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Taylor, R. H., van Wijk, L. G. A., May, J. H. R., & Carhart, N. J. (2015). A study of the precursors leading to 'organisational' accidents in complex industrial settings. Process Safety and Environmental Protection, 93, 50-67. 10.1016/j.psep.2014.06.010

Peer reviewed version

Link to published version (if available):
10.1016/j.psep.2014.06.010

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# A STUDY OF THE PRECURSORS LEADING TO 'ORGANISATIONAL' ACCIDENTS IN COMPLEX INDUSTRIAL SETTINGS

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## Abstract

**This study aggregates the narrative findings from the investigation of 12 accidents or 'near hits' across a wide range of industrial settings to build a catalogue of organisational and cultural precursors to accidents. It was found that many were important factors in multiple events. It is argued that by addressing these potential vulnerabilities using the findings and proposed tools based upon them, organisations undertaking safety related activities will not only develop greater awareness of these deeper-lying issues but should be able to better control the risks associated with them.**

**The precursors have been classified under eight headings and examples of key findings from three of these are presented. Statements providing potential defences against the identified vulnerabilities have been developed which should enable organisations to scrutinise the adequacy of existing expectations or requirements within their business. Probing questions have been developed based on the statements which should allow an assessment to be made as to whether these have been 'embedded' in the organisation.**

**It is argued that organisational vulnerability tools should be developed to enable a systematic approach to 'diagnosing' incubating precursors. It is also argued that there is the potential for**

**further resilience to be achieved through the use of models of the complex dynamics of socio-technical processes within organisations.**

**Keywords**

Organisational vulnerabilities

Organisational resilience

Accident precursors

Systems thinking

Hierarchical process modelling

Socio-technical dynamics models

## 1. Introduction

Significant ‘man-made’ industrial accidents or serious ‘near-hits’ still occur quite regularly despite continuing efforts in all areas of technology to reduce both their scale and frequency. These events usually have both engineering and human performance failures as direct causes, and much work has gone into trying to minimise these. However, research and formal accident reports have confirmed that a systematic and deeper analysis of the complex interaction between engineered defences, organisational processes and the cultural and psychological factors which 'shape' organisational learning must be addressed if organisations are to achieve greater resilience against 'organisational accidents'.

This paper provides an analysis of findings from twelve significant events, from a range of settings, based on a qualitative ethnographic study of the original event investigation reports. This analysis reveals the common learning relating to the underlying organisational and cultural ‘precursors’.

A pilot study by Taylor and Rycraft (2004) and an earlier account of the present study (van Wijk et al., 2008) found that the organisational and cultural precursors to several events in different industrial sectors appeared to be very similar. This was noted by Haddon-Cave QC (2009) in his Report on the Nimrod aircraft crash. The research reported in this paper confirms this by looking in greater detail at a wider range of events, and collating and synthesising the findings into a comprehensive and focussed catalogue of common potential precursors. In general, operational organisations and regulatory bodies attempt to respond to the recommendations arising from each successive event in relative isolation. It is argued that using synthesised findings can provide an improved basis for assessing organisational vulnerability and the development of tools with wider applicability to protect against it. It also has the potential to minimise the additional requirements arising from successive event analyses and the potential overlap and interaction between successive organisational changes. Furthermore, these are not always considered in more conventional auditing processes which tend to concentrate on adherence to existing processes and procedures rather than deeper-lying issues, something recognised in several post event analyses (Baker et al., 2007; Office of Rail Regulation, 2006).

In addition to extracting the generic organisational and cultural issues present in the twelve events, two specific outputs have been developed using this approach:

1.0 **Statements of Expectation** - These interpret the recommendations from the original investigations to extract the qualities of a ‘good’ organisation. They have been developed to encourage pro-active action.

2.0 **Diagnostic Questions -** These are aimed at assessing whether the organisational and cultural issues identified in the statements of expectation are actually 'embedded' in the organisation. They aim to allow a deeper assessment of the incubating 'causes' of organisational failure and (importantly) are laid out explicitly for organisations to use directly.

The body of this paper focuses on three common areas important to all of the studied events. These have been chosen to illustrate the approach used. They are:

- Leadership;
- Oversight and Scrutiny; and
- Organisational Learning.

The following section outlines the theory and method of analysis while Section 3 provides the full list of events studied and the basis for their selection. Section 4 summarises the common issues identified and Section 5 looks at the statements of expectation and diagnostic questions.

This paper concludes with a discussion outlining the direction the modelling might take in order to develop tools which might be used in organisations to utilise more fully the issues revealed in this analysis. The first approach considered, Hierarchical Process Modelling (HPM), shows how the diagnostic questions might be placed within a framework rather like the use of PRA in considering vulnerability to engineering failures thus providing a systematic and disciplined approach to their use. However, it is suggested that the complex process dynamics can also be important, and therefore HPM can be enhanced by approaches based on systems theory.  The second approach considered  is based on a systems methodology, recognising the importance of the interaction between elements in the system and potential emergent properties (Leveson et al., 2003b). It is suggested that the use of such models will allow organisations to obtain a clearer picture of their complex vulnerabilities and hence the ways in which they might develop greater organisational resilience.

An overview of the approach used is shown in Figure 1 which also serves as an outline to this paper. The method and qualitative analysis used to extract the learning from the event reports is described in the following section.

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INSERT FIGURE 1 ABOUT HERE

Figure 1 – Overview of approach used in this study

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## 2. Background and Method

Complementary theories which have arisen in the development of accident models and the nature of the underlying causes and their relation to warning signs have influenced the method of analysis implemented here and discussed throughout this paper. This section provides a brief overview of this.

### 2.1. Development of Accident Models

The analysis reported here draws on important early work in developing the conceptual framework of complex accidents, aimed at obtaining an understanding of the underlying causes of accidents carried out by such authors as Turner, Pidgeon and Blockley (Pidgeon et al., 1991; Turner and Pidgeon, 1997), Reason (1997), and Toft and Reynolds (1994). Over the last sixty years accident models and the associated tools for event investigation can be shown to have developed from simple linear models of cause-and-effect (such as fault trees) to complex models of the whole system (see Saleh et al (2010), Hollnagel (2004) and Qureshi (2007)).

Other accident models, following studies into complex socio-technical systems, have been developed to model failure processes at a richer level of detail. Perrow's normal accident theory (Perrow, 1984) with its concept of coupling and complexity, presented an argument for the need for a greater understanding of the inherent interdependence within the systems being modelled and attempts to exercise control. These 'Systems' models and tools have been developed by Rasmussen (1997), Hollnagel and Goteman (2004), Leveson (2004), Léger et al. (2009) and others.

The analysis of the twelve events, as described in this paper, set out to identify and catalogue the inherent weaknesses and shortfalls which can exist within an organisation's operations and associated defences. In doing this, it draws primarily on the theoretical framework of Reason's Swiss-Cheese Model (SCM). Thus the collected precursor weaknesses and shortfalls could be regarded as 'holes' in the defences or the wider cultural issues which facilitate or allow these holes to develop. The SCM of how accidents occur has been influential within industry, forming the basis (implicitly or explicitly) of many of the accident investigation methods used by organisations and event investigators, despite not being designed specifically for this purpose.

The analysis and development of statements of expectation and diagnostic questions were developed with review by industry and regulatory practitioners, and were based on externally conducted investigations which effectively used an SCM approach, although this was not generally acknowledged by them. Thus, this theoretical framework influences the extraction of the required information. However, the SCM and its theoretical assumptions have limitations (as recognised by Reason) and it is also important to understand these and how they can be addressed.

The selection of an appropriate accident model can influence the conclusions of an investigation (Lundberg et al., 2009), so it is accepted that there may be value in attempting to adopt complementary methods. The SCM is seen, largely by those who advocate systems based approaches (e.g. Hollnagel and Goteman, 2004; Leveson, 2012) as reductionist, linear and focused on specific failures rather than emergent system level behaviours. This focus and sequential modelling can be at the expense of understanding more complex accident aetiology, particular in situations where an accident can be shown to emerge at the system level without any specific ‘failures’ at lower levels. This behaviour can occur due to the structure of the system itself (Marais et al., 2006; Senge, 1990). While Reason has argued that the actual theory underlying SCM better reflects the complexity of reality than the often replicated visual interpretation of the SCM may suggest (Reason et al., 2006), there is still scope for the approaches which have derived from it to be complemented by systems based tools (Underwood and Waterson, 2013a).

The analysis of the twelve events initially sits within the framework of the SCM but the later part of this paper advocates and outlines a method through which the initial conclusions can be complemented by being placed back within more complex systems based models. In this way specific failures can be identified, while the complexity and influence of the system itself can also be modelled and used both in identifying the underlying causality and ensuring the corrective actions are appropriate.

Such modelling could provide additional insights into the complex interactions and compromises taken to meet operational demands as drawn from the rich description of the issues amalgamated from the learning from multiple events. This may assist in achieving the longer term objective of developing a ‘vulnerability tool’ which has both a sound theoretical basis and is straightforward to use in practice. This would also allow for the application of the SCM-influenced analysis of the twelve events to be extended through tools based on the complementary systems-based accident causation models.

## 2.2. Organisational Accidents and Precursors

As well as these conceptual models, knowledge in this areas has been contributed to- and developed through- several investigations into the nature and impact of the 'safety culture' present at large industrial facilities (notable examples include Zohar (1980), Lee and Harrison (2000), Hofmann and Stetzer (1996), Ostrom et al. (1993), Mearns et al. (2003), Reiman and Oedewald (2006), and Sorensen (2002)) and how it can be enhanced (e.g. Mengolini and Debarberis (2007) and Taylor (2010)).

Reason, in particular, has given a simple and compelling presentation of the importance of some of these deeper issues (Reason, 1997). This involves the concept of incubation (see also Turner and Pidgeon, 1997) or 'latent pathogens'. This brought with it a greater appreciation of the importance of organisational and cultural issues leading to what Reason (1997) referred to as 'organisational accidents'.

The term precursor is used here in a general sense to encompass "the conditions, events and sequences that precede and lead up to an accident" (National Academy of Engineering, 2004, p. 6). In this general sense they are similar to the pathogens which are often thought of as creating the conditions for unwanted events. In a review of whether accidents within the chemical industry are foreseeable, Sonnemans and Körvers (2006) note that precursors date back to Heinrich (1931), but that the term has been extended beyond technical precursors to "organizational precursors" (Perrow, 1984; Reason, 1997; citing Turner, 1978)). Indeed a structure within the system through which variables interact to create a failure at the system level, without any elements individually failing or indicating failure (Marais et al., 2006), can also be described as pathogens which exist within the system. The International Atomic Energy Agency (2008) best practice for Organizational Learning states that the identification of precursors is an important aspect of the process, however many authors have identified a failure within process industries to either recognise accident precursors (Cooke and Rohleder, 2006; Rudolph and Repenning, 2002; Woods and Cook, 2002) or to embed the knowledge of them and ensure the right people know which precursors to look out for (Pasman, 2009). The Diagnostic Questions aim to identify latent conditions and behaviours in the organisation and highlight them as common precursors to unwanted events.

### 2.3. Method

This research translates the findings extracted from previous event investigations into useable statements and questions that can be implemented in a practical way by operating organisations and regulatory bodies. In order to do this it adopts an empirical, qualitative, ethnographic method with an acknowledged underlying phenomenological position. Ethnography in the analysis of accidents is common as implemented (1997) and explained (2004) by Vaughan in respect to her analysis of the Challenger disaster. It is applied here in the sense that the analysis of the documentation sets out to understand the cultural and organisational issues involved within the events. Vaughan also highlights an aspect of Grounded Theory (Glaser and Strauss, 1967) that suggests the comparison of similar activities in different settings can lead to the emergence of an explanatory theory. While the method employed here differs from this in detail, it uses the underlying approach of Grounded Theory to perform a qualitative meta-level ethnographic study to synthesise the learning already extracted from separate investigations which exist within often disparate engineering communities.

Kletz (1994) demonstrates the power of accident narratives in understanding deep underlying influences, but it is in comparing these events and the synthesis of the subsequent recommendations that we see the similarities, the common underlying issues and actions. Thus, to arrive at the outputs presented here, a Grounded Theory inspired analysis and comparison of accident reports has been implemented using the lessons and recommendations of existing reports in order to identify those which occur most frequently across a range of industries

The qualitative analysis was initially conducted independently by two of the authors following the practice established by Taylor and Rycraft (2004) . The process began by extracting all references (in the form of direct quotes) from the event reports which related to organisational and cultural issues (rather than specific details of engineering failures) found by the investigations to be contributory to the event in question. While these were not rated in any way in terms of their contribution to the event, they were catalogued so as to retain the context within the wider narrative of the events occurrence.

Once this database had been prepared the authors then collated the extracted issues into higher-level themes through a first-pass labelling of the extracted quotes. This was again conducted by each author independently from one another in order to minimise any inadvertent bias.  The output of the two authors was then compared and collectively analysed through a further iteration leading to the development of eight high-level categories under which all of the labelled issues could be collected. The output was then independently reviewed by regulatory and industry research partners who collectively had significant knowledge of the events studied.

Table 1 (presented in an Annex to this paper) provides by way of illustration, the observed commonality of findings through quotes from the investigation reports relating to the organisational and cultural issues grouped under the theme of Organisational Learning. This demonstrates the relationship between the findings of the individual event reports and the synthesis into a richly described complex issue, as well as the related statement of expectation and diagnostic questions.

## 3. Events Considered

The choice of events studied was made in the light of the following factors: a) availability and quality of published reports, including the extent that organisational and cultural issues were discussed, b) the desire to obtain coverage of a spread of industries and operational contexts, c) the importance of the events to recent thinking in industry and regulatory bodies, and d) occurrence over the last two decades or so.  The final list of events was chosen through engagement and discussion with industry and regulatory experts who were asked identify those which were viewed as particularly significant in terms of their organisational and cultural learning and/or were the subject of particular interest/ concern. Some of the less recent events studied (e.g. HSE 2000a) had led to significant changes to regulation in, for example, the UK. This is not, however, necessarily true of all regulatory regimes and where changes emerged, they tended to relate to specific lessons leading to improvements in 'process' rather than to the broader learning identified here. It is thus judged that the use of these events has continued relevance. An initial selection of ten events was supplemented by a further two in response to industry interest.

Taking these factors into account, twelve events were chosen for detailed scrutiny:

1) **Port of Ramsgate walkway collapse - UK, September 1994** (Health and Safety Executive, 2000a)

2) **Heathrow Express NATM tunnel collapse during construction - UK, October 1994** (Health and Safety Executive, 2000b)

3) **Longford gas plant explosion - Australia, September 1998** (Hopkins, 2000; Royal Commission, 1999; State Coroner Victoria, 2002)

4) **Tokai-mura criticality accident - Japan, September 1999** (International Atomic Energy Agency, 1999; US Nuclear Regulatory Commission and Safeguards, 2000)

5) **Hatfield railway accident - UK, October 2000** (Office of Rail Regulation, 2006)

6) **Davis Besse pressure vessel corrosion event - USA, February 2002** (US Nuclear Regulatory Commission, 2002)

7) **Loss of the Columbia Shuttle - USA, February 2003** (Columbia Accident Investigation Board and Office, 2003)

8) **Paks nuclear plant fuel cleaning event - Hungary, April 2003** (Hungarian Atomic Energy Authority, 2003; International Atomic Energy Agency, 2003)

9) **Texas City oil refinery explosion - USA, March 2005** (Baker et al., 2007; Chemical Safety Hazards Investigation Board, 2007; Mogford, 2005)

**10) Loss of containment at the THORP Sellafield reprocessing incident - UK, April 2005** (Health and Safety Executive, 2005)

**11) Buncefield Fuel Storage Explosion - UK, December 2005** (Buncefield Major Incident Investigation Board, 2008)

**12) Loss of the Nimrod XV230 Aircraft - Afghanistan, September 2006** (Haddon-Cave QC and Office, 2009)

Risk of bias and error in the original investigation reports are acknowledged, but are not thought to be of significant impact to the synthesis of lessons reported here. The reports represent the best available knowledge regarding the events and were chosen, using the above criteria, based on their perceived quality as established by wider industrial and academic review. This selection process also attempts to mitigate the potential for bias being introduced by the authors of this paper in their selection, while the criteria and aggregation of lessons attempts to mitigate any potential bias in individual event report authors.

## 4. Organisational and Cultural Issues Identified

The initial analysis identified 71 organisational and cultural issues across the events. In order to synthesise the event findings and generate tools to improve resilience to organisational accidents, it is necessary to collect the organisational and cultural precursors into broad categories. There are many ways in which this could be done, and indeed a number of approaches were tried in this and earlier associated studies (Taylor and Rycraft, 2004). The exact categorisation is a subjective choice, but one grounded in the themes identified in the initial analysis of the collated issues. It is designed to ensure that the issues are collected on a systematic and comprehensive basis, and other categories may have performed the same function successfully. The eight categories/headings chosen for the present analysis were:

### 1. Leadership

Weak or ineffective leadership has been identified as a fundamental issue in relation to all of the events studied. This is related to organisational culture (see, for example Schein, 2002) and may be strongly influenced by external pressures. Clearly leadership in a conventional sense spans a range of levels in an organisation from the boardroom to the supervisor or team leader. In presenting issues identified under this category it would ultimately be helpful to consider their relevance and impact at various organisational levels and to develop diagnostic questions on this basis. This was done, for example, in a relatively straightforward way and without the benefit of the analysis of events, in the INSAG 15 (2002) report published by the IAEA.

### 2. Operational attitudes and behaviours (operational 'culture')

The events studied provided many examples of issues which can be brought together under this broad heading. Precursors were recognised in areas such as inappropriate (un-useable or poorly explained) procedures, the development of complacent attitudes, 'organisational drift' and a lack of conservative decision making. These issues are strongly connected to weaknesses in leadership because they would not have been able to develop to such an extent that they degraded safety, had leaders been effective in maintaining awareness and taking appropriate action. In many cases, The issues are likely to have developed in an atmosphere where the workforce no longer believed that they had the support of leaders and where mistrust and cynicism had developed over time.

### 3. The impact of the business environment (often commercial and budgetary pressures) and consequent changes

Nearly all of the events studied arose against a background of significant commercial and/or operational pressure. In any organisation there is always a balance to be struck between the pressures of production/delivery and the achievement of acceptable levels of safety performance. Understanding the complex interactions between the precursors and operational pressures is one reason for the need to model these situations. Dangers arise when efficiency is achieved at the expense of safety (as postulated in

Hollnagel, 2009). In the events studied there was rarely a considered decision to accept poor safety performance in order to achieve commercial objectives, but there was frequently a failure to recognise and challenge their potential impact. This can be a difficult area to deal with since such pressures are often taken as necessary and not easily challenged. In some instances, the situation is made more difficult by a failure of the message sender to see the implications of their communication (or lack of it) - see also 8, below..

### 4. Competence and training (at all levels)

When incidents are investigated, failures in competence are often identified leading to recommendations for new or improved training. This, however, is often a surrogate for dealing with some of the deeper and more fundamental issues discussed in this paper. In particular, it is not just the operator or system designer whose competence needs to be addressed, but that of senior managers and leaders who may not adequately understand the risks that they manage and have a responsibility to control. Competence requirements at all levels should thus be systematically addressed, including the need to train people in the cultural, organisation and other people-related issues, as well as those relating to engineering and procedural controls.

### 5. Risk assessment and risk management (at all levels)

This covers a broad range of issues from the ability of the organisation at senior levels to recognise and remain vigilant to the key risks that it faces, through to ensuring that risks are properly assessed through tools such as risk assessments, safety cases and periodic reviews. Engineering risks are an important part of this, but other risks relating to the organisation (and particularly the impact of organisational change) are also very important. When risks have been identified, it is vital that actions to minimise them are adequately resourced and monitored to completion and that effectiveness is the subject of review.

### 6. Oversight and scrutiny (internal - and in some cases from regulators)

Some deficiencies can be put right before a major incident occurs through appropriate oversight systems. Audit and management review through the responsible line management function is one such safeguard, while audit and scrutiny by the broader business function or corporate organisation is another. The line management audit and review processes are likely to be most effective at detecting more detailed shortfalls in procedures and compliance, whilst the higher level processes should give a broader perspective, enabling cultural and organisational issues to be identified with the benefit of greater independence. However, information and data become more ‘rolled up’ in progressing up the organisation and this has the danger of leading to superficiality unless there is a strong questioning approach and a constructive, open relationship between those at the ‘sharp end’ and those whose responsibility it is to inform and provide reassurance to company boards and executive committees.

### 7. Organisational learning

For most of the events studied, other events had occurred previously either within the organisation or in other parts of the industry which provided opportunities to learn and establish defences against the occurrence of similar types of event. These opportunities were frequently not taken for the events studied and reporting of near-hits and other potential learning opportunities was often not encouraged within a supportive culture. In some cases, there appears to be evidence for a narrow response where opportunities for learning are only viewed in the specific context in which they occurred. This may be encouraged by operational pressures and/or feedback processes leaving recipients feeling inundated by requirements to review and take action (initiative overload). Another important factor in failure to learn from earlier events appears to be the inability to retain knowledge in the corporate memory. This is sometimes exacerbated by the loss of staff with the relevant understanding and knowledge.

### 8. Communication (at all levels)

In many of the events there were common areas where communication was seen to fail - in particular, the two-way communication between different levels of the organisation, between distinct functions within the organisation, and between the organisation and contractors. For example, in some situations operational staff and lower level managers may read signals from more senior managers regarding efficiency as a need to take short cuts which impact on safety. This can, of course, be intended, but in many cases it is not. This is a communication issue arising from the business environment, illustrating how the categories are not disjoint.

Several of the events offered specific learning relevant to external regulation and the management of contractors. The latter issue, which is of growing importance given the increase in reliance on contractors, has been subsumed within the eight chosen categories but this is not intended to minimise its importance. The issue of regulatory control, where applicable, is also of particular interest. Many of the issues relevant to operating organisations may also be relevant to regulatory bodies (e.g. shortcomings in leadership or organisational learning). The findings of this study may thus be of interest to regulatory bodies, not only in terms of their oversight of operators/licensees, but also in terms of their own opportunities for organisational and cultural improvements.

## 4.1. Examples of Issues Identified

A large amount of information was extracted, synthesised and developed from the study of the twelve accidents to produce the 'statements of expectation' (Section 5.1) and associated question sets (Section 4.2). The remainder of this paper focuses on the findings and output in three of the categories: Leadership, Oversight and Scrutiny, and Organisational Learning. These reflect important issues in all twelve of the events studied.

### 4.1.1. Leadership

- Insufficient commitment to organisational and cultural process safety issues from ‘the top’ of the organisation. The communication of this as an organisational core value in a compelling and intelligible way is frequently lacking, such that the workforce question the priority attached to this by the organisation.

- A poor understanding of operational ‘reality’ resulting from an absence of leadership visibility and awareness. This can occur though an unquestioning attitude about matters as they really are and allowing or implicitly encouraging the transmission upwards of primarily ‘good news’.

- An insufficient understanding of the importance of the type of issues addressed in the analysis described in this paper and their impact on the risks of organisational accidents in a business context.

- The existence of unclear roles and responsibilities or an overly complex organisational structure, while taking little or no action to mitigate complexity. This complexity can lead to poor communications and the development of organisational ‘silos’ and barriers between them.

- Failure to ensure that the organisation maintains its capability as the ‘controlling mind’ and as an intelligent customer for services that it buys in, often coupled with an insufficient understanding of the responsibilities attached to the role of licensee, duty holder or equivalent.

- Not ensuring there is an effective safety management system (SMS) that is embedded in a strong safety culture which leads to the reporting of deficiencies and an understanding of the basis of the SMS and the need for compliance.

- Insufficient information to monitor and review performance effectively – for example, not regularly reviewing a suitably detailed range of performance indicators for process safety which contain leading as well as lagging parameters.

- Implementing a decision making process which fails to recognise the importance of organisational and cultural issues, their impact on safety and the need to integrate them with decision making relating to other aspects of business performance. The issues are not given sufficient prominence (e.g. when compared to the review of financial and commercial performance). Associated with this is a lack of help and advice in implementation and a poorly understood balance between requirements from leadership at the ‘centre’ and the discretion given to operational units.

- Failure to ensure an approach to communication which transmits key expectations and issues to the workforce in an appropriate and timely manner, and which encourages and facilitates feedback which is then used to drive improvement.

- Missing or insufficient processes and systems which ensure that process safety risks are properly assessed and reviewed, and that the actions to address them have been satisfactorily implemented. A failure to do this in such a way that independent challenge is welcomed within a ‘just’ reporting culture, that learning is encouraged and shared and that there is clarity about priorities backed by adequate resources.

- When commercial and other pressures require organisational changes to be made, this is done with insufficient consideration for the effect on these process safety risks or with inadequate resources to manage them both at the desired end state and during the transition to it.

#### 4.1.2. Oversight and Scrutiny

- A failure to have in place a hierarchical, layered, defence-in-depth system of checks and balances. In some cases there was only a conventional internal audit process which did not encourage independent challenge against a broader perspective of good practice. In some cases this did not look beyond paper systems, did not identify failures to comply with requirements and failed to address deficiencies in the underlying safety culture.

- Oversight processes were sometimes ineffective because they were either poorly resourced or reports and feedback were not given sufficient weight and/or were not the subject of sufficient questioning by responsible managers, safety committees, and boards and/or their advisory groups. This was sometimes reinforced by a ‘good news culture’.

- In some cases, information fed up to senior leaders was aggregated such that weaknesses relating to particular plants or functions could not easily be identified and addressed. Findings were not always acted upon and addressed urgently when necessary, and where ambiguous or incomplete, were not always questioned. This may have been because of a lack of expertise at this level in relation to the issues involved, but also it appeared in some cases, that the needs of the broader business agenda did not ‘align’ with the information on process safety being made available through the oversight processes.

- A failure to identify the early warnings of emerging issues as a result of a disjointed oversight process. It is not sufficient to rely just on performance indicators, even where these are meaningful and provide useful insights to process safety performance. An effective system uses these together with audit findings, event reports, the judgement of independent reviewers, the insights of those directly involved, and a willingness to question safety performance to the same (or greater) depth to which financial and project related programmes are scrutinised.

- Safety Departments (which might be expected to provide independent authoritative advice) were often not sufficiently resourced or competent and/or did not have sufficient awareness and authority to stop potentially unsafe practices.

- In several of the events studied, organisations had once been strong performers with a good reputation, but this had gradually eroded without the organisation being aware of this. This ‘organisational drift’ is often an important precursor to organisational accidents and oversight processes need to be designed to assess whether such organisational drift is occurring.

- Failure to detect weaknesses in organisational and cultural aspects of safety performance also arose from the lack of suitable metrics, particularly a failure to develop and use proactive KPIs for safety. In several cases over-reliance was placed on KPIs relating to personnel/industrial safety. In nearly all cases, suitable KPIs were not available, or contained only lagging indicators.

### 4.1.3. Organisational Learning

- There sometimes did not appear to be an effective system for event reporting, particularly in relation to process safety. Reporting was poor for a variety of reasons, including apparent concerns from staff that their reports would not be part of a ‘just’ response, that bad news would not be welcome at more senior levels, that there was insufficient knowledge to recognise precursors and/or that there was simply a culture of mistrust or complacency which did not encourage open reporting.

- Previous events had not been investigated on a systematic basis. This was reflected in a failure to investigate some events at all and in other cases there was a failure to go beyond immediate causes such as engineering failures, procedural shortcomings or poor training.

- Learning from events was often not shared within the organisation or beyond as part of an effective operational experience feedback programme. A narrow view was taken of the relevance of learning to the wider organisation, often related to the narrow view of causation arising from the underlying accident model (as described in Section 2.1).

- In organisations with a culture of reporting, the volume of 'learning opportunities' appeared on occasions to overwhelm those with responsibility for implementation. Inability to prioritise and to aggregate learning opportunities led to initiative overload. Repeated implementation of recommendations from events taken singly rather than seen holistically can also increase complexity in management systems leading to the potential for staff to seek 'workarounds'.

- Historical events, both internal and external to the organisation, recognised as significant learning opportunities, had often faded in significance within the corporate memory, or improvement actions taken had not been tracked to completion or carried out effectively, with a failure to check effectiveness leading to a view that a problem had been ‘fixed’ when in reality it had not..

- Members of the workforce were sometimes not aware of the risks being run through poor practices or failed equipment. For many of the events studied there appeared to be little evidence that organisations were actively encouraging the workforce (with their understanding of operational reality) to become involved in improvement activities in the area of process safety as individuals or as teams.

- The existence of ‘organisational silos’ also meant that important knowledge which might have minimised the risk of the resulting event was not transferred. There was, for example, a failure to transfer learning between engineering or technical staff and operations staff, or to share learning with (and from) contractors.

## 5. Statements of Expectation and Questions derived from the above findings

The cultural and organisational pathogens and precursors relating to leadership, oversight and scrutiny, and organisational learning identified from the event investigations have been presented in the previous section of the paper as findings. Issues relating to these broad categories were found to have been a factor in nearly all of the events study. The more specific issues which sit beneath these broad categories were also identified as contributing in some way to multiple events despite the range of industries, technologies and contexts.

The next phase of the research carried out was to review the totality of findings under the eight categories and attempt to develop what might be described as ‘Statements of Expectation’ which might be part of business requirements and which, if reflected in operational reality and embedded within the organisation, might provide defences which would minimise the risk of the organisational and cultural issues identified.

The statements were then developed into an initial set of hierarchically structured probing questions. These have been designed to allow operating organisations and regulatory bodies to assess the effectiveness of their defences by:

a) eliciting the extent to which the system or commitment embodied in the expectation is present;

b) assessing the degree to which this is embedded in the organisation; and

c) identifying whether there is evidence of implementation with positive outcomes.

An assessment of an organisation's safety processes using the questions might cover specific areas (where concerns had been already identified) or might attempt to provide an overall picture of the organisation's vulnerability to the types of accidents studied in the paper.

Organisational Learning is currently receiving much attention in industry. Thus, this has been a particular focus for implementation and refinement for the research reported in this paper. Eleven Statements of Expectations for Organisational Learning are presented below along with some of the more detailed Diagnostic Questions as an illustration of the approach.

### 5.1. Statements of Expectation on Organisational Learning

The following eleven Statements of Expectation represent the distillation of the findings relevant to Organisational Learning in a form which might provide a basis for developing or assessing the completeness of organisational requirements or policy:

1 There is evidence that reporting of events and near-hits relevant to process safety is encouraged and is effective. It is part of a 'just' and simple-to-use reporting system.

2 All events are investigated to the extent warranted by their significance. There is a systematic process for achieving this, with clearly assigned terms of reference and responsibilities for those involved in investigations.

3 Investigations, as warranted by event significance, lead to the identification of underlying causes including cultural/organisational issues (even where these have implications for senior management).

4 The findings from investigations into events are prioritised and actions are subject to confirmation that they have been completed and have been effective. The responses also recognise that further procedures /requirements can lead to complication and that a ‘systems’ view’ needs to be taken. It can be demonstrated that this results in fewer 'repeat' events.

5 There is an effective communication process to ensure that learning from internal and relevant external events/near-hits is fully shared across the organisation and that these are the subject of effective follow-up action. They are open-mindedly assessed as a source of potential learning, even when the processes or equipment being used is different to that involved in the reported event.

6 Learning from events and near hits is an important input to training and there is evidence that past learning is retained in the corporate memory.

7 The organisation provides time and resources to encourage teams to review and improve processes and practices in process safety within their work area.

8 There is awareness of the need to retain corporate knowledge and systems are in place to ensure that this is transferred when changes are made to the organisation. Where particular expertise has the potential of being lost, this is identified and appropriate action taken.

9 It is accepted that learning can be obtained from the knowledge of the workforce – particularly from those at the ‘sharp end’ and from specialists. There is evidence that this is actively sought and their participation in improvement activities encouraged.

10 Leaders and others are aware of external events in process safety relevant to the organisation and can show evidence that such learning has been sought and actively used as an input to minimise risk and generate improvement.

11 Active steps are taken to encourage communication on key process safety issues between operational and engineering/specialist staff as well as between company employees and contractors. The existence of organisational ‘silos’ is assessed and minimised.

## 5.2. Diagnostic Questions

The question sets represent the means to assess whether these expectations are 'embedded' in the organisations in practice. The questions sets for each of the eight categories of issues are split into sub-areas. For example Organisational Learning is split into internal reporting, investigation, sharing and utilising findings, knowledge retention, peer review and minimising silos. As an example, some detailed questions relating to the sub-areas of reporting and investigation are outlined below. These would be the subject of assessment and scrutiny through discussion with a relevant operational manager at the plant being reviewed. In practice, the assessor would look for evidence to confirm the responses obtained both from sampling procedures/processes but also, where relevant, by checking that responses align with workforce perceptions and practices.

### 5.2.1.Reporting

- Describe the systematic process used to promote the reporting of events (including near-hits) and other opportunities for improvement (e.g. procedural inadequacies)?
- Demonstrate that this is simple to use and that there is evidence that it is well used (e.g. through staff feedback)?
- What is the evidence that it is used to report process safety issues (including procedural issues) as well as industrial safety related events?
- Is the reporting done on a ‘just’ or ‘no-blame’ basis? What is the evidence for this based on some recent examples?
- How is the use of the reporting system promoted and encouraged by management?

- What process is used to screen reports or learning opportunities in order to assess their significance and required level of follow-up?
- How does the organisation ensure that there are sufficient resources available to ensure that assessment is carried out on a timely, prioritised basis and that backlogs are monitored and minimised?
- Is feedback given to those reporting events so that they feel that their efforts have been recognised?
- Is the reporting approach agreed with the workforce and what evidence is there to support this?
- Is there workforce agreement that the reporting approach is 'just' and what evidence is there to support this conclusion?
- Is the organisation clear that reporting is encouraged at all levels and, in particular, are checks actively made that there are no concerns among staff?
- Is there a parallel system which allows members of the workforce to raise matters of concern on a non-attributable basis in cases where they would prefer to retain anonymity?
- Can you give examples of improvements that have occurred as a result of the use of event reports?
- How many reports on process safety issues have there been in (say) the last two years and how do these break down into actual events, near hits and the proactive recognition of improvement opportunities?

### 5.2.2. Investigation

- How many process related events have been investigated and findings issued in (say) the last two years?
- Which reported events have- and have not- been investigated?
- What are the criteria used for choosing whether an investigation is carried out?

- Are there systematic processes for event investigation with adequate depth, reflecting the significance and learning potential of the event?
- Does each investigation team have clear terms of reference?
- Who nominates and approves the membership of the investigation team into the most significant of events to ensure appropriate independence?
- How is assurance obtained that investigation team members are suitably qualified and experienced (SQEP) to investigate the event and have an understanding of cultural and organisational factors as precursors to events?
- How are findings reviewed for those events with more severe consequences (or with the potential for severe consequences)?
- How are the findings from the most significant events communicated widely?
- Is there evidence that findings go beyond immediate causes and consider organisational and cultural issues?
- Can you describe the process by which recommendations from investigations are followed up?
- How are these recommendations prioritised, and adequate resources made available, for actions to be carried out?
- Is there a systematic process to check that actions have been completed?
- Is there a systematic process to check that the completed actions are effective?
- What conclusions have been drawn from such reviews?
- Do you have in place a system to check whether new events have arisen from inadequate follow-up to earlier events?
- Do you monitor the number of such repeat events and investigate the reasons for the inadequate follow-up?
- Have the reasons for continuing repeat events been investigated?

- Can evidence be provided to show that significant events - and those with learning potential or a significant likelihood for being repeated - are used as part of safety training and as part of team briefing/discussion?

## 6. Modelling

In this section of the paper we review some approaches which with further development, might be used to build the findings from the study into tools which could be used to evaluate, from a systemic perspective, the vulnerability of an organization to events of the type studied and to assess the remediation in such a way as to minimise the incorporation of new vulnerabilities.

The above output from the study of the events has already begun to be used and tested in the context of assessing corporate process safety requirements against the Statements of Expectation (McBride et al., 2011) and in refining the Diagnostic Questions to facilitate their effective use (McBride et al., 2012). Testing and further consideration of the output has led to further research involving the use of the output in developing more sophisticated models. Firstly, by analogy with the disciplined and systematic approaches (such as fault trees and PSAs) now widely used to analyse vulnerabilities to engineering failures, work has begun in developing a framework by which findings relating to organisational and cultural issues might also be addressed in a systematic and structured way. Thus an approach has begun to be developed involving **Hierarchical Process Modelling** (HPM) coupled, where required, with interval probability theory, to allow consideration at different layers of the system and, importantly, offering the potential to model uncertainty. This approach should enable a snapshot to be obtained of vulnerability to organisational accidents.

The catalogue of issues, Statements of Expectation and Diagnostic Questions may give the impression that the underlying pathogenic causes and precursors to events exist in relative isolation from one another and the wider socio-economic and operational pressures at play. Whilst the identified issues provide a valuable process to reveal vulnerabilities and good practices they may also lead to corrective actions which are not beneficial at the whole system level. These are all criticisms which emerge from the application of a SCM based theoretical framework and, as discussed in Section 2, could be suitably complemented by approaches based on systems theory views of accident causation.

A systems approach using **System Dynamic Modelling** has thus begun to be used in the context of the findings as part of a 'systems' approach to examining interdependencies and temporal effects - particularly as remedial actions are developed.

The aim of developing more sophisticated models using this approach is to reflect some of the diversity, interdependence and complexity of accident pathogens and precursors. The consideration of the relationships between the elements of a system (and between the systems and its environment) is an important aspect of the systems approach. The study reported here found that the interactions between the levels of an organisation’s structure were often of particular importance. This is reflected in the question sets, but as has been recognised previously (Leveson, 2004; Leveson et al., 2003b; Waterson, 2009), there is a need for these to be investigated and modelled in more detail. It is unlikely that any viable model or resulting tool for vulnerability assessment will be capable of reproducing the full complexity, time dependence and interactive nature of real life situations. Any such tool may need to be a compromise between completeness and ease of use. However, it is suggested that this approach would, as a minimum, raise awareness of the need for consideration to be given to such issues and in some cases may allow important factors to be identified which would otherwise not have been addressed.

These approaches are not intended to be exhaustive and strong arguments may be made to employ other techniques. For instance, Bayesian Belief Networks provide a well-developed framework for modelling uncertainty. Their foundations are strong, being implementations of pure probability theory. Early applied work in this field studied typical problems in artificial intelligence such as diagnostics, but a later strand of work has focused on formalising engineering judgement. For example, Gran (Gran, 2002) showed how it might be possible to formalise the reasoning present in international safety standards for software quality. These standards look at various techniques deployed within the software development process, and use these to predict software quality. The techniques are viewed as defences against latent software faults, and this is closely analogous to observing organisational factors and predicting vulnerability to accidents. Developments of this work have found ways to model the development processes in more detail, and also to introduce cost factors so that it is possible to optimise the process to achieve quality at lowest cost (Brito and May, 2007, 2006), using genetic algorithms to perform the optimisation over the Bayesian Belief Networks.

### 6.1. Hierarchical Process Modelling (HPM)

HPM describes any activity in terms of hierarchies of 'processes', and provides a means of assessing the quality of those processes in terms of performance indicators. It provides a detailed understanding of a top-process (i.e. the highest level process, which defines the overall purpose of the activity) in terms of its sub-processes. The hierarchy elaborates these factors in increasing levels of detail. This improves transparency by enabling stakeholders to 'walk through the model' and can help develop an understanding of how lower level processes affect the performance of higher level processes.

In HPM, processes are described by process holons which represent an activity in terms of 'getting from where you are to where you want to be' (Blockley and Godfrey, 2000). A high level process is described as an interacting collection of lower level process holons, which can represent both 'hard' and 'soft' processes and is therefore applicable to complex problems involving human performance and organisational issues. The basic technique can, if required, be further elaborated to deal with issues such as uncertainty and the measurement of progress through Performance Indicators but even without these, it constitutes a powerful and systematic tool to assess vulnerabilities.

One of the greatest difficulties of safety performance assessment resides in the treatment of evidence or data which might be uncertain, incomplete, inaccurate or inconsistent (or even simply missing). Several mathematical approaches exist to quantify uncertainty and have been discussed in various sources

(Jeffrey, 1990; Jeffreys, 1998). One such approach is Interval Probability Theory which can be used to handle in a simple way, fuzziness, incompleteness and randomness and has been found to be particularly appropriate for managing uncertainty in an HPM (Cui and Blockley, 1990; Hall et al., 1998).

The ‘state’ of an HPM process holon and its progress towards eventual success are defined in terms of Performance Indicators (PIs). The value of a PI is measured using an interval probability. The values of all of the PIs for a single process can be combined into a single interval probability to reflect the process performance. This interval probability can be represented diagrammatically in the form of an ‘Italian Flag’ where green represents supporting evidence, red represents contradictory evidence and white represents explicit uncertainty (Blockley and Godfrey, 2000). This allows non-experts to ‘get a feel of how well a process is performing' without knowing all the technical and non-technical details.

A fully developed organisational safety assessment is not yet available, but a simple example is provided to demonstrate the key elements of the methodology based on the statements and more detailed question sets relating to ‘reporting’ and ‘investigating’ as presented in Sections 5.2.1and 5.2.2 of this paper. An illustration of the approach is shown in Figure 2 below. In this example, the top level process relates to the effectiveness of organisational learning. In a complete model, this would be one of eight sub-processes feeding into the overall evaluation of the organisation’s capability to minimise the risk of cultural and organisational issues acting as precursors to an organisational accident.

‘Organisational learning’ has been broken into four sub-processes. The first of these covers the ability of the organisation to identify and retain the learning from events. The second deals with the capability to communicate this learning more widely within and beyond the organisation. The third sub-process reflects the ability of the organisation to ‘keep the learning alive’ so that it has continuing usefulness. The final sub-processes at this level in the HPM reflects the need to ensure that actions are taken as a result of the learning, and their effectiveness is monitored.

To simplify the example presented, the first of these sub-processes has been followed deeper into the HPM, drawing on the expectations and questions presented in Section 5.2 of the paper. Thus the need to identify and retain on a systematic basis the learning from events, needs to consider: a) past events from within the organisation and from outside, and b) learning from new events within the organisation as they occur. This second sub-process has thus been further divided into the need to have effective processes for the reporting of events inside the organisation and for their investigation. The bottom level of the HPM uses the statements and questions to obtain evidence on the effectiveness of the internal reporting and investigation processes.

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INSERT FIGURE 2 ABOUT HERE

Figure 2 – An illustration of an HPM based on issues related to some aspects of ‘Organisational Learning’

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In this simple illustration, no attempt has been made to introduce interval probability theory, PIs etc. However, the figure serves to illustrate how the findings from the study could, in principle, be built into a logical hierarchical process in order systematically to assess vulnerability.

### 6.2. System Dynamics

System Dynamics (SD) originates from the work of Forrester (1958) and has been used in a wide range of applications. The first stage of building an SD model is usually the construction of a causal loop diagram. These are directed representations of influence showing terms linked with arrows, labelled to indicate the basis of relationships. Thus a ‘+’ labelling indicates a positive relationship where the value of the ‘child’ variable changes in the same direction as the ‘parent’, whilst a ‘-‘ represents an inverse relationship (i.e. a decrease in the ‘parent’ variable would lead to an increase in the ‘child’). The causal loops can be developed, for example, into SD models of sub-processes in the HPM, or entire events.

SD has been used in the context of accident analysis, for example, as part of the Systems Theoretic Accident Model and Process or STAMP (Leveson, 2004; Leveson et al., 2003a), used to investigate events ranging in the water and aerospace industries, to the outbreak of infection in UK hospitals (Waterson and Chung, 2010). The analysis models hierarchy, emergence, control and feedback rather than a ‘linear’ investigation of root causes. Others have advocated the greater use of SD in the analysis of major accidents (Goh et al., 2010) and specifically in the nuclear industry (Hansen and Golay, 1997), particularly in risk analysis and testing of mitigating actions. It has been used in the analysis of the Chernobyl accident (Salge and Milling, 2006) and in the context of specific issues relating to operational problems and safety case production (Carhart, 2009). By looking at the causal structure and dynamics of events, it has been possible to identify some common cycles of event evolution and these system archetypes (Marais et al., 2006) have begun to be developed in the context of organisational safety.

A particular strength of SD is in drawing out potentially ‘hidden’ consequences of what might first appear as straightforward interventions to improve performance. In SD, causal feedback loops capture the complexity present in some processes, explain why consequences can be subtle or hidden, and demonstrate long term trends. These loops can also model the lags in response to actions. In Figure 3 below, an example is shown relating to one potential issue drawn from the findings, expectations and associated questions sets, again relating to Organisational Learning. The questions can be used as a basis to extract the structure of the relationships used to construct the models, to gauge the strength of influence between factors, or to assess the values of variables within the models. The models can also be used to communicate generic interactions and relationships involved in the common organisational and cultural issues extracted from the events. A simple System Dynamics approach is used to consider the possible consequences of management actions and exhortations to increase the number of events being reported. In some ways it can also be seen to build on Cooke and Rohleder’s models of incident learning (Cooke and Rohleder, 2006) with elements of Senge's archetypes (Senge, 1990). The right hand loop shows that more reporting will lead to more investigations and thus to more corrective actions. Unless carefully controlled, prioritised and resourced, this may lead to a significant increase in the workload and as this increases, the number of visible improvements and completed actions may go down, leading to disillusion, complacency, reduced reporting in future and, in particular, a loss of faith by the workforce in the commitment of managers and leaders to the improvement process and reduced 'buy-in' from those who might report events. This will then run counter to the continued endeavours of managers to encourage the workforce to increase the level of reporting as exemplified by the left hand loop in the figure. Thus the model in Figure 3 ties together many aspects raised by the events and captured by the expectations and questions. It suggests a level of complexity in the processes determining the 'Fraction of Events Reported,' which might be overlooked in a simple management initiative, yet has a clear influence on an organisation's vulnerability.

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INSERT FIGURE 3 ABOUT HERE

Figure 3 – Causal loop diagram illustrating the possible impact of an initiative to improve event reporting

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There are several different ways in which SD models might be used in a vulnerability tool.

1. SD models can be used for prediction and subsequent planning. As explained above, a vulnerability tool based on SD can offer an important facility for testing the potential impact of remedial measures before they are employed. Figure 3 has implications for the prioritization and resourcing of the management initiative it describes.

2. A tool that acts as a repository for archetypes is a powerful vehicle for organisational learning. The twelve events studied in this paper have led to the preliminary identification of a range of such archetypes.

3. A vulnerability tool could offer important functions beyond organisational learning. It would be possible to use SD models in a tool performing direct diagnostic functions. For example, whilst it is unlikely the ‘Fraction of Events Reported’ could be measured directly, it is plausible that other parameters used in the model such as ‘Workforce Buy-in’ and ‘Encouragement from Management...’ could be sampled periodically using simple anonymous questionnaires. These assessments would be fed into a vulnerability tool based on the SD model that computes the likely trajectory of the ‘Fraction of Events Reported’ and identifies whether it is departing from a pre-defined region of acceptability. This approach builds a ‘protection system’ or 'safety envelope' for socio-technical systems that is analogous to existing protection systems that monitor plant such as nuclear reactors. Parameters deemed important to organisational safety would be proactively monitored for drift towards and beyond identified safe boundaries.

The simple example in Figure 3 can readily be extended to include many of the other issues relating to the statements and question sets developed in the context of organisational learning and connections may also be made with issues/findings identified under the other seven categories extracted from the analysis of the ten events. The next stage in this research will aim to construct detailed models of organisational safety using the techniques described in this section, and use them to build consensus amongst relevant stakeholders

## 7. Discussion

This section discusses why the same organisational and cultural issues may exist in different industries, and why they are repeatedly thought to contribute to the emergence of an unwanted event. Potential limitations of the work are also discussed together with its validity and further work to enhance the conclusions and its impact.

### 7.1. Similarities across events and the value of collective analysis

This study helps confirm that the same underlying causes can be identified in multiple events as suggested elsewhere, motivating this study (Haddon-Cave QC and Office, 2009; Taylor and Rycraft, 2004). Combining the findings of multiple events provides an opportunity for further investigation as to why these same underlying causes appear to recur.

In conducting this process and cataloguing the results it became apparent that collectively the twelve accidents revealed information about precursors and the complex interaction of pathogens that are not necessarily present in any of them individually. Each accident offered a slightly different perspective on issues common to all of them, leading to opportunities for a richer conceptualisation of these reoccurring issues. Contemporary and emerging modelling approaches often used to study separate events in relative isolation from one another, may be of value if they are instead applied to the collective learning and evidence along the lines of the synthesis reported here. This is particularly important because the repeated incorporation into management systems of lessons from individual events introduces the risk of over-complication and repetition of remedial actions. Whilst it is clearly necessary to continue to incorporate the learning from new events there are also advantages in a more integrated collective approach in addressing organisational and cultural issues of the type identified in this paper. Articulating the facets underlying issues, common to many organisational accidents, from a synthesis of multiple separate accounts could be likened to a descriptive version of the identification of generic archetypes underlying the emergent system behaviour (Marais et al., 2006; Senge, 1990).

### 7.2. Limitations

Although it is argued that the approach discussed in this paper offers significant value in learning from events and addressing ways in which vulnerability to organisational accidents might be reduced, it also has some potential limitations.

Firstly, the events chosen cover a broad range occurring at different times within different industries; however, it is possible that the generalisations developed from them and presented here are constrained by the choice of events. A different or larger set of events and their investigation reports could, in principle, have the potential to result in a different set of conclusions. Addressing this, and the other acknowledged limitations, is discussed in the subsequent two sections on validation and further work. However for the investigation reports analysed, the authors were surprised by the extent to which individual findings from each event investigation covered the eight areas - suggesting that for each event there was a wide range of organisational and cultural factors at play rather than a predominance of particular findings. The more detailed findings within each generic area illustrated by the three examples given above, whilst their context and detail differed, again reflected similarities - thus enabling patterns or archetypes to be recognised in such a way as to provide a basis for system dynamic modelling. The study of further events will allow this issue to be assessed more fully (see below) and provide the opportunity for a 'living catalogue' of issues to be developed.

Secondly, a further recognised question arising from the research relates to the approach used in categorising the findings into eight generic areas. As discussed above, this choice was made following trials of a number of alternatives but is recognised that other classifications might have been adopted. The use of generic areas offers a number of advantages including the potential for organisations to address areas of particular concern and to facilitate simplification in the development of subsequent models and tools. Other ways of grouping the issues may be possible, but the chosen groupings represent a complete picture of the organisational and cultural issues for the 12 events studied. The specific statements which sit beneath these are arguably of more value, but the generic nature of the classification means that in extracting organisational and cultural precursors from each event investigation, specific findings will often be identified which will 'populate' each of the generic areas. Thus, they function as an effective framework albeit one that may need to be expanded as the set of events expands, as described above.

Thirdly, in each of the 12 events studied in this report, the investigations were predominantly focused on identifying the complex sequencing of failure events. Despite minor differences in practice their theoretical underpinning was predominantly aligned with the SCM.  This focus on failure events could also introduce limitations into the completeness of the issues identified.  It should be acknowledged that an investigation based on a different model of event causality, such as a systems theory based model, may have identified further factors. In particular such an approach could identify issues not specifically linked to failure. . It is for this reason that further research will also use systems based approach as outlined above.

Fourthly, whilst the organisational issues and corresponding statements of expectation are derived from the findings and recommendations of widely accepted inquiries and investigations, this study does not provide evidence that defences to these common failings will improve reliability or safety beyond that presented in the original reports. The opportunity to construct systems models may go some way to assess whether the original recommendations are appropriate.

Lastly, the study only confirms that these same underlying causes were identified by the original investigators. There may be some unacknowledged bias, distinct from the actual reasons why the accident occurred, which resulted in the investigations drawing similar conclusions. Indeed, Haddon-Cave clearly acknowledged the influence of previous investigations and existing organisational accident theories. This may also be a factor of the similarity in the adopted models of accident causation across the event investigations (Lundberg et al., 2009). These limitations can be addressed by further work, as described below.

### 7.3. Validation and Further Work

Validation of the output is of course important. The identified issues are collated directly from previous incidents in which they were recognised to have a causal influence. The positive statements of expectation are interpreted directly from an analysis of these negative issues. These and the diagnostic questions, being formulated to assist in the development of a more resilient organisation, are being trialled and developed in collaboration with industrial partners (McBride et al., 2012, 2011). The expectations and questions have also been used as an input to developing new approaches to underpin the regulation of the UK nuclear industry in the area of 'Leadership and Management of Safety' based on the requirements of the Safety Assessment Principles of the Office for Nuclear Regulation (Health and Safety Executive, 2008).

Further validation of the identified set of issues and diagnostic questions will be achieved through the application of the same method to additional event reports as they become available. This will include actively seeking those events which have been investigated using tools based on the systems model of accident causation, including those from the research literature. This will allow the completeness of the current material to be assessed and further findings and their associated expectations and questions to be added to the catalogue. It is intended that this would thus be a systematic 'living' body of learning material.

The longer term intent of the research is to use this material to construct practical ‘vulnerability tools’ which would allow industry and regulators to assess the extent to which defences are in place either within specific identified areas of concern or against the eight identified areas collectively. This would be analogous to tools used to 'condition monitor' engineered systems and organisational processes currently in place in many organisations with the potential for organisational accidents, but by addressing areas which this research has shown are not currently sufficiently addressed, the approach envisaged should be able to make a further substantial contribution to reducing vulnerability. Furthermore, the tools should enable a much clearer picture to be obtained of the impact of changes by modelling the rarely-considered interactions and time lags involved offering the potential, among other things, for the impact of organisational change to be more effectively visualised and addressed - akin to an organisational 'flight simulator'. The question sets, when refined through further industry trials might be used as input to modelling techniques which should provide the basis for such tools, including Hierarchical Process Modelling and System Dynamics. An example is given of the former approach using a sub-set of questions relating to organisational learning. System Dynamics Modelling may provide a strong basis to assess the way in which interactions, dependencies and the effect of lags might influence outcomes and a simple example is presented to illustrate this, again, in the context of issues relating to organisational learning.

We note that whilst the objective of this paper is to explore the possibility of using findings from events to develop a vulnerability tool, the results may be applicable to the development of a tool aimed at the investigation of events. System Dynamics models have already been used in the context of this type of post-hoc analysis (for example Cooke, 2003; Salge and Milling, 2006), but the objective of combining approaches in both contexts to provide capability for both post-hoc and a priori analysis might be an important longer-term objective.

There has been a great deal of interest from industry in the application and development of the diagnostic question sets. The continued collaboration with practitioners in the advancement of this work and, crucially, its extension into the systems theory based group model building of the issues identified in the study of the 12 events will help close the recognised gap that exists between research and application in systemic accident analysis processes (Underwood and Waterson, 2013b).

The research described here has wider application. First, consideration of these modelling techniques may facilitate improvement in methods of post-hoc event analysis and investigation as mentioned above. For example, it could lead to a checklist to ensure that all root causes have been fully considered since some accident analyses still pay significant attention to 'engineered failures' at the expense of considering the deeper issues which it is argued usually underpin these mechanisms. Second, it should be noted that the approach described here has concentrated on failures in what are broadly referred to in this paper as ‘process industries’. As shorthand, this term has been extended to cover all technologically-based industries with a particular need to defend against organisational accidents. There is some evidence that the common underlying issues identified in this study have identifiable analogues in other major events in which complex, multi-layered processes and defences are present. It would be instructive to consider the role of the issues identified in failures in such areas as delivering major projects to time and cost, in health and social service provision and in the financial sector.

## 8. Conclusions

The study of the published investigation reports into twelve major organisational accidents provides evidence that common organisational and cultural issues exist as precursors across a range of industries and operations.

These common issues can be grouped into eight themes. From the common issues it has been possible to derive corresponding ‘statements of expectation’ which, if put into effect and embedded within operations, have the potential to provide defences against these common cultural and organisational shortfalls.

In order to assess the extent to which such defences are in place, questions have been developed which test whether these expectations are met in practice. Thus a diagnostic tool has been developed, grounded in the lessons common to twelve significant safety failures.

While the issues have been derived from what are essentially sequential models of event causality, the cultural and organisational concepts embedded in them and the statements of expectation are complex. To address this, suitable modelling of the outputs has been investigated in order to best represent and help understand the true complex socio-technical systems which they describe and emerge from. Hierarchical

Process Modelling and System Dynamics modelling have been investigated. The first offers promise of providing a systematic approach to the use of the findings, analogous to those used in assessing vulnerability to engineering failure, whilst the second employs a systems based approach to draw out the interdependencies and time lags involved between the issues. Such a view of the system is considered very important in assessing remedial actions and minimising the introduction of new and unintended vulnerabilities through the change process.

### Acknowledgements

The authors wish to thank Rear-Admiral Paul Thomas and what was then BNFL plc, for initial funding of this work and for his advice and encouragement. Particular thanks are due to Paul Harvey and his colleagues at the UK Office for Nuclear Regulation for major funding to develop further the initial thinking, for allowing a full analysis to be undertaken, and in providing valuable insights and testing of ideas in a regulatory context. We would also like to thank Centrica Plc for their interest and involvement in testing of some of the findings from the research. Finally, we would also like to thank Professor David Blockley of Bristol University for his strategic advice and Helen Rycraft of Magnox Plc and Sarah Peck of the National Nuclear Laboratory (both previously part of BNFL) for their input and contributions at various stages of the project.

## 9. References

Baker, J.A., Bowman, F.L., Ermin, G., Gorton, S., Hendershot, D., Leveson, N., Priest, S., Rosenthal, I., Tebo, P. V, Wiegmann, D.A., Wilson, L.D., 2007. The Report of the BP U.S. Refineries Independent Safety Review Panel.

Blockley, D.I., Godfrey, P., 2000. Doing It Differently. Thomas Telford Books, London.

Brito, M., May, J.H.R., 2006. "Gaining Confidence in the Software Development Process Using Expert Systems " 25th Int. Conf. Comput. Safety, Reliab. Secur. (SAFECOMP 2006).

Brito, M., May, J.H.R., 2007. "Safety Critical Software Process Improvements by Multi-Objective Optimisation Algorithms". 1st Int. Conf. Softw. Process (ICSP 2007).

Buncefield Major Incident Investigation Board, 2008. The Buncefield Incident 11 December 2005 - The final report of the Major Incident Invetigation Board.

Carhart, N.J., 2009. Investigating the potential use of system dynamics as a tool for event analysis in the nuclear industry. IET Conf. Publ. 2009, 3C3–3C3.

Chemical Safety Hazards Investigation Board, 2007. “Investigation Report: Refinery Explosion and Fire.”

Columbia Accident Investigation Board, Office, N.A. and S.A. and the G.P., 2003. “Columbia Accident Investigation Board Report”. Washington D.C.

Cooke, D.L., 2003. A system dynamics analysis of the Westray mine disaster. Syst. Dyn. Rev. 19, 139–166.

Cooke, D.L., Rohleder, T.R., 2006. Learning from incidents: from normal accidents to high reliability. Syst. Dyn. Rev. 22, 213–239.

Cui, W., Blockley, D.I., 1990. Interval probability theory for evidential support. Int. J. Intell. Syst. 5, 183–192.

Forrester, J.W., 1958. Industrial Dynamics. Harv. Bus. Rev. 36, 37–66.

Glaser, B.G., Strauss, A.L., 1967. The discovery of grounded theory: strategies for qualitative research. AldineTransaction.

Goh, Y.M., Brown, H., Spickett, J., 2010. Applying systems thinking concepts in the analysis of major incidents and safety culture. Saf. Sci. 48, 302–309.

Gran, B.A., 2002. Assessment of programmable systems using Bayesian belief nets. Saf. Sci. 40, 797–812.

Haddon-Cave QC, C., Office, T.S., 2009. The Nimrod Review - An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 Aircraft XV230 in Afghanistan in 2006. London.

Hall, J.W., Blockley, D.I., Davis, J.P., 1998. Uncertain inference using interval probability theory. Int. J. Approx. Reason. 19, 247–264.

Hansen, K., Golay, M., 1997. “System Dynamics: An Introduction & Applications to the Nuclear Industry”, in: Advances in Nuclear Science and Technology. pp. 197–221.

Health and Safety Executive, 2000a. “Walkway collapse at Port Ramsgate: A report on the investigation.”

Health and Safety Executive, 2000b. Collapse of NATM tunnels at Heathrow Airport. A report on the investigation by the HSE into the collapse of New Austrian Tunneling Method (NATM) tunnels at the Central Terminal Area of Heathrow Airport on 20/21 October 1994.

Health and Safety Executive, 2005. “Report of the investigation into the leak of dissolver product liquor at the Thermal Oxide Reprocessing Plant (THORP), Sellafield.”

Health and Safety Executive, 2008. “(NII SAPS) Safety Assessment Principles for Nuclear Facilities.”

Heinrich, H.W., 1931. Industrial accident prevention : a scientific approach, McGraw-Hill insurance series. McGraw-Hill, New York.

Hofmann, D.A., Stetzer, A., 1996. A Cross-Level Investigation of Factors Influencing Unsafe Behaviors and Accidents Pers. Psychol. 49, 307–339.

Hollnagel, E., 2004. Barriers and Accident Prevention. Ashgate, Aldershot.

Hollnagel, E., 2009. The ETTO principle: efficiency-thoroughness trade-off : why things that go right sometimes go wrong. Ashgate.

Hollnagel, E., Goteman, O., 2004. “The Functional Resonance Accident Model”. Cogn. Syst. Eng. Process Plant 2004.

Hopkins, A., 2000. Lessons from Longford: The Esso Gas Plant Explosion. CCH Australia Limited.

Hungarian Atomic Energy Authority, 2003. “Report to the Chairman of the Hungarian Atomic Energy Commission on the Authority’s investigation of the incident at Paks Nuclear Power Plant on 10 April 2003” (Idenitifcation number of the event: 1120).

INSAG-15., 2002. International Nuclear Safety Advisory Group (INSAG), “Key Practical Issues in Strengthening Safety Culture.”

International Atomic Energy Agency, 1999. “IAEA report on the preliminary fact finding mission following the accident at the nuclear fuel processing facility in Tokaimura, Japan, 26 November 1999”. Vienna, Austria.

International Atomic Energy Agency, 2003. "Report of the Expert Mission conducted under the IAEA Technical Co-operartion Project HUN/9/022 Support for Nuclear Safety Review Mission. ’To Assess the Results of the Hungarian Atomic Energy Authorities Investigation of the 10 April 2003 Fuel Cleaning .

International Atomic Energy Agency, IAEA, 2008. Best Practices in the Organization, Management and Conduct of an Effective Investigation of Events at Nuclear Power Plants. IAEA, Vienna.

Jeffrey, R.C., 1990. The Logic of Decision. University of Chicago Press.

Jeffreys, H., 1998. Theory of Probability. Oxford University Press: Clarendon Press.

Kletz, T., 1994. Learning From Accidents, 2nd Editio. ed. Butterworth-Heinemann, Oxford.

Lee, T., Harrison, K., 2000. Assessing safety culture in nuclear power stations. Saf. Sci. 34, 61–97.

Léger, A., Weber, P., Levrat, E., Duval, C., Farret, R., Iung, B., 2009. Methodological developments for probabilistic risk analyses of socio-technical systems. Proc. Inst. Mech. Eng. Part O J. Risk Reliab. 223, 313–332.

Leveson, N., 2004. A new accident model for engineering safer systems. Saf. Sci. 42, 237–270.

Leveson, N., Daouk, M., Dulac, N., Marais, K., 2003a. “A Systems Theoretic Approach to Safety Engineering.”

Leveson, N., Daouk, M., Dulac, N., Marais, K.B., 2003b. “Applying STAMP in accident analysis.”

Leveson, N.G., 2012. Engineering a Safer World: Systems Thinking Applied to Safety. Mit Press.

Lundberg, J., Rollenhagen, C., Hollnagel, E., 2009. What-You-Look-For-Is-What-You-Find - The consequences of underlying accident models in eight accident investigation manuals. Saf. Sci. 47, 1297–1311.

Marais, K., Saleh, J.H., Leveson, N.G., 2006. Archetypes for organizational safety. Saf. Sci. 44, 565–582.

McBride, M., Taylor, R.H., Marsh, C., 2011. Organisational and cultural causes of accidents - A Pilot Study, in: Hazards XXII - Process Safety and Environmental Protection. IChemE, Liverpool, UK.

McBride, M., Taylor, R.H., Sibbick, G., 2012. Organisational and Cultural Causes of Accidents - a Pilot Study, in: HAZARDS XXIII. Southport.

Mearns, K., Whitaker, S.M., Flin, R., 2003. Safety climate, safety management practice and safety performance in offshore environments. Saf. Sci. 41, 641–680.

Mengolini, A., Debarberis, L., 2007. Safety culture enhancement through the implementation of IAEA guidelines. Reliab. Eng. Syst. Saf. 92, 520–529.

Mogford, J., 2005. “Fatal Accident Investigation Report - Isomerization Unit Explosion Final Report”. Texas City, Texas.

National Academy of Engineering, 2004. Accident Precursor Analysis and Management: Reducing Technological Risk Through Diligence. National Academies Press.

Office of Rail Regulation, 2006. “Train Derailment at Hatfield: A Final Report by the Independent Investigation Board.”

Ostrom, L., Wilhelmsen, C., Kaplan, B., 1993. Assessing safety culture. Nucl. Saf. 34, Pages: 163–172.

Pasman, H.J., 2009. Learning from the past and knowledge management: Are we making progress? J. Loss Prev. Process Ind. 22, 672–679.

Perrow, C., 1984. Normal Accidents. Basic Books, New York.

Pidgeon, N.F., Turner, B.A., Blockley, D.I., 1991. The use of Grounded theory for conceptual analysis in knowledge elicitation. Int. J. Man. Mach. Stud. 35, 151–173.

Qureshi, Z.H., 2007. A review of accident modelling approaches for complex socio-technical systems. Proc. twelfth Aust. Work. Saf. Crit. Syst. Softw. safety-related Program. Syst. - Vol. 86.

Rasmussen, J., 1997. Risk management in a dynamic society: a modelling problem. Saf. Sci. 27, 183–213.

Reason, J., 1997. Managing the Risks of Organizational Accidents. Ashgate, Aldershot.

Reason, J., Hollnagel, E., Paries, J., 2006. Revisiting the Swiss Cheese Model of Accidents. EUROCONTROL - European Organisation for the Safety of Air Navigation.

Reiman, T., Oedewald, P., 2006. Assessing the maintenance unit of a nuclear power plant - identifying the cultural conceptions concerning the maintenance work and the maintenance organization. Saf. Sci. 44, 821–850.

Royal Commission, 1999. “The Esso Longford Gas Plant Accident: Report of the Longford Royal Commission.”

Rudolph, J.W., Repenning, N.P., 2002. Disaster Dynamics: Understanding the Role of Quantity in Organizational Collapse. Adm. Sci. Q. 47, 1–30.

Saleh, J.H., Marais, K.B., Bakolas, E., Cowlagi, R. V, 2010. Highlights from the literature on accident causation and system safety: Review of major ideas, recent contributions, and challenges. Reliab. Eng. Syst. Saf. 95, 1105–1116.

Salge, M., Milling, P.M., 2006. Who is to blame, the operator or the designer? Two stages of human failure in the Chernobyl accident. Syst. Dyn. Rev. 22, 89–112.

Schein, E.H., 2002. “The Difficult Cultural Issues in Promoting Safety”. Int. Conf. Saf. Cult. Nucl. Install.

Senge, P.M., 1990. The Fifth Discipline: The Art and Practice of the Learning Organisation. Century Business, London.

Sonnemans, P.J.M., Körvers, P.M.W., 2006. Accidents in the chemical industry: are they foreseeable? J. Loss Prev. Process Ind. 19, 1–12.

Sorensen, J.N., 2002. Safety culture: a survey of the state-of-the-art. Reliab. Eng. Syst. Saf. 76, 189–204.

State Coroner Victoria, 2002. “Inquest into the deaths of Peter Brubeck Wilson and John Francis Lowery and the fire at Longford Gas Plant Number 1”. Melbourne, Australia.

Taylor, J.B., 2010. Safety Culture: Assessing and Changing the Behaviour of Organisations. Ashgate Publishing Company.

Taylor, R.H., Rycraft, H.S., 2004. “Learning from disasters”. IAEA Conf. Top. Issues Nucl. Instal. Saf.

Toft, B., Reynolds, S., 1994. Learning from Disasters: A Management Approach. Butterworth-Heinemann, Oxford.

Turner, B., Pidgeon, N., 1997. Man-Made Disasters, 2nd ed. Butterworth-Heinemann, Oxford.

Turner, B.A., 1978. Man-Made Disasters. Wykeham Science Press, London.

Underwood, P., Waterson, P., 2013a. Systems thinking, the Swiss Cheese Model and accident analysis: A comparative systemic analysis of the Grayrigg train derailment using the ATSB, AcciMap and STAMP models. Accid. Anal. Prev.

Underwood, P., Waterson, P., 2013b. Systemic Accident Analysis: Examining the Gap between Research and Practice. Accid. Anal. Prev. null.

US Nuclear Regulatory Commission, 2002. “Davis-Besse Reactor Vessel Head Degradation Lessons-Learned Task Force Report.”

US Nuclear Regulatory Commission, Safeguards, D. of F.C.S. and, 2000. “NRC Review of the Tokai-mura Criticality Accident” US Nuclear Regulatory Commission.

Van Wijk, L.G.A., Taylor, R.H., May, J.H.R., 2008. “Cultural and Organisational Factors Leading to Major Events”, in: Topsafe. Dubrovnik, Croatia.

Vaughan, D., 1997. The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA. University of Chicago Press.

Vaughan, D., 2004. Theorizing Disaster: Analogy, historical ethnography, and the Challenger accident. Ethnography 5, 315–347.

Waterson, P., 2009. A critical review of the systems approach within patient safety research. Ergonomics 52, 1185–95.

Waterson, P., Chung, P.W.H., 2010. Investigating the potential to simulate hospital-based infection outbreaks using the STAMP architecture, in: The 5th IET International System Safety Conference 2010, Manchester, UK, 18th-20th October. Manchester.

Woods, D.D., Cook, R.I., 2002. Nine Steps to Move Forward from Error. Cogn. Technol. Work 4, 137–144.

Zohar, D., 1980. Safety Climate in Industrial Organizations: Theoretical and Applied Implications. J. Appl. Psychol. 65, 96–102.

## Annex

*Table 1- Evidence of commonality in Organisational and Cultural Issues - relevant quotes from investigation reports*

| Organisational and Cultural Issue: Organisational Learning | |
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| Port of Ramsgate Walkway Collapse | “[W]hen defects became patent to certain individuals, the lack of adequate systems of liaison and communication prevented effective action being taken to remedy them” (p49, Health and Safety Executive, 2000a) |

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| | “Port Ramsgate failed as the port operators and main contractor to:[…] (d) react competently to the warnings that there were serious technical deficiencies” (p50, Health and Safety Executive, 2000a) |
| Heathrow Express NATM Tunnel Collapse | “'There were no effective arrangements for involving workers or for seeking their views on health and safety issues” (p2, Health and Safety Executive, 2000b)<br>“[S]enior management failed to have sufficient regard to disquiet expressed by middle and junior management. high-level expressions of commitment proved ineffective” (p63, Health and Safety Executive, 2000b)<br>“NATM problems were well-known to junior engineers and people at the workface who could have volunteered advice about the difficulties they were facing. However, there were no effective arrangements through which such views could be channelled” (p65, Health and Safety Executive, 2000b) |
| Longford Gas Plant Explosion | “The obligation to report was construed narrowly by Esso's management and operations personnel. The Commissioners commented:<br>*`process upsets were rarely, if ever, the subject of an incident report, unless they were accompanied by injury to persons or damage to property.'”* (p25, State Coroner Victoria, 2002)<br>They recommend “Enhancing a non-blame based reporting culture” (p33, State Coroner Victoria, 2002)<br>“There is still a risk in any workplace that workers may not report near miss incidents or safety related problems for any number of reasons, including: embarrassment or fear of approbation of fellow workers; thinking that the issue is far too minor to report; fear of being disciplined or losing a job, etc. An anonymous reporting scheme like that used by the Aviation Industry might be a useful addition to ensure that all potential problems are captured.” (p33, State Coroner Victoria, 2002)<br>“[H]ad Esso used its own incident and `near miss' reporting system effectively and proactively, there was real potential to avoid the incident'” (p37, State Coroner Victoria, 2002) |
| Tokai-mura Criticality Accident | No specific mention in the analysed reports and thus nothing extracted to directly influence the synthesised issue. However, it could be argued that lack of knowledge and normalisation of deviation to procedures muted the reporting of such events e.g.<br>“It is also apparent that operators departed further from the revised procedures as the operators tried to be more efficient in response to financial pressures felt throughout the company.....It is not clear at this time whether senior management was aware of these deviations from approved procedures” (p6, US Nuclear Regulatory Commission, 2000) |
| Hatfield Railway Accident | “[K]ey reporting and minimum action requirements were ignored” (p98, Office of Rail Regulation, 2006)<br>*“The culture in the Company is currently such that Zone Track Engineers are in fear of losing their jobs if they do not accept noncompliance.” (a quote from the Head of Track writing to Railtrack’s Head of Safety and Risk Management quoted implying reporting deviation was muted through fear of reprisal, p108, Office of Rail Regulation, 2006)* |
| Davis Besse Pressure Vessel Corrosion | “The circumstances surrounding the VHP nozzle leakage and RPV head corrosion event indicated that it was caused, in part, because the licensee failed to assure that |

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| | plant safety issues would receive the appropriate attention. This lack of assurance directly contributed to the untimely identification of VHP nozzle leakage and the boric acid-induced wastage of the RPV head." (p60, US NRC, 2002)<br>"[T]here were a number of problems indicting weaknesses with the employee concerns program" (p60, US NRC, 2002)<br>"Plant problems were not always entered into the corrective action program because the problem resolutions identified were often assigned to the person who identified the issue, resulting in an increase in the already high-level of work assignments." (p60/61, US NRC, 2002)<br>"This decrease in effort to resolve a problem that had existed for a prolonged period was indicative of management's willingness to accept degraded equipment and was indicative of lack of commitment to resolve issues that clearly had the potential to be significant." (p61, US NRC, 2002) |
| Loss of the Columbia Shuttle | "The Naval Reactor Program encourages minority opinions and "bad news." Leaders continually emphasize that when no minority opinions are present, the responsibility for a thorough and critical examination falls to management. Alternate perspectives and critical questions are always encouraged. In practice, NASA does not appear to embrace these attitudes. Board interviews revealed that it is difficult for minority and dissenting opinions to percolate up through the agency's hierarchy, despite processes like the anonymous NASA Safety Reporting System that supposedly encourages the airing of opinions." (p183, Columbia Accident Investigation Board and Office, 2003)<br>"Program managers created huge barriers against dissenting opinions by stating preconceived conclusions based on subjective knowledge and experience" (p192, Columbia Accident Investigation Board and Office, 2003)<br>"[T]he structure of NASA's Shuttle Program blocked the flow of critical information up the hierarchy" (p197, Columbia Accident Investigation Board and Office, 2003) |
| Paks Nuclear Plant Fuel Cleaning Event | "Problems in implementing the procedural requirement for ensuring the fuel assemblies were properly positioned in the fuel cleaning tank were not reported and addressed through established methods" (p14, IAEA Report) |
| Texas City Oil Refinery Explosion | "BP Texas City lacked a reporting and learning culture. Personnel were not encouraged to report safety problems and some feared retaliation for doing so." (p25, Chemical Safety Hazards Investigation Board, 2007)<br>"The prevailing culture at the Texas City refinery was to accept cost reductions without challenge and not raise concerns when operational integrity was compromised" (p154, Chemical Safety Hazards Investigation Board, 2007)<br>"The incentives used in this workplace may encourage hiding mistakes." (Quoting a previous investigation within the organisation, p160, Chemical Safety Hazards Investigation Board, 2007)<br>"BP Texas City lacked a reporting and learning culture. Reporting bad news was not encouraged" (p179, Chemical Safety Hazards Investigation Board, 2007)<br>"BP Texas City managers did not effectively encourage the reporting of incidents; they failed to create an atmosphere of trust and prompt response to reports" (p181, Chemical Safety Hazards Investigation Board, 2007) |

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| | "BP has not established a positive, open and trusting environment at Texas City" (p75, Baker et al. 2007)<br>"[A] significant number of hourly workers stated during interviews that incidents, near misses, and safety-related concerns sometimes did not get reported because of fear of repercussion, and in some cases out of a belief that the refinery would not act on the report" (p75, Baker et al., 2007) |
| Loss of Containment at the THORP Sellafield Reprocessing Incident | "[T]here is a need to encourage a culture where shortcomings in working practices and pant conditions are challenged by the workforce through a system of open reporting" (p23, Health and Safety Executive, 2005) |
| Buncefield Fuel Storage Explosion | "The investigation revealed that fault logging at HOSL, in relation to key equipment and working practices, was inadequate." (p19, Buncefield Major Incident Investigation Board, 2008)<br>"The Operations Co-ordinator had devised an electronic defect log but the supervisors did not use it properly. […]. It appears that the defect logging system was not consistently used, especially where the symptoms of a defect were apparently remedied quickly" (p19, Buncefield Major Incident Investigation Board, 2008)<br>"There should have been an effective system of reporting and recording all significant faults and their resolution. This system should have been understood and implemented by both contractual partners." (p20, Buncefield Major Incident Investigation Board, 2008) |
| Loss of the Nimrod XV230 Aircraft | "There are also numerous bodies involved in assimilating and processing data received who cannot between them effect a coherent reporting system that stimulates and coordinates action from the appropriate agency." (p517, Haddon-Cave QC and Office, 2009)<br>"With no single authority responsible for monitoring mandatory reporting, the current system relies on many action addressees identifying issues that fall within their area of responsibility with the real risk that issues are not adequately considered and that some risks may be missed." (p517/518, Haddon-Cave QC and Office, 2009)<br>"A New Engaged Safety Culture be built by the adoption, promulgation and inculcation of the above five-element model, namely a *Reporting Culture, Just Culture, Flexible Culture, Learning Culture and Questioning Culture*" (p576, Haddon-Cave QC and Office, 2009) |
| Synthesised Issue | Ineffective System for Event Reporting:<br>There sometimes did not appear to be an effective system for event reporting, particularly in relation to process safety. Reporting was poor for a variety of reasons, including apparent concerns from staff that their reports would not be part of a 'just' response, that bad news would not be welcome at more senior levels, that there was insufficient knowledge to recognise precursors and/or that there was simply a culture of mistrust or complacency which did not encourage open reporting. |
| Statement of Expectation | There is evidence that reporting of events and near-hits relevant to process safety is encouraged and is effective. It is part of a 'just' and simple-to-use reporting system. |
| Diagnostic Questions | • Describe the systematic process used to promote the reporting of events (including near-hits) and other opportunities for improvement (e.g. procedural inadequacies)?<br>• Demonstrate that this is simple to use and that there is evidence that it is well used |

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| | (e.g. through staff feedback)?<br>• Is the reporting done on a 'just' or 'no-blame' basis? What is the evidence for this based on some recent examples?<br>• How is the use of the reporting system promoted and encouraged by management? |