSB], Aircraft Accident Report NTSB/AAR-04/01). In addition to a maintenance failure which affected the ability to control the plane, the investigation found that the pilots had significantly underestimated the weight of the passengers and luggage on the plane. The plane was ultimately found to be around 250 kg over its maximum allowable take-off weight. This was a result of the use of old data for adult passengers and baggage. A survey, conducted after the accident, found that the average weight of a passenger and their luggage was around 13 kilograms higher than the figures the pilots were using. Similar issues apply in the process industries, where the average weight of UK offshore workers has increased by almost 19 % since the mid-1980s (Robert Gordon University website). This has implications for critical actions, such as the ability to get out of helicopters in an emergency.

In a human factors integration plan, a framework for ensuring that human factors issues are considered at each stage of a system design (developed originally in a military context), the first stage of the process is the development of a target audience description (TAD). The TAD contains full details of the potential user population, e.g. physical dimensions, skills and abilities.

5.2 HAVE THE ENVIRONMENTS IN WHICH THE TECHNOLOGY WILL BE USED BEEN IDENTIFIED?

Understanding the environments where the technology will be applied is essential for establishing whether it will be usable. For example, if a touch screen tablet computer is being proposed for use on a process plant, then the ability of the user to operate it whilst wearing any specified gloves and in conditions of bright sunlight should be evaluated.

Features of the environment to consider include the following:

– Lighting levels: for example, a display screen may need to be visible under all circumstances e.g. indoors, in enclosed areas, or at night where lighting may be absent, or outdoors where light levels may be excessive due to sunlight.
– Noise levels, which might make it difficult to hear alarms produced by the technology.
– Physical layout of plant and equipment.
– Other activities taking place in the same environment which may create distractions for the user.
– Whether the device will be used whilst moving (e.g. in a car), which may have implications for the ability to use the interface.
– Specific requirements of the operating environment (e.g. intrinsically safe equipment).

These features of the environment should be considered alongside the properties of the technology to determine whether they will undermine it in any way. Considerations should include:

– the size and shape of the device;
– how the technology presents information to the user (e.g. graphical interfaces, alarms);

- actions that the user is required to perform using the technology (e.g. inputting data), and
- procedures that the user may need to refer to when using the technology.

Failure to consider the impact of the environment on the usability of equipment may result in:

- the performance of the product/technology being substandard;
- user confidence in the product/technology being negatively affected;
- reduction in the user's willingness to use the product/technology, and
- changes in how the work is carried out (e.g. promoting workarounds) increasing risk (see box 4).

Box 4: Introduction of bar code medication administration (BCMA) in US hospitals

BCMA is a technology that is being introduced in healthcare settings as a means of reducing medication administration errors. It does this by acting as a double-check that the correct medicine is being given to the right patient, in the correct dose and form, and at the right time. A scanner is linked to a network server, and the user scans their own identification, the medication barcode and the patient’s wristband; an alarm sounds to warn of any deviations. The administration of the medication is recorded by the system. One study examined how well the technology was working in its context of use, and found a range of workarounds being employed by nurses (Carayon et al., 2017).

A particular issue was the use of the BCMA when patients were in contact isolation in a room (i.e. quarantine). In these situations, the nurse is required to cover the scanner with a plastic bag before entering. However, the scanner does not work well under these conditions, and the study found workarounds being employed, such as a nursing assistant scanning herself (to identify as the administrator) and the medication in a corridor, before handing the medication to a colleague for administration, undermining the potential benefits of the tool in linking patients to their prescribed medication. The authors concluded that it is important to consider the context of use when designing and acquiring technology, specifically how the characteristics of the work system can facilitate or hinder its use.

5.3 HAVE USERS OF THE TECHNOLOGY BEEN INVOLVED IN THE DESIGN OR PROCUREMENT PROCESS?

Involving potential users of a technology in the design or acquisition of a new technology has several benefits:

- Helping to understand the capabilities, limitations and attributes of the user population to inform the design process (see 5.1).
- Provision of essential information regarding how the tasks or processes (which are the focus of the new technology) are carried out, as an input to design decisions.
- Insights into the strengths and weaknesses of the technology during the design process.
- Giving feedback regarding design prototypes and participation in evaluation exercises.

Users might be involved in the following:

- Formative evaluations (a process whereby early design solutions are tested by means of simulation or evaluation of prototypes), which should improve the chances of a technology being useful to its intended user group.
- Verification and validation activities (sometimes called summative evaluation), which provide the final assurance that usability issues and foreseeable user errors have either been eliminated or managed to a level which is considered tolerable to the design team.

If the technology is being purchased, then the organisation buying the technology should ask whether end-users have been involved in the design, and consider the possibility of conducting their own validation exercises. If user testing identifies problems (for example the omission of a particular feature as specified by human factors design activities, or the failure of participants in user trials to successfully meet defined performance criteria) then, depending on criticality, the technology might need to be modified. Clearly, this will be less expensive if the issues are identified at an early stage.

Any design/development process which fails to incorporate end-users is likely to:

- Fail to fully understand the demands of the task, resulting in a technology which lacks the appropriate functionality to bring the desired performance improvements.
- Result in the incorporation of features which are incompatible with the needs or expectations of the user population. This could result in a product which is difficult or confusing to use, or which is unsuited to the demands of the task.

Box 5: End-user involvement in IT projects

The underlying reasons for failures of new IT systems are often not technical, but arise from deficiencies in the organisational arrangements which surround the change, including end-user involvement. One study identified several issues related to end-user involvement (Clegg, et al, 1997), specifically:

- A disconnect between designers and users of the new technology. Designers failing to appreciate organisational barriers to the use of a technology.
- A failure to appreciate the impact of the technology on ways of working, e.g. the impact on jobs only being appreciated late in the design process. This problem originates from the change being technology-led, rather than being driven by the needs of the end-user.
- A tendency to solicit end-user input only at the acceptance and testing stage (i.e. when the product has been designed, with limited opportunity for redesign).
- Multiple barriers to end-user participation:
  - time pressures involved in developing a finished product;
  - lack of design methods which actively facilitate end-user involvement;
  - adversarial relationships between designers and end-users, and
  - costs in involving end-users in terms of time away from day-to-day work.

A fundamental finding of the research was the failure of management to understand and address these organisational factors to support end-user involvement.

5.4 HAS THE TECHNOLOGY BEEN DESIGNED WITH REFERENCE TO RELEVANT STANDARDS, GUIDELINES AND OTHER SOURCES OF INFORMATION?

Often there will be existing standards or guidelines which will apply to the technology being designed, and an organisation purchasing a piece of technology should ensure that it meets the requirements of these standards.

The requirements of standards will typically be of two types:

- Process requirements: for example, control room design standards (e.g. ISO 11064) require that some form of task analysis is undertaken as part of the design process.
- Specific requirements: for example, a standard might specify the necessary font size on a display screen, appropriate for the typical distance of the screen from the user. These should be checked against the proposed design.

An important concept is usability, defined as 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use' (ISO 9241). There may be a requirement for heuristic evaluations during the design process – this is an informal evaluation of the human-machine interface to ensure it meets agreed norms (e.g. Nielsen and Molich, 1990). For example, the technology should always keep users informed about what is going on, should use standard terminology, and allow users to tailor frequently performed actions.

If a technology has been in use at other locations, or in other industries, it may be worthwhile to investigate whether there are any known HOF issues associated with the technology. Companies with multiple sites may share incident reports or have forums for sharing information. In some industries, there are central databases which are used to collate information on known problems (see, for example, FDA medical device safety communications website).

5.5 HAVE CRITICAL TASKS RELATED TO THE TECHNOLOGY BEEN IDENTIFIED?

All important tasks that may have the potential to be affected by a new technology should be identified. Without this, it will be difficult to carry out a meaningful risk assessment.

At UK process industry sites governed by the Control of Major Accident Hazard (COMAH) regulations, there is an expectation that sites will identify their principal major accident hazards (MAHs) and related tasks (HSE, *Inspecting human factors at COMAH establishments (operational delivery guide)*). Such a list could be used as a starting point for identifying critical tasks affected by a proposed technology. But it may also be useful to consider other types of outcomes such as, for example, those that are personal safety-related or commercially important.

In some cases, identifying tasks related to a new technology will be straightforward. If, for example, the technology is a new electronic shift log, then it will most directly affect shift handover tasks. In other cases, the technology may have an impact on a large number of tasks.

For significant technological changes (e.g. introduction of new centralised process control systems), where many critical tasks and a significant number of organisational roles are affected, and where there are fundamental implications for the way work is organised, it may be useful to evaluate the introduction of the technology as an **organisational change** (see HSE CHIS7).

5.6 HAVE RISK ASSESSMENTS CONSIDERED HOW THE TECHNOLOGY MIGHT BE USED?

As discussed at the start of this section, the proposed technology might bring with it the possibility of exposure to certain hazards, but the probability of a hazard being realised will often depend on how it is used. Part of this risk will be related to the specific context of use (see, for example, 5.2), but some will also arise from the interface between the technology and the user.

Box 6: The Therac-25 radiation therapy machine

The importance of a risk assessment which considers the interface between a technology and its user is well illustrated by the infamous example of the Therac-25 radiation therapy machine (Leveson, 1995). Between June 1985 and January 1987 six people suffered massive radiation overdoses whilst being treated using the device.

The Therac-25 had two modes of operation, one a high-power X-ray mode, and the other a relatively low power electron beam mode. The ability to switch between modes made the device more versatile and useful, but also introduced the possibility of selecting the incorrect mode. In one of the accidents, the operator inadvertently selected the more powerful mode, but realising the error, quickly engaged the edit function, changing it to the less powerful electron mode. However, these rapid actions had not been anticipated when the device had been programmed: the thick metal plate used in X-ray mode retracted, but left the machine on full power, delivering a dose of radiation that resulted in the death of the patient a few months later.

Any potentially hazardous technology should therefore be subject to a risk assessment that considers how it might be used. Whilst an organisation purchasing such a technology is unlikely to have been involved in its design, they should consider whether the appropriate standards have been followed in the design process. HOF techniques, such as task analysis and failure analysis, which facilitate consideration of the interaction between the user and the technology, should form part of these assessments.

5.7 HAVE RISK ASSESSMENTS CONSIDERED HOW TECHNOLOGY MIGHT CHANGE THE WAY WORK IS PERFORMED?

Where a technology has implications for the way work is carried out in an organisation, the important features of the existing work should be identified and compared with the new ways of working. Without this, the transition from the way work was performed prior to the introduction of the technology will be much harder to manage.

This issue is related to the importance of undertaking a risk assessment of the technology which considers how it may be used (see 5.6), but is more specific to a given organisation. One way of addressing this from a HOF perspective is to identify the key features of tasks that are related to the introduction of the technology, and then consider how they might be affected by the change (a type of gap analysis).

For example, if an organisation is planning to introduce remote control of an offshore platform, they might identify a key element of the existing work arrangements as the need for the operator to maintain their understanding of what is happening (i.e. their situation awareness, see for example, Endsley et al, 2003). They may also establish that this situation awareness is created and maintained by a combination of information from displays, communication with field operators (both face-to-face and via radio), and the confirmation of assumptions using direct plant feedback (e.g. equipment noises, visual checks). The new technology may create opportunities for better information presentation (although care should be taken not to lose existing features which the operators prefer), but could also mean the loss of the ability to discuss issues face-to-face with field operators and the ability to step out of the control room to receive direct feedback from the plant environment. If these losses are identified as important, it may be possible to replicate some elements in the remote location (e.g. face-to-face communication via videoconferencing). Tools such as task analysis are useful for describing the work arrangements before and after the change.

Box 7: The feasibility of shore-controlled shipping

The importance of understanding the differences created by new technology was illustrated by a European Union project examining the feasibility of an autonomous dry bulk ship being monitored, and controlled, by an individual based remotely onshore (Man et al., 2015). Whilst the technology exists for this to happen, in terms of the situation awareness of the person responsible for the ship the project found several important discrepancies between the existing situation (with the ship controlled by a captain and crew) and the proposed automated option (where the primary control is onshore). These included the inability to feel the movement of a ship directly, the requirement to scan the outputs of several instruments as surrogates for the information one would receive visually if on the vessel, and the need to apply previously acquired experience to make sense of the presented information. Participants in the work also indicated that they missed the ability to rapidly verify emerging situations. Alarms, which would have given sufficient time for a response if they had occurred on the ship, were perceived to present too late in the remote setting. Taken together, the onshore control role clearly has very different requirements to the same role performed on the ship. Therefore, if remote control is ever to become a reality, it will not be possible for the control system to be a mimic of the ship's bridge: instead the technology would need to be designed based on the needs of the person(s) monitoring the process onshore.

5.8 HAVE RISK ASSESSMENTS CONSIDERED POSSIBLE ALTERNATIVE USES OF THE TECHNOLOGY?

People are very good at finding uses for technology that the designer may not have anticipated. Once introduced, the users may find that it provides opportunities for saving time, or being more productive, or even for carrying out completely different tasks. Many of these innovations will bring benefits; however, some may introduce unanticipated risks.

Box 8: Failure to consider possible alternative uses of new technology

A company had introduced a new barcode scanning system as a stock control measure. The aim was to provide greater control over the use of drummed raw materials in a chemical process, to ensure that raw materials were replaced as soon as they were running low. However, the scanning system gave rise to an incident where the incorrect chemicals were charged to a process vessel.

The investigation found that the operators had started to use the handheld scanning gun to support the chemical identity checking processes, which had previously been done entirely manually (i.e. the operator had had to visually confirm the chemical identity by checking the drum label). After the introduction of the barcode scanner the operating team had begun to listen for the sound given by the scanner to confirm the chemical's identity (if the scanner scanned an unexpected chemical it would give a different sound), thus undermining the requirement to visually check the chemical identity. This was implicated as a factor in the failure of the chemical identity check on the day of the incident.

A different kind of alternative use is the opportunity for sabotage presented by networked systems. New technologies are often designed for communication with other digital systems. This presents many opportunities (see the discussion on pervasive technology in 2.1), but also introduces the risk of outside agencies taking advantage of this interconnectedness to hack the technology.

In 2010, Iran reported that computers at its Bushehr nuclear power plant had been infected by the Stuxnet worm (*New Scientist*). This type of virus potentially enables an attacker to gain control of process control systems. Therefore, the risks from this type of attack should be considered for any new technology which has an interface with other systems.

6 WILL IT BE ACCEPTED?

Even where the safety/security (or other) risks associated with a new technology have been fully considered and managed, and the potential benefits clearly identified, there remains a possibility that the technology will fail if the workforce do not accept it. In this domain, the workforce has significant power, and even if they do not reject the technology outright, they will have many opportunities to undermine it.

There may be many reasons for a workforce disliking a new technology. For example, even if it is useful, they may see it as a way of reducing staffing levels and as a threat to their job security. It may also be difficult to distinguish between a necessary transition period, to adjust to new ways of working, and serious problems with the design of the technology. This section discusses steps that should be taken to increase the probability of users accepting the technology.

6.1 WERE POTENTIAL USERS INVOLVED IN THE DESIGN (OR SELECTION) AND EVALUATION OF THE TECHNOLOGY?

The importance of involving users in the development process, to reduce the safety risks associated with a new technology, is discussed in 5.3. However, another reason for involving users is to improve the likelihood of the technology being accepted by the wider workforce. This is particularly important where the technology will have significant implications for the way work is performed. It will be difficult for all members of the workforce to have a direct input into the design or selection process, therefore careful consideration should be given to how those individuals who will participate are selected. The following should be considered:

– Users should be fully representative of the full group of potential users (i.e. they should not just be the most capable members of the user population).
– Opportunities should be provided for those who are taking part in the design or selection to provide feedback to their colleagues, and discuss potential issues.
– Users should participate in all stages of the design (or selection process), including following implementation.

Box 9: User involvement in the early stages of development of a new medical device

A medical device company trialled a new approach to user involvement in the development of a blood imaging device (Martin, et al., 2012). The aim was to achieve early validation of the device concept, and understand user needs and preferences before committing further resource to prototype development.

Previous work of this type had used a small number of participants from a single medical department. In this case, a multidisciplinary design team (incorporating engineers, scientists and clinicians) identified a wide base of potential users. A series of interviews were then carried out to understand:

– how clinical procedures relevant to the use of the device were undertaken;
– the kind of problems which were experienced when carrying out procedures using current ways of working, and
– any factors which may affect the safe and effective uptake of a new device.

Prior to conducting this research, the design team believed that the main barriers to the success of the device were likely to be size and weight, and that the main customer-base would be hospitals. However, the interviews found that clinicians were primarily concerned about time pressure associated with the use of the device. It became apparent that, unless the device could provide quick results, it was unlikely to be accepted. Furthermore, the interviews suggested there was limited scope for use in a hospital setting, but opportunities for use in other clinical settings were suggested.

Ultimately, the decision to invest in user involvement challenged preconceived design assumptions, preventing the company from developing a prototype based on an incorrect set of design priorities. This saved the company money and enabled them to bring their product to market more quickly.

6.2 HAVE POTENTIAL BARRIERS TO THE ACCEPTANCE AND ADOPTION OF THE TECHNOLOGY BY THE WORKFORCE BEEN CONSIDERED?

The likelihood of a new technology being accepted by a workforce will depend on both the design of the technology and effective management of change processes. Depending on the nature of the innovation it is possible that there may be fundamental changes in ways of working, staffing levels and/or organisational structures. Considerations include the following:

– Ensuring that both technical and organisational aspects are addressed: organisational aspects are of vital importance (for further guidance see HSE CHIS7).
– Identifying job roles which will be affected by the new technology: some effects will be direct, such as the introduction of pervasive technology resulting in a shift operator spending less time on plant checking readings. Others will be indirect, such as new technology making it easier for operators to take plant samples, resulting in increased workload for laboratory staff. Roles affected by the technology should already have been identified in the risk assessment process (see 5.3).
  – These job roles should be reviewed to establish how they might be changed by the introduction of new technology, and what the consequences of these changes might be. This review should include the perceptions of the end-users

regarding issues such as whether it: makes their job more interesting; reduces opportunities for social interaction; reduces autonomy; increases workload; or changes the way their work is supervised and monitored.

Formally evaluating the potential impact of the new technology on job roles, in the form of a user-centred cost-benefit analysis, should help determine the likelihood of a technology being accepted. Factors to consider might include (adapted from Eason, 1988):

- job content:
  - task variety;
  - effort required;
  - new skills gained/old skills no longer relevant;
  - work pacing;
  - workload, and
  - satisfaction.
- work organisation:
  - discretion/autonomy;
  - power and influence;
  - privacy;
  - communications, and
  - status.
- personnel issues:
  - pay;
  - other rewards;
  - career prospects, and
  - industrial relations.

Potentially, these dimensions could be scored using a simple scale for each job role (e.g. 1-5 for each change considered a benefit, -1 to -5 for each change considered a cost). This will enable a comparison of the impact on different job roles, and give an indication of whether the change is likely to be accepted or rejected. Where the overall scores are positive, there is a good chance the technology will be accepted, and vice versa.

Once the potential barriers to the acceptance of the technology have been identified, steps should be taken to mitigate their consequences to increase the probability of new technology being accepted. If the impact on a job role is overwhelmingly negative, and the technology is certain to be adopted (e.g. because the potential cost savings on throughput are so great), then there is likely to be unavoidable organisational turmoil. However, where the analysis indicates more specific issues, then it may be possible to redesign the work in a way that addresses the users' concerns. For example, if the users are worried about the monotonous nature of a job following the introduction of automation then potentially, if addressed early enough in the design, the allocation of function between users and technology might be modified. If this is not feasible, then job rotation could be explored (e.g. limiting shift time in the monitoring role).

The quality of leadership is a key factor in ensuring that these issues are adequately addressed. This includes leaders (HSE, *Leadership for the major hazard industries*):

- being receptive to bad news and feedback;
- ensuring that safety issues are addressed as part of the change process;

- establishing and maintaining reliable performance measures which show how well the technology is working;
- ensuring that HOF issues are addressed alongside technical issues, and
- being visible to the workforce during the change, and ensuring that they are involved in, and consulted on, the change process.

Box 10: Introduction of a new automatic bus monitoring technology

The real-time bus monitoring system of a large transport company was outdated, unintuitive and contributed to bus scheduling problems (Harper, et al., 1998). Work was carried out to review the existing technology and develop a prototype for improvement.

Industrial relations proved to be a fundamental barrier to the success of the project. The job role of controller (which used the existing bus monitoring system) was seen as important, and those performing it progressed through the company to that position. Consequently, despite recognition that the existing system was flawed, there was a significant degree of scepticism about the new system, rooted in the concern that it would undermine the importance of the controller role.

This problem was overcome by spending time with the controllers to gain trust and acceptance. The argument for change was strengthened by highlighting the link between the shortcomings of current working methods and the workforce frustrations. A new prototype vehicle management system was developed, and controllers were given time to trial and assess the prototype, and to provide feedback. A number of changes were made in response to the feedback.

After implementation, the existing and new vehicle management systems were compared. The new system scored higher both in terms of user evaluation and task performance. Therefore, involving users has the potential to support the development and selection of better technologies, whilst also increasing the probability of their acceptance.

6.3 HAVE COMPETENCE MANAGEMENT ISSUES FOR THE TECHNOLOGY BEEN IDENTIFIED?

For acceptance, it is essential that users of a new technology have sufficient understanding of how it works, and how to use it. This information is likely to be communicated through a combination of procedures and training.

Training and competence management is a topic that is impossible to fully cover in this publication (for a regulatory perspective at MAH sites, see HSE, *Inspection of competence management systems at COMAH establishments*). However, some barriers particularly relevant to the introduction of new technology include:

- Underestimation of training requirements when a new technology is introduced. Businesses may not develop implementation plans which incorporate training requirements, and they may underestimate the support end-users need.
- Incorrect assumptions being made about the existing competence of the users, or that informal mentoring and support within the workforce will be adequate.

- Technology being sold to an organisation on the basis that it simply substitutes for the existing technology, providing a better way of working without requiring much in the way of new skills. Often this turns out not to be the case, with the technology having a transformational impact on the way tasks are performed (Woods, 2015).

Box 11: Introduction of IT in learning environments

In one study, examining the introduction of IT in learning environments, students reported their teachers not being fully confident in the use of the available IT, with the result that teachers did not use it, or did not use it to its full potential (Zandvliet and Straker, 2001). In this example, the user's lack of confidence in the use of the technology, rather than the quality of the technology itself, proved to be a limiting factor in the success of IT as a learning resource.

The training requirements for new technology should, therefore, be properly established. One dimension is to consider how frequently the technology will be used. Often, an organisation's preference is to train more people than necessary in the use of technology as this, in theory, gives more flexibility in the deployment of resources. Consider, for example, a company wishing to train some of its employees in the operation of UAVs for equipment inspection. This is a motor skill which will be best maintained through practice. For such a task, it may therefore be better to limit the training to a smaller number of individuals who will have sufficient opportunities to practise and maintain their competence. Where it is unavoidable that a technology will only be used infrequently, thought should be given to how performance will be supported, which might involve the use of refresher training.

When an individual expects to be a frequent user of technology (e.g. following control room automation), they will have more of an incentive to understand a technology and to practise with it. However, the skills and knowledge they require should be established. Therefore, a formal training needs analysis (TNA) should be completed. There are several different methods that may be used for TNA. For example, task analysis will help with the identification of what needs to be done, how it should be done, and specifying the necessary skills and knowledge (Truelove, 2006).

Note that there may be a difference between understanding the technology in theory, and working with it in the specific environment of use. For example, if an individual is trained in UAV usage at a controlled offsite location, this may be very different from using it on a process plant, where there may be restrictions about where it can be flown. Factors that may affect ease of use, such as a requirement to wear gloves when operating the controls, or environmental factors (e.g. process steam) which make the UAV harder to see, should also be considered.

Procedures are a further consideration. New procedures will usually need to be developed, or existing procedures refined, to support task performance. Often, procedure development is overlooked or left until the last minute, with the main focus on technical aspects. There may also be a failure to identify all procedures that might be affected by the new technology, or an assumption that, if the technology is replacing an older one, no changes are required. These issues can be addressed by the use of task analysis during the risk analysis stage, as this information can easily be used as the basis for new procedures.

6.4 HAS THE IMPLEMENTATION OF THE TECHNOLOGY BEEN PLANNED?

If the new technology is genuinely a substitute for an existing technology, then an implementation plan will be less important. However, as previously discussed, this is often not the case, and so-called disruptive technologies can have a significant impact on the way work is carried out. In these situations, an implementation plan is essential for ensuring that the technology has the best chance of being successfully adopted.

In the short term, failure to plan for implementation could result in, for example, high workload and the risk of loss of control of a process (HSE, CHIS7). In the longer term, a failed implementation could result in the workforce losing confidence in the technology, leading to increased resistance to its introduction.

The approach chosen for the implementation will depend on the characteristics of the technology and the potential risks to normal business. A so-called 'big bang' approach – where the changeover to a new technology happens in one moment – may be appropriate if the service depends on all elements working at once, such as in the case of the switchover to electronic trading on the London Stock Exchange in the 1980s (Eason, 1988). However, more gradual approaches, such as phased introduction, reduction in workload, and/or parallel running of the new and old systems, may be appropriate in other situations. For example, the authors observed the introduction of an electronic prescription system on a hospital ward. To manage this, the patient list for the duration of the implementation period was reduced, and the users had the option of falling back on the existing system in the event of any problems.

6.5 IS THERE A PROCESS FOR EVALUATING THE TECHNOLOGY ONCE IN USE?

When a technology has been introduced, a company should have processes for establishing that it has been accepted and is working as intended. This information should be actively sought by the organisation implementing the technology, by monitoring and measuring the impact of the new technology to ensure that it is working as intended and being used as planned.

One aspect of this is enabling users to provide feedback on issues with the technology. Even if users have been involved in its development, there is likely to be a period after the implementation of the technology where they uncover issues and would like changes to be made.

For example, one organisation introduced a new electronic shift handover system, with the assumption that the processes involved were similar to the old paper-based approach. Even though users had been involved in the design process, the system was perceived by the users to be too comprehensive and time-consuming to complete. This was partly to do with a difference between the designers' intention, which was that information should be added throughout a shift, and user practice, which was to try and complete the log at the end of a shift. This resulted in the use of workarounds such as emailing information to colleagues. These types of issues are more likely to be addressed if there is a post-implementation period where users can discuss their concerns with the individuals responsible for the implementation of the technology.

Box 12: Assessing the impact of multiple technologies on a cardiovascular operating room

A surgical team were assessed interacting with a suite of medical technologies during cardiac surgery (Pennathur et al., 2013). Multiple deficiencies associated with medical technologies were identified which increased the possibility of confusion among the operating team, treatment delays and potential medical errors. In some cases, the usability shortcomings were so extreme that workarounds were being adopted by entire medical teams to circumvent problems during surgery.

For example, several automated medication pumps were being used to deliver medicines during surgery. Each of these pumps incorporated a digital display with scrolling text to show which medication was being delivered. However, the scrolling text quickly became a nuisance to the surgical team who often, when viewing the device to determine medication status, found that the text had scrolled off the screen and had to wait until it next appeared. This was disrupting treatment. The solution was to permanently tape the medication names to the various medication pump screens.

Opportunities for interactions between the users of a technology and those responsible for its implementation (e.g. designers, vendors) are often limited, and not included as part of the implementation plan. In the authors' experience, there was a situation at a process plant where the operating team were unhappy with the design and usability of some recently installed equipment. They did not have an opportunity to discuss these issues with the vendors. Whilst they did not expect that it would have been possible to make changes at that point, they did feel that the information would have been useful for the vendors in future projects with other clients.

ANNEX A
REFERENCES AND BIBLIOGRAPHY

A.1 REFERENCES

British Broadcasting Corporation (BBC) – http://www.bbc.co.uk

BBC website. *Do you want your company to know how fit you are?* Available at: http://www.bbc.co.uk/news/business-33261116. Accessed October 2016

BBC website. *Drone industry delight at new US rules*. Online news article, available at: http://www.bbc.co.uk/news/technology-36584515. Accessed October 2016

Energy Institute (EI) – http://www.energyinst.org

Guidance on human factors safety critical task analysis. Available at: https://www.energyinst.org/technical/human-and-organisational-factors/scta

Food and Drug Administration (FDA) – http://www.fda.gov

Applying human factors and usability engineering to medical devices. U.S. Department of Health and Human Services. Available at: http://www.fda.gov/downloads/MedicalDevices/.../UCM259760.pdf

Medical device safety communications website. Available at: http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/

International Organization for Standardization (ISO) – http://www.iso.org

ISO 11064, *Ergonomic design of control centres. Principles for the design of control centres*

ISO 9241, *Ergonomics of human system interaction*. Available at: http://www.iso.org/iso/home/standards.htm

Health and Safety Executive (HSE) – http://www.hse.gov.uk

CHIS7 *Organisational change and major accident hazards*. Available at: http://www.hse.gov.uk/pubns/chis7.pdf

HSE website. *Horizon scanning and futures*. Available at: http://www.hse.gov.uk/horizons/. Page accessed October 2016

Inspection of competence management systems at COMAH establishments. Available at: http://www.hse.gov.uk/comah/guidance/inspection-competence-management-systems.pdf

Inspecting human factors at COMAH establishments (operational delivery guide). Available at: http://www.hse.gov.uk/comah/guidance/hf-delivery-guide.pdf

Leadership for the major hazard industries. Available at: http://www.hse.gov.uk/pubns/indg277.pdf

National Transportation Safety Board (NTSB) – http://www.ntsb.gov

Aircraft accident report NTSB/AAR-04/01, *Loss of pitch control during takeoff. Air Midwest flight 5481, Raytheon (Beechcraft) 1900D, N233YV, Charlotte, North Carolina, January 8, 2003*. Available at: http://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0401.pdf

Various authors

Anderson, S. and S. O. Johnsen (2006) *How can remote operations become more resilient?* Second Resilience engineering international symposium, Sophia Antipolis (France). Available at : http://www.resilience-engineering-association.org/download/resources/symposium/symposium-2006(2)/Andersen_Johnsen.pdf

Bainbridge, L. (1983) *Ironies of automation*. Automatica, Vol. 19, No. 6

Carayon, P., Wetterneck, T. B., Hundt, A. S., Ozkaynak, M., DeSilvey, J., Ludwig, B., et al. (2007) *Evaluation of nurse interaction with bar code medication administration technology in the work environment*. Journal of patient safety, 3(1):34–42

Clegg, C., Axtell, C., Damodaran, L., Farbey, B., Hull, R., Lloyd-Jones, R., Nicholls, J., Sell, R. and C. Tomlinson (1997) *Information technology: a study of performance and the role of human and organisation factors*. Ergonomics, Vol.40

Control Engineering website, Industrial internet of things (liofT) benefits, examples. Available at: http://www.controleng.com/single-article/industrial-internet-of-things-iiot-benefits-examples/a2fdb5aced1d779991d91ec3066cff40.html. Accessed October 2016

Coye, M. J. and J. Kell (2006) *How hospitals confront new technology*. Health affairs 25, no. 1: 163–173

Eason, K. (1988) *Information technology and organisational change*. Taylor and Francis: London

Embrey, D. E. (2014) *Application of SHERPA to predict and prevent use error in medical devices. 2014 International symposium on human factors and ergonomics in health care: advancing the cause*. Available at: http://hcs.sagepub.com/content/3/1/246.full.pdf

Endsley, M. R., Bolte, B., and D. G. Jones (2003) *Designing for situation awareness: an approach to user centered design*. Taylor and Francis: London

Guardian. *German rail dispatcher 'playing mobile phone game' before train crash*. Newspaper article 12 April 2016

Harper, J. G., Fuller, R., Sweeney, D. and T. Waldmann (1998) *Human factors in technology replacement: a case study in interface design for a public transport monitoring system*. Applied Ergonomics, Vol. 29. No.2

Jordan, P. (2002) *Designing pleasurable products: an introduction to the new human factors*. CRC Press. Available at: http://www.crcnetbase.com/isbn/9780203305683

Katz, C. M, Choate, D. E., Ready, J. R., Nuno, L. and M. Kurtenbach (2014) E*valuating the impact of officer worn body cameras in the Phoenix Police Department*. AZ: Centre for Violence Prevention and Community Safety, Arizona State University

Kirwan, B. and L. K. Ainsworth (1992) *A guide to task analysis*. Taylor and Francis: London.

Leveson, N. (1995) *Safeware: system safety and computers*. Addison Wesley

Living Internet website. *The internet toaster.* Available at:

http://www.livinginternet.com/i/ia_myths_toast.htm. Accessed October 2016

Man, Y., Lundh, M., Porathe, T. and S. MacKinnon (2015) *From desk to field – human factor issues in remote monitoring and controlling of autonomous unmanned vessels*. Procedia Manufacturing 3, 2674–2681

Martin, L. J., Clark, D. J., Morgan, S. P., Crowe, J. A. and E. Murphey (2012) *A user-centred approach to requirements elicitation in medical device development: a case study from an industry perspective*. Applied ergonomics 43

New Scientist website. *Why the Stuxnet worm is like nothing seen before*. Available at: https://www.newscientist.com/article/dn19504-why-the-stuxnet-worm-is-like-nothing-seen-before/. Accessed February 2017

Nielsen, J., and R. Molich (1990) *Heuristic evaluation of user interfaces*. Proceedings of Association for Computing Machinery CHI'90 conference (Seattle, WA, 1–5 April), 249–256

Pennathur, P. R., Thompson, D., Abernathy III, J. H., Martinez, E. A., Pronovost, P. J., Kim, G. R., Bauer, L. C., Lubomski, L. H., Marsteller, J. H. and A. P. Gurses (2013) *Technologies in the wild (TiW): human factors implications for patient safety in the cardiovascular operating room*. Ergonomics, Vol.56, No.2

Reliability Analysis Center, *Failure modes and criticality analysis (FMECA)*. Available at: http://www.handle.dtic.mil/100.2/AD78508

Robert Gordon University website. *Taller, heavier and wider: 3D study charts the size and shape of North Sea offshore workers*. Available at:

http://www.rgu.ac.uk/news/taller-heavier-and-wider-3d-study-charts-the-size-and-shape-of-north-sea-offshore-workers/. Accessed February 2017

Techworld website. *16 UK companies using drones: Royal Mail, Asda, the BBC and more – Here's how drones are being used in 2016*. Available at:

http://www.techworld.com/picture-gallery/personal-tech/6-best-uses-of-drones-in-business-3605145/. Accessed October 2016

Truelove, S. (2006) *Training in practice*. Chartered Institute of Personnel and Development

Woods, D. (2015) *Releasing the adaptive power of human systems*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/417712/Prof_David_Woods__Ohio_State_University.pdf. Accessed September 2016

A.2 BIBLIOGRAPHY

The Engineering Equipment and Materials Users Association (EEMUA) – https://www.eemua.org

EEMUA Publication 201 *Process plant control desks utilising human-computer interfaces: a guide to design, operational and human-computer interface issues*. Available at:

https://www.eemua.org/Products/Publications/Print/EEMUA-Publication-201.aspx

Various authors

Casey, S. (1998) Set phasers on stun. Aegean, Santa Barbara

Zandvliett, D. B. and L. M. Straker (2001) *Physical and psychological aspects of the learning environment in information technology rich classrooms.* Ergonomics, Vol. 44, No9

ANNEX B
ABBREVIATIONS AND ACRONYMS

BBC	British Broadcasting Corporation
BCMA	bar code medication administration
COMAH	Control of Major Accident Hazard
CT	computed tomography
CTA	critical task analysis
EEMUA	(The) Engineering Equipment and Materials Users Association
EI	Energy Institute
FDA	(U.S.) Food and Drug Administration
FMEA	failure modes and effect analysis
FMECA	failure modes effect and criticality analysis
HFA	human failure analysis
HFCTA	human factors critical task analysis
HMI	human-machine interface
HOF	human and organisational factors
HSE	Health and Safety Executive
HTA	hierarchical task analysis
IOT	internet of things
ISO	International Organization for Standardization
IT	information technology
MAH	major accident hazard
NTSB	National Transportation Safety Board
PIF	performance influencing factor
ROI	return-on-investment
SCTA	safety critical task analysis
SHERPA	systematic human error reduction and prevention analysis
TAD	target audience description
TNA	training needs analysis
UAV	unmanned aerial vehicle

ANNEX C
NEW TECHNOLOGY IMPLEMENTATION CHECK-SHEETS

See sections 4, 5 and 6 for detail regarding these questions.

Table C.1: Will the technology be beneficial?

Question	✓	Actions and considerations	Related tools and processes
Have the anticipated benefits been identified?	☐	1. Specify the problem(s) that the technology will address 2. Describe how the technology will address the problem(s) and the expected benefits 3. Summarise any other benefits that are anticipated. Consider: a. cost reduction (e.g. as a result of staff savings); b. improved productivity (e.g. increased throughput); c. improved support (e.g. support for decision making), and d. organisational enhancement (e.g. making new forms of business, or safer ways of working, possible) 4. Identify measures that can be taken to establish the success, or otherwise, of the technology. For example, if a new automated technology is expected to improve productivity, identify indicators of productivity to be measured. Note that these measurements should be taken prior to the introduction of the technology to allow for a before and after comparison 5. Ensure that the focus of the implementation remains the achievement of the anticipated benefits, and not the introduction of the technology	Cost-benefit analysis Management of change
Have the possible costs been considered?	☐	1. Formally specify the anticipated costs associated with the technology (e.g. purchase price, training, lost opportunities, disruption) 2. If the technology will have a significant effect on the way work is organised, consider knock-on effects to the organisation 3. Use the information collected about costs and benefits to support a cost-benefit analysis and a consideration of ROI, before deciding to proceed with the technology 4. If the technology is to be adopted, consider how the identified costs might be mitigated	

Table C.2: Will the technology affect the level of safety/security risk?

Question	✓	Actions and considerations	Related tools and processes
Have the potential users of the technology, and their characteristics, been identified?	☐	1. Undertake a formal analysis of the possible users of the technology and their characteristics. Consider: a. physical, cognitive and sensory capabilities and attributes; b. experience levels; c. relevant existing knowledge and skills, and d. behaviours 2. Where issues are identified, consider possible mitigation measures, including training needs. Consider whether characteristics of users may change over time	User identification TNA
Have the environments in which the technology will be used been identified?	☐	1. Identify the different environments where the technology is likely to be used 2. Identify the properties of these environments (e.g. illumination, noise, physical layout, other tasks, requirement to use technology whilst moving) 3. Identify the properties of the technology (e.g. size and shape of the device, information presentation, actions required of user, procedures to refer to) 4. Consider whether the interaction between the environment, the technology and the user might affect its usability. Where issues are identified, consider whether they could be mitigated	Task analysis
Have users of the technology been involved in the design or procurement process?	☐	1. If the technology is being designed from scratch, ensure that end-users are involved at all stages, from initial design through to validation and testing 2. If the technology is being purchased, establish whether end-user involvement has formed part of the design and evaluation process 3. Consider the possibility of a trial to carry out user testing in the context of use	Formative evaluation Summative evaluation (or human factors validation testing)
Has the technology been designed with reference to relevant standards, guidelines and other sources of information?	☐	1. Identify standards and guidelines relevant to the new technology 2. If designing a new technology, ensure that the technology and the design process meets the requirements of the standards and guidelines 3. If the technology is being purchased, confirm with the vendors that relevant standards have been adhered to in the design and development	Assessment against standards Heuristic evaluation

Table C.2: Will the technology affect the level of safety/security risk? (continued)

Question	✓	Actions and considerations	Related tools and processes
Have critical tasks affected by the introduction of the technology been identified?	☐	1. Develop a list of tasks that will be, or may be, affected by the new technology 2. Consider how the tasks might be affected by the introduction of the technology, and identify potential mitigation measures 3. If the technology has significant implications for the way work is organised, consider assessing it as an organisational change	Critical task identification Management of change
Have risk assessments considered how the technology might be used?	☐	1. If the technology is being purchased, ensure that, during its design, the technology has been subject to a risk assessment which has included a consideration of the risks associated with user interactions with the technology 2. Consider undertaking a task-based risk assessment of the new technology in its context of use	Task analysis Failure modes and effect analysis (FMEA) Critical task analysis (CTA)
Have risk assessments considered how technology might change the way work is performed?	☐	1. Identify key HOF features of the existing ways of working for tasks potentially affected by the new technology. Features to consider might include, but will not be limited to: a. physical environment (noise, illumination, temperature); b. information entry and presentation, human-machine interface (HMI), ergonomics; c. situation awareness, communication, teamwork; d. workload, time-pressure, multitasking, decision-making, and e. acceptance (see Table C.3) 2. Consider how these key features might be affected by the introduction of new technology 3. If the key features are affected negatively, consider whether they can be mitigated	Task analysis
Have risk assessments considered possible alternative uses of the technology?	☐	1. Consider other possible uses for the technology in addition to than those intended by the designer. This may be easier to do once the technology is in place, as part of a review process 2. If the technology is part of an interconnected digital system, consider evaluating the cyber-security risks	Task analysis Failure analysis Cyber-security risk assessment

Table C.3: Will the technology be accepted?

Question	✓	Actions and considerations	Related tools and processes
Were potential users involved in the design (or selection) and evaluation of the technology?	☐	1. Ensure potential users have been identified, and that a representative group has been involved in the design, validation and implementation of the technology 2. To encourage acceptance, provide opportunities for those individuals involved in the design process to give feedback and discuss issues with wider groups of their colleagues 3. Identify metrics for establishing acceptance of the technology following implementation. This might include: a. statistics on usage, on the basis that if it is being used it is likely to be of value; b. measures of performance, and c. user satisfaction ratings	Task analysis
Have potential barriers to acceptance and adoption of the technology been adequately identified and planned?	☐	1. Identify all roles directly and indirectly affected by the new technology 2. Analyse how the roles might be affected by the technology, and how the users perceive the impact (e.g. job satisfaction, social interaction, workload, autonomy, supervision, pay) 3. Consider whether steps can be taken to address user concerns about the impact of the technology upon their roles 4. Ensure that leaders of the change process are: a. receptive to bad news and feedback; b. aware of ensuring that safety issues are addressed as part of the change process; c. establishing and maintaining reliable performance measures which show how well the technology is working; d. conscious that HOF issues should be addressed alongside technical issues, and e. visible throughout the change process	User cost-benefit analysis Allocation of function

Table C.3: Will the technology be accepted? (continued)

Question	✓	Actions and considerations	Related tools and processes
Have competence management issues for the technology been identified?	☐	1. Conduct a TNA: a. Identify actions to be performed and how they should be carried out (e.g. through task analysis) b. Identify knowledge requirements for the technology (to include the consequence of failures, perhaps obtained from a CTA). Consider specific training in the context of use c. Identify skill requirements for the technology d. Consider how knowledge and skills will be communicated to users (e.g. through education and training) e. Determine how the required skills and knowledge will be assessed f. Consider how skills and knowledge will be maintained (particularly if the technology is used infrequently) 2. Ensure that procedures have been updated or developed to support task performance	TNA Task analysis Procedures development
Has the implementation of the technology been planned?	☐	1. Establish whether the new technology is a simple substitute for an existing technology, or whether it will have an impact on the way work is performed. If the latter, then a formal plan should be developed 2. Decide on a strategy for implementation (e.g. 'big bang', parallel running, phased introduction) based on the characteristics of the technology and the potential risks of failure 3. Ensure that training time is sufficient 4. Ensure that back-up plans are in place should there be problems during the implementation to ensure that normal business can continue, as far as possible	Implementation plans
Is there a process for evaluating the technology once in use?	☐	1. Provide scope in the implementation process for users to provide feedback on usability, after the technology has been in use for a period of time, to those individuals responsible for the implementation (e.g. designers, vendors) 2. Set up processes for reviewing the technology once in use, to identify any issues which were unanticipated during the planning and implementation	Human factors validation testing

ANNEX D
RELATED TOOLS AND TECHNIQUES

This section provides brief descriptions of some of the relevant tools and techniques mentioned in Annex C and links to resources with more information.

D.1 COST-BENEFIT ANALYSIS

Cost-benefit analysis is the collective name for any technique that enables the comparison of the pros and cons of alternatives. In the context of this publication, this means comparing the situation prior to the introduction of a new technology and the expected situation afterwards. There will be several different dimensions of interest to the organisation planning the introduction of a novel technology. These might include possible benefits (resource reduction, optimisation of performance), issues related to the operation of the work system (e.g. reliability, security, compatibility with existing processes, vulnerability to disruption), and issues related to the suitability of the technology to the organisation (e.g. flexibility, adaptability, whether the technology is in line with culture and values of the organisation) (Eason, 1988).

D.2 CRITICAL TASK IDENTIFICATION

To evaluate the potential impact of a new technology, it should be understood how it will affect the way tasks are carried out. As a precondition to this, an organisation should understand what its important tasks are. These may be tasks that are critical from a process safety perspective (e.g. those tasks, if performed incorrectly, that have the potential to contribute to the release of MAH) from an environmental perspective, from a personal safety perspective, or may have implications for production. Most organisations in the energy sector will have risk assessment matrixes to enable comparison between these different types of outcomes, but not every organisation will have systematically derived task lists to assist with identifying important tasks that may be affected by the introduction of a new technology (for a discussion of this in the context of the COMAH regulations, see HSE, *Inspecting human factors at COMAH establishments (operational delivery guide)*).

D.3 MANAGEMENT OF CHANGE

Management of change processes are an important part of an organisation's approach to risk management. Where new technology has implications for the way work is performed, its impact on the organisation should be considered. This might involve identifying those roles affected by the technology, identifying how the technology will change these roles and the tasks they perform, and then assessing the risks associated with these changes. This should include a consideration of HOF issues such as workload, competence, and job satisfaction (for more details see HSE, CHIS7).

D.4 TASK ANALYSIS

Task analysis is the collective name for a wide range of analysis techniques which can be used to describe task performance (for further information, see Kirwan and Ainsworth, 1992). One of the most commonly applied techniques is hierarchical task analysis (HTA), which is especially useful for describing tasks that are sequential in nature, such as starting-up a piece of process equipment. Where the new technology has a more significant impact on the mental aspects of a task (e.g. decision-making, problem-solving, and attention focus), a cognitive task analysis may be more appropriate. This type of analysis may be more appropriate for software-based changes.

CTA can be used to help determine allocation of function between user and technology, and can also be used to support TNA.

Management of the introduction of new technology involves having a detailed understanding of how important tasks are carried out. Task analysis provides a framework for describing how tasks are performed prior to the introduction of a new technology, understanding the critical aspects of the tasks from a HOF perspective, and evaluating how they may be affected following the change.

D.5 SAFETY CRITICAL TASK ANALYSIS (SCTA)

This technique, also sometimes referred to a qualitative human reliability analysis (HRA), human factors critical task analysis (HFCTA), or human failure analysis (HFA) is in widespread use at UK MAH sites, as part of their requirement under the COMAH regulations to demonstrate that risks associated with human failures are being managed (HSE, *Inspecting human factors at COMAH establishments (operational delivery guide)*). The approach is based on the systematic human error reduction and prevention analysis (SHERPA) first set out in the 1980s (for a recent description, see Embrey, 2014).

It typically includes at least three elements: task analysis, failure analysis and performance influencing factor (PIF) analysis. The aim is to identify steps within an overall task which, if not performed correctly, have the potential to result in unwanted outcomes. In the context of COMAH, these outcomes are major accidents, but the technique may also be used to identify personal safety or production outcomes. The analysis identifies areas where control measures can be improved to reduce the probability of failures or mitigate their consequences. PIFs which affect the probability of the identified failures occurring (e.g. time pressure, workload, information availability, training) may also be improved. Guidance on these techniques is available in many locations (see EI, *Guidance on human factors safety critical task analysis*).

D.6 FAILURE MODES EFFECT AND CRITICALITY ANALYSIS (FMECA)

This technique has some similarities to the failure analysis used in the context of SCTA (see D.5). As with many such techniques, it was developed initially for military applications, before being applied in a wide range of industrial settings. It is typically qualitative in nature and can be applied to both hardware and functions (more detail can be found in Reliability Analysis Center, *Failure modes and criticality analysis (FMECA)*). In contrast to SCTA, it is usually applied to equipment rather than tasks.

D.7 FORMATIVE EVALUATION

This is an analysis of usability issues with a technology in the early stages of its development. It will only be relevant to an organisation planning the introduction of a new technology if they wish to establish that good practice was followed in the design, or if they themselves are involved in the design process. The aim is consider the design of the interface so that it is optimised with regard to safety and effectiveness (for more details, see FDA, *Applying human factors and usability engineering to medical devices*). There is a wide range of techniques which may be used as part of a formative evaluation, including some of the techniques described in this section (e.g. task analysis, FMECA), and others such as expert review and simulated use testing.

D.8 TRAINING NEEDS ANALYSIS (TNA)

As discussed elsewhere in this publication, providing appropriate training is an important part of supporting the adoption of a new technology. Without it, there is a risk of a technology being underused, rejected by its users, or, in the worst cases, being used incorrectly with the potential for contributing to accidents. There are many available guides to TNA (for example, Truelove, 2006). An important aspect of the analysis is to describe how the task should be performed following the introduction of the new technology; techniques such as task analysis are particularly useful for doing this.

D.9 HUMAN FACTORS VALIDATION TESTING

Sometimes referred to as summative evaluation, this technique is designed to demonstrate that a technology can be used without significant failures in the intended context of use. It requires the involvement of representative users, that all important tasks carried out using the technology are tested under realistic test conditions, and using the final design of the technology (FDA, *Applying human factors and usability engineering to medical devices*). It might involve observations of performance and feedback from the users.

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