Issue 36 / Autumn 2019

RISKworld

The Newsletter of Risktec Solutions

In this issue

Welcome to Issue 36 of RISKworld. Feel free to pass it on to other people in your organisation. We would also be pleased to hear any feedback you may have on this issue or suggestions for future editions.

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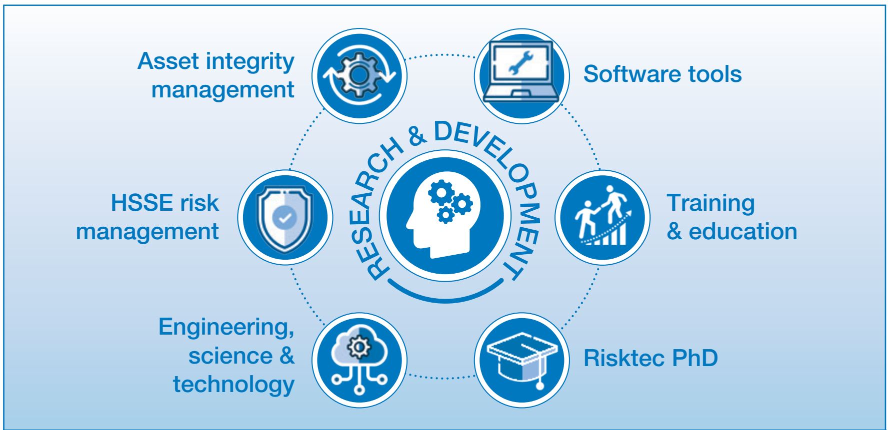
Investing in the future



Risktec's circle of innovation

We are delighted to have maintained very high levels of client satisfaction during the first half of 2019. Our overall client satisfaction score was 97%, with 100% of clients rating our flexibility as very good or good and 100% of clients saying they would recommend us to other organisations. This is a very positive result which underlines our strong client focus and we remain committed to supporting our clients both in the EU and internationally.

To further support our international business we are pleased to announce the opening of a new office in the Kingdom of Saudi Arabia (KSA) later this year. We have been working in the KSA since 2004 and believe that the time is right for us to establish an office in the Kingdom to be closer to our clients. A key aim of the office will be to develop Saudi nationals in line with the In-Kingdom Total Value Add Program. We will be located in the Al Khobar offices of our parent company, TÜV Rheinland.

We have also introduced a new Research and Development (R&D) business line. Whilst R&D is not new at Risktec, as it is a key element of our postgraduate education programmes and an integral part of our innovation culture, we firmly believe that investing more resources in R&D will have long-term benefits both for our business and for our clients. Our current involvement in two major Carbon Capture and Storage (CCS) R&D projects, which are developing cutting edge approaches to managing the associated risks, is a perfect example of this.

In related news, in partnership with the Allianz Manchester Business School, we recently completed a study to look at emerging technological markets most in need of effective risk management solutions. Two of the sectors highlighted by the study – the hydrogen economy and digitalisation – are discussed inside this edition of RISKworld.

We hope you enjoy all the articles, which are intended to highlight our forward thinking approach. As always, we welcome your feedback and look forward to your continued support.

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Launched: Sept 2001
Projects: 7,149
Clients: 1,455
Employees: 295
Offices: 17
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The price of (single point) failure

With two Boeing 737 MAX aircraft crashing in less than six months in seemingly identical circumstances and killing 346 people, there is a real sense that there is something wrong, not only with the aircraft design, but with safety culture at the company.

Preliminary accident data suggest the cause of the Ethiopian Airlines crash in March 2019 (Ref. 1) was essentially identical to the Lion Air crash in October 2018 (Ref. 2) – in both cases an automated control system known as the Manoeuvring Characteristics Augmentation System (MCAS) functioned erroneously, repeatedly forcing the nose down, with confused pilots ultimately unable to control pitch.

GRASSROOTS

The story of these catastrophes appears to be rooted at the very creation of the concept for the 737 MAX (Ref. 3). Challenged by the commercial pressure on market share posed by the latest Airbus A320neo (new engine option), Boeing had neither the time nor the money to develop an all-new aircraft (Ref. 4). Instead, Boeing settled upon a strategy for modification, once again, of their workhorse 737 airframe design – the 737 MAX is the fourth generation of this aircraft, which first flew in 1967.

An overarching requirement was for the incorporation of the very latest jet engines, guaranteeing a dramatic and genuinely competitive improvement in fuel efficiency. A further pillar of the marketing strategy for the 737 MAX would be that no additional training of flight crew should be necessary; demanding in turn that any changes to flight systems be both minimal and operate in the background without any need for pilot intervention.

The incorporation of the new engines into the 737 MAX was not straightforward, on account of their sheer size in comparison to their forebears. The engines had to be mounted higher up and, as a consequence, further forward. This, critically, determined that under certain in-flight conditions the 737 MAX would tend to pitch upwards (Ref. 5).

OUT OF SIGHT

A brand new, additional flight system known as MCAS was therefore incorporated to run in the background, automatically adjusting the aircraft trim to ensure the aircraft handled in the same manner as earlier versions.

Importantly, the MCAS system was designed to be so deeply integral to the control of the aircraft, beyond the influence of the crew, that it was not referred to in the flight manual. Prior to the crash of the Lion Air 737 MAX, pilots of the aircraft were unaware that it even existed.

SINGLE POINT OF FAILURE

A flaw in the configuration of the MCAS appears to be its reliance on data from a single Angle of Attack (AoA) sensor (Ref. 5), even though the aircraft is equipped with two such sensors. These AoA sensors provide a measure of the pitch of the aircraft against which, together with other relevant flight data, the MCAS dynamically determines and implements optimum trim of the aircraft. The MCAS, despite being critical to the safety of the aircraft, was not resilient to a single point of failure.

In both the Lion Air and Ethiopian Airlines 737 MAX disasters, it appears to have been a single failure of an AoA sensor that activated operation of the MCAS, with immediate knock-on effects upon instrumentation read-outs and cockpit alarms. The unfortunate crews faced contradictory indications and false warnings, from their port and starboard instrumentation respectively, including simultaneous warnings of air speed too high and too low (Ref. 5). The ultimate result in both cases was an unrecoverable downward pitch beyond the control of the pilots, leading directly to 346 fatalities.

In the second quarter of 2019, Boeing provisioned $4.9 billion for airlines' compensation. The final price tag is likely to be much, much higher.

CULTURAL FAILINGS?

From a safety engineering perspective, the configuration of the MCAS system is difficult to defend. Whilst born out of a perhaps ill-conceived concept design, it nonetheless survived the detailed design and assessment process, as well as internal and regulatory approval regimes.

In particular, beyond the immediate forensic investigation findings, a

broader malaise has become apparent in respect of the relationship between Boeing and the Federal Aviation Administration (FAA) responsible for the flight certification of its aircraft.

A pivotal accusation against the FAA is that, lacking sufficient resources to discharge its duties directly, it has entrusted Boeing with a significant regime of self-inspection – genuine independent inspection is routinely absent. Instead "Authorised Representatives" (ARs), employees of Boeing, officially designated to act on behalf of the FAA, work to provide the necessary oversight. Notably, the managerial structure that supports the work of ARs has also changed, so that they are now both appointed by, and report to Boeing (instead of the FAA as of old). Quite simply, the ARs now no longer have anyone to safeguard their independence (Ref.6).

LESSONS TO BE LEARNED

In the 1960s Boeing established itself as the leading passenger aircraft manufacturer in the wake of a series of crashes of the de Havilland Comet. Today, one cannot help but wonder if the aviation giant has fallen behind its peers in terms of continuous improvement. Perhaps modern aircraft design practice could benefit from best practice within other highly regulated industries – such as the incorporation of diversity into safety systems, alongside its existing and long-standing commitment to redundancy; and the use of independent technical assessment or peer review as part of a rigorous management of change process.

CONCLUSION

The loss of 346 lives caused by a single failure reveals as much about the safety culture at Boeing as it does about the flawed aircraft design. Moreover, it should give all safety engineering professionals across all industrial sectors pause to reflect on the adequacy of both our individual efforts and the wider cultural environment in which we work. As ever, the need to challenge the status quo and seek continuous improvement never sleeps.

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Hydrogen: The lifeblood of a low-carbon energy future?

At the Paris Climate Conference in 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement sets out an action plan to put the world on track to avoid dangerous climate change by limiting global warming and has been followed by a growing number of carbon net zero commitments around the world. Hydrogen is being widely touted as a key solution to phasing out our reliance on fossil fuels. But what is the so-called 'hydrogen economy', what benefits does it offer and what are the challenges and risks?

HYDROGEN ECONOMY

The term 'hydrogen economy' refers to the vision of using hydrogen as a complete, low-carbon energy source. Using hydrogen as a fuel is attractive because, whether it is burned to produce heat or combined chemically with oxygen in a fuel cell to produce electricity, the only by-product is water. Figure 1 illustrates its potential scale and diversity.

PRODUCTION

Hydrogen isn't found in pure form on Earth, so it must be produced from other compounds such as natural gas or water. It takes energy to convert these into pure hydrogen. As such, hydrogen is really an energy carrier rather than an energy source in its own right.

'Green hydrogen' is generated from zero-carbon energy sources, such as renewables or nuclear. For intermittent generators, such as wind, wave and solar, converting electricity into green hydrogen provides a medium to overcome fluctuations in supply and demand.

'Blue hydrogen' is produced from natural gas via a process known as steam reforming. Its environmental footprint is greater than for green hydrogen as it is generated from a non-sustainable energy source that emits greenhouse gases. However, if

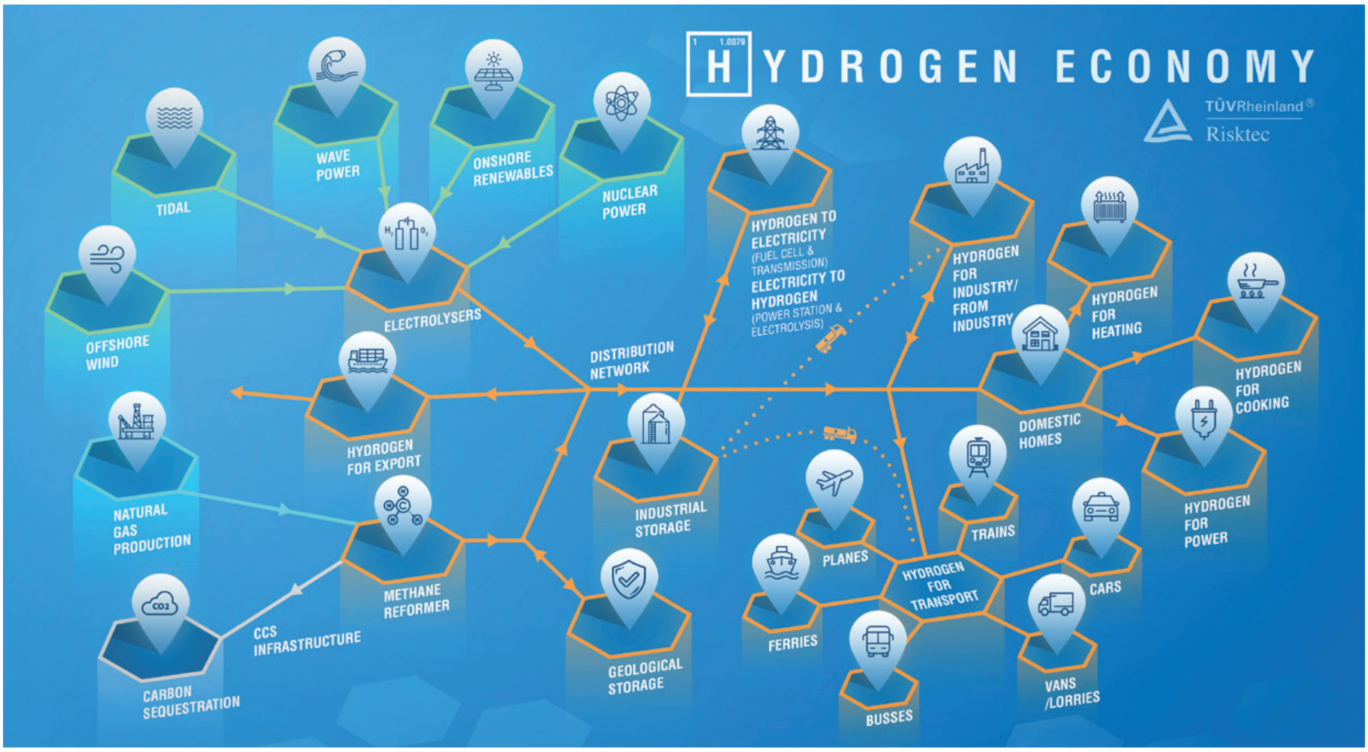

Figure 1 - Potential scale and diversity of a hydrogen energy economy

generated on a large scale, the carbon dioxide produced can be captured and stored by Carbon Capture and Storage (CCS) facilities, buying time for zero-carbon energy technologies to deliver in the longer term.

STORAGE AND DISTRIBUTION

Hydrogen can be stored as a gas, liquid or solid, the last by either reacting the hydrogen with a storage compound or through absorption into a storage material. These options imply varying volumetric efficiency and distribution solutions. For example, gaseous and liquid hydrogen can be stored underground in caverns, salt domes and depleted oil fields, which can serve as responsive large scale energy reservoirs.

Whilst hydrogen can be transported via road, rail or marine vessel, there is also the opportunity to convert existing natural gas distribution grids to supply hydrogen directly to domestic and commercial users.

USES

The most likely beneficiary of a hydrogen economy is transportation. Road transport, rail and even aviation can use hydrogen as a zero-carbon fuel source, with an onboard fuel cell converting the hydrogen into electricity, for instance. Fuel cells are far more efficient than the internal combustion or jet engines they would replace. In contrast to electric vehicles, which have received much attention in recent years, hydrogen vehicles can be rapidly refuelled and have a much greater range.

More generally, fuel cell technology means that hydrogen could be used to generate electricity on a national, district or consumer scale.

Finally, hydrogen has the potential to deliver a domestic heating revolution. Blended with natural gas it can supply heating and cooking appliances with only fairly simple modifications required. Better still, it could replace natural gas altogether, providing a zero-carbon domestic fuel.

HAZARDS AND RISKS

That liquid hydrogen is used as a fuel for space flight is testament to its exceptionally high energy density. In its gaseous form, hydrogen is highly flammable and easily forms an explosive mixture in air across a wide range of concentrations with a very low ignition energy.

Its small molecular size makes it highly buoyant, with a high diffusion rate and low viscosity. The first two characteristics are beneficial in terms of mitigating the risk of explosion. But its small size means that leaks are more prevalent than for natural gas. This is a key consideration in repurposing gas networks to supply hydrogen.

To compound matters, hydrogen is odourless, colourless, and tasteless and burns with an invisible flame making leak detection difficult. It can also cause embrittlement of higher carbon content metallic alloys, so care must be taken when choosing materials.

Storage presents a number of hazards. To ensure volumetric efficiency, gaseous hydrogen must be stored at very high pressures (up to 700 bar), whilst liquid hydrogen needs to be stored at very low, cryogenic temperatures.

However, broadly speaking, all of these hazards are well understood and tried and tested processes, tools and techniques exist to manage the risks effectively. For over forty years hydrogen has been used in vast quantities as an industrial chemical and fuel for space exploration.

The challenges of enabling and supporting a hydrogen economy will more likely relate to the sheer scale and proliferation of development required to make a meaningful impact on climate change. Greater still will be the challenge of overturning negative public perception. Hydrogen is perceived as a very dangerous substance, given its association with the Hindenburg airship disaster and the hydrogen bomb. Whilst the hazards of hydrogen are very real, there is no reason why hydrogen cannot be used safely. Demonstrating this to the general public through clear and effective communication will be as fundamental to the success of a hydrogen economy as the associated technical case for safety.

CONCLUSION

As a versatile, high density energy storage medium, hydrogen has the potential to play a leading role in the fight against climate change and become the lifeblood of a low-carbon energy future. The success of a hydrogen economy hinges on the will and ability to scale-up the infrastructure and facilities required to achieve a meaningful impact; and reverse the public's perception of hydrogen as a dangerous substance.

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2. ISO/TR 15916, Basic consideration for the safety of hydrogen systems.

Dress to impress: Security risk analysis using bowties

The use of bowties as a risk assessment technique is a well-proven method. But whilst commonly used in the assessment of safety risks, is it a suitable tool for the assessment of security risks? Can bowties address the full scale of security threats?

Security threats can appear on vastly different scales, against an almost unlimited list of targets, employ a bewildering array of attack vectors and achieve staggeringly diverse consequences.

Scales can range from global cyber-security attacks on international networks, to regional-level conflicts, to targeted terrorist or criminal activity against organisations and individuals. Consequences can be equally wide-ranging, from widespread fear, terror and paralysis of networks to the theft of an individual's personal data.

VIVE LA DIFFÉRENCE

Putting this into context, the key differences between safety and security risk assessment and management are:

- **Basis of assessment** – safety assessment reviews events on an accidental and random basis, whilst security assessment considers acts to be deliberate and intentional.
- **Terminology** – safety assessment identifies hazards with the potential to cause harm, whereas security risk assessment starts with a threat.
- **Mitigation** – safety measures typically consider mitigation to a predefined (often regulated) level of risk, whilst security measures mitigate risks to meet the organisation's risk appetite, sometimes making it hard to decide when sufficient security mitigations are in place.
- **Understanding the risk** – a safety risk usually acts within a set of identified parameters (e.g. defined operations) and is inherently predictable, at least in principle. A security risk, delivered by a third party with their own agenda, able to choose from one of many options which can change over time, can be much less predictable with much less certain consequences, making the selection of effective barriers far more difficult.

APPRAISING BOWTIE

Clearly, any viable assessment technique must be able to cater for the entire range of security threats and risks, as well as its unpredictable nature. One strong candidate is the bowtie method. The risk management standard IEC 31010 describes a bowtie as:

'A simple, diagrammatic way of describing and analysing the pathways of a risk…and reviewing controls…[T]he focus of a bowtie is on the barriers between the causes and the risk, and the risk and the consequences.'

It is these qualities that make bowties so adaptable and suitable for the assessment of security risks at any scale and with the widest range of consequences.

A good example is aviation security. A national aviation security agency could conduct a security risk assessment using bowtie at the national level, and then pass these risks down to the entity level (e.g. airport or

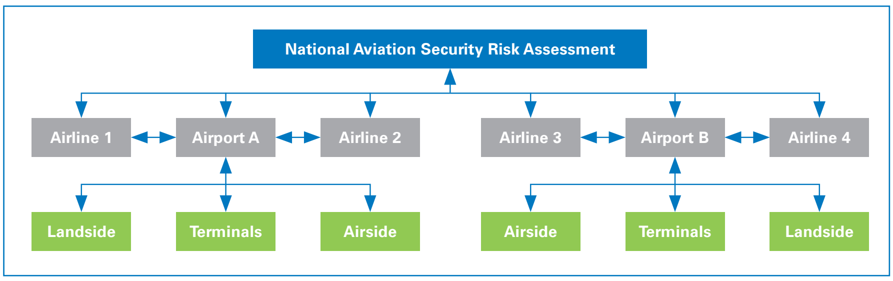

Figure 1 - Aviation security risk assessment flow

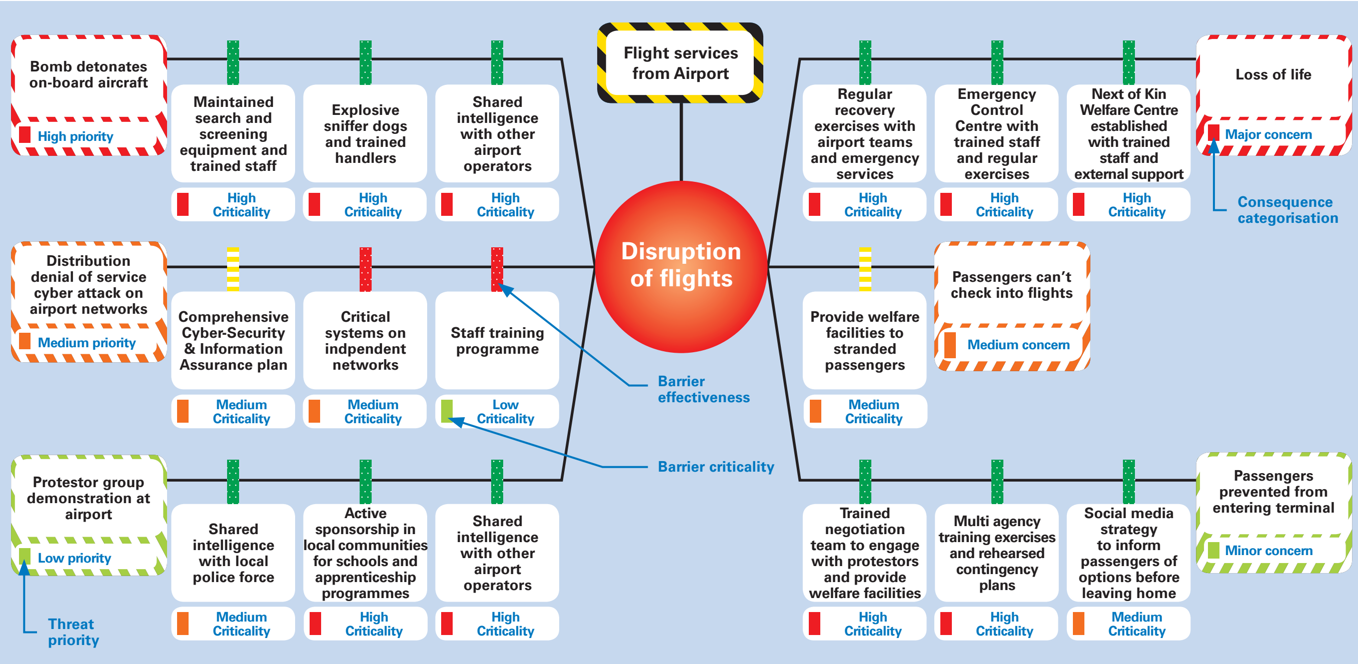

Figure 2 - Aviation security bowtie example

airline) for detailed assessment and mitigation. Each entity can assess its risks at the appropriate level, and pass its mitigations up to the national level. Bowties at each level can link into the level above and below, so that a coherent picture of security is established (see Figure 1).

But what further advantages does the use of bowties bring to the assessment of security risks? Three distinct strengths are:

Strength 1. Bowties focus the attention on controls (barriers) that are supposed to be in place.

A bowtie is very powerful at showing on the same diagram:

- **Threat priorities** – which threats are most important and should be addressed first.
- **Consequence categorisation** – which consequences could deliver the worst outcome.
- **Barrier criticality** – which barriers are the most crucial for mitigating the threats or their consequences.
- **Barrier effectiveness** – which barriers are actually effective and those that are not.

The combinations of these attributes can be used to prioritise the focus of effort or to drive a maintenance programme. An example of an aviation security bowtie for an airport is illustrated in Figure 2.

Strength 2. Bowties do not need a high level of expertise to be understood.

Security impacts all personnel in an organisation and a complicated assessment technique can be unhelpful. A simple technique that can be used and understood by everyone is greatly beneficial and keeps the assessments alive and useful.

The bowtie technique stimulates debate and is particularly well-suited to brainstorming events.

Strength 3. A bowtie gives a clear pictorial representation of the problem.

This is probably the greatest strength of a bowtie as it enables a full assessment of each risk. In the example in Figure 2, a visual review of the airport's security bowtie would indicate that the barriers are effective against both a terrorist bomb onboard an aircraft, which is the highest threat priority, and also against the worst consequence category of loss of life. The barriers against cyber-attack on the other hand are poor and insufficient, meaning that the airport remains vulnerable to the threat and the consequences, whilst the barriers for protestor activity appear to deliver more mitigation than is required.

From such a review, the airport can redirect its resources to deliver balanced and proportionate mitigation against each threat.

CONCLUSION

The assessment and management of security risk poses a unique challenge, given the scope, uncertainty and evolution of the associated threats. Bowtie analysis provides an extremely versatile and informative risk assessment technique that is straightforward to adapt to meet this challenge.

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Digitalisation: The impact on risk management

In Issue 32 of RISKworld we cut through buzzword phrases such as 'The Second Machine Age' and 'Industry Revision 4.0' to explore what 'Digitalisation' is and what it means to high hazard industries. Whilst it's very easy to be seduced by all the exciting engineering and technology that sits behind this innovation, it is crucial that we do not overlook the considerable impact it will have on how we manage risk.

THE LAW

The UK's legislative risk management framework, which has shaped the practices of many major hazard organisations around the world, originated in 1949 through a court judgment (Ref. 1) which enshrined in law the concept of reasonable practicality, and later became the principle of ALARP (As Low as Reasonably Practicable). This has formed the basis of how safety risk has been managed ever since. As a thought experiment, it is interesting to ask how something born out of the mining industry, where workers braved arduous conditions to extract coal manually with basic tools, remains relevant and appropriate within a digitised world featuring robots and autonomous vehicles, all powered by artificial intelligence (see Figure 1)? Similar questions can be asked of other regulatory regimes around the world.

NO DINOSAUR!

Make no mistake, established risk management frameworks are no dinosaurs. They have helped nurture, evolve, challenge and legislate huge advances in technology from nuclear power generation to worldwide passenger flight, to name just two. Yes, they've changed with the times, and need to keep evolving, but the fundamental principles and ethos remain the same. They've been a strong, stable and consistent guiding light in very changing times.

STEP CHANGE?

Perhaps Industry 4.0 will prove to be a series of small incremental steps not dissimilar to the evolution we've seen over the last few decades. It may all prove to be a fuss about nothing. However, there is sufficient informed opinion to suggest that it will create such a significant step change in what society looks like and how it functions that it is only right that we take a step back to consider the suitability of our existing risk management approaches.

THE IMPACT

So, what is the likely impact of digitalisation on how we manage risk?

Firstly, it will allow us to do entirely new things, realising entirely new risks. For example, consider collaborative robots (known as cobots), where humans and robots work together. If the cobot is controlled by Artificial Intelligence (AI) and handling hazardous tools or equipment, how do we assure the safety of its human co-worker?

We must develop a detailed understanding of the associated risks and adapt or develop appropriate techniques to ensure we manage them effectively.

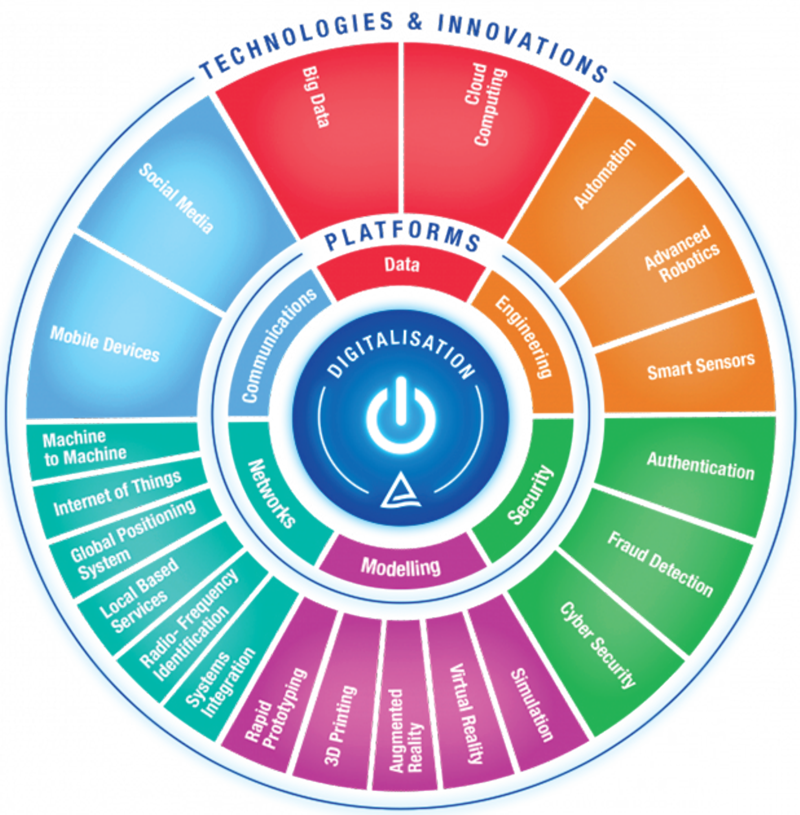

Figure 1 - Digitalisation framework © Risktec Solutions Limited

In the case of AI, which is characterised by the capacity to learn continually and make decisions, how do we identify what can go wrong and how can we prevent serious injury or at the very least minimise the associated risk?

Whilst this and similar challenges should not be underestimated, we have a strong track record of adapting to change over many decades. Perhaps of equal importance is managing society's perceptions of these new risks.

Returning to AI safety, again, how safe does an autonomous vehicle have to be to gain public acceptance? At least as safe as a human driver, ten times safer, or one hundred times safer? Certainly, AI will not eliminate vehicle accidents altogether.

And if a step-wise improvement in safety is achieved across multiple industries, we might well expect regulators to set a more stringent standard on what constitutes tolerable risk across the board (see Figure 2).

Secondly, digitalisation will help us do things better - faster and cheaper. But what about safer? Surely we have a responsibility to channel some of this innovation towards reducing risk rather than just maximising business or commercial gain. For instance, big data analysis can be used to identify trends in equipment health and optimise maintenance for large, complex, highly instrumented facilities. Could it be used in real time to predict failures and suggest preventive actions to operators?

Automated inspection technology could identify defects or degradation at a fraction of current costs, improving both operational availability and safety.

Thirdly, digitalisation will allow us to do things that were previously considered unsafe. Visual Reality (VR) or Augmented Reality (AR) could be used to direct robotic avatars in undertaking inspection or repairs in otherwise hostile environments, such as nuclear reactor cores, oil pipelines or confined spaces. Such solutions, will no doubt bring new risks into play.

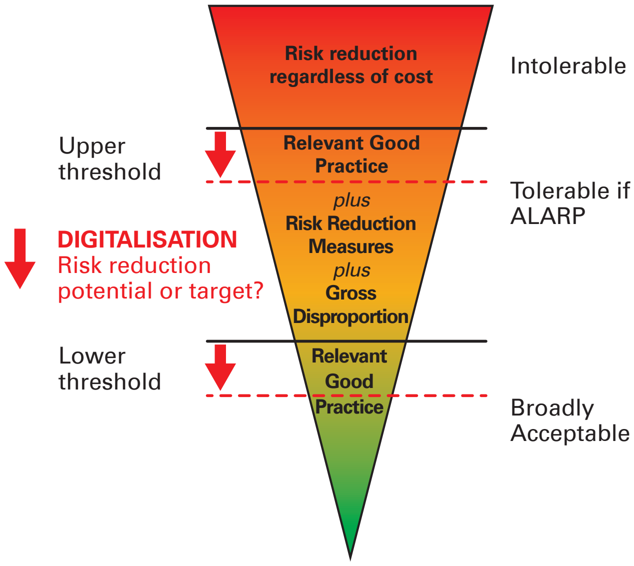

Figure 2 - Tolerabilty of risk framework

Fourthly, digitalisation will change our understanding of known risks. Most likely this will be in the direction of lower risk estimates, as more sophisticated techniques and big data analysis allow excessive conservatisms to be stripped away from simpler, cruder historical approaches. For example, a combination of cutting edge statistical analysis and millions of thermo-hydraulic computer runs might demonstrate that failure of passive heat removal systems for the next generation of nuclear reactors isn't credible.

There is a risk here that the new found risk 'budget' gets snapped-up for commercial gain, e.g. in the last example, this might be the removal of any provision for a second line of defence against core melt. However, as now, these decisions will need to be weighed using the ALARP principle.

Lastly, digitalisation will provide a means to directly reduce risk in its own right, which might become essential if safety goals become more onerous, as postulated earlier. This could involve the widespread use of automation, AI, smart sensors, VR or AR, to name but a few emerging technologies. Fortunately, existing risk management frameworks already demand that new technologies are evaluated when taking all reasonably practicable measures to reduce risks (Ref. 2).

CONCLUSION

Digitalisation will likely transform our lives profoundly, both directly as technology influences our daily lives, and indirectly in contributing to a safer, more secure industrial landscape.

There are clearly exciting times ahead for the safety profession in understanding new hazards and new technological controls as they emerge; and adapting and developing the techniques and tools needed to assess and manage the associated risks. Although the detail may change, the broad principles of our existing risk management frameworks are as relevant today as seventy years ago.

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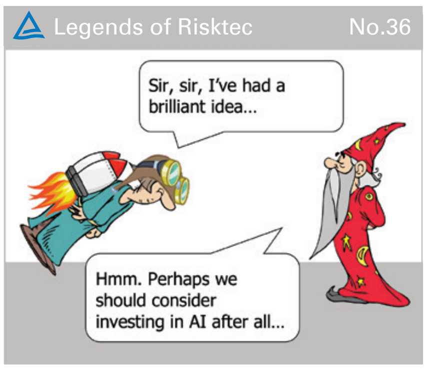

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Environmental risk assessment of major accidents

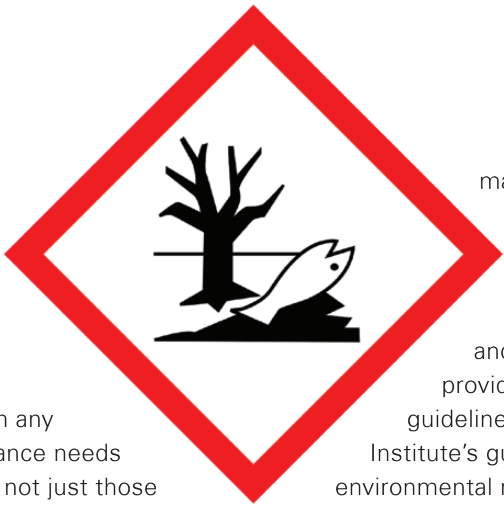
The Sea Empress oil spill, which occurred off the coastline of a national park in Wales in 1996, was the world's twelfth largest marine oil spill at the time. One observer commented; "...you can't insure a habitat, an ecosystem that is so important. It is irreplaceable". Since then much has been done in the UK to protect the environment from major accidents on a par with protecting people. Environmental Risk Assessment (ERA) provides a key tool for helping to manage the risk associated with Major Accidents To The Environment (MATTEs).

The UK's Control of Major Accident Hazards (COMAH) Regulations for onshore industrial facilities, which implement the EU Seveso Directive, apply equal protection to the environment from major accidents as is given to the safety of people. COMAH sites are required to produce a Safety Report that includes assessment of the risks of MATTEs. These are submitted to regulatory bodies, the Environment Agency (EA) working jointly with the Health and Safety Executive (HSE). The risk-based framework for the assessment of major accidents is derived primarily from the experience of the HSE. Arguably the fire at the Buncefield oil storage facility in 2005 was the catalyst for a complete change in the assessment of the risk of MATTEs, with the EA taking a leading role in the investigation and prosecution of several companies for failing to protect the environment.

Industry initiatives were set up including the Chemical and Downstream Oil Industry Forum (CDOIF) working group on the tolerability of risk from environmental major accidents. The CDOIF guidelines (Ref. 1) introduced an environmental risk tolerability framework and assessment process and are today the standard for ERA. By building a better understanding of the low-frequency high-consequence risks to the environment, ERA allows companies to ensure the right measures are put in place, including emergency response plans.

COMAH REGULATIONS

The definition of a major accident under the COMAH regulations is an accident "that leads to serious



danger to people or the environment" and "involves dangerous substances". The risk to the environment from any dangerous substance needs to be assessed – not just those chemicals that are classed as "very toxic" or "toxic to aquatic life with long term effects" (Ref. 2), but also those that could cause harm through a direct physical effect such as fire, or an indirect effect such as oxygen depletion by plant growth arising from increased nutrients in bulk water.

COMAH operators must take all necessary measures to prevent and limit the consequences of MATTEs. ERA is used to define the MATTE risk and then demonstrate that prevention, control and mitigation measures are in place to manage the risk to a level that is As Low As Reasonably Practicable (ALARP).

MATTE SCREENING

The ERA process involves the high level screening of sub-MATTE scenarios to filter out dangerous substances that either will not cause a level of harm equivalent to a MATTE, or where the likelihood of a MATTE is sufficiently low such that the risk of a MATTE is broadly acceptable.

Where the screening does not satisfy these conditions then a detailed risk assessment is undertaken including Source-Pathway-Receptor (S-P-R) analysis.

SOURCE–PATHWAY–RECEPTOR ANALYSIS

Many excellent resources are now available to support S-P-R analysis, including interactive maps such as magic.defra.gov.uk. A list of information sources, both for the UK and EU wide, are provided in the CDOIF guidelines and the Energy Institute's guide to predicting environmental recovery (Ref. 3).

The S-P-R linkages are identified considering the worst case release of each dangerous substance. For screening purposes it is assumed that all mitigating measures, such as bunds, fail to prevent or reduce the release. The source could be a liquid or aerial release of a toxic or eco-toxic substance. Liquid releases to the aquatic environment are the most common, but environmental harm from releases of toxic clouds, fires or explosions also need to be considered.

The pathway is the route by which the substance could travel through the environment to any receptor. Typical pathways include onsite drainage systems, offsite streams or rivers, drift and solid geological features and groundwater.

A receptor is any part of the environment that could be harmed. Fifteen categories of receptor are defined such as protected habitats or groundwater. Threshold levels of harm for receptors include an area or percentage of a population affected. The sensitivity of the environmental receptor is reflected in the thresholds. For instance, a Ramsar site of international importance for wading birds has the lowest thresholds of harm to qualify as a MATTE.

CONSEQUENCES

The consequence level for each receptor is based on a combination of two factors; the severity of harm and the duration of that harm. The severity of a MATTE could be "severe", "major", or "catastrophic" based on an assessment of the harm caused by the release. The duration of harm can be difficult to quantify. Studies of the long-term effects arising from historical accidents are used as evidence. The long-term effect on the population of a particular species may require an ecological assessment to take account of reproduction rates.

AWARENESS AND TRAINING

ERA can be a useful tool for raising awareness as well as training. Operations personnel should be made aware of MATTEs, the potential pathways such as drainage systems, and emergency response measures and onsite resources that can be deployed. Improved awareness of the environmental risks will help not only to protect the environment, but also the company's reputation.

CONCLUSION

Long-term studies of areas affected by environmental disasters show nature's resilience and powers of recovery. However, as the environment comes under more stress through climate change and habitat loss the threat of harm needs to be managed carefully.

ERA provides a tool for managing the risk to the environment from major accidents, on a par with protecting people.

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