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What Went Wrong? Accident Reports and Other Breakdown Narratives

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What Went Wrong? Accident Reports and Other Breakdown Narratives[1]

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Abstract

Scholars in Science and Technology Studies read reports of accidents and other breakdowns as revealing otherwise concealed dynamics of socio-technical systems. But such reports have their own distinct narrative structures, which shape the ways in which they are read and the lessons which can be drawn from them. Safety practitioners also have their own understandings of how reports of system failure can contribute to change. Through close readings of work by the systems theorist Jens Rasmussen, the sociologist Charles Perrow, and the chemical safety engineer Trevor Kletz, I examine the narrative character of this knowledge, and what this entails for ascribing responsibility and changing behaviour. Then I contrast these safety reports with narratives from within the field of STS, which are also premised on interrogating breakdown. The concluding section considers what is at stake in comparing safety narratives with these STS studies.

1. Introduction

When things go wrong, we are often told, an investigation will be conducted and an expert will get to the bottom of what went awry. Public inquiries are held in the wake of technological accidents; when a child is harmed, social workers conduct a serious case review; failures of procedure lead to investigations. All of these reports contain significant elements of narrative: this paper is about these narratives, how they are put together, the lessons which can be drawn from them, and how they compare to other

[1] Research for this paper was conducted during my employment as Research Officer on the Narrative Science project, which is funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 694732). I am grateful to Mary Morgan for her comments on previous drafts of this paper, and to Hannah Roscoe for suggesting the line of thought on which it is based. The mistakes which remain are my own.

narratives which seek to challenge established pictures of science and technology. It starts from an observation made within the field of Science and Technology Studies (STS), about the effect of accidents. Jack Stilgoe writes, summarising a considerable body of research, "Technological accidents can wrest control of the social experiment away from the technologists, laying bare the rules and assumptions that shape black boxes and exposing the uncertainties that are so easy to ignore when things work well […] Except in cases of total cover-up, accidents can force public reframing and institutional reflection."[2] In this view the accident is revelatory, in a way which normal working conditions do not allow. Exposure, of course, also depends upon reports of the accident, the reconstruction of events which I want to call breakdown narratives. Such narratives are premised on the claim that failure can uncover how a system, process, or technology works, and contribute to a fuller account of its operation.

On closer examination, however, the accident reports of many fields tend to be presented in highly conventional forms. Practitioners have reflected at considerable length on how narratives should be constructed, the effects of particular structures or allocations of agency, and this has impacted on the ways in which analysts have used these narratives. Section two examines in detail the construction and use of accident reports by three analysts: the systems theorist Jens Rasmussen; the chemical safety engineer Trevor Kletz; and the sociologist Charles Perrow. Where STS has drawn chiefly on the reporting of public inquiries and the like, these narratives often involve everyday and small-scale incidents, and the question of how they can be aggregated in order to draw larger conclusions. My second argument is that work in STS can also be considered as providing similar small-scale breakdown narratives, typically by contrasting an analyst's personal observations and experiences of a scientific or technical setting with a conventional portrayal of how science and technology work, which is shown to fall short in practice. Although these narratives do not rely on the evident breakdown of existing systems which results from an accident, they provide glimpses of alternative ways of understanding existing processes, for which narrative is advantageous as it can bring out processual and relational dynamics missing from conventional accounts. Section three discusses examples from works by Harry Collins, Natasha Myers, and Lucy Suchmann which can be read as this kind of breakdown narrative. Finally, section four compares the accident reports with the works of STS, and draws some general conclusions about breakdown narratives.

Before we embark on the analysis of specific narratives, I want to make some more general remarks about narrative, a term which has many meanings and a tendency

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[2] Stilgoe, 2018, p. 27.

to creep. The sense in which I use it here follows recent work in the history and philosophy of science, especially by Mary Morgan, to emphasise how narratives gather together an heterogeneous collection of entities into an order which is used to solve problems; it is also indebted to a longer tradition of narratological analysis which seeks to establish the structure of a narrative as the first step to grasping its meaning.[3] This is far from the only possible definition, of course: studies of narrative in science have examined the possibility of non-temporal narrative forms, or defined all scientific activity as potentially narrative in form, or have read scientific papers through a prism of narrative.[4] It is helpful to distinguish this emphasis on ordering narratives from the more *contextual* sense which invocations of narrative often possess in academic and public discourse.[5] A story from the *Financial Times* about recent power cuts in England and Wales, for example, remarks that

> Keith Bell, a professor in electronic and electrical engineering at the University of Strathclyde and a member of the government's advisory Committee on Climate Change, said that while there were valid questions for National Grid to answer, there had been a 'natural inclination to connect this to some bigger narrative'. 'This has become an opportunity for people—from the Labour party to climate change deniers—to promote a particular agenda, even though it basically seems like an unfortunate series of events,' he said.[6]

What Bell means by 'narrative' is something like a pre-existing stereotypical storyline, to which events are made to conform.[7] For those seeking to use the power cut to demonstrate their existing agendas, the specific sequence of events does not matter—or rather, an attempt to establish causes does not need to be made, because they already 'know' that the problem was caused by renewables or privatisation. At the Grid, meanwhile, inquiries are underway to establish exactly what failed when, and how this led to the unexpected consequence of a large-scale power cut. This latter kind of narrative is my main focus here. Such narrative sequences are not, of course, innocent of contextual framing narratives; when the Grid's findings are made public, they will be shaped by considerations of political context, and when they are reported their interpretation will respond to existing narratives of the type which Bell identifies. Nevertheless, the effort

[3] Morgan and Wise, 2017.
[4] For example: Rouse, 1990; Mellor, 2017.
[5] Shen, 2005; Sommer, 2007.
[6] Shephard, Raval and Thomas, 2019.
[7] As such they bear comparison with Goffman's account of framing. See Goffman, 1974; Durham, 1998.

to establish a specific causal sequence (on *this* occasion *this* led to *this*) will be a starting point for the Grid's own narrative.

Why should narratives be helpful for understanding breakdowns? First, the form which I have identified for breakdown narratives (a system seems to be working; it breaks down; we learn lessons from the breakdown) maps quite closely onto some influential accounts of the structure of most narratives. According to the narrative theorist Tzvetan Todorov, for example, narratives typically open in a state of equilibrium, which is complicated or disturbed in some way; the complication or disturbance is resolved, and a new equilibrium is established, which incorporates the experiences caused by and lessons learned from addressing the disturbance.[8] The sociolinguist William Labov offers a somewhat similar pattern for oral narratives, identifying a number of stages which they go through and emphasising the importance of evaluation as an aspect of narrative.[9] The view of narrative as stemming from a disturbance to equilibrium fits with this general emphasis on the need for scientific knowledge and technical practice to be unsettled so that they can be studied.

Second, narratives are characterised by actualities, rather than potentials.[10] Even if they are imaginary, they involve imagination of a specific sequence of events. Even doubts and hesitations, or the argument that nothing can be done, become things which happen in the narrative. In her discussion of cosmological narratives, Felicity Mellor quotes the theorist Gerald Prince: "Narratives live in certainty: this happened and then that; this happened because of that; this happened and it was linked to that. Though they need not preclude hesitation or speculations or negations….narratives perish under the effect of sustained indecision and ignorance."[11] In relation to rule-governed activities (such as the operation of a safety procedure, or a game) narrative refers to how rules are applied in specific circumstances, and how they interact with contingencies. They do not, in the process, say anything about what is going to happen on subsequent occasions. Narratives are thus good at exposing what can happen on the basis of what has happened, and raise questions about the likelihood of whether a sequence of events will recur. (For example, whether a problem in an organisation is caused by a single bad actor, or by more systemic factors, such as management of risk).

[8] Todorov and Weinstein, 1969.

[9] Labov and Waletsky, 1967.

[10] Some views of narrative explanation emphasise the role of possibilities in making sense of narratives; in Geoffrey Hawthorn's resonant phrase, each particular sequence of events is situated in a "space of possibles". As Hawthorn emphasises, however, any such explanation depends on the contrast between what could have happened with what actually did at each turn of the tale. See Hawthorn 1990, p. 17.

[11] Prince 2008, p. 22, quoted in Mellor, 2016, p. 227.

Third, it is helpful to think about *narrative distance*. This is a term introduced by the narratologist Gérard Genette to identify how far the teller of a narrative seems to stand from the events described.[12] The following short narrative has a great deal of distance: *I created some universe or other in six days; it lasted a while; destroying it took three weeks, I think, I don't remember*. By contrast other narratives adopt the point of view of figures involved in them, which may be the narrator. Sociologists and philosophers concerned with narrative have written quite a lot about the different roles which a narrator involved in the events which she describes (known as a *diegetic narrator*) can play in shaping scientific understanding.[13] Although the role of narrative distance may appear aesthetic or arcane, it can have important implications in the shaping of breakdown narratives. For example, some guides to writing reports encourage investigators to put themselves in the shoes of the people who were there at the time, instead of relying on hindsight and treating the failure as inevitable.[14] By reducing the narrative distance between themselves and the protagonists of their narratives, these investigators try to provide accounts which can be helpful for people in the future, who also possess imperfect knowledge and a limited access to information about what is going to happen next.

If narratives are good at relating general principles to specific circumstances, and often emerge from disturbances to normal situations, this poses two dangers. The first is that we may believe that we can only learn from extreme cases, those which tend to prompt inquiries or large-scale investigations. The second is that the narrative will dwell on contingencies—especially those which may be lurid or dramatic—at the expense of considerations which are more likely to recur in future situations. These problems shape the construction and use of accident reports, to which I will now turn.

2. Accident Reports

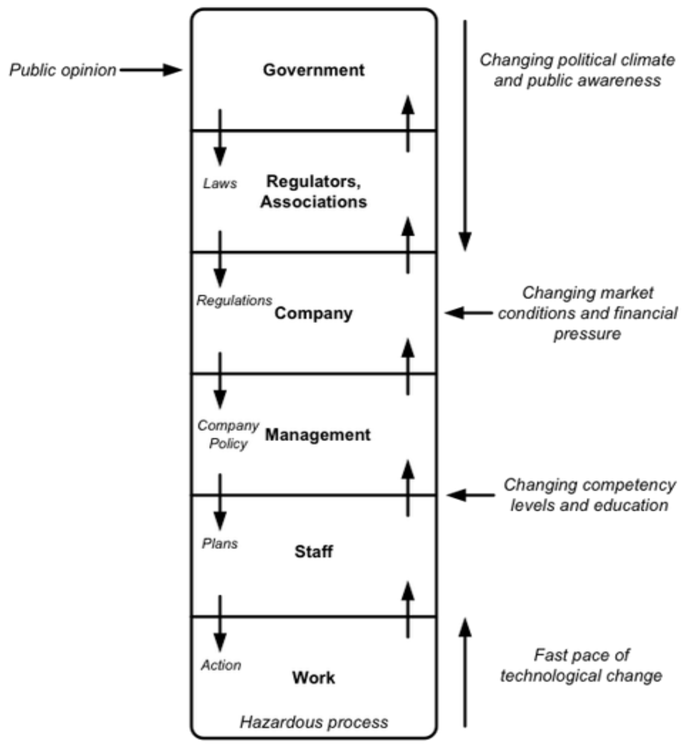
In this section I am going to discuss work by three practitioners who have reflected extensively on accident reports: the systems theorist Jens Rasmussen, the chemical safety engineer Trevor Kletz, and the sociologist Charles Perrow. Each pays attention to how reports should be ordered and used, and the lessons which can be drawn from everyday breakdowns as well as larger problems. Half-joking, Kletz wrote that every accident in a chemical plant should be considered an investment: you have paid for the research, he claimed, so you might as well write up the results. Accident reports are

[12] Genette, 1980.
[13] Griffin, 1991; Morgan and Wise, 2017.
[14] SCIE, 2019.

produced as a matter of routine in many sectors, and present a number of well-established difficulties. They may blame front-line workers, without considering how workers came to fail, or what might lead to more satisfactory performance on future occasions; this can lead workers to be wary about reporting problems, from the fear that they will be held culpable. In some sectors, reports also serve political ends: holding someone responsible can be punitive, as in notorious cases where a child has been harmed, and newspapers call for social workers to be sacked. The question then is how reports can be constructed in a form which allows for more general lessons to be learned, despite these constraints.

The systems theorist Jens Rasmussen, who originally trained as an electrical engineer before working extensively on organisational and safety studies, devised a number of tools to diagnose types of human error, and to indicate how decisions made at different organisational levels contribute to accidents, often in a non-linear fashion. That is, decisions made by regulators or by management can have unpredictable effects upon the behaviour of frontline operators, which may not be caught if the narrative of failure focuses on these workers without considering the wider organisational context in which they are located. Rasmussen's diagram for showing the interaction of different organisational levels is shown in figure one. Decisions at each level are transmitted to the next in the form of laws, regulations, policies, plans, and finally action: action by

Figure One: Jens Rasmussen's Accident Causation Schema, adapted from Rasmussen, 1997, and published by Uploads Project, 2015.



operators thus emerges from this much larger organisational context. At the same time, each level is affected by external forces and pressures from the lower levels, including responses to technological change, market conditions. In order to understand a mistake in the conduct of hazardous work, we need to understand the interaction of these different factors. So, for example, a company which has strong safety policies may feel compelled to weaken them by de-emphasising staff training as a result of adverse market conditions; this course of action may be strengthened by a lax attitude from regulators. The schematic diagram shown in figure one has been adapted for different sectors; the point is to give a wider view than close focus on operators' decisions would allow by itself. Rasmussen's work has been very widely cited within safety studies, and applied to a number of different sectors.

How do schematics like Rasmussen's shape the production and interpretation of accident reports in practice? To answer this question, it is helpful to look at a field where practitioners are trying to introduce this method in order to aggregate and improve the production of existing reporting. I will give the example of an effort by Australian researchers to introduce the schematic to outdoor pursuits: economically significant activities where accidents often happen and where they are reported in a standard format and collected together into a database, the New Zealand Outdoor Education/Recreation National Incident Database.[15] Entering data into this database involves a combination of completing multiple choice fields, alongside a more qualitative narrative. Paul Salmon and his colleagues analysed 1014 accident reports from the database, seeking to find a series of interacting levels which could serve as a framework for future accident reports. The levels which they identified in advance of the classification exercise were: equipment and surroundings; physical processes and instructor/participant; technical and operational managements; local government; activity centre management planning and budgeting; regulatory bodies and associations, schools and parents; and government policy and planning decisions.

The existing reports were re-classified according to these levels, with a combination of multiple choice codings for instructor, participant, equipment and environment, and themes abstracted by a separate researcher from the database's narrative field. Overall the existing incident reports rarely reported much effect of government policy and budgeting or regulatory bodies; slightly more frequently, local government were held responsible, especially for a lack of risk management systems. The researchers conclude that "a challenge moving forward is […] the development of data collection systems that are capable of gathering data on contributory factors at the higher

[15] The researchers note that there are few such collections in Australia, and that this is the reason they have used data from New Zealand.

levels of the led outdoor activity systems."[16] In other words, when the existing reports were slotted into Rasmussen's framework, they were held to fall short because they lacked attention to the higher organisational levels.

The presumption of this study is that an accident reporting form which required attention to higher levels would lead to different narratives about why accidents occur. The researchers touch briefly on the reliability of the reports which they have analysed, noting that the diversity of viewpoints which they represent is both a strength and a weakness. As they put it:

> One notable limitation of this study surrounds the accuracy and validity of the incident reports analysed. It is worth pointing out that the incident reports were compiled by a range of different reporters and that they represent what causal factors each reporter believed were involved in the incident. Prior to the present study the incident reports had not been subject to any further analysis or validation and so may be vulnerable to under/over reporting or erroneous reporting of causal factors. Caution from the readers is therefore urged when considering the analysis findings. As it is not possible to verify the accuracy of the incident data reported, it is acknowledged that the analysis presented provides a description of what causal factors were reported rather than a verified accurate picture of incident causation in the activities analysed.[17]

In this application, Rasmussen's schema is meant to be generative, rather than inductive: it does not simply record what reporters were already noticing, but aims to encourage a wider perspective on accident causation, which in turn can challenge the focus on frontline failures. Yet this effort to combine numerous small narratives also raises questions about the extent to which each is constructed with sufficiently similar principles in mind to allow them to be comparable.

The applications of Rasmussen's schema can be contrasted with the method of diagramming accident causation employed by the safety engineer Trevor Kletz, examples of which are shown in figures two and three. Kletz was one of the first dedicated safety engineers to work in British chemical industry. He was born in 1922 in Chester; after a degree in chemistry at the University of Liverpool, he started to work at Imperial Chemical Industries Billingham in 1944, initially in the research department, where he learned about chemical engineering on the job. After seven years, he was promoted to

[16] Salmon et al, 2014, p. 118.
[17] Salmon et al, 2014, p. 119.

plant manager, and gained further first-hand experience of problem solving in chemical industry, and (as he later recalled) the importance of learning from failure. Of his first assignment he reported that the "iso-octane plant to which I was first assigned had been operating for 12 years, the shift foremen were experienced. Everything that could go wrong had gone wrong before so the foremen knew exactly what to do and just got on with it, despite the lack of any up-to-date operating instructions (something I was to remedy)."[18] In 1955, Kletz received his first safety assignment; safety was not at this time a corporate priority and he later claimed to have concluded that it was dull. Meanwhile Ken Gee, a production manager at ICI, had started to transfer principles already at work in the company for the scrutiny of managerial decisions to the design of new plants. This procedure which would subsequently become formalised as "HAZOP": a "hazard and operability study", an approach to risk assessment which remains in wide use.[19] Following a number of accidents which had occurred at ICI, Gee recommended to the Board that a technical specialist should be appointed to focus on safety—Kletz claimed that he was selected for this role because he had shown more interest in safety than anyone else then working for the company, and that he was invited to write his own job description. In safety publications, Kletz's work is credited with contributing to a reduction of accidents at ICI of around 50%.

Kletz was fascinated by narratives, and sought to embed reports of accidents within the institutional culture of ICI. He compiled incident reports of industrial accidents into bulletins which circulated within ICI and among the wider community of industrial chemists; starting with a very small circulation, at the time of his retirement these bulletins had a readership of around 3,000, which included academics as well as company personnel. In the aftermath of a fire at the ICI Aromatic Plant in North Tees in 1972, which caused substantial damage though no injuries, Kletz "started a series of discussions on the causes of accidents that were to continue for the rest of [his] ICI career, and afterwards".[20] Each week 12-20 people, who had been nominated by their own departments gathered together on a morning. Kletz "described an accident, briefly, and illustrated it by slides. The group then questioned me to find out the rest of the facts, the facts that *they thought* important and that they wanted to know. They then said what *they thought* ought to be done to prevent similar incidents happening again. Because they were involved in a discussion, the audience remembered more than if I had lectured to them and they more were [*sic*] committed to the conclusions, as they were *their*

[18] Quoted in Flavell-White, 2018.
[19] Kletz, 1997.
[20] Kletz, 2000, p. 80.

conclusions."[21]

Kletz wanted to use narratives to preserve the experiential quality of learning from mistakes. He argued that every rule or regulation should be accompanied by a note describing the original failure to which it was a response, and described his efforts to get colleagues to pay attention to safety through accident reports. Accident narratives are attention-grabbing, he wrote, whereas an article describing "a management system" is likely to be put aside; or in the case of a talk on the same subject, "we may yawn and think, *Another management system designed by the safety department that the people at the plant will not follow once the novelty wears off."* By contrast, "we remember stories about accidents far better than we remember disconnected advice."[22] Instructions, codes and standards should all be accompanied by "accounts of accidents that would not have occurred if the instruction, etc. had existed at the time and had been followed."[23] Accounts should "[d]escribe old accidents as well as recent ones, other companies' accidents as well as our own, in safety bulletins and discuss them at safety meetings."[24] Chemical engineers should also "[k]eep a folder of old accident reports in every control room. It should be compulsory reading for recruits and others should look though it from time to time."[25] In his final book, Kletz noted that in principle computer databases of accidents should help to "keep the memory of past incidents alive and prevent repetitions"; he argued that they failed to have this effect because they relied on investigators searching for individual named hazards which were generic and immediately recognisable, rather than allowing for the more holistic and open-ended questions about causes which narratives could raise.[26]

From his safety bulletins and reports of inquiries, Kletz compiled a series of narratives which he published in a series of books.[27] In his reports of historical accidents, Kletz provides diagrams (versions of which are reproduced in Figures 2 and 3) which indicate a sequence of actions which may belong to a range of actors: front line workers, management, designers, even the public at large. The top levels of his schema show the most proximate actions, emphasising what front-line workers can do, or what decisions can be made on their behalf; those further down indicate decisions which could have been made earlier, which would have prevented the problem from arising in the first place.

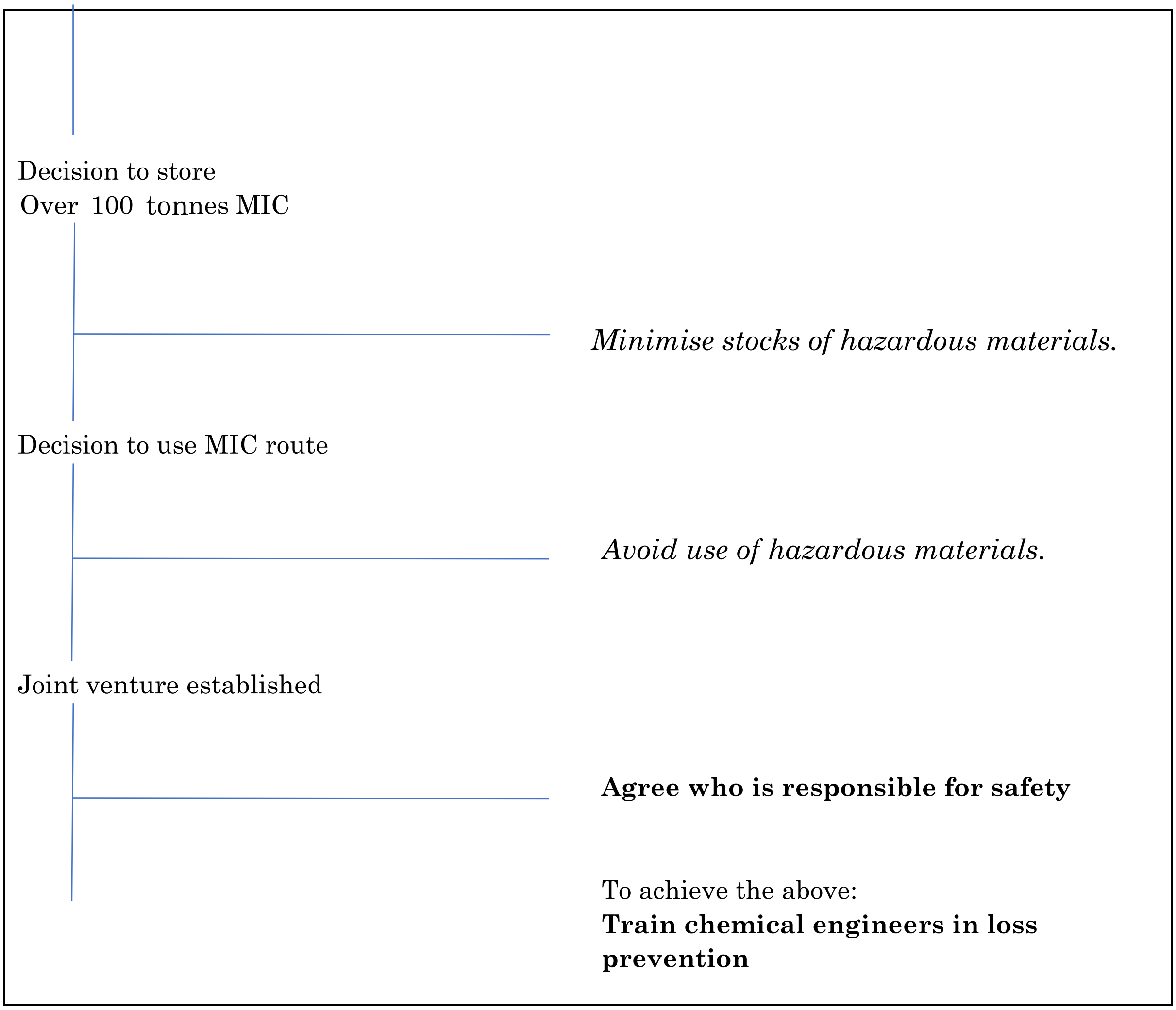
[21] Kletz, 2000, p. 80.
[22] Kletz, 2003, p. 212.
[23] Kletz, 2003, p. 212.
[24] Kletz, 2003, p. 212
[25] Kletz, 2003, p. 211.
[26] Kletz, 2003, p. 212.
[27] Kletz, 1988, 1998, 2003.

Figure Two: A Man Injured by an overhanging bucket. From Kletz 1988, p. 19.

Event	**Recommendations for prevention/mitigation** 1st layer: Immediate technical recommendations *2nd layer: Avoiding the hazard* **3rd layer: Improving the management system**
Man injured	
	Do not let people work beneath heavy suspended equipment (or be exposed to other potential energy risks).
Lid fell off mixer	
	Inspect regularly—treat as pressure vessel or lifting gear.
Cracks appeared in lid	
	Check that maintenance standards have been followed.
Lid repaired	
	Specify maintenance standards.
Lid modified	
	Before modifying equipment, carry out systematic search for unforeseen consequences and authorize at management level.

Figure Three: Reconstruction of events of the Bhopal Disaster. From Kletz 1988, p.118.

Event	**Recommendations for prevention/mitigation** 1st layer: Immediate technical recommendations *2nd layer: Avoiding the hazard* **3rd layer: Improving the management system**
Public concern compelled other companies to improve standards	
	Provide information that will help public keep risks in perspective.
Emergency not handled well	
	Provide and practise emergency plans.
About 2000 people killed	
	Control building near major hazards.
Scrubber not in full working order Flare stack out of use Both may have been too small	
	Keep protective equipment in working order. Size for foreseeable conditions.
Discharge from relief valve	
Refrigeration system out of use.	
	Train operators not to ignore unusual readings.



The linear sequence of actions pertaining to a given accident becomes less generally applicable the further up the schema you go: its top levels pertain to the specific conditions and possibilities once the conditions for a problem to occur are already in place. Kletz summarises his reasoning as follows: "Often, accident reports identify only a single cause, though many people, from the designers, down to the last link in the chain, the mechanic who broke the wrong joint or the operator who closed the wrong valve, had an opportunity to prevent the accident. The single cause identified is usually this last link in the chain of events that led to the accident."[28] This approach resembles Rasmussen's in refusing to dwell on the proximate cause of accidents, but does not treat different organisational levels as distinct. Instead, every action and decision is presented as directly implicated in the possibility of an accident.

Figure two shows how Kletz uses this presentation to structure his reconstruction of accidents. On the top layer, it places immediate agency to prevent accidents on decisions about the locations of front-line workers; they should not, in the first instance,

[28] Kletz, 2003, p 204.

be working in a place where something might fall on them. Each section of the sequence is also summarised initially in terms of a past historical non-verb: man injured / lid repaired / lid modified: it is these actions which are the primary unit of analysis, rather than the institutions with responsibilities for issuing and enforcing strategies, policies and so on. Each layer is also accompanied by recommendations, which pertain to either avoidance of hazards or alternative management policies. The events and their associated recommendations do not become more general or systemic as the sequence descends— rather they are intended to indicate how vigilant regulation and maintenance should operate at each stage of working, from (re-)design to shop-floor practice. The left hand side of the schema provides a list of problem events and activities, to which the more general right hand side is meant to provide a solution. More upstream problems, which can be solved on the level of design, appear further down the diagram, but all of the right hand side proposals are offered as examples of good practice, which may become necessary if this precautionary work has not occurred.

Kletz uses the same format to identify appropriate responses to much more serious disasters. Figure three shows his schematic description of the causes of the Bhopal disaster of 1984, recognised as among the worst accidents to have occurred within the chemical industry. On the 2-3 December 1984, a leak occurred at a plant whose ultimate owner was the American company Union Carbide. The plant produced pesticides using methyl isocyanate as an intermediate; safety systems failed, and a large number of people were killed as a result of exposure to the gas. As with the simple case of the bucket which has caused injury, the recommendations at each stage are simple and based on a sequence of actions, though these are slightly more complex and involve a greater range of interacting entities than the noun-verb combinations in the bucket example. Kletz presents the origin of the accident as the decision to establish a joint venture without also deciding responsibility for safety, followed by the selection of a hazardous production procedure. Working up the chain, a series of plant failures are described: operators appear as undertrained in response to anomalous readings, and as having to deal with poorly maintained safety equipment; at the top, after the accident has occurred his recommendation is for a PR campaign to present disasters of this kind as anomalous within the chemical industry—the public are to be taught to keep "risks in perspective." This chain of events is more involved than the sequence involving the bucket, but it also adopts the perspective of industry, and situates Kletz within that perspective. His role as a safety engineer is to construct a version of industry where risks such as those which fed into Bhopal are minimised; this means implementing design principles which reduce the conditions of possibility in which accidents could occur are not present. This design philosophy, which Kletz sought to publicise, was called "inherent safety", summarised in the slogan "what you don't have, can't leak". Kletz wanted to establish this as the underlying cause of accidents, and wrote against what he perceived as resistance to this claim:

> Designers today often consider inherently safer options but the authors of incident reports do so less often. The very simplicity of the idea seems to make it hard for some people to grasp it. Perhaps they are expecting something more complex or— and this is perhaps more likely—it goes against the widely accepted belief that accidents are someone's fault and the job of the investigation is to find out whose. Having identified the culprit, we are less likely to blame him or her than in the past; we realize that he or she may not have been adequately trained or instructed, and that everyone makes occasional slips, but nevertheless his or her action or inaction caused the incident. In some companies, they blame a piece of equipment. It is hard for some people to accept that the incident is the result of a widespread and generally accepted practice in design and operation.[29]

The top level of the narrative (about controlling public concern) is thus meant to validate the claims of the lower levels, and the views of the safety expert: industry can, in this view, prevent the belief that it is risky by emphasising how well-developed and clearly explicable its safety procedures are. Notable for their absence from this schema are any concern with environmental hazards, or a sense of how common poor safety practice was within the twentieth century chemical industry. Indeed, Kletz always wrote about poor safety as if it was anomalous, emerging from poor corporate practice and an increasingly adversarial approach towards risk which discouraged information-sharing between different companies.

Where Rasmussen's tool defines organisations as systems, Kletz was much more immersed in the narratives which he read and wrote. Kletz's schemes provide specific narratives and the possibility of different turning points within them, whereas Rasmussen's schemata track the organisational levels which should be seen as contributing to a given accident. With less narrative distance, Kletz's readings of reports grew out of his sense of how managers and investigators should behave, and he evaluated some of their judgments about how failures had occurred against this standard. challenged some reports on the basis that they lacked an understanding of how supervisors seriously concerned with safety should behave—behaviour which he

[29] Kletz, 2003, p. 65.

modelled on his own professional persona, hands-on and curious. Of one report involving an overhanging bucket he remarked that

> [t]he report blamed poor communication. The shift foreman's note in his log and in the job list did not draw attention to the fact that the temporary work method was hazardous and so the job got the priority given to an inconvenience, not a hazard. However, this is not very convincing. The unit manager, the other shift foremen, the fillers and the safety representative, if there was one, should have spoken to the maintenance team and drawn attention to the hazard. In a well-run organization, written messages are for confirmation, precision, and recording; things get done by talking to the people who will have to do the work, asking them, persuading them, sweethearting them, call it what you will.[30]

Kletz also claimed that reading and compilation of accident reports could lead to the discovery of unexpected phenomena. He remarked that in preparing the index for one of his books, he was "surprised to find that certain words appeared, often as secondary or incidental causes, much more often than I expected. I expected to find (and did find) frequent references to fires, explosion, pumps, tanks, modifications and maintenance, but was surprised how many references there were to rust, insulation and brittle failure."[31] His later books were organised according to these phenomena, placing particular emphasis on those which were often overlooked. Little sequences of action abstracted from larger reports served to illustrate how rust, insulation, static electricity and the like could cause very serious problems. Kletz strives to exemplify likely causes of problems with eye-catching little narratives about problem solving, occasionally ranging outside the accident prevention literature to quote incidents from memoirs. In his final book, *Still Going Wrong,* he discusses a short passage from the scientist and inventor James Lovelock's autobiography, *Homage to Gaia*, where Lovelock realises while working for a firm of consultant chemists that errors have arisen from a simple failure to understand the dimensions of a bucket. As Kletz summarises Lovelock's little narrative:

> There had been a sudden deterioriation in the quality of the gelatine used for photographic film, and he and another chemist were sent to visit the manufacturers. They asked the foreman if anything had changed. He replied that

[30] Kletz 2003, p. 42.
[31] Kletz, 2003, p .76.

nothing had changed; everything was exactly as before. Lovelock's colleague noticed a rusty bucket next to one of the vessels and asked what it was for. The foreman said that a bucketful of hydrogen peroxide was added to each batch of gelatine but as the bucket was rusty he had bought a new one the previous week. "We soon solved the firm's problem when we found that the new bucket was twice the volume of the old one." Its linear dimensions were only 25% greater but the foreman had not realized that this doubled the volume.[32]

The failure to understand the effects of the change in the bucket's dimension is a blunder, but in Kletz's telling the foreman is not passive, and the moral of the story is to pay attention to apparently minor changes which can contribute to larger problems—which could be learned by someone in the position of the foreman or a technical consultant like Lovelock.

The sense that investigators like Kletz legitimate industry's claims to have made things safe underpins a more critical method of reading and retelling accident reports, best exemplified by the work of the sociologist Charles Perrow, especially his 1982 book *Normal Accidents.* Focusing chiefly on the nuclear industry, Perrow emphasises that in complex and 'tightly coupled' technological systems, routine accidents are inevitable, and likely to lead to disastrous consequences. Perrow defines tight coupling as follows: systems in which "processes happen very fast and can't be turned off, the failed parts cannot be isolated from other parts, or there is no other way to keep the production going safely" with the result that "recovery from the initial disturbance is not possible; it will spread quickly and irretrievably for at least some time. Indeed, operator action or the safety systems may make it worse, since for a time it is not known what the problem really is".[33] Unlike Kletz's broken-down sequences, the point of highly coupled interactions is that they cannot be grasped as individual parts, and proceed uncontrollably. Where Rasmussen locates complexity within the interacting levels of an organisation, and Kletz attempts to produce a linear sequence of actions and plausible precautionary interventions leading back to principles of design, Perrow thinks that serious accidents emerge unpredictably and inevitably from trivial causes.

One way in which Perrow demonstrates the chronicity of runaway risks arising from small beginnings is by retelling and interpreting accident reports from the journal *Nuclear Safety*. Of this journal he writes that "one of its regular features is a compilation of safety-related occurrences, selected by the editor and briefly described. Though technical, they provide endless, numbing fascination as they describe all the things that

[32] Kletz, 2003, pps. 33-4
[33] Perrow, 1999, [1984], p. 4.

can go wrong in these awesome plants."[34] Perrow enjoins his readers not to pay attention to the details of these narratives, but rather to attend to the habitual lack of care in nuclear power plants, and how small problems can turn into big ones, avoiding catastrophe only by good fortune. The technicalities of the narratives do not unpack the social assumptions about the decisions which went into designing the nuclear powerplant; instead their detail is supposed to be alarming, to show how many uncontrolled and unrecognised variables even routine operation of a nuclear plant involves, and how little knowledge operators possess of how the plant is working. In Perrow's readings of these narratives the causal sequences identified by investigators are less important than the possibility of unexpected runaway interactions, and operators play a mainly passive, if not harmful, role; they are not protagonists whose actions avert worse disasters, but rather a workforce unable to deal with the complexity of their working environments. Here is how Perrow retells one of the reports from *Nuclear Safety*:

> A small, early BWR reactor at Humboldt Bay, California, (Pacific Gas and Electric) lost its offsite power source on July 17, 1970, and scammed, as designed. The emergency power supply came on, but it was not designed to provide power to the particular sensors that turned out to be needed. Reactor pressure rose, but the emergency condenser, which would reduce it, did not come on because the gate on the switch stuck in the guides, probably as a result of a poor setting on a valve. The operators knew the emergency condensor did not operate, but assumed that a safety valve had opened to reduce pressure. Instead, a different safety valve opened, and, due to coolant shrink from its discharge, a low water level signal came on. This, combined with loss of feedwater and an increase in dry-well pressure, opened the reactor vent system. Meanwhile, a pipe joint ruptured in the safety valve discharge line. The vent valves were open for four minutes before the operators discovered them. There was no indication of a rupture, so they closed them. Then the fire pumps started automatically, indicating excessive pressure in the reactor, low water level, high pressure in the dry well, and loss of power to some safety systems. The accident was successfully contained, but the pressure in the reactor had exceeded safety levels; 24,000 pounds of reactor water was "blown down" (forced out of the core), indicating that the top of the fuel rods in the core were in danger of being uncovered.[35]

[34] Perrow, 1999 [1984], p. 46.
[35] Perrow 1999, [1984], p. 47, retelling Castro, 1971.

Perrow claims that this accident, in itself, is unremarkable; what is extraordinary is the journal's evaluation of the narrative--that it shows the effectiveness of safeguards, and the reasons it has such a good safety record. One could easily imagine how Kletz might diagram this sequence of events, treating each problem as a possible intervention for plant design, operator training, or other kinds of precautionary activity. Perrow, by contrast, wants to show each small failure is a loose end which could lead to more significant problems: even in this case, where there was no disaster, multiple mistakes were made and the building problem was hidden from view for a considerable period of time.

In subsequent chapters, Perrow discusses other industries which also display a tendency towards normal system accidents, but where the consequences seem not to be as catastrophic as the nuclear industry. One of these is chemical plants. Perrow notes that in general the chemical industry is exceptionally safe, at least as regards deaths and injuries among its workforce (he does not discuss pollution or other hazards) but also notes that ordinary accidents continue to occur, and their extent is often unknown, especially in the United States. He contrasts this with the comparatively more open culture around accident reporting which exists in Europe; citing narratives by Kletz among other investigators as evidence of this difference between national cultures.

This section has examined three approaches to the construction of accident narratives: Rasmussen's interacting organisational levels; Kletz's linear sequences; and Perrow's view of runaway risk. In each case, narratives are shaped and interpreted according to a larger understanding of how accidents are caused and what can be done about it—trying to take a step back beyond proximate causes to examine institutional conditions of possibility; emphasising principles of inherent safety and reduction of hazards; and demonstrating the inescapability of potentially catastrophic risks. Susan Walsh and Stephen Shipley have recently argued that complex systems present a limit case for narrative: while narratives can pick out individual sequences of events emerging from such systems, they argue, the underlying dynamics of the system cannot be given in narrative form.[36] Perrow and Rasmussen grapple with versions of this problem: Perrow, because he is convinced that lessons cannot be learned from single narratives where accidents have been prevented in tightly-coupled systems, on the grounds that no past sequence of events can anticipate runaway consequences. Kletz meanwhile, appeals to simplification, a reduction in the number of possibly interacting parts accompanied by clear observation within the chemical plants as a way to cut through some of the

[36] Walsh and Stepney, 2018.

insuperable risks associated with chemicals and the plants where they are produced. His narratives aim to pick out causal sequences where a series of interventions, leading back to the original principles of design, can be clearly specified.

I now want to look at a slightly different kind of breakdown narrative, which is widely used in STS scholarship. In these narratives, a conventional and usually abstract or codified picture of scientific or technical knowledge or practice is contrasted with a narrative of the STS investigator's own observations of and interactions with such activity. The narrative shows the inadequacy of the conventional presentation, but also substitutes in its place a more processual, relational account of knowledge and practice in the making.

3. Breakdown Narratives in STS

The term narrative is widely used within STS, though it is rarely a topic of theoretical or methodological discussion.[37] To give a few examples: scholars have reflected on the ways in which controversial field science becomes enmeshed in widely circulated claims about human origins; reflect on the relations between cosmologists' claims about histories of nature, their accounts of their experimental methods, and how both "ontological" and "epistemic" narratives are refracted through existing visions of eschatology; they talk about the narratives which scientists tell of their own professional formation, and their own practices in constructing narratives as ethnographic observers of scientific sites.[38] I am going to focus on the third type of narrative.

Self-consciousness and reflexivity about the role of the investigator and how she relates to her research subjects are cornerstones of ethnographic writing, even where this does not draw directly on narrative models from other domains.[39] What distinguishes many STS accounts is that they dwell on the study of controversies, or periods of negotiation before the meaning of scientific and technical concepts becomes fixed. Scholars arguing from a wide range of theoretical perspectives share a sense that

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[37] To take two journals from the field: 'narrative' occurs in 397 articles which have appeared in *Science, Technology and Human Values*, compared to 1857 which use the word 'technology' and 1959 which use the word 'science'; it occurs in 375 articles from *Social Studies of Science*, compared to 1975 articles which contain the word 'science', and 1174 with the word 'technology'. Of course most of these meanings are not technical, and do not represent the main focus of the article in question. But although the term 'narrative' appears in the third edition of the *Handbook of Science and Technology Studies* forty times, each occurs only in passing and does not provide a main analytic focus.

[38] Rees, 2001; Mellor, 2007; Mellor, 2016; Traweek, 1982.

[39] Bruner, 1997.

there is a moment before the meanings of scientific and technological entities becomes fixed, which is useful for analysts because it reveals considerations—uncertainties, situational details, interpersonal and political dynamics—which will be more difficult to trace when knowledge has become accepted. In Karin Knorr-Cetina's evocative phrase, "once knowledge has 'set' (once it is accepted as true), it is as hard to unravel as concrete."[40]

Even where STS analysts are not studying obviously controversial knowledge, they often juxtapose their observations to conventional depictions of science: those which can be found in textbooks or scientific papers, for example. Through direct observation and personal interaction with scientists, the STS analyst can show that in practice science is unlike these idealised images. And a narrative, because it can combine heterogeneous elements and contingencies that may be excluded from more static, idealised picture, can serve as a different picture of knowledge in the past and present, more attuned to interpersonal dynamics between scientists, the specificities of interaction with materials and measuring instruments, and the wider historical and institutional contexts in which science occurs. It is in this sense that works STS may take the form of breakdown narratives: not (only) by responding to explicit failure, but by showing in detail how other pictures of science fall short of giving a faithful picture of how science is actually practiced. If STS is positioned against existing pictures of scientific activity, this raises the question of what would happen if scientists incorporated STS analyses into their own understandings of their practices; if they could learn from STS in a manner analogous to the lessons which are supposed to be drawn from accident reports. Polemics on this subject are notorious—stereotypically, natural scientists argue that they do not recognise the picture of their work found in STS reconstructions. But many individual works of STS discuss scientists' engagements with descriptions of their own activities, and the efforts of STS researchers to do justice to their research subjects' own understandings of their activities, as well as reflexive discussions about their own interactions with the researchers whom they study.[41] These careful reflections aim to indicate that STS is not, only, an intrusive presence from outside.

In their most affirmative moments, some STS scholars claim that if conditions change radically, their re-descriptions of science will be generally accepted, including by natural scientists themselves. Just as an accident lifts the lid on technical decision making, compelling engineers to ask and answer questions more commonly associated

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[40] Knorr Cetina, 1995, p. 140.
[41] For example, Collins 2005; Traweek 1982.

with sociologists, conditions of crisis are supposed to lead to a shift in the vocabulary and self-understanding of scientists which will allow the findings of STS to have their day. Here, for example, Bruno Latour argues that the collapse in distinctions between nature and culture for which he has often argued will be (and to an extent, are already) accepted as a result of catastrophic climate change:

> For years, my colleagues and I tried to come to grips with [the] intrusion of nature and the sciences into politics; we developed a number of methods for following and even mapping ecological controversies. But all this specialized work never succeeded in shaking the certainties of those who continued to imagine a social world without objects set off against a natural world without humans – and without scientists seeking to know that world. While we were trying to unravel some of the knots of epistemology and sociology, the whole edifice that had distributed the functions of these fields was falling to the ground—or, rather, was falling, literally, back down to Earth. We were still discussing possible links between humans and nonhumans, while in the meantime scientists were inventing a multitude of ways to talk about the same thing, but on a completely different scale […] my original discipline, science studies, finds itself reinforced today by the widely accepted understanding that the old constitution, the one that distributed powers between science and politics, has become obsolete.[42]

The form of this claim is *apocalyptic*: in the future, truths which are presently restricted to some communities and some locations will be widely recognised. Whatever one makes of this view—I admit that I am sceptical—it represents one horizon for the claim that breakdown can lead to breakthrough, for new conceptualisations which are considered marginal in the existing dispensation. But note how little this has to do with any specific sequence of events, akin to the accidents narrated by Kletz: it pertains to big general transitions, not the lessons which might be learned from a single destructive episode. As such, in this phase of Latour's work, the specificities of narrative ordering are less significant than the sense of widespread change.

The narratives which I want to consider in detail are quieter and more restricted in scope than Latour's vision of the general triumph of STS' formerly restricted findings.

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[42] Latour, 2017, p. 3. Latour's claims can also be likened to the debate within Environmental Humanities about the adoption of realist and apocalyptic modes for depicting environmental catastrophe. Those in favour of realist approaches argue that they do not dramatize or inflate what are already serious crises; those who support apocalyptic discourses argue that realism forecloses what may be possible in the future, and extends the inequities of the present into the future. Latour thinks radical change will allow new homes for new terms. On this, see Hurley, 2017.

Rather than proclaiming a new conceptual language, they are closely attached to specific settings and the provisional, negotiated roles which investigators can play within these, the different picture which they can provide through careful narration of their embodied, specific experiences. I will give three examples: Harry Collins' apprenticeship narratives; Natasha Myers' enacted metaphors; and Lucy Suchman's human-machine conversation analyses.

Collins has conducted participant observations in scientific settings since the early 1970s. One method often found in his work is a contrast between some abstract or codified knowledge and his personal observations and experiences of scientific work. One of his goals has been to demonstrate the indispensably interpersonal character of the transmission of scientific knowledge—how knowledge construction involves the application of rules and procedures which can be discussed at length, but which cannot be generalised completely. Narrative is thus a helpful mode for Collins, because it allows him to present a sequence of decision-making and rule-application in detail, without assuming that such a sequence can be generalised beyond a specific occasion.

Collins' 1990 book *Artificial Experts* describes an experiment in tacit knowledge, which involves a comparison between his own attempts to learn to grow semi-conductor crystals in the laboratory, and an expert system based on the published literature and knowledge elicitation from established practitioners. The expert system is at first constructed by Rodney Green, from Bath University's School of Management, and the experiment is designed to separate Collins' hands-on apprenticeship from Green's elicitation as far as possible. Green is "allowed only one initial tour of the laboratory. Thereafter all his interchanges with Draper [the technician from the university's physics department] took place in his office. He was able to read and talk about crystal growing but not to see the process in action."[43] Green's questions to Draper are constrained by his reading of textbook accounts, with the result that a technique (crystal pulling), which is not used in Bath, becomes a major focus of their discussion. This, Collins observes, is the problem of knowledge elicitation: "There is too much respect for theorized, textbook knowledge, and this made it hard for Green and Draper to talk of practicalities. *Talk* about procedures is far greater in volume and content than program rules or text and far more revealing of doubts, qualificiations and uncertainties."[44] As Green and Draper continue to speak, Draper's descriptions "ramify": "the field of crystal growing unfolds again and again as one tries to articulate everything. […] Green's struggle was to reduce this cornucopia of particulars into some general rules. It turned out that for the system

[43] Collins, 1990, p. 152.
[44] Collins, 1990, p. 152.

to be useful the overarching schematization of the textbook was not the appropriate starting point—rather, we needed a more detailed description of the narrow areas of expertise available in the Bath laboratory. But even these narrow areas threatened to become unmanageable as the interviews progressed."[45]

Collins then moves on to narrate his own apprenticeship in crystal-growing. Here the framework is not about what would be done in all situations, but the specific interactions between Collins and Draper in Bath (and subsequently other masters, including a graduate student), given the materials which they have available. Here is an excerpt from their sessions:

> I ask permission to load the bismuth myself. This is my first practical experience in the art of crystal growing—putting bismuth shot into an ampule. There is no textbook that tells one how to do this.
>
> Draper makes sarcastic comments as I do my best but the pieces of bismuth shot continually miss the ampule and fall noisily onto the paper placed beneath. (The sound is nicely captured on my tape recorder.)
>
> **Draper:** One in, three out, so far. Ten percent. Up to forty percent [and so forth]…[and then, sarcastically quoting into the tape recorder:] 'Harry is now scraping together the results of our combined first attempts and we'll see whether the percentage gets better as he perfects the art…One thing he didn't notice when he was commenting on how I was doing it was that I actually had one finger touching the top of the tube so that when you actually vibrated the hand just by tapping it you didn't actually vibrate it very much and so there was a sort of relationship between the top of the ampule and the boat and this because of a finger that he hadn't noticed actually. That's right. Now he's adopted that style and the results are much better—ten percent loss rather than ten percent going in. Just a little thing like that makes all—'
>
> Here then, we have another insight into the science and art of crystal growing. I have partially described what is involved in putting the substances into the ampule. Look at the length of this description—and it is a description of a part of crystal growing that does not appear anywhere in textbooks or in conceivable expert systems. Resting one's finger on the ampule as you vibrate one hand with

[45] Collins, 1990, p. 153.

the other is the crucial technique! Why is it nowhere mentioned? After all, the fact is that if you cannot do it, you cannot grow crystals.[46]

Decanting the bismuth is one example of the kind of thing which tends to be excluded from codified accounts; but if all textbooks featured lengthy passages on decanting, there would still be other practical details, based on situational judgment, which they missed. Draper possesses this judgment and can guide the ingenuous Collins: once Collins has acquired even a measure of expertise, as a combination of theoretical knowledge and practical sense about how to apply it in specific situations, it becomes increasingly difficult to narrate it in the abstract, away from the specific task at hand. As he puts it, "two opposite effects began to unfold as I worked in the laboratory. On the one hand, if I try to describe my experience in detail, the description becomes more and more ramified; on the other hand, the process of crystal growing becomes demystified and simplified as it is encountered. The actual common sense as it becomes *my* common sense, gets simpler and simpler—less and less forbidding and mysterious—and, of course, less and less visible."[47]

Narration in this mode is thus possible only in the early stages of acquiring a new skill; the belief that specific sequences of mistakes and learning can be picked out in the abstract is a function of immaturity. There is thus no sense of the narratives which might be important for mature practitioners; the point of the apprenticeship narrative is to break down assumptions about codification on the basis of published literature, and to affirm the kinds of social dynamics on which apprenticeship depends. Although Collins as narrator plays a very active role in the depiction of crystal-growing, he does not reflect on the social dynamics in a broader sense—such as the role of class, gender, or ethnicity on the interaction between Draper and himself, nor about the stories which are told by experienced practitioners. The point is to show how codified knowledge falls short, and to foreground the dynamic of apprenticeship. The apprentice-narrator's distinct, specifying, voice disappears as it learns how to say too much.

Natasha Myers' 2015 laboratory ethnography *Rendering Life Molecular*, by contrast, offers a "tactical, aspirational account", which aims to challenge pictures of the life sciences which assimilates them too readily to instrumentalising agendas, especially their use for biotechnologies. Myers argues that even critical accounts of instrumentalization accept that it is the chief factor in life science laboratories, which ignores the importance of other kinds of knowledge, and so obscures aspects of scientific labour which are resistant to these pressures. She pays a lot of attention to the gestural

[46] Collins, 1990, pps. 160-1.
[47] Collins, 1990, p. 178.

knowledge of the scientists she studies, the ways in which they perform the structures of crystals as a kind of dance—acknowledging that this is a "selective amplification", whose aim is to give a picture of science as a bodily and relational activity which can be likened to dance.

Part of Myers' method is to take reductive claims about science and to show the work which, in practice, their achievement involves. Unlike Collins, she does not depict herself as learning skills in the lab; instead she combines detailed portraits of individual research subjects which incorporate biographical details, showing how their formations have contributed to their distinct perspectives on laboratory work and what it involves. In the fourth chapter of the book, Myers discusses the metaphor that molecular life should be considered in mechanistic terms. Working against the assumption that this claim is just reductive, she draws out the specific skills and life experience needed to acquire a 'feeling for machines', on which the metaphor relies. She gives a brief biographical sketch of one of the 5th year PhD students in the lab, Fernando, who is successful in handling the mechanical metaphor:

> Machine analogies are not just pedagogical devices for Fernando. He likes to use the metaphor in part because he has a particularly nuanced feel for machines and their parts. He is a latecomer to science, and at forty, he is significantly older than most of the graduate students in his cohort. He grew up in a working-class Hispanic family and spent his twenties working as a plumber and manual laborer, and he took much pleasure in building cars. He later went back to school and eventually started teaching computer-aided design (CAD) to architecture and engineering students at a community college.[48]

As well as giving Fernando's biographical details, Myers quotes from an interview with him in which he attempts to show her the validity of comparing molecules to machines. Foregrounding the intensity of this encounter, and presenting Fernando's views as a monologue, Myers individuates him within the laboratory, and encourages the reader to follow the gestural and experiential specificity which contribute to his views:

> So you know, you are talking about the machine that screws in the fender at the Ford car plant. We're studying that machine because we are trying to find out what it does. And without [the X-ray crystal] structure we are just feeling it, just tentatively, sometimes with big thermal gloves. So we can't really get to feel the

[48] Myers 2015, p. 175.

> intricacies or the nuances of the drill bits. And all of a sudden crystallography is a snapshot of the machine. Okay. It [the machine] can even be in multiple states. Standing still, turned off. In a state when there is a screw being drilled into the fender. You know, it can be somewhere in between. Alright? But because we've seen a similar machine in another company, we kind of have an idea of what the machine does. We've seen the individual parts and stuff like that. I'm not going to mistake the machine for drilling for the machine for welding. Okay. What crystallography allows you to do is to say, "Hey that is a drilling machine, not a welding machine." Okay. And by looking at certain parts of the machine you can tell whether the drill bit is six inches long or two inches long or whether it has a neck that moves up and down, or whether the neck is static. That's the sort of stuff you get in a crystal structure that you don't have before.[49]

In effect, Fernando's monologue supplies the analogy which was Myers' starting point. Yet through biographical details (the Ford car plant), a rapid series of comparisons which assumes shared familiarity with differences between machines, and a syntax which keeps punctuating its claims with words like 'okay', 'alright', and qualifiers like 'you know', which does not invite questions but rather assumes that his listener is following his descriptions, she animates his point of view as an active way of knowing and interacting with machines and crystallization.

Myers juxtaposes engaged discussion of machines with the challenges faced by a group of biology students who struggle to apply even basic concepts about electrical engineering. Their tutor has to give them a rudimentary tutorial, which keeps checking their understanding of even basic terms, lacking the presumptive confidence of Fernando's narration: "Current flow, resistors, converters, photodiodes, signal matching, and ground all had to be explained. Meera, who had assembled all the circuit boards herself, seemed a little surprised by how hard it was for the students to get the concepts: "'Inverters … you all know what that is? … Okay? … Does it make sense when I say current flows through a wire? … Does that make sense?'"[50] Where Fernando is definite, leading Myers and the reader through his view of the problem, these repeated questions and ellipses suggest how students may struggle with even foundational concepts—in whose absence the analogy between molecular life and electrical engineering cannot get started. As with Collins, this knowledge is incomplete in the sense that the students are still learning; Myers' evaluation of this episode involves a claim about how the students'

[49] Myers, 2015, p. 175.
[50] Myers, 2015, p. 178.

initial difficulties subsequently help them to identify the gaps in their knowledge, and the work which they have to do in enacting the mechanical metaphor. As Myers writes:

> One might expect that analogies are most useful when they draw on knowledge of a familiar realm to illuminate another, less well-known realm. The bacterial system they had been using throughout the module depended on an in-depth understanding of electrical circuits. Cellular signaling and regulation were consistently rendered as circuits in classroom lectures, yet the students did not yet have an appreciation of the full import of the appreciation of the full import of the circuit metaphor. They were not yet fluent in the proper terminology and techniques. The circuit-building exercises were, in this regard, quite productive: they were diagnostic of where students' understanding came undone; and they also offered to remedy the situation by enabling students to cultivate a feeling for these machines.[51]

The moral of this story is, then, that performance of the mechanical analogy takes work. For the students, recognising their inept grasp of the concepts of electrical engineering helps to clarify what they don't know about the bacterial system as well. Where Collins' apprenticeship narrative concludes with the ramifying sense that individual sequences of events are less and less easy to specify in the abstract, Myers offers Fernando's achieved sense of a feeling for the machine as a perspective on what it means to grasp the analogy in functional terms. This does not commit her to any claim about how the students— whose formation has been very different to Fernando's—will come to understand the analogy, or to move between the two domains of electrical engineering and cellular functioning.

Finally, I want to turn to Lucy Suchmann's *Plans and Situated Actions*, first published in 1983, who seeks to challenge pictures of mechanical agency which understand machines as carrying out pre-programmed plans. Instead, she urges a more situated view of action and interaction, where humans and non-humans are constantly responding to each other, in the manner of a structured conversation. Empirically, Suchmann's study was conducted while she was embedded in the Xerox PARC research centre, and involved in questions about the design of a smart photocopier. Against the protests of her colleagues who were engineers that users were failing to operate the copiers effectively, leading to poor performance, Suchmann suggested that the machines should be brought back to PARC. The goal of this was to encourage engineers to identify

[51] Myers, 2015, p. 178.

with outside users, and to identify problems which arose from interaction more generally rather than from the failures of ignorant outsiders.

Suchmann deploys the techniques of conversation analysis to transcribe the interactions between the machines and their human users. She summarises her findings as follows:

> human–machine communications take place at a very limited site of interchange; that is, through actions of the user that actually change the machine's state. The radical asymmetries in relative access of user and machine to contingencies of the unfolding situation profoundly limit possibilities for interactivity, at least in anything like the sense that it proceeds between persons in interaction.[52]

The focus of analysis is thus the interface between human and machine. The photocopier is responsive to users' actions, but has access to only a small range of these. For their part, the humans believe the machine's actions are predictable to a degree, but also "internally opaque", premised on design principles to which they have no access. Because of this opacity, the mysteriousness of the machine's intentions, Suchmann argues that humans are more likely to regard it as a centre of intentionality like themselves—it appears to want something from the interaction, and to the extent that it does not do exactly what they want, there is a gap between its 'wishes' and its actions.

To elicit the specific quality of individual interactions, Suchmann describes watching video-recordings of these interactions, transcribing the human decisions and what she can infer of the machines' access to their intentions using a method of her own devising, which emphasises the highly structured quality of these interactions. The sequences are gathered into what Suchmann characterises as "an exhaustive (some might even say exhausting!) explication of a collection of very specific, but, I suggest, also generic, complications in the encounter of users with an intendedly intelligent, interactive expert help system. Each of these sequences is presented through Suchmann's transcriptions, accompanied by a verbal commentary. The sequences have an order among themselves; some of the commentaries refer back to previous sequences, which have shaped the operators' interpretation of the situation. An example of one of these sequences is given in figure four.

[52] Suchmann 2007, p. 4.

Figure Four: Sequence of Human-Photocopier interactions from Suchmann 2007, p. 132.

The Users		The Machine	
Not Available to the Machine	Available to the Machine	Available to the User	Design Rationale
B: Okay, and then it'll tell us,			
okay, and:: It's got to come up with the little start thing soon. (pause)		DISPLAY 1	Selecting the procedure
Okay, we've done all that. We've made our bound copies. (pause)		DISPLAY 2	Instructions for copying a bound document: Accessing the Bound Document Aid
A: It'll go on though, I think. Won't it?			
B: I think it's gonna continue on, after it realizes that we've done all that.			

The accompanying commentary is as follows:

> In [this sequence], A and B have completed the unbound master copy of their document and have gone on to attempt to make their two-sided copies. They find that the page order in the copies is incorrect (a fault not available to the system, which has no access to the actual markings on the page), so they try again. As in [a previous sequence], for them this is a second attempt to accomplish the same job, whereas for the machine it is just another instance of the procedure. On this occasion, however, that discrepancy turns out to matter.
>
> In [the previous sequence], the system's ignorance of the relation between this attempt to make copies and the last did not matter, just because a check of the current state of the machine caused the appropriate behavior. Or, more accurately, the 'current state' of the interaction could be read as a local, technical matter independent of the embedding course of events. Here, however, a check of the

> machine's current state belies the users' intent. To appreciate what they are doing now requires that the relation between this attempt and the last is recognized, and the machine state does not capture that relation. So although both users and system are, in some sense, doing the job again, there are two different senses of what, at this particular point, it means to do so. As far as the users are concerned, they are still trying to make two-sided copies of a bound document, so they leave their job description as such. For the machine, however, the appropriate description of their current goal, having made their master copy, is two-sided copying from an unbound document. The result is that what they in effect tell the machine they are doing is not what they intend to do, and what they intend to do is not available from the current state of the world as the machine is able to see it.[53]

Each of these sequences, with its excruciatingly detailed commentary, situates the machine and its human users in a time which incorporates past states of the system, and focuses on the ways in which they misread each other's intentions. The highly structured format of the conversation analysis provides a structure in which turn-taking and response to one's interlocutor would be the norm; using this as a template, these narratives show how communication breaks down despite the best efforts of the users and the careful programming of the copier. Using these carefully composed sequences of interaction gone awry, Suchmann also makes some suggestions for alternative principles of design.

4. Conclusion: While Things Work

The juxtaposition of accident reports and STS narratives in this paper is not intended to assimilate the two—of course the aspirations and analytic intentions of inspectors and STS analysts are not the same, and attention to narrative should not paper over meaningful differences. Additionally, I do not want to claim that narrative is or should be a new agenda for STS; STS practitioners have effectively deployed narratives for a range of purposes, although they have not always reflected on the distinct epistemic contributions of narrative form. Nevertheless, I hope that reading STS narratives alongside those of practitioners may provide some grounds for comparison, and raise some unexpected questions. I think that there are three such grounds: openness vs

[53] Suchmann, 2007 p. 133.

standardisation of narratives; the role of narrators and their constructions of narrative distance, and the structuring of narratives through schemata and methods of transcription.

As noted in section three, much work in STS proceeds from the study of openness, unfinishedness, and controversy. Occasionally, STS scholars will even argue that knowledge which has become widely accepted can not be studied using their methods at all. Accident reports are privileged because of their capacity to open up decisions which had been closed down. One lesson to be drawn from detailed consideration of routine accident reports is that they are, to a considerable degree, conventionalised, devoted to presenting findings which might recur in the future along established lines. This might, at first blush, limit their utility for the type of questioning and reframing sought by STS. But the kinds of aggregation accomplished using Rasmussen's framework or Kletz's compilations—these ways of reading the social and material details of accidents, and to place them within repeatable structures—might invite the question of whether narratives from STS could also be gathered together in a similar fashion, and what the effect of this might be. Would it draw attention away from the specific affordances of different laboratories, field sites, scientific disciplines and interpersonal relations—or might it also generate suggestive hints about phenomena which cannot be detected from a single narrative by itself? How would a collection of laboratory studies look, if they were placed in a framework like Rasmussen's? Could aggregation preserve the attention to openness which is the stock in trade of much STS? Of course, any aggregation would require a degree of standardisation, in a similar manner to Kletz and Rasmussen. But the question about what kinds of things which can happen in an STS narrative, and how similar narrative patterns recur across different settings and theoretical commitments, is still I think worth asking.

Second, accident reports and STS narratives turn out to have sophisticated approaches towards the role of their narrators, and the narrative distances involved in their accounts. Rasmussen invites a view from multiple interacting levels simultaneously; Perrow, a reading and retelling of accident reports which casts doubt on the assurances of their narrators' evaluations; Kletz a picture of accident causation and prevention which places a curious, questioning style of oversight at the centre of management, investigation, and evaluation. Collins presents as an apprentice in order to reveal the shortcomings of codification and the untellability of mature expertise; Myers choreographs her research subjects to show the active and bodily work involved in enacting even austere metaphors; and Suchmann sits at the distance from her human subjects provided by a video camera and her pre-existing familiarity with the machines they try to use. Part of what distinguishes these different narratorial roles is their position as insiders or outsiders—Kletz speaks most obviously as an insider to chemical industry, while Collins' role is a complicated combination of outsider to the physics laboratory and high-status insider within the university of Bath; Perrow, most obviously, speaks as a horrified outsider, who has not been lulled by the soothing tales of industry into minimising the seriousness of everyday accidents. Many distinguished works in STS have addressed the status of their authors in relation to the scientists which they study. Thinking in terms of narrative distance generalises this question beyond the specific role of the ethnographer, to encompass a variety of other positions from which analysts might speak.

Finally, the ordering of narratives matters, both for the specific sequences which it generates and for the sense of coherence and rule-boundedness which it provides. If Suchmann had not transcribed her observations of the photocopier operators using the conventions of conversation analysis, this would have reduced the sense of orderly communication gone awry which is central to her analysis. Likewise, if Rasmussen's advice was simply to try to consider more distant factors as well as those which impinge directly on the front line—rather than the more involved and non-linear schema which he provides—the narratives produced as a result, and the interpretations offered of them, would presumably be quite different. It matters what schemas tell stories.[54]

References

Bruner, Edward M. "Ethnography as narrative." *Memory, identity, community: The idea of narrative in the human sciences* (1997): 264-280.

Castro, W. R., "Safety-Related Occurrences Reported in Oxtober-November 1970", *Nuclear Safety* 12:2 (March-April, 1971): 145.

Cetina, Karin Knorr. "Laboratory studies: The cultural approach to the study of science." *Handbook of science and technology studies* (1995): 140-167.

Durham, Frank S. "News frames as social narratives: TWA Flight 800." *Journal of Communication* 48.4 (1998): 100-117.

Flavell-White, Claudia "Trevor Kletz—A lifetime spent saving lives", *The Cehmical Engineer,* 12 Jan 2018, https://www.thechemicalengineer.com/features/cewctw-trevorkletz-a-lifetime-spent-saving-lives/, accessed 01/10/2019.

[54] Adapating Haraway, 2016's refrain—"it matters what stories tell stories".

Goffman, Irving, *Frame Analysis: An Essay on the Organization of Experience,* Harvard University Press, 1974.
Haraway, Donna J. *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press, 2016.
Hawthorn, Geoffrey *Plausible worlds : Possibility and understanding in history and the social sciences,* Cambridge University Press, 1991.
Hurley, Jessica. "Impossible Futures: Fictions of Risk in the Longue Durée." *American Literature* 89.4 (2017): 761-789.
Kletz, Trevor, *Still going wrong! : Case histories of process plant disasters and how they could have been avoided.* Amsterdam ; London: Elsevier/Gulf Professional Pub, 2003..
Kletz, Trevor. "Hazop—past and future." *Reliability Engineering & System Safety* 55.3 (1997): 263-266.
Kletz, Trevor. *By accident : A life preventing them in industry* London: PFV, 2000
Kletz, Trevor. *Learning from Accidents in Industry.* Oxford: Butterworth-Heinemann, 1988.
Labov, William and Joshua Waletzky. 1967. "Narrative analysis". Essays on the Verbal and Visual Arts, ed. J. Helm, 12-44. Seattle: U. of Washington Press.
Mellor, Felicity, "Narrating the Universe", in Ormrod, James S., and Peter Dickens, eds. *The Palgrave handbook of society, culture and outer space*. London: Palgrave MacMillan 2016, pps. 219-242.
Mellor, Felicity. "Colliding worlds: Asteroid research and the legitimization of war in space." *Social Studies of Science* 37.4 (2007): 499-531.
Morgan, Mary S., and M. Norton Wise. "Narrative science and narrative knowing. Introduction to special issue on narrative science." *Studies in History and Philosophy of Science Part A* 62 (2017): 1-5.
Perrow, Charles. *Normal accidents: Living with high risk technologies-Updated edition.* Princeton university press, 1999.
Rasmussen, Jens, "Risk management in a dynamic society: a modelling problem." *Safety science* 27.2-3 (1997): 183-213.

Reason, James. "Human error: models and management." *British Medical Journal* 320.7237 (2000): 768-770.
Rees, Amanda. "Practising infanticide, observing narrative: Controversial texts in a field science." *Social Studies of Science* 31.4 (2001): 507-531.
Rouse, Joseph. "The narrative reconstruction of science." *Inquiry* 33.2 (1990): 179-196.
Salmon, Paul M., Goode, Natassia, Lenné, Michael G., Finch, Caroline F., Cassell, Erin,

"Injury causation in the great outdoors: A systems analysis of led outdoor activity injury incidents", Accident Analysis & Prevention, 63, (2014): 111-120.

SCIE 2019, https://www.scie.org.uk/children/learningtogether/

Shen, Dan. "Why contextual and formal narratologies need each other". *Journal of Narrative Theory* 35.2 (2005): 141-171.

Sheppard, David, Raval, Anjili, Thomas, Nathalie, "Pressure Mounts on National Grid after UK Blackout", The Financial Times, 11 August 2019, https://www.ft.com/content/2db14892-bc3f-11e9-b350-db00d509634e

Sommer, Roy. "Contextualism Revisited: A Survey (and Defence) of Postcolonial and Intercultural Narratologies". *Journal of Literary Theory* 1.1 (2007): 61-79.

Stilgoe, Jack, "Machine learning, social learning and the governance of self-driving cars." *Social studies of science* 48.1 (2018): 25-56.

Todorov, Tzvetan, and Arnold Weinstein. "Structural analysis of narrative." *Novel: a forum on fiction*. Vol. 3. No. 1. Duke University Press, 1969.

Traweek. Sharon. *Beamtimes and Lifetimes. The World of High Energy Physicists*. Harvard University Press, 1988.

Uploads Project, "Rasmussen's (1997) Risk Management Framework", https://uploadsproject.org/rasmussens-1997-risk-management-framework/

Walsh, Richard, and Susan Stepney, eds. *Narrating Complexity*. Dordrecht: Springer, 2018.