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Coping with failure

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This working paper is designed to offer an incomplete overview of work related to coping with failures. This encompasses people coping with failures on a one-off basis, go-live failures, repeat failures and workarounds, resilience, high reliability organisations and incident reports.

Coping behaviour

Working through Failures

Ethnographic studies often deal with routine work, rather than out-of-the-blue failure. This is partly because its hard to be at the right place at the right time to witness failure, and that ethnographers are often thrown out of the field when things do start going wrong (it is also because most ethnographies are interested in routine work rather than failure).

One celebrated study that covers how people cope in the face of a severe systems failure is Hutchins (1995), which describes the events following an engine failure on a US Navy ship as it approached port. Hutchins follows through the ways in which a disaster is averted, arguing that it is through team-work, procedures, technologies and artefacts that this is done (ie through the wider, socio-technical system). In this case, the failure is coped with by using what is available – and essentially Hutchins arguments are about 'ordinary work' rather than failure, and the example is just an exciting account of how work is done in the real world.

Some studies have looked at more mundane failures, for example how programmers deal with problems in their systems in development (eg Martin et al 2007). When people become aware of problems they engage not only in questions about what the problem is and what the solution might be but "is it my problem?", "does it matter if we don't fix it?", "does this problem look like problems we've seen before?". Workers usually try to understand the problem only to the extent that a solution can be found.

There are also studies of emergency workers (eg Bucher et al 2007), of troubleshooting and technical support (O'Neill et al 2005, Firth et al 2005), and seeking expertise in organisations (Ackerman e al 2003) – which may or may not be relevant.

Ongoing failures / Workarounds

The subject of workarounds has been quite widely studied in the ergonomics/human factors literature. Part of the need for workarounds arises out of the need to make things work on the ground. There is generally a gap between work as prescribed, and work as practised. The way that work should be carried out is often determined away from the sharp end of the system where it is actually carried out. So standard operating procedures, for example, are determined at an organisational level. These procedures can be seen in two different ways. First they can be thought of as informal, routine ways of coordinating work. Second, they can be considered as documented prescriptions of how tasks should be done (such as electronic checklists in aviation, or paper based documents). The use of procedures tends to be most common in safety-critical industries.

Procedures written for domains like transportation, nuclear power and so on, tend to follow what Dekker (2005) calls the safety model of procedures. In this view, a failure to follow procedures is held to lead to unsafe situations because:

- Procedures are the best thought out (and hence safest) way to do the job

- Procedure following is essentially a simple rule-based activity (Rasmussen, 1986), and hence relatively straightforward
- Safety arises as a result of following procedures
- In order for an organisation to achieve safety it needs to make sure that people know what the procedures are, ensure that they follow them

There are situations where the procedures are not adapted to the context in which they are supposed to be used, so operators end up working around them. Take the operation of one particular flight management system in a glass cockpit aircraft, for example. The pilots cannot start to enter the details of the route of the flight (in terms of waypoints that it will follow), until they have entered the amount of fuel that the aircraft has on-board. So the system is enforcing a particular sequence of steps as part of the procedure. The problem is that the amount of fuel is not known until the pilots are given it after the aircraft has been refuelled. The way that pilots get around this is to enter some large number for the amount of fuel (e.g. 999999) so that they can go on and enter the flight details. In order to make sure that they go back and enter the correct number at a later point, when the real figures are available, they either place a coffee cup over the yoke/side stick, or clip their tie to the check list as a reminder.

The alternative view that Dekker suggests is that procedures have to be interpreted with respect to a situation that they cannot fully specify. This is particularly so for new systems. In this view, procedures are regarded as a resource for action, and applying them is a skilled cognitive activity. People have to make a judgement about when and how to adapt procedures to particular situations. This means that for an organisation to make progress on safety, it has to understand the gap between procedures and practice and teach people how and when to adapt procedures to the situation at hand.

(Don Norman and workarounds)

Project failures

Go-live failures

John gave a presentation the other day about a couple of projects that were 'failures' at the time of go live but went on to be a success. It is possible that go-live is best viewed as a project within a project, for which potential for failure needs to be managed differently to long-term risks of failure.

Systems do take time to learn, and for them to get embedded or domesticated within an organisation and so it is unrealistic for a system to be designed that is perfect from the outset. And so 'design' for go-live inevitably has to be strongly socio-technical, with an emphasis on things like redundancy.

Unsuccessful projects

There are plenty of (usually retrospective) studies of failed projects– eg the London Ambulance Service. There often seem to be more lessons from failure stories than success stories.

Failure and Organisations

High reliability organisations

There has been considerable work looking at how some organisations seem to manage to achieve high levels of reliability almost as a matter of course (Rochlin, 1997). These people suggest that it is the ability to manage the systems, rather than design and build them, that is the limiting factor, with something like 80% of the events contributing to a disaster being human or organisational, and only around 20% being down to design or other factors. A large part of the research on HROs comes from the military domain, although they also consider health care, industrial process control, transportation and so on, and suggest that the ideas apply to any complex technological system (Roberts & Bea, 2001).

HRO is often pitted against Perrow's (1984) theories of complexity (called Normal Accident Theory in some places). Perrow basically says that complexity basically has two dimensions: interactions (ranging from linear to complex) and coupling (from loose to tight). His argument is that, where possible, systems should not include complex interactions and tight coupling. There are some domains where this naturally occurs, though.

There has been recent work in Nancy Leveson's group at MIT which tries to show the limitations of both HRO and NAT. They suggest that a more systemic approach based on STAMP offers the best way forward (Marais et al, 2004).

Supply Chain Failures

The way in which the Toyota group dealt with the aisin fire is a celebrated example of coping with failure and of how good working relations with the supply chain are helpful in the face of a disaster. See Nishiguchi and Beaudet 1997.

Averting failure

Risk management and disaster planning

Risk management is well established in software engineering. Barry Boehm's work (eg Boehm 1991) was key to the development of the existing techniques. Essentially risks are identified, along with means to mitigate them.

Disaster planning seems similar to risk management, but deals with extreme circumstances. It is probably more relevant to systems at a particular site, rather than to individual systems that risk management might focus on.

Resilience

Resilience is the persistence of dependability when facing changes (Laprie, 2008). Making a system resilient means that it is able to deliver service that can justifiably be trusted even in the face of continuous changes. The source of these changes can come from the organisation that is using the system (as the result of organisational changes, technology changes and so on), or may come from external sources, such as attempts to hack into the system, natural disasters (fire, flood and so on).

Resilience is more than just fault tolerance, because it includes the capacity to deal with unanticipated changes. In general resilience relies on using feedforward control to anticipate changes. One other aspect that is importance in resilience is impact analysis, in which the effect of any changes are considered.

Modern complex systems are heterogeneous, networked and open, so they generally reside in a dynamic environment which can change quite quickly in some cases (e.g. mobile phone networks). The ongoing changes in the environment can introduce new challenges for the system to meet. It is therefore important that these systems are managed proactively, and that risk management and impact analysis are routinely carried out throughout the lifetime of the system.

Incident reporting

Incident reporting offers another way of identifying situations where the human intervened to prevent the escalation of failure into a catastrophic failure. Not all incident reporting systems work in the same way, however, and much of the way that reporting is carried out depends on the culture of the organisation. (Here we use to term incident to describe any event which involves an unsafe or potentially unsafe occurrence or condition.)

It is not always possible to prevent all failures. Managing failure at the sharp end of the system, however, critically depends on the ability to discriminate between different types of incidents, which in turn relies on being able to discriminate between different manifestations of errors. The process of discrimination is founded on the ability to appropriately categorise incidents on the basis of their defining features. These features, in turn, can only be identified by contrasting and comparing several examples of incidents. Incident databases provide one way of gathering together information about several incidents in one place, thereby creating a basis for identifying and defining different types of incidents, and categorising the incidents accordingly.

There is a rich supply of incident data available. There is a major problem in accessing much of this data for research purposes, however, usually for commercial reasons (companies do not want competitors know about their failings). There are also issues to do with fears of possible litigation. Where incident databases do exist and are publicly accessible they tend to be industry wide, and are managed by a central organisation.

Although public enquiry reports are a potential source of data, they can be eliminated because they are too disparate and too detailed for the purposes required here. Such reports are usually only produced when a major accident occurs, and it is deemed to be in the public interest to hold an open inquiry into the circumstances surrounding that accident. The enquiry often lasts months, with the resulting reports extending to hundreds of pages, containing several sections of expert testimony about the various individual facets of the accident. These reports are generally difficult to use as a way of establishing what happened because the way in which the information is often presented makes it difficult to generate a coherent view of the true nature of the accident (Johnson, McCarthy and Wright, 1995).

Most organisations collect incident data in some form. The motivations behind making incident reports generally available has helped to provide an impetus to produce databases that are available in the public domain. The remainder identified several of the databases that are available, focusing only on those databases which contains specific records of individual incidents (rather than the bibliographic database which refer out to other sources of information about incidents). Where these are maintained by an individual company, the data is usually not publicly accessible. There are some databases which are maintained by a central authority, such as a regulatory or professional body, however, and in general, these tend to be available to the public.

Nuclear power

The International Nuclear Information System (INIS) is co-ordinated by the International Atomic Energy Agency (IAEA) in Austria. INIS is an extensive bibliographic database which is concerned with peaceful applications of nuclear science and technology. Details about INIS can be found at the IAEA web site (*www.iaea.or.at*), and it is available as a CD-ROM from Silverplatter. The IAEA also maintains an incident reporting system (IRS), details of which are available at *www.iaea.or.at/worldatom/inforesource/other/iaeanea/iaeanea-irs.html*.

The Health and Safety Executive (HSE) in the UK produce a quarterly statement on incidents at nuclear installations, which is available from their information centre in London. Press releases about various nuclear incidents where the HSE has been called in to investigate are also made available on-line, at the HSE's web site (*www.hse.gov.uk*). These press releases are usually summaries of the full reports which can be purchased from the HSE.

The UK nuclear power industry have their own internal database of incidents, called the Nuclear Plant Event Reporting (NUPER) system. There is no information generally available on it, however.

Scottish Nuclear also produce regular reports for public consumption on incidents that occur at their various power stations.

The Public Document Room (PDR) of the Nuclear Regulatory Authority in the USA is accessible at *www.nrc.gov/nrc/pdr/pdr1.htm*. The PDR has links to some incident reports, and allows indirect access to the PDR Bibliographic Retrieval System and the PDR Bulletin Board System.

Oil and chemical production

These two domains are considered together because they overlap to varying extents, most noticeably in the Petrochemical industry.

The Chemical Safety Newsbase covers information on health and safety in chemical and associated industries. It is a bibliographic database.

The Institution of Chemical Engineers in the UK produced an accident database, which was released in 1998. This database, which contains over 8000 records, includes details of some incidents that have not previously been made available. The database has been extended and upgraded to include more data since its initial release. The database no longer appears to be available.

The American Institute of Chemical Engineers has also recently developed its own database, called the Process Safety Incident Database (PSID). The PSID is only available to subscribers for a one-off payment fee. Details are available at *www.aiche.org/ccps/lldb.htm.*

The Health and Safety Executive office in Bootle in the UK maintains a database of Offshore Accidents which is available on CD-ROM from Silverplatter. The HSE also publish press releases which are available on-line, and are usually summaries of the HSE's report into incidents involving organisations from the chemical industries.

Aviation

Aviation is probably the most enlightened domain when it comes to making accident and incident data available. The net effect is that there are several sources of aviation incident reports available, most of which have details available on the Internet. It needs to be stressed, however, that the way in which the aviation system works differs across the world, which makes it difficult to directly integrate incident report data from different regions. As a result, the available databases tend to be restricted to individual geographical regions.

The Air Accident Investigation Branch (AAIB) in the UK produces a monthly bulletin of accident reports which is accessible at *www.gtnet.gov.uk/aaib/aaibhome.htm*. The bulletin contains textual reports of incidents that have been investigated by AAIB.

Also within the UK there is the Confidential Human Factors Incident Reporting Programme System (CHIRPS; Green, 1990), which was originally set up by the RAF Institute for Aviation Medicine. It is now maintained by a separate charitable trust. Although the data is not currently directly available, they may run queries on the data upon request. A quarterly bulletin, *Feedback*, which contains a summary of reports received, is available at *www.users.dircon.co.uk/~chirp*.

In the United States there are a number of incident reporting systems available. Probably the best known is the Aviation Safety Reporting System (ASRS; Reynard, Billings, Cheaney, & Hardy, 1986) which was set up by the FAA's Office of the Assistant Administrator for System Safety and is administered by NASA. The *Callback* bulletin, which includes reporting figures, is produced monthly, whilst *ASRS Directline*, which has in-depth reports on a number of reported issues, is published infrequently. Both of these bulletins are available at *asrs.arc.nasa.gov*; the ASRS CD-ROM is available separately for purchase.

Three other databases are accessible on-line through the Office of System Safety's web site. The first of these is the FAA Incident Data System (FIDS) which is accessible at *nasdac.faa.gov/asp/asy_fids.asp*. The second is the National Transportation Safety Board's Aviation Accident/Incident Data Base, which can be accessed at *nasdac.faa.gov/asp/asy_ntsb.asp*. The third is specifically for near mid air collisions (NMACs) and can be accessed at *nasdac.faa.gov/asp/asy_nmacs.asp*.

The International Civil Aviation Organisation (ICAO) have a database called the Aircraft Accident/Incident Reporting System (ADREP). This is maintained by the Accident Investigation and Prevention Section of the Air Transport Bureau of the ICAO. Information from the database is available in printed form. ICAO can be found at *www.iaco.org*.

The Joint Research Centre of the European Commission has been setting up a database to overcome compatibility problems of different individual databases. The European Co-ordination Centre for Aircraft Incident Reporting Systems (ECC-AIRS) is based on the ICAO standard for accident and data reports. The details of ECC-AIRS were originally at *www.jrc.org/isi/atia/activities/eccairs.asp* although this location no longer appears to be valid.

The European Confidential Aviation Safety Reporting Network (EUCARE) was based in Germany. After a successful introductory phase, however, internal wranglings led to the closure of the system in June 1999. Details about EUCARE are still available at *www.eucare.de*.

In Australia, the Bureau of Air Safety Investigations (BASI) maintains an incident database, called the Confidential Aviation Incident Reporting System (CAIRS). Details on CAIRS can be found at *www.basi.gov.au/cair/cair1.htm*.

New Zealand also has its own incident reporting system. Details of the Independent Confidential Aviation Reporting System (ICARUS) can be found at *www.icarus.co.nz/icarus/*.

The Transportation Safety Board of Canada has an integrated system for reporting incidents in the marine, rail and air transport domains. The details of the system, which is called SECURITAS, can be found at *www.bst-tsb.fc.ca/eng/about/securitas/securitase.html*.

In addition to the national initiatives reported above, South Africa collects incident reports via the Aviation Safety Council (SAASCo), and Russia has its own Voluntary Aviation Reporting System. Neither of these are directly available to the public.

A more general resource for safety issues in the aviation domain is the Aviation Safety Network. It includes descriptive reports of some accidents, and can be found at *aviation-safety.net/database*.

Railways

After a spate of accidents in the UK, the government set up the Critical Incident Reporting and Analysis System (CIRAS) for the railways. CIRAS produces a bi-monthly newsletter which contains a selection of key reports and company responses.

Shipping

The US Coast Guard keeps data on shipping accidents in US waters. Lloyds of London maintains a database for world wide operations. Arthur Mackenzie, director of Tanker Advisory Center, Inc, collects some of this data.

The Marine Accident Investigation Branch in the UK maintains a database of shipping incidents. Details are available on-line at *www.open.gov.uk/maib/maibhome.htm*. In addition, there is now a CHIRP Maritime reporting system which, like the aviation one, is accessible at http://www.chirp.co.uk/.

Medicine

Incident reporting is used by NHS organisations in their efforts to improve patient safety.

In healthcare the Adverse Incident Centre of the Medicines and Healthcare products Regulatory Agencey(MHRA) in the UK keeps a record of adverse incident reports. In 1995, for example, over 4000 incidents were reported, covering all aspects of the delivery of health services. The reports range from technical aspects such as the problems of a syringe pump providing excessive amounts of medication, to seemingly more mundane matters, such as drawers of supplies which are jammed closed and cannot be opened. Although superficially these two incidents would appear to have widely differing effects on patient safety, both turned out to be potentially life threatening. In the latter case, the drawer in question was used to store life saving drugs and equipment on an emergency trolley.

There seems to be a tension between comparability of reports, and the qualitative insight offered by an individual report. In their comprehensive review of the literature surrounding technology related adverse events in healthcare, Balka et al (2007) point to the differences between incident reporting schemes, particularly the lack of definition regarding the scope and nature of adverse events, as the major barrier to extrapolating meaningful data from them at a national or international level. They recognise the potential benefits of large-scale analysis of incident data, but point out that in doing so the situatedness of medical practices can be overlooked and incidents wrongly conceptualised as device or user problems. Balka et al suggest "new forms of governance may be required, that place greater emphasis on socio-technical and systems issues".

Disasters such as a patient death are extreme examples of an incident and although lessons should be learned from these, the ethos of a reporting scheme is to pick up the little incidents such as dysfunctional equipment, unmanageable situations, and (often harmless) mistakes, and to address these so as to circumnavigate disasters (Barach & Small, 2000; Short et al., 1996; Johnson, 2003). In the aviation industry (the first industry to adopt incident reporting), evidence (NHS National Patient Safety Agency, 2004) from British Airways shows a correlation between high levels of incident reporting with reduced levels of high and medium risk events that actually occur. Disasters, or incidents involving patient distress or harm are usually caused by a combination of smaller issues, have early warning signs or involve repetitions of mistakes or issues that have arisen before (Liang, 2002; Boëlle et al., 2000). Incidents are systems issues, not a chain of events resulting from a failure and leading to an incident; non-systems models are limited in their ability to account for the incident and support the improvement of safety (Barach & Small, 2000; Leveson et al., 2003).

Although the NHS National Patient Safety Agency has a National reporting and Learning Service http://www.npsa.nhs.uk/nrls, it is not clear how effective this is, and the details of the incidents are not made available to the public. Much of the use of the database seems to be to show that numbers are falling, i.e. it is a management tool, rather than one that benefits clinical staff by allowing them to learn from previous incidents.

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Appendix: Incident Reporting Systems

Summary links to incident reporting databases (taken from Chris Johnson's web pages. Some of these links may not work!

- • Aviation
  - Australian Confidential Aviation Incident Reporting
  - BASIS
  - European Confidential Aviation Safety Reporting
  - EUROCONTROL HEIDI - Harmonisation of European Incident Definition Initiative for ATM
  - European Turbulent Wake Incident Reporting System
  - REC : Recueil d'Evenements Confidentiel
  - Global Aviation Information Network (GAIN)
  - Harmonisation of European Incident Definition Initiative for ATM
  - KAIRS (Korea Confidential Aviation Incident Reporting System).
  - TACARE (Taiwan Confidential Aviation Safety Reporting System).
  - UK Airprox Board
  - UK Confidential Human Factors Incident Reporting Programme
  - US Airforce Investigation Guidelines (AFI91-204)
  - US Aviation Safety Reporting System (From January 2000)

- Leisure-Related Industries
  - British Hyperbaric Association (Diving)

- Maritime
  - CASMET: Causality Analysis Methodology for Maritime Operations
  - Hong Kong Reporting System
  - International Maritime Human Element Forum
  - Japanese Maritime Accidents Inquiry Agency IMO Reports
  - Marine Accident Investigators International Forum
  - Det Norske Veritas (SYNERGI)
  - UK Confidential Human Factors Incident Reporting Programme
  - US Navy/George Sharp Site
  - US Coast Guard International Maritime Information Safety System
  - US Coast Guard Office of Investigation and Analysis
  - US National Maritime Incident Reporting System

- Medical
  - Australian Patient Safety Foundation (AIMS)
  - Genie project
  - Intravenous Incident Reporting Network.
  - Swiss Anaesthesia Incident Reporting System
  - UK Medical Devices Agency
  - UK NHS An organisation with a memory
  - UK National Patient Safety Agency
  - UK Royal College of Anaesthetists, Critical Incident Reporting
  - US FDA Manufacturer and User Facility Device Experience Database
  - US National Coordinating Council for Medication Error Reporting and Prevention
  - US National Patient Safety Foundation
  - US Joint Commission on Accrediation of Healthcare organisations (Sentinel System)

- Military
  - Canadian Vice Chief of Defence Staff Safety Digest
  - Canadian Defence lessons Learned
  - Singapore Army Safety Site
  - UN Peacekeeping Lessons Learned
  - UK RAF Inspectorate of Flight safety
  - US Army Safety organisation
  - US Center for Army Lessons Learned
  - US Center for Army Engineering Lessons Learned
  - US Army Technical Centre for Explosives, Safety Bulletin

- Process Industries
  - European Process Safety Centre Incident Reporting
  - IAEA (Nuclear) Incident Reporting System
  - IAEA (Nuclear) Incident Reporting Database
  - UK Institute of Chemical Engineers, Incident Reporting Training
  - US DoE CAIRS - Causal Analysis System

- Rail
  - CIRAS, University of Strathclyde.
  - European Rail Traffic Management System
  - National CIRAS System
  - Railway Safety Databases
  - UK HSE Safety Case Requirements for Rail Incident Reporting
  - UK Railway Safety
  - US FRA Safety office
  - US FTA Lessons Learned

- Space

  - European Space Agency Lessons Learned Systems
  - NASA Safety Reporting System
  - NASA Office of Logic Design

- Others

  - Omnisafe
  - UK Major Hazard Incidents Data Service (MHIDAS)
  - US Consumer Product Safety Incident Report
  - US Govmt-Industry Data Exchange Program
  - US Navy Lessons Learnt Site
  - US Lawrence Livermore National Lab, Incident Reporting Programme
  - US National Renewable Energy Lab Incident Reporting Program
  - Yale Risk Management Handbook - Incident Reporting