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Productivity and safety:
adjustments at work in socio-technical systems

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1 Introduction

On the evening of November 10, 2009, three transmission lines of the large Itaipu Power Plant on the border of Brazil and Paraguay were knocked down. In quick succession, other components of the highly-interconnected Brazilian national grid were also disconnected (Operador Nacional do Sistema Elétrico [ONS], 2009, Nov. 11). Several states plunged into darkness from which they did not emerge until hours later.

The country's Minister of Energy initially indicated that the event had been caused by bad weather in the region (Rodrigues, 2009, Nov. 11). The President of the Republic was careful to explain that he did not wish to blame anyone before finding out what had happened and ordered a thorough investigation (Motta, 2009, Nov. 11). An expert in transmission lines argued that "in all the blackouts that have occurred in the world, there were humans doing silly things" (Ordoñez, 2009, Nov. 13).

In the aftermath of a failure, large or small, it is important to understand what caused it (Hollnagel, 2002). That understanding can then be used to determine what preventive measures should be taken to avoid recurrence. The search for the cause(s) of failure has often pointed to the human element of systems (Rasmussen, 1997) - as illustrated by the transmission lines expert who spoke of "humans doing silly things."

The participation of humans in failure causation is often reduced to the issue of procedure violation. As Rasmussen (1997, p. 187) notes, "following an accident it will be easy to find someone involved in the dynamic flow of events that has violated a formal rule by following established practice, and who is, therefore, likely to be exposed to punishment. Consequently, accidents are typically judged to be caused by 'human error'."

The same logic is applied in reverse when explaining success: the absence of failure indicates that procedures have been followed (Dekker, 2003). However, work-to-rule strikes and cases of "malicious compliance" have been documented (Vicente, 1999).

Those events clearly point to the limitation of procedures as necessary and sufficient conditions for successful operation. Indeed, successful operation can take place even in the absence of procedures; and failures can take place even when procedures have been strictly followed (Besnard & Greathead, 2003). There must be a way of explaining how either success or failure comes about that goes beyond the reductionism of "procedure followed = success" and "procedure not followed = failure."

It stands to reason that individuals are fairly predictable in the sense that one's ways of behaving and misbehaving do not fluctuate wildly. Indeed, people in general do not appear to suffer from any sort of "Dr. Jekyll and Mr. Hyde syndrome" whereby their modes of conduct at play and at work are very different or in opposition to one another. Yet, in daily life, people appear to do reasonably well without constantly referring to any procedures or rigid rules. That one often hears of people who "played by the rules" with bad results should be enough to make one wary of strict procedural compliance. An analogy with the world of fractals may be useful at this point. Fractals are geometric shapes that can be split into parts, whereby each part has the same properties as the whole. The analogy goes as follows: regardless of the activity being carried out, be it leisure driving or controlling the reactions in nuclear power plant, the properties of human behavior remain the same.[1]

1.1 A new view

In the 1980s, a new view began to gain momentum (Hollnagel & Woods, 1983; Rasmussen, 1997). This new view, the result of years of research decision making, organizational theory and safety, stresses that socio-technical systems have become so complex that complete descriptions of how they work is not possible[2]. Modern socio-technical systems are said to be underspecified. As a result of the increased

1 This analogy and its implications for safety studies were first suggested by Dr. E. Hollnagel, during an orientation session.

2 The issue is not simply that socio-technical systems have become so complex – it is that the environment in which they operate is also more complex. Global financial markets are evidence of that complexity. A good description of a system will necessarily include a good description of the environment in which it operates.

complexity of systems, procedures are always incomplete or represent only one of many ways of accomplishing a given objective.

In essence, the notion of underspecification highlights the difficulty in understanding how modern socio-technical systems – systems comprised of human/social and technical elements – actually work. As a consequence of this difficulty, procedures are incomplete: not all situations are described or are described with uneven depth. Procedures may be outdated, non-existent or inadequate. A working environment may change before its characteristics make it into procedures. New situations, which had not been envisioned before, come into being.

According to traditional Safety Management principles, success is the result of procedural compliance. However, if procedures are not ever complete because modern systems are always underspecified, how can success be explained? Everyday experience strongly suggests that systems work most of the time. Airplanes rarely crash, chemical plants rarely blow up, and most people are unlikely to ever be involved in automobile accidents (Hollnagel, 2009). In other words, success is the rule, and failure, the exception.

The answer appears to lie in the human ability to make adjustments – to bridge the gap between what must be done and what can be done with the resources at hand. Indeed, the new view suggests that work is what happens as humans perform such adjustments: "Le travail, c'est l'activité coordonnée deployée par les hommes et les femmes pour faire face à ce qui, dans une tâche utilitaire, ne peut être obtenu par la stricte exécution de l'organisation prescritre" (Dejours, 2007, p. 43). The adjustments made are generally so effective that they tend to remain invisible to workers at all levels of the organization (to the workers themselves as well as to managers). Unless an effort is made to see them as they happen, adjustments are usually only visible when they are implicated, as explanatory factors, in the occurrence of failures.

This is insufficient. As this thesis will demonstrate, adjustments are not simply causes of failure. They are, more importantly, causes of success. The "right" adjustments will contribute to work being performed in a timely and safe manner.

The “wrong” adjustments will result in failures and losses. Yet, today the focus is on failures. But should safety science, and safety management, not be concerned with how success comes about?

1.2 Success and failure: two sides of a coin

Perrow (1984) notes that “we have complex systems because we don't know how to produce the output through linear systems.” At the heart of Perrow's remark is the observation that many of the socio-technical systems of the modern world tend to increased complexity – and as a consequence, to increased underspecification. Adjustments are a response to the underspecification of systems. In systems of lesser complexity, descriptions may be more complete, and in those cases, the need for adjustments is reduced.

Purely technological systems are also able to respond to a range of situations, but that range is embedded in, and therefore limited by, the design of the system itself. As noted above, the ability to perform adjustments is essentially a human ability. However, just as the designer, the planner, or the manager of a complex socio-technical system is unable to fully understand its functioning, so is each individual human who is part of that system.

The human elements – secretaries, mechanics, drivers, painters, managers, etc. - who make up the social part of a socio-technical system also have an incomplete understanding of how the system works. The adjustments they make respond to their understanding of a local, limited, context (Woods & Cook, n. d.). Adjustments are needed because complex systems cannot be fully described. Paradoxically, they contribute to the difficulty in describing complex systems. In that sense, adjustments have the characteristic of being approximations based on the available means (time, resources, information, etc.).

The evidence of everyday experience indicates that success is common, and failure is rare. This state of affairs is only possible if an equilibrium emerges from the adjustments performed by the human actors within the socio-technical system. The approximation of one adjustment must be compensated by the approximation of a second adjustment, and so on. One may speak of socio-technical systems as being in a dynamic equilibrium. Failures are in this sense the result of a collapse in equilibrium. Given the argument that a human actor has limited understanding of the socio-technical system, this equilibrium cannot be accomplished in the absence of regularity in the behavior of the system. As von Mises (1996, p. 2) puts it, “in the course of social events there prevails a regularity of phenomena to which man must adjust his actions if he wishes to succeed.”

A brief example will help make this point clear. Consider that in a manufacturing plant, one of the many tasks which a machine operator must attend to is to check the output of the machine. At the end of the production line is another operator, who is in charge of, among other things, making a final quality check of the output. The machine operator may reasonably forego the quality checks, *on the assumption that the second operator will make the final quality checks*, and dedicate himself to his other tasks; the final quality check operator is equally justified in foregoing the checks, *on the assumption that the machine operator will have made his*. The caveat is that this arrangement will work so long as the output does not vary. The system (the manufacturing plant) will benefit from this arrangement since both operators have made themselves available to execute other tasks.[3]

The traditional approach to Safety Management emphasizes the need to constrain adjustments. The operators of the example above would likely be sanctioned for their actions and forced to make the mandatory checks. The unfortunate effect of this is that the adjustments would simply move elsewhere: to the other tasks that compete for the operators' attention. It follows that to constrain adjustments is an endeavor of limited value. It does not address the essential issue, which is that adjustments are necessary for the proper functioning of complex socio-technical systems. However, given that adjustments may result either in success (most of the time) or in failure (more rarely), it is clear that a more powerful approach is needed. This thesis

3 A complete description of the system would include all the tasks that the operators must perform. From this description, it would become apparent that the operators would be unable to perform all of those tasks with the time and resources available.

concerns precisely the development of a new approach to the management and control of adjustments, so that socio-technical systems may profit from adjustments that bring about success, and prevent adjustments that bring about failure.

1.3 Objectives

This thesis adopts the point of view that the ability to understand how complex socio-technical systems function is limited. The absence of a full understanding of the system means that the social element of the system (humans) must perform constant adjustments aimed at matching the system's resources to its multiple objectives (including the objectives of the workers themselves). Indeed, adjustments are necessary for the functioning of socio-technical systems, and therefore they should be understood in the context of success. Those adjustments are generally successful, but they may also increase risks and lead to failures. Therefore, adjustments must be properly managed in such a way that the system may accrue their benefits and avoid their drawbacks.

This thesis contributes to the understanding of adjustments by presenting a number of cases in which adjustments took place without any noticeable negative consequence in the operation of the system. These cases come from several days of observation of workers in the offshore industry in the North Sea as their performed their daily activities. On the basis of those cases, it then proposes a framework that may be used to describe the adjustments taking place in the routine operation of any given socio-technical system. The use of this framework is expected to enhance one's understanding of how workers may respond to the challenges they face, and therefore give one the opportunity to anticipate surprises and plan for the future with confidence (Woods & Cook, 2001).

1.4 Organization

The remainder of the document is organized as follows:

Chapter 2 presents the theoretical foundations of the study. The objective of this chapter is to delimit the area of interest of the thesis – a complex socio-technical system at work. It introduces the issue of adjustment and describes how the issue is addressed according both to traditional and new approaches to Safety Management. The traditional approach emphasizes a separation between safety and productivity, and supports the idea that adjustments must be constrained.

The new approach, based on the principles of Resilience Engineering – argues that safety cannot be dissociated from productivity: otherwise, the safest system is one that is not involved in any activity whatsoever (in this echoing the words of von Mises & Greaves, 2006) according to which a perfect world is a world of non-action). The Resilience Engineering view therefore emphasizes the need to understand how adjustments are made and what their consequences may be, rather than uniformly attacking them as accident mechanisms.

Chapter 3 presents the method used to collect data, namely the unaided observation of several crews working aboard natural gas production platforms in the North Sea It follows a "natural history" approach aimed at the production of a corpus of cases (Woods & Hollnagel, 2006). The reliability of the data, as well as ethical issues relative to their use, is then considered. The working environment of the platforms visited is described using a set of descriptors of complex systems (Vicente, 1999). Finally, the organizational structure of the platforms is presented.

Chapter 4 presents adjustments made by 1) Operators, 2) Mechanics, and 3) Electricians and Instrumentation Technicians (E & I Technicians). These adjustments are contextualized as stories of normal operation. The stories portray routine situations that offshore workers face at work. These situations are handled in such a way that potential negative consequences are avoided. Indeed, a central feature of all the stories presented is that *they end well*. These stories are in striking contrast to most of what is seen in the safety science literature, which almost uniformly focuses on stories that in one way or another, *end badly*. Therefore, the stories should be seen, in themselves, as a significant contribution to the study of safety in socio-technical systems.

Chapter 5 presents a functional synthesis of the data collected. This synthesis consists of identification and discussion, of the main themes that cut across the stories of the preceding chapter. It is a first layer of analysis aimed at rendering visible the issues that affect offshore work – and to a large extent, work in general.

Chapter 6 brings the threads together. Adjustments were seen in three groups of professionals. This is taken as evidence that adjustments occur across a range of situations. From the analysis of the specific adjustments observed, it is possible to arrive at a set of common underlying factors which, on the one hand, make the adjustments necessary, and on the other hand, make the execution of those same adjustments possible. The set of underlying factors can be summarized in two grids: a grid of *objectives* and a grid of *facilitators*; those grids can be used as a framework to aid in the understanding of the phenomenon of adjustments in socio-technical systems. The chapter ends with an example of how the framework may be used in practice to explain why a certain adjustment was made.

French summary of Chapter 1

À la suite d'un échec, qu'il soit grand ou petit, il est important de comprendre ses causes (Hollnagel, 2002). Cette compréhension peut alors être utilisée pour déterminer quelles mesures préventives devraient être prises pour éviter sa reproduction. La recherche des causes de l'échec a souvent souligné la dimension humaine des systèmes (Rasmussen, 1997).

La participation de l'homme dans l'échec est souvent réduite à la question de la violation de procédures. En fait, Rasmussen (1997, p. 187) note que « following an accident it will be easy to find someone involved in the dynamic flow of events that has violated a formal rule by following established practice, and who is, therefore, likely to be exposed to punishment. Consequently, accidents are typically judged to be caused by 'human error'. »

Dans les années 1980, une nouvelle vision commence à prendre un certain essor (Hollnagel & Woods, 1983; Rasmussen, 1997). Ce nouveau point de vue, le résultat d'années de recherche sur la prise de décision, la théorie organisationnelle et la sécurité, souligne que les systèmes socio-techniques sont devenus si complexes que leur description complète n'est pas possible. En effet, Les systèmes socio-techniques modernes sont sous-spécifiées. Leurs procédures sont toujours incomplètes ou ne représentent qu'une façon parmi d'autres d'accomplir une tâche donnée. Selon les principes traditionnels de gestion de la sécurité, la réussite est le résultat du respect des procédures. Toutefois, si les procédures ne sont pas toujours complètes parce que les systèmes modernes sont sous-spécifiés, comment expliquer le succès ?

La réponse réside dans la capacité de l'homme à faire des ajustements, c'est à dire à combler le fossé entre ce qui doit être fait et ce qui peut être fait, avec les ressources disponibles. En effet, la nouvelle vision des années 1980 suggère que le travail est ce qui se passe quand les humains effectuent des ajustements (Dejours, 2007). Ceux-ci sont si efficaces qu'ils restent généralement invisibles pour les travailleurs eux-mêmes ainsi que pour les dirigeants. À moins qu'un effort soit fait pour les voir tels qu'ils se produisent, les ajustements ne sont généralement visibles que quand ils sont impliqués, en tant que facteurs d'explication, à la suite des échecs.

L'absence d'une description complète du système implique que l'élément social du système (l'homme) doit effectuer des ajustements constants visant à adapter les ressources du système à ses objectifs multiples (y compris les objectifs des travailleurs eux-mêmes). En effet, des ajustements sont nécessaires pour le bon fonctionnement des systèmes socio-techniques, et par conséquent ils devraient être compris dans le contexte de la réussite. Ces adaptations sont généralement efficaces mais peuvent également augmenter les risques et conduire à des échecs. Par conséquent, les ajustements doivent être correctement gérées de telle manière que le système puisse recueillir leurs avantages et éviter leurs inconvénients.

Cette thèse contribue à la compréhension des ajustements par la présentation d'un certain nombre de cas dans lesquels des ajustements ont eu lieu sans aucune conséquence négative notable. Ces cas proviennent de plusieurs jours d'observation des activités quotidiennes des travailleurs dans l'industrie offshore en mer du Nord. Et sur la base de ces cas, par la proposition d'un cadre qui peut être utilisé pour décrire les ajustements qui s'opèrent dans le fonctionnement de routine de tout système socio-technique. L'utilisation de ce cadre devrait permettre d'améliorer la compréhension de la manière dont les travailleurs relèvent les défis auxquels ils font face, et donc donner l'occasion d'anticiper les surprises et de planifier l'avenir avec confiance (Woods & Cook, 2001).

2 Theoretical Foundations: understanding socio-technical systems

Following the celebrated 1979 Three Mile Island accident (Woods & Cook, 1999), Perrow (1984) introduces the so-called "Normal Accident Theory." This theory suggests that accidents in socio-technical systems are inevitable, and in that sense, should be seen as "normal". According to the author, socio-technical systems can be classified along the lines of their *interactivity* and *level of coupling* (see illustration 1 below). In highly-complex, tightly-coupled systems, there are many types of accidents, but more specifically catastrophic ones, that could simply not be properly predicted and prevented. The author calls these *systemic accidents*. Normal Accident Theory argues that accidents are intrinsic to socio-technical systems and should therefore be expected to happen. In essence, the Normal Accident Theory was an eye-opener to those who, upon hearing the news of accidents elsewhere, claimed, "it could never happen here."

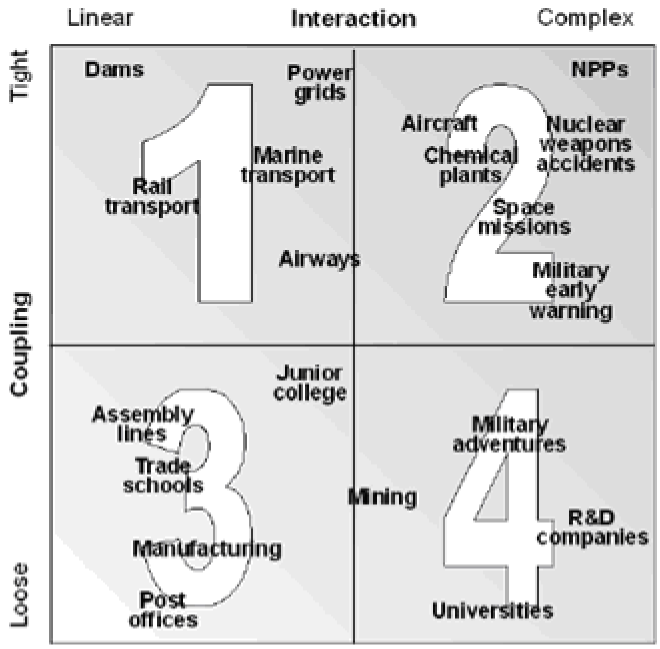

Illustration 1: Classification of socio-technical systems according to Perrow (1984), showing the dimensions of interaction and coupling.

Subsequent research sought to show how some organizations attempted to escape the predicament of normal accidents. Thus was born the "High Reliability Organizations Theory" (HRO) (Weick, 1987). This theory highlights that some factors related to the organization's adaptive abilities were responsible for successful operation under changing circumstances.

Leveson, Dulac, Marais, & Carroll (n. d.) criticize Normal Accident Theory and the High Reliability Organizations Theory on the grounds that a lack of rigor in the definition of key terms such as *complexity* and *coupling* led to flawed conclusions about safety in socio-technical organizations. The authors ask, "Does a plane crash mean that NAT is right or does the reduction of crashes over time mean that HRO is right?" (p. 2). The argument advanced by the authors is that "Accidents in particular industries are not inherently normal or non-normal – risk depends on the specific design features selected and the technical and social uncertainties involved in that particular system" (p. 5). Adopting a systems-theoretical perspective, the authors suggest that NAT and HRO did not properly address two fundamental questions: *What are systems*? and *How do systems do what they do?*

Vicente (1999) defines a System as "[a] set of interrelated elements that share a common Goal or Purpose. ... The System can be an Actor, the thing being acted on, or both." A Joint Cognitive System (JCS) is "a system that can modify its behaviour on the basis of experience so as to achieve anti-entropic ends" (Hollnagel & Woods, 2005).

The origins of Joint Cognitive Systems may be found in the thinking expressed by the Socio-technical[4] School, led primarily by the Tavistock Institute of Human Relations in England (Cooper & Foster, 1971). The Socio-technical School proposes a view of organizations that takes into consideration the relations between the internal processes of the organization and the environment, as well as the relations between those internal processes and the relations between parts of the environment.

4 The reader will notice that it is suggested here that a socio-technical system is a collection of joint cognitive systems. This is not wrong, although the Joint Cognitive Systems theory would suggest that joint cognitive systems are embedded into each other – thus making the term "socio-technical system" unnecessary. A similar term is "organization."

Organizational systems can be described according to the relationships between internal elements and the organization's environment.

A theory of JCS was born out of the recognition that man-made systems (i.e., tools) embed in themselves an element of cognition. Applying this notion to modern technological systems (notably computers), JCS theory suggests that it is insufficient to speak of the interaction between human and machine, as was then fashionable. Rather, it highlights the need for a view of systems in terms of the *joint* performance of human and machine (Hollnagel & Woods, 1983). In effect, this means that a system should not be decomposed in human and technological entities, but that the unit of investigation should be the performance of humans and machines working together toward a given end. Evidently, since a human is a cognitive agent, team work also falls under the JCS caption, even when no machine/artefact is involved. JCS can be as simple as a single shoemaker in a shop to a large corporation or society.

With respect to large systems, Vicente (1999) lists eleven dimensions of interest. These dimensions, presented below, will be used later when describing the system which provided the data used in this thesis.

Large spaces: Corresponds to the number of components of the system and the possible configurations which these components can assume, both independently and in relation to each other.

Social: Joint Cognitive Systems require the involvement of at least one human being, but there is no upper boundary.

Heterogeneity: People involved in a Joint Cognitive System may have different perspectives due to age, gender, training, experience, and so on. The heterogeneity of human beings is further discussed in section 2.3.

Distribution: Refers to the spatial distribution of the Joint Cognitive System. A system can be entirely local, when all of its components are located in a single site, such as a store considered in isolation; or remote, when its components are located in two or several sites, such as retail organization that operates stores in several cities.

Dynamics: Corresponds to the responsiveness of the system to actions taken by the workers.

Hazard: The risks involved in the activity. This involves both the likelihood of accidents and their potential severity.

Coupling: Relates to the connectedness of the components of a system. In a loosely-coupled system, events (e.g., failures) affecting one component have no or little effect on other components. In a tightly-coupled system, events affecting one component can spread to other components.

Automation: Refers to the level of human intervention needed for the functioning of the system. In systems with a low level of automation, work, both physical and mental, is carried out by humans. In highly automated systems, humans have a primarily supervisory role, and are called to action when the system approaches or enters a state for which the automate has no response algorithm.

Uncertainty: Refers to the availability of data about the functioning of the system.

Mediation: Refers to the presentation of data and how control is effectuated.

Disturbances: Refers to the disturbances that can affect the functioning of the system. Generally speaking, the more open a system is, the more exposed to disturbances it tends to be.

2.1 Tractability and Intractability

For a system to perform adequately, it must be controllable. According to Hollnagel (2009), the control of a system depends on how *tractable* it is. The notion of tractability comes as a response to the classification of systems along the lines of complexity and coupling proposed by Perrow (1984). According to Hollnagel (id.), complexity is an insufficient concept for safety. What matters is not how complex a system is, but rather, how controllable it is. Tractability is in this sense a measure of how well understood the system is, as table 1 below illustrates.

Table 1: Characteristics of tractable and intractable systems. Adapted from (Hollnagel, 2009).

	Tractable system	**Intractable system**
Number of details	Description is simple with few details	Description is elaborate with many details
Comprehensibility	Principles of functioning are known	Principles of functioning are partly unknown
Stability	System does not change while being described	System changes before description is completed
Relation to other systems	Independence	Interdependence
Controllability	High, easy to control	Low, difficult to control
Metaphor	Clockwork	Teamwork

It is worth pointing out that Hollnagel's parameters of tractability overlap with the defining characteristics of complex socio-technical systems suggested by Vicente (1999). An intractable system cannot be fully known. It follows that it is impossible both to prescribe what it should do and to predict what it will do. Moreover, intractable systems most often have a relation of interdependence with other systems (which may or may not be intractable themselves), and *variability* is the result of this relation.

2.2 Openness and Closedness of Systems

One of the key aspects of systems is that they exist in an environment. The impact of the environment in the system gives a measure of the system's openness. In fact, no system is completely closed and impervious to the environment. For practical reasons, however, the distinction between open and closed system remains useful. Reiman and Oedewald (2009) speak of organizations as open systems, and emphasize the need of an organization to be able to adapt to its environment, as well as to meet its “internal needs” (i.e., what makes the organization function) if it is to achieve long-term survival. Illustration 2 depicts an open system and its interactions with the surrounding environment.

An open system uses *inputs* (materials, energy, human, economic and information resources), which are transformed by *processes and structures* (i.e., activities) and that generate *outputs* (e.g., products and services) and outcomes (e.g., job satisfaction, safety, productivity). An open system must also have a feedback mechanism which allows it to compare intended goals and accomplished goals.

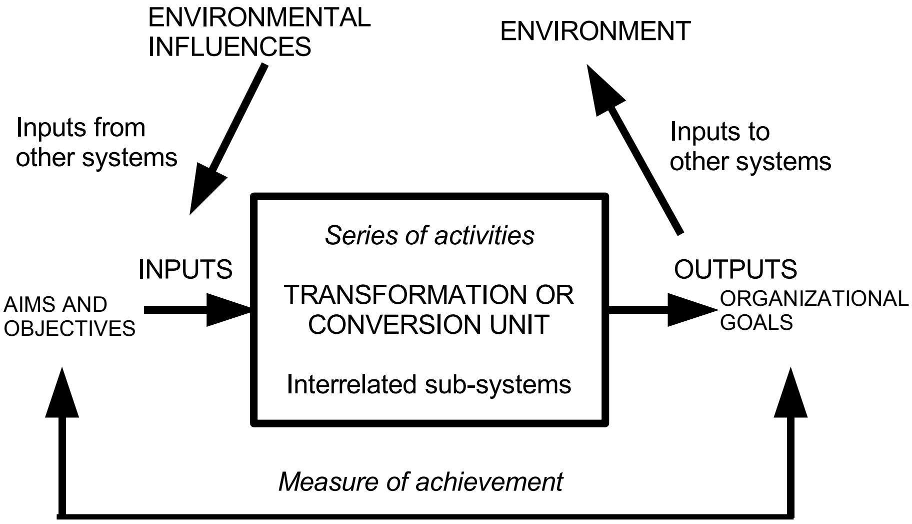

Illustration 2: An open system and its interactions with the environment. Adapted from (Reiman & Oedewald, 2009).

Vicente (1999) distinguishes between the two types of systems: "*Closed systems* are completely isolated from their environment. From the view point of the analyst, the behavior of the system can be well understood by examining influences that are internal to the system itself. Conversely, *open systems* are subject to influences (i.e., unpredictable disturbances) that are external to the system" (italics added). To this distinction it must be added that socio-technical systems are made of both technical and human components. Because humans are open systems, a socio-technical system is subject not only to influences *external* to the system, but also *internal* to it.

Finally, von Bertalanffy (2006) points out that closed systems are *entropic* systems, whereas open systems possess anti-entropic characteristics. Indeed, Wiener (1988, p. 12) drives this point home by arguing, in a philosophical tone, that "while the universe as a whole, if indeed there is a whole universe, tends to run down, there are local enclaves whose direction seems opposed to that of the universe at large and in which there is a limited and temporary tendency for organization to increase.”

2.3 Variability and the need for adjustments

Guérin, Laville, Daniellou, Duraffourg & Kerguelen (2006) speak of two types of constraints affecting work within an organization: variability of production and time. The variability of production is described as follows:

Normal variability: emerging from the nature of the work itself. A salesperson will interact with a number of clients in the course of a day. Each client is different. For example, some clients may know exactly what they want and require little assistance, while others may need the constant attention of the salesperson.

Circumstantial variability: unpredictable, discrete events. For example, consider a payroll officer who handles the workers' paychecks. When opening a file for a new employee, the officer may realize that the employee did not submit all required documents.

Furthermore, the authors affirm that the variability of production is only partially controllable, because it is itself subjected to other types of variability:

Seasonal variability: production is affected by demand and demand varies (with some regularity) throughout time cycles. At a hotel, for example, rooms may be taken over mostly by families during the holiday season and by businesspeople during the rest of the year.

Periodic variability: these result from how work is organized. At an immigration services agency, for example, half of the day may be dedicated to handling the public, and the other half, to handling paperwork (Spire, 2008).

Product/service diversity: an organization may offer a range of products/services each with different characteristics.

Raw material diversity: the raw material used within an organization may vary. For example, at a furniture making company, different types of timber and fabric may be used. Even within the same type of material, there may be differences – timber extracted from the same species of tree may have different qualities depending on where the tree grew and how old it is.

Part of the variability of production is random, and therefore less amenable to control. It may be known to occur, but difficult to predict or to avoid, for example:

Variability of demand: demand for a product or service may be uniform or entirely irregular. A hospital receives a more or less regular number of patients per day. This regularity may be disturbed by a large number of incoming victims of an accident (Cook & Nemeth, 2006).

Technical failure: the failure of a technical component (a machine, a computer, a tool...) may occur at any time. Rabardel, Carlin, Chesnais, Lang, le Joliff & Pascal (2007) briefly describe how an operator monitors the output of a machine in order to prevent failures.

Variability of material: there may be sudden changes in the material that is being worked on. In Saint Cloud, Minnesota, an accident occurred when a drilling crew attempted to break through what was later determined to be a solid slab of concrete. In trying to use force, the workers inadvertently bent the drilling bit, which then hit a nearby underground natural gas pipeline (National Transportation Safety Board, 2000).

Variability of the environment: weather conditions, a strike of transportation workers, etc.

Guérin et al. (2006) also recognize the diversity and variability of humans at work. The authors dismiss the myth of the “average man,” noticing that people have different physical, educational, cultural, etc., backgrounds that have an impact on how they execute their tasks. This diversity can be controlled only to a certain extent (e.g., requiring a specific diploma or certificate, minimum height...), but not entirely eliminated. The authors also note that the same individual “varies” due to biological factors both in the short-term (e.g., alertness during the course of a day) and in the long-term (e.g., the effects of aging). In addition to biological factors, individuals vary in their response to the environment in which they live and work: two workers may respond differently to the same event (e.g., a broken piece of machinery), or may acquire further education or professional experience, which in turn will change the way they perceive and execute their tasks.

As a general rule, socio-technical systems have limited ability to either modify or shape the environmental conditions in which they operate. Consider the case of the individual automaker which spends considerable amounts of money in marketing campaigns with the objective of enticing the consumer to acquire its products. The individual automaker has no say whatsoever neither in the advertising campaigns of its direct competitors nor in those of indirect competitors – other organizations fighting for a bite of the consumer's limited economic resources.

As a consequence of this limitation, most changes must occur at the level of the system itself. In order to survive in the market, every automaker is driven to constantly change the way it operates, so as to be a step ahead of the competition. The automaker rebuilds the production line to reduce operational costs, researches new materials to reduce material costs, and designs new auto models with exclusive features to please customers.

Embedded in a socio-technical system – whether it is an automaker, a store, a club, or in the case of this thesis, natural gas production facilities – are several joint cognitive systems that operate to realize the objectives of the system. Each joint cognitive system operates within an environment, which is given and that can be shaped only to a small degree. As a consequence, each joint cognitive system within the larger system also must perform some adjustments to accomplish its objectives.

There is a particular aspect of socio-technical systems that deserve clarification. The system itself is the environment in which joint cognitive systems operate. Consider a natural gas production platform, which constitutes a full-blown socio-technical system. Aboard, several joint cognitive systems operate to make the platform work: the cook cooks, the mechanics fix the machinery, the operators keep an eye on the processes, and so on. What each of those systems does affects the others – to varying degrees. As a consequence, performing adjustments are necessary if the platform is to run efficiently and safely.

Socio-technical systems often codify rules or procedures for responding to many common events, and to several uncommon ones as well. When joint cognitive systems abide by the rules, all joint cognitive systems are able to know what each other is doing, and nasty surprises are thereby avoided. So goes the theory.

As it turns out, except for the most simple socio-technical systems, rules hardly ever cover all possible events which can take place within it *as well* as those which arise in the environment. This has been termed *underspecification* (Hollnagel, 2009), and affects all socio-technical systems to a degree.

The underspecification of systems means that joint cognitive systems must be able to "fill in the gap" to respond to events for which there are no rules, or for which the rules do not quite match what can or must be done. As Dekker (2003) says, "work, especially that in complex, dynamic workplaces, often requires subtle, local judgments with regard to timing of subtasks, relevance, importance, prioritization and so forth" (p. 235). Given the current state of technology, it falls to the human element of the joint cognitive system to perform those "subtle, local judgments" which are at the root of adjustments.

Adjustments are then a common-place feature of socio-technical systems. Researchers as well as the practical people whose task is to design and operate such systems have therefore devoted considerable attention to understanding how adjustments actually enhance or inhibit the performance of systems.

2.3.1 Work as imagined and work as done

Central to the whole discipline of ergonomics is the question, “What do people do?” This question leads to two concepts that merit explanation : task and activity. According to Guérin et al. (2006), task is related to the anticipated results of work. In other words, what workers are expected to accomplish, both individually and as a group. When asked about their work, the authors say, workers will usually make reference to their tasks.

The concept of task is directly linked to that of work as imagined. This concept refers to how workers are expected to work. Simply, work as imagined reflects the management's idea of what should be done and how. Note here that management must be understood in a broad sense. First, in that it is external to the work environment, to the place where things get done. This externality has at least two dimensions. Managers may be removed in space (the boss's office is on a different floor, even if it is in the same building), and in time (a manager's decision remains valid until further notice). Second, in that managers are also members of the workforce (in a business environment, at least) – they are hired, they have their own tasks, and they can be fired if they do not perform well. The word “manager,” in this context, is used as a synonym to the expression “blunt end,” as suggested by Cook & O'Connor (n.d.).

This “idea” of what must be done is imposed on workers in different, and most usually complementary, ways: the physical layout of a plant, the machines and tools given to workers implicitly determine the ways in which work can be done. In addition, training, manuals and rule books explicitly tell workers how they are expected to behave. This idea of work may be internal to the organization (for example, a business plan that determines that a plant must produce so many units of a given product), but its drivers may be external as well (for example, the perceived needs of the market that serve as a basis for the writing of the business plan).

In its turn, activity refers to the enactment of tasks, that is, what workers do to accomplish them, although Daniellou (2005) suggests this notion is currently under debate, as other factors influencing what humans do are brought forward. As it happens, the definition of tasks is most often insufficient or inadequate, particularly so in the case of complex industrial processes. This is because humans' ability to comprehend the complexity of reality is limited. In very practical terms, workers must guess what is missing, adapt the tools they are given, and make decisions on their own with the knowledge they have available. The direct consequence of this human limitation is that there exists a gap between the work as imagined and the work as done. Guérin et al. (2006, p. 36) illustrate this gap through the French expressions “ce qu'on demande and ce que ça demande”, or in other words: the work as prescribed and the real work.

Daniellou (2005) argues that the concept of activity is central to the French ergonomics community. He identifies its origin, tracing it back to Soviet psychology, inputs from already-existing notions in France and comments on its development both in France and abroad.

Daniellou & Six (2000) speak of “work as imagined” in terms of instructions. These fall into two categories. The instructions that descend from the organizational structure, and are symbolized by the rule books and manuals that workers are expected to conform to[5]. The other set of instructions arise from the interaction with the world. The authors identify four sources of such ascendant instructions: matter – the physical matter that humans aim to transform through work; the living – humans are living beings and are as such constrained by the laws of biology; the psychic – the mental structure of humans, including creativity, intelligence, subjectivity and; the social – work that takes place within social settings requires coordination of activities, trust, ability to negotiate, etc. To them, the problem ergonomics faces is that the meeting of descending and ascending instructions occurs in real time, forcing workers to try to find what works and what does not. In this sense, the authors speak

5 Daniellou, Simard & Boissières (2010) distinguish *rules* (describing general principles), *procedures* (framing an operation), and *instructions* (information about a specific context). However, the authors caution that these definitions are not standardized in the field of safety. Throughout this thesis, they will be used interchangeably.

of the existence of a space where workers create their work conditions, concluding that in the end, instructions are socially constructed.

Dien (1998) discusses the use of procedures in emergency situations in the context of French nuclear power plants. According to him, procedures can be viewed from two different perspectives, that of the designers (who write the procedures) and that of the operators (who use the procedures). The author says that designers maintain a “mechanistic and static” view of operators:

- The operators' task is merely to execute the instructions presented in the procedures.
- All requirements for the application of the procedures are available to the operators.
- The individuals using procedures are conceived of in terms of an “average” level of competence.

In this way, Dien (1998) says, procedures are not intended to help the operator to control a process, but rather to control the operators themselves. From the point of view of operators, procedures constitute incomplete guidelines. Therefore , operators may:

- Face situations that are not at all addressed in procedures.
- Face the unavailability of certain requirements specified in procedures.
- Have to rely on their expertise (level of competence, know-how) to interpret the content of procedures.

Dien (1998) argues then that it is not realistic to expect operators to follow procedures to the letter at all times. Operators are often called to make up for the oversights (elements not considered), as well as to “compensate for the static aspect of the procedures” (p. 183). The author says that pushing either point of view to the extreme is impractical. Designers are unable to cover every single aspect of operation and to produce recommendations for all of them. At the same time, operators' knowledge and ability to process information are limited, so procedures cannot be entirely eliminated. The author then goes on to propose what he calls the “intelligent application of procedures” as a compromise between the two points of view. In relation to the use of procedures, he suggests “strict adherence to them as long as they are adapted to the situation, and use of initiative at times when there is a divergence between the actual situation and what is expected by the procedure” (p. 184). The author concludes by acknowledging two issues with his proposition. First, that the intelligent application of procedures require that operators be able to identify when procedures are no longer applicable to the situation. Second, that the problem cannot be solved unless the question of responsibility is addressed. In the event of an error , who is responsible, the designer, the operator, or both?

Besnard & Greathead (2003) speak of violations in the context of two accidents: the Tokaimura (Japan) criticality event and the emergency landing of a DC-10 airplane in Sioux City (USA). Following Reason, the authors define violations as “actions that intentionally break procedures, usually aiming at easing the execution of a given task” (p. 275). The authors argue that violations do not always and necessarily result in accidents. Indeed, according to them, violations may prevent accidents, particularly in degraded situations.

The first case presented is the Tokaimura criticality event. In plain words, when a certain amount of uranium is put together, a chain reaction occurs spontaneously. This amount is called critical mass. To prevent it from happening, uranium is handled in batches. In this accident, the number of batches handled at the same time was enough to initiate a chain reaction, and thus a nuclear accident. In the sequence leading to the accident, several procedures were broken. Besnard & Greathead (2003, p. 277) say that “the crew [handling the uranium batches] have a) inaccurately assessed the situation, b) developed a flawed set of actions and c) ignored the consequences of such actions.”

The second case presented is the emergency landing of a DC-10 airplane in Sioux City. The failure of a mechanical component of the engine ultimately led to the complete loss of hydraulic control of the airplane. The pilots found themselves in a situation in which they were not able to control the direction of the plane by normal means. Nevertheless, the pilots were able to devise an alternative way to control the plane and were able to land it, saving many lives. In the process, the pilots violated several flight procedures.

According to Besnard and Greathead (2003), what is at stake in both examples is not whether the Tokaimura crew or the Sioux crew violated procedures. As they explain, "when interacting with a system, humans need to understand what is currently happening and what is likely to happen next (Sarter & Woods, 1995). For this reason, they maintain a mental representation of the various ongoing and expected processes in a system. This representation is called a mental model" (p. 273). The issue then is that the representation that the Tokaimura crew had of the process it was managing did not correspond to what was really happening. On the other hand, the DC-10 pilots were able to correctly identify what the situation called for and adapted their actions accordingly . For the authors, violations can be seen as reconfigurations. In routine situations, such adaptations indicate "a need for different working practices or tools" (p. 276). In emergency situations, violations represent an attempt to recover or maintain control when established procedures are no longer adequate.

Besnard & Greathead (2003) recommend two measures to reduce the gap between procedures and real work. First, that those who elaborate procedures should acknowledge that procedures are always incomplete and therefore they should direct their efforts at making better rules, not more exhaustive ones. The second recommendation is that systems (and in particular operation support systems) should be designed in such a way as to allow workers to develop more accurate mental models of their work.

2.4 Approaches to Safety

Safety, both as a scientific discipline, and as a domain of industrial management is conventionally presented as evolving over time, an idea summarized by illustration 3. Hale & Hovden (1998) capture this evolutionary thread in defining three main phases, or ages, of safety. The first age of safety began in the late 1800s with the progress of mechanization and of manufacture methods. The concern at the time was with mechanical failure, or to put it more broadly, with the technical elements of work.

The second age of safety came about in the 1930s, with the acceleration in technological development, but also with an increased interest in the human aspects of work. The following war, and in particular the mass use of airplanes as war machines, gave rise to a large number of studies on training, motivation, and management, to cite a few of the areas of research. Hale & Hovden (1998) then note that after the Second World War, a merge occurs between the two first ages of safety. It is the birth of human reliability assessment, attempting to bring "mathematical rigor" to what had primarily been a qualitative/anecdotal enterprise. It was around this time that the idea of "human error" appeared, together with the notion that it was possible to classify types of "errors" and calculate both their frequencies and their consequences.

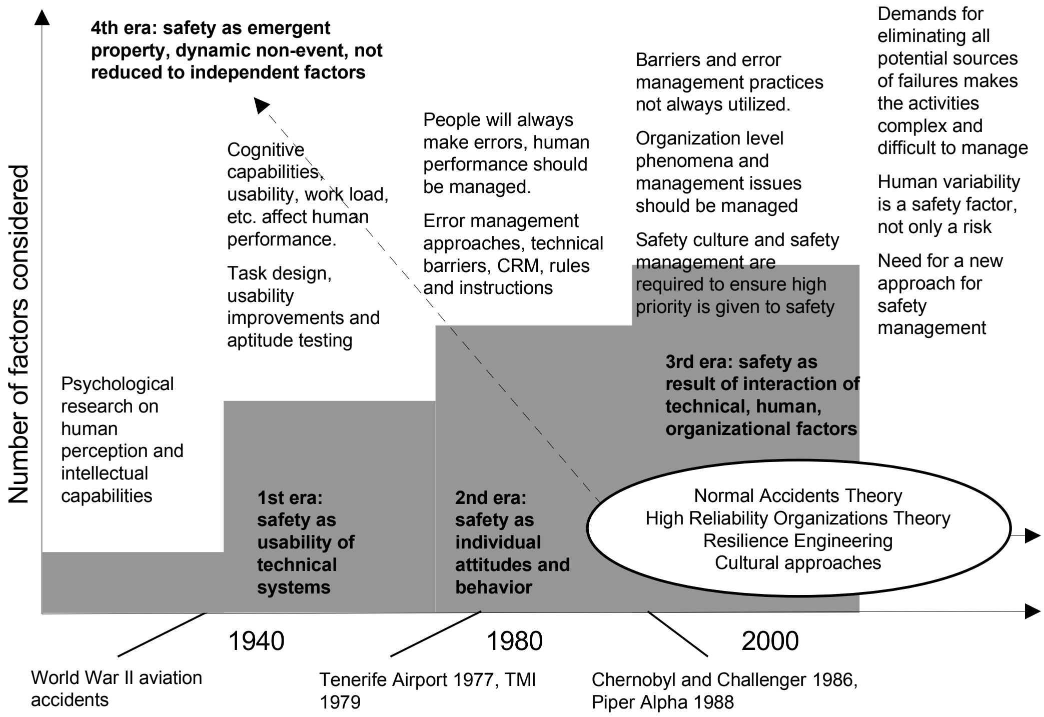

Illustration 3: The eras of safety and the number of factors which are taken into consideration by those concerned with safety issues. Adapted from Reiman (2009).

The third age of safety came with further technological progress. The increase in the use of computers in the workplace, the complexity of work processes, as well as a series of spectacular accidents, stimulated research into the organizational aspects of work. In other words, how organizations "behave", and how their behavior contributes to either increased safety or increased risk. Researchers working within this age paradigm suggest that organizations "as a whole" are behind accidents, not individual human actions. This is at odds with the second age paradigm, which squarely points to humans as the "weak links" in accidents.

More recently, a fourth age of safety has been identified. The Resilience Engineering approach, one of the representatives of this latter age, stresses the need for performance variability (and therefore, of adjustments) for a socio-technical system to remain under control. Resilience Engineering adopts the principle of emergence, which states that "the variability of normal performance is rarely large enough to be the cause of an accident in itself or even to constitute a malfunction. Both failures and normal performance are emergent rather than resultant phenomena, because neither can be attributed to or explained only by referring to the (mal)functions of specific components or parts” (Hollnagel, 2008b).

In the following sections, two approaches to safety are presented, with an emphasis on Resilience Engineering. This approach does away with the idea that safety is a separate process to be managed within the socio-technical system and introduces a distinction between “success” and “failure” as they relate to the accomplishment of the system's objectives. In order to enhance the contrast between Resilience Engineering and other approaches, the latter are collectively termed “the traditional approach.”

2.4.1 The traditional approach to safety

The traditional approach to safety draws from a classic view of rationality (Dejours, 2007). According to this view, it is possible to arrive at a determination of the best course of action to be taken by following a rigid formula for the evaluation and selection of alternatives.

The consequence of adopting the normative view of rationality has been a dichotomy between the “designers” and the “operators” (Busby, 2003). The designers are responsible for designing the processes, the workplace, the tools, as well as the management structures needed for the organization to achieve a desirable level of performance. Using their knowledge, the designers are capable of defining the actions that the operators must perform. These actions are then described in the form of procedures. Operators must then comply with those procedures.

From this line of reasoning it follows that if the procedures are the result of a rational process, they are correct. Indeed, they are the “one best way” (Livian, 2000) for performing work. Accordingly, compliance to procedures is a guarantee that work will be performed in an efficient, safe manner. Conversely, deviation from those procedures necessarily results in inefficient, and unsafe work.

Actually, it was soon realized that operators often did not perform as expected. Instead of prompting a revision of the model of rationality, this realization was followed by a search for the reasons for the supposed sub-performance. Two schools of thought from this time deserve mention (Bernoux, 1985). Maslow suggested that humans had an innate set of hierarchical *needs*, which had to be to be satisfied. The problem of performance was then simply a consequence of a misalignment of the characteristics of the work as described in the procedures, and the workers' needs. McGregor suggested three hypotheses about humans: (a) the average person has an innate aversion of work, and will do everything to avoid it; (b) given this aversion, people must be constrained, controlled, directed, and threatened to work; (c) the average person prefers to be directed, avoids responsibility and has little ambition.

The notion that humans had some “innate” characteristics that did not conform to the classic rational model eventually led to the proposition of revised models that did account for those characteristics. One of the best-known revised models was proposed by Simon (1991), who suggested the “bounded rationality” model. Simon argued that the human being has limited cognitive resources. Therefore, rather than being wholly rational, in the manner of the classic model, humans were only rational to the extent of their resources. As Hollnagel (2009, p. 44) says, “instead of trying to find the best alternative, a decision-maker would stop as soon as an acceptable or satisfactory one was found.”

Cooper & Foster (1971) summarize the traditional view, saying that, “[these] philosophies of work organization ... are based on the assumption that work is best performed under maximally specified regimes” (p. 473). The consequence of such philosophies is that they do not allow for self-regulation, and as a consequence, “a superstructure of supervision, inspection, scheduling, and so on is required in order to control the unwanted variances that occur at each level. This additional structure creates the possibility of further variance” (p. 473).

It should be clear at this point that a central issue in safety management has to do with the management of what people actually do in contrast with what they *ought to* *do* according to the "superstructure of supervision, inspection and scheduling" to which Cooper & Foster (1971) make reference.

2.4.2 The new approach to safety – Resilience Engineering

Speaking of ecological systems, Holling (1973) suggests their behavior can be viewed in two different ways. The first way of viewing the behavior of systems is concerned with consistent, non-variable performance. He explains that this view is well-suited to systems that operate under a narrow range of variability, that is, systems which are not constantly faced with perturbations. The second view is concerned with the persistence – the continued existence – of systems. This view is more appropriate to systems that operate under variable conditions and are thus constantly faced with perturbations.

Holling (1973) says the first way of viewing system behavior is therefore concerned with the stability of the system, or the system's ability to return to a state of equilibrium even after a disturbance. The second way of viewing system behavior is concerned with a system's *resilience*, its ability to absorb changes in the conditions under which it operates, and persist.

After discussing several examples from ecological systems, Holling (1973) concludes that systems that are highly stable have little resilience and that conversely, highly unstable systems are very resilient. In the field of ecology, this conclusion leads to the suggestion that the management of natural resources should focus on resilience (so that biological species do not become extinct), rather than on stability, which albeit providing for a more predictable world, leaves a system more at risk of extinction in the case of unexpected disturbances.

The use of the notion of resilience in safety studies comes from a 1993 book chapter by H. Foster, titled "Resilience Theory and System Evaluation." He defined resilience as "the ability to accommodate change without a catastrophic failure, or the ability to absorb shock gracefully." Hansson, Herrera, Kongsvik & Solberg

(2009) suggest that this notion has been a catalyst for the move towards a new approach to improve safety – aptly named, a resilience approach.

Woods & Cook (2003) argue that looking for error is a "mirage-like" effort. They then proceed to summarize some of the conclusions that research on safety from a resilience point of view has come to:

- When error is defined as a cause of failure, finding the person who erred generally marks the end of analysis. This, in effect, "blocks learning by hiding the lawful factors that affect human and system performance" (p. 4).
- When error is defined as failure, a mere replacement of terms occur, without any progress on the problem of how accidents happen.
- When error is defined as deviation, one encounters the problem of multiple standards. According to the authors, "standard operating practices capture only a few elements of work and often prescribe practices that cannot actually be sustained in work worlds" (p. 6).
- Calling an act an error "marks the end of the social and psychological process of causal attribution".

To Woods & Cook (2003), the search for errors will not result in progress on safety. Rather, because it is people who "*create safety under resource and performance pressure*" (p. 9, italics in the original), progress will come from understanding how safety is created, and "helping workers and managers create safety" (p. 9).

Since 2004, the Foundation of Research Science and Technology of New Zealand has funded the "Resilient Organizations" program. The two core questions this program addresses are "What is a resilient organization," and "How can we make our organizations more resilient?" (Seville, Brundson, Dantas, le Masurier, Wilkinson, & Vargo, 2006). The program is concerned with how organizations (government agencies, private business and non-government organizations) can appropriately respond to different types of crises. Seville et al. (2006) define a resilient organization as, “one that is still able to achieve its core objectives in the face of adversity. This means not only reducing the size and frequency of crises (vulnerability), but also improving the ability and speed of the organisation to manage crises effectively (adaptive capacity). To effectively manage crises, organisations also need to recognise and evolve in response to the complex system within which the organisation operates (situation awareness) and to seek out new opportunities even in times of crisis” (p. 4).

Seville et al. (2006) suggest that the resilience of an organization may be measured by the “severity and duration of impact on performance”, according to the illustration 4 below.

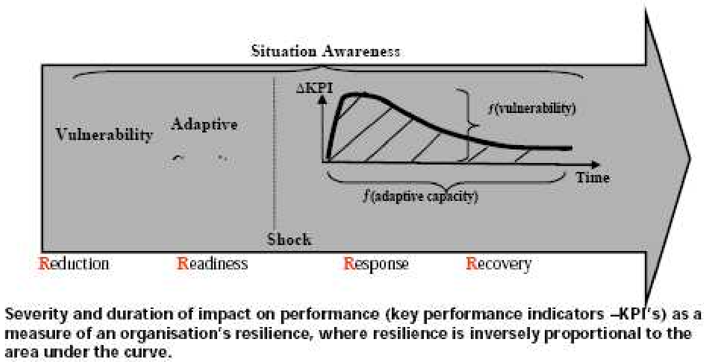

Illustration 4: Measuring resilience, reproduced from Seville et al., 2006.

Nevertheless, the measurement suggested can only take place once what the authors call “shock” has already occurred. The problem of measuring resilience in advance of an unexpected event remains unresolved.

Speaking of system safety (in particular safety in complex organizations such as the nuclear and aviation industries), Hollnagel (2006) suggests that resilience is “the intrinsic ability of an organisation (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of continuous stress” (p. 16). He later adds that resilience is the “ability of a system or an organisation to react to and recover from disturbances at an early stage, with minimal effect on the dynamic stability” (p. 16). More recently, Hollnagel (2008) redefines resilience as “the intrinsic ability of an organisation (system) to adjust its functioning prior to or following disturbance to continue working in face of the presence of a continuous stress or major mishaps" to emphasize the role played by adjustments to the establishment and maintenance of control in socio-technical systems.

Woods (2006) goes further, suggesting that resilience is not simply the ability to adapt (because all systems are able to adapt to some extent), but the ability to handle events that fall outside the pre-defined adaptation models and mechanisms of a system. In this sense, the successful application of an "emergency plan" in a situation of distress is not sufficient demonstration of resilience. To find resilience, in this case, one must look for the ways in which the system adapted to the situation, beyond the adaptations formally established in the plan.

Hale & Heijer (2006) suggest that resilience is not only the ability to "bounce back from adversity" (examples are given: recovery from a fire by moving production lines to a temporary building; restoring power after an outage by drafting in extra staff), but also "the ability to steer the activities of the organisation so that it may sail close to the area where accidents will happen, but always stays out of that dangerous area" (p. 36). It seems that the authors here advocate what Hollnagel (2006) calls "the traditional approach to safety". It is not surprising, then, that at the end they ask "whether we do not have other terms already for that phenomenon" (p. 40). Nevertheless, they make an important point in saying that "what is interesting for safety is preventing accidents and not just surviving them" (p. 40).

Leveson, Dulac, Wipkin, Cutcher-Gershenfeld, Carroll, & Barrett (2006) also disagree with a definition of resilience that equates it to a bouncing back, and add that "resilience is the ability of systems to prevent or adapt to changing conditions in order to maintain (control over) a system property" (p. 95). As such, they argue that a resilient system is one in which controls are in place, and function adequately, to prevent risk from increasing as the system and the environment in which it operates change over time.

In the same tone, McDonald (2006) offers a “provisional definition of resilience”. He suggests that it represents the ability to anticipate and manage risk, through adaptation of actions, systems and processes, in such a way as to ensure that it can carry out its functions “in a stable and effective relationship with the environment” (p. 157).

Rasmussen (1997) says that “it should not be forgotten that commercial success in a competitive environment implies exploitation of the benefit from operating at the fringes of the usual, accepted practice. Closing in on and exploring the boundaries of the normal and functionally acceptable boundaries of established practice during critical situations necessarily implies the risk of crossing the limits of safe practices” (p. 189). The clear implication of Rasmussen's observation is that safety efforts often tend to simply trail behind production efforts. Indeed, a study carried out by the US Department of Mineral Resources, cited by Laurence (2005), found that there is widespread belief on the part of mine workers, that breaking the rules (or, at least, not following them) is necessary to get the job done: “Any mine that operates 100% within the rules will not produce a single tonne of coal.”

Perin (2005, p. 196) echoes this understanding, noting the consequence of the continuous exploration of the boundaries of established practice. Commenting on how nuclear power plants in the US manage safety, notably from a command-and-control perspective that derives largely from the naval-military culture that permeates the nuclear industry in that country, she says, “moving the same pieces around the same board, they play the same game, hoping to do so more skillfully (more training) while paying more attention to the rules (rewrite procedures), to equipment (more inspections), to team signals (more and better cross-department communication), to the referees (listening to oversight), to who does what (reallocating responsibilities), to new techniques (decision-making tools), and to motivation (“reinforce management expectations”).

2.4.3 Safety revisited: Success and Failure

Some debate exists about whether Resilience Engineering represents a fundamental shift in the way safety ought to be understood and managed, or is more modestly, a complement to traditional thinking about safety. Proponents of the first position argue that "resilience engineering tries to take a major step forward, not by adding one more concept to the existing vocabulary, but by proposing a completely new vocabulary, and therefore also a completely new way of thinking about safety" (Woods & Hollnagel, 2006b, p. 2). The second position suggests that Resilience Engineering "complements existing safety methods. It offers a different perspective, but is not intended to be a wholesale replacement" (Eurocontrol, 2009, p. 12).

Regardless of the status of Resilience Engineering in the study and practice of safety, the message conveyed is still an important one. From a Resilience Engineering perspective, it is more important to remain in control of the system than it is to follow the rules. There is ample evidence that rule following is no guarantee of safe performance (Besnard & Greathead, 2003; Dekker, 2003; Dekker, Siegenthaler & Laursen, 2007). Control – irrespective of whether the actions actually taken conform to prescribed actions – is essential for the proper functioning of the system (Wiener, 2007; Hollnagel, 1993).

This chapter argues that socio-technical systems are subjected to both internal and external variability arising from many different sources. Control is achieved and maintained by successfully addressing this variability – either by *reacting* to it as it happens, or by *anticipating* and acting before it strikes. In either case, as Ashby (1957) explains, "an essential feature of the good regulator is that *it blocks the flow of variety from disturbances to essential variables*" (p. 201, italics in the original).

Traditional safety management has been dominated by two questions: *How is control lost?* and *How can loss of control be prevented?* Yet, experience shows that most of the time, control is *not* lost – most flights take off and land, most power plants produce energy with a high level of reliability, most natural gas platforms extract gas without disturbing incidents. Therefore, Resilience Engineering contends that the important questions in safety are *How is control maintained under varying conditions?* and *How can control be enhanced?*

2.5 What this thesis is about

Ashby (1957) proposes what has since been called “the law of requisite variety.” Woods & Hollnagel (2006, p. 171) state it as “only variety can destroy variety.” The thrust of this law is that control can be achieved and maintained by making use of a repertoire of actions that is as large as the number of potential disturbances in the system. These actions are the adjustments that systems – but more specifically, humans – make as they attempt to maintain control.

This chapter argues that it is hardly ever possible to arrive at a complete description of a socio-technical system. The consequence of this is that the “number of potential disturbances in the system” alluded to in the previous paragraph can never be known. It would therefore be of limited interest to merely compile a list of concrete disturbances and concrete adjustments. More than that, it must be possible to identify commonalities among the concrete examples of adjustments.

The Resilience Engineering approach distinctly emphasizes the need to understand how success is produced in “a world fraught with hazards, tradeoffs, and multiple goals” (Woods & Cook, 2003). This understanding will not come from looking at accidents, as safety studies most often do (Lagadec, 1981; Perrow, 1984; Reason, 1997; Llory, 2001). Rather, Resilience Engineering suggests that it will come from looking at how people handle work in normal situations. The story about an event that took place in the Intensive Care Unit of a hospital reported by Cook (2006) shows the value of looking at events which did not end badly. Indeed, the event hardly “ended” at all – it simply blended with myriad other activities that the practitioners in the story had to deal with in the course of time.

Instead, this study takes a different route, and asks what individual adjustments may have in common. Prompted by the call for stories of what Weick (1987) called “dynamic non-events”, and armed with the idea that socio-technical systems remain safe as a result of adjustments proposed by Resilience Engineering, the study seeks to understand adjustments *in context*. As the following chapters show, by looking for the commonalities that cut across adjustments, it is possible to arrive at a smaller, and in a sense more tractable, set of features that describe adjustments. This set can then be used to better understand individual adjustments, which in turn opens the possibility for a more appropriate control of the phenomenon and its consequences.

French summary of Chapter 2

Vicente (1999) définit un système comme « [a] set of interrelated elements that share a common Goal or Purpose. ... The System can be an Actor, the thing being acted on, or both. » A Joint Cognitive System (JCS) est « a system that can modify its behaviour on the basis of experience so as to achieve anti-entropic ends » (Hollnagel & Woods, 2005).

La théorie des JCS met en évidence la nécessité d'une vision des systèmes en termes de performance collective de l'homme et de la machine (Hollnagel & Woods, 1983). En effet, cela signifie que le système ne devrait pas être décomposé en entités humaines et technologiques, mais que l'unité d'enquête devrait être la performance des hommes et des machines travaillant ensemble vers un but donné. Evidemment, étant donné qu'un homme est un agent cognitif en soi, le travail d'équipe entre également dans la rubrique JCS, même si aucune machine / artefact n'est pas impliqué.

L'un des aspects clés des systèmes est qu'ils existent dans un environnement. L'impact de l'environnement dans le système donne une mesure de l'ouverture du système. Vicente (1999) établit une distinction entre les deux types de systèmes : « *Closed systems* are completely isolated from their environment. From the view point of the analyst, the behavior of the system can be well understood by examining influences that are internal to the system itself. Conversely, *open systems* are subject to influences (i.e, unpredictable disturbances) that are external to the system » (nous soulignons).

Les JCSs doivent alors être en mesure de « combler l'écart » pour répondre aux événements pour lesquels il n'existe pas de règles, ou pour lesquels les règles ne correspondent pas tout à fait à ce qu'il peut ou qu'il doit fait. Comme Dekker (2003, p. 235) l'explique : « work, especially that in complex, dynamic workplaces, often requires subtle, local judgments with regard to timing of subtasks, relevance, importance, prioritization and so forth. »

Des ajustements sont alors une caractéristique commune des systèmes socio-techniques. L'approche de l'Ingénierie de la Résilience souligne la nécessité de la variabilité des performances (et par conséquent, des ajustements) dans un système socio-technique pour qu'il puisse rester sous contrôle. L'Ingénierie de la Résilience adopte le principe d'émergence, qui stipule que « the variability of normal performance is rarely large enough to be the cause of an accident in itself or even to constitute a malfunction. Both failures and normal performance are emergent rather than resultant phenomena, because neither can be attributed to or explained only by referring to the (mal)functions of specific components or parts » (Hollnagel, 2009). Hollnagel (2008) redéfinit la résilience comme « the intrinsic ability of an organisation (system) to adjust its functioning prior to or following disturbance to continue working in face of the presence of a continuous stress or major mishaps » pour souligner le rôle joué par les ajustements de performance et le maintien d'un contrôle dans des systèmes socio-techniques.

Ce chapitre montre que les systèmes socio-techniques sont soumis à la variabilité venant de nombreuses sources différentes. Le contrôle est maintenu en traitant convenablement cette variabilité - soit en réagissant à ce qu'il se passe, soit par l'anticipation à ce qui peut se passer. Dans les deux cas, comme Ashby (1957, page 201) l'explique : « an essential feature of the good regulator is that it blocks the flow of variety from disturbances to essential variables. »

L'approche de l'Ingénierie de la Résilience met l'accent sur la nécessité de comprendre comment le succès est produit "in a world fraught with hazards, tradeoffs, and multiple goals” (Woods & Cook, 2003). Cette compréhension ne viendra pas de la recherche sur les accidents (Lagadec, 1981; Perrow, 1984; Reason, 1997; Llory, 2001). Plutôt, l'Ingénierie de la Résilience donne à penser qu'elle viendra en regardant comment les gens font leur travail dans des situations normales. Le récit d'un événement qui a eu lieu dans l'unité de réanimation d'un hôpital raconté par Cook (2006) montre la valeur de la recherche lors d'événements qui ne terminent pas en accident. En effet, l'événement décrit par lui n'a de “fin” claire et précise – il s'est mélangé tout simplement avec d'autres activités menées par les practiciens au cours du temps.

L'étude présentée ici prend un chemin différent, et se demande ce que les ajustements individuellement observés ont en commun. Comme les chapitres suivants le montrent, en recherchant les points communs qui transcendent les ajustements, il est possible de parvenir à un ensemble de caractéristiques qui décrivent les ajustements. Cet ensemble pourrait alors être utilisé pour mieux comprendre les ajustements individuels, ce qui ouvrirait la possibilité d'un contrôle plus approprié du phénomène et de ses conséquences.

3 Finding adjustments

This chapter presents the method used for data collection in this study. The argument will first be made for a data collection strategy aimed at building a corpus of real cases in which adjustments took place. Section 3.1 is dedicated to explaining why there is a need for data collected through the observation of work in a natural setting. Once the type of data needed for the study is identified, there is the issue of how to obtain it. This is the core subject of section 3.2, which addresses the approach taken to data collection, verification, and analysis. It also details the ethical issues involved in the study and the measures taken to mitigate them.

Section 3.3 comprises an overview of the setting of the observations, namely natural gas production platforms, with an emphasis on the organization of work on the platforms where the observations were made.

3.1 Investigating Work as Done

The preceding chapters have made the case for the study of workers' everyday “routines” or the activities that offshore workers would consider typical. This is in contrast with approaches that focus either on the handling of extraordinary situations (e.g., emergency response) or on past undesirable outcomes (e.g., accidents). Indeed, Hollnagel (2009) argues that accidents are the result of unexpected combinations of the variability of normal performance, corroborating the value of studying non-accidents.

For a long time, the French ergonomics school has used the observation of work as a tool to uncover the differences between the work described in procedures and the work actually carried out. The emphasis is, of course, on identifying the characteristics of work as it is performed, at a specific point in time and under specific conditions (Leplat, 1997). In the Cognitive Systems Engineering approach and in Resilience Engineering, observation is described as a method of primary importance when one seeks to understand the relations between strategies adopted (the choice of action) and the context of action (i.e.,the demands, the constraints, the expectations, but also the affordances of that context) (Hollnagel & Woods, 2005; Hollnagel, Woods & Leveson, 2006).

3.1.1 Data for what?

Vicente (1999) has grouped work analysis methods into three categories: Normative, Descriptive and Formative. Normative approaches correspond to “classic” or “taylorist” task analysis, where a given task is decomposed, analyzed and then re-assembled in the form of a procedural description which workers are expected to follow to the letter – the so-called “one best way.” Vicente argues that a Normative approach may be appropriate for tasks executed in a very controlled environment (e.g., an automotive assembly line), but not for tasks executed under constantly changing conditions, particularly where conditions are not fully specified (open systems).

The Descriptive approach, as the name indicates, is concerned with describing how work is executed in practice. This is the specialty of the French ergonomics school, mentioned above. Vicente (1999) notes the benefits of such approach in terms of theoretical advancement (e.g., naturalistic decision making, situated action and distributed cognition are founded in descriptive studies), but suggests that it is limited in terms of how it contributes to the process of designing a new system. In his view, descriptive approaches describe current practice. The Cognitive Systems Engineering approach, however, retorts that the primary goal of description is not merely to paint a picture of the system, but to aid in the process of discovery of general principles of human work in a given domain.

Vicente (1999) proposes the Formative approach in order to address the shortcomings of the two approaches presented above. The Formative approach may be summarized as a modeling of the constraints that the system is subject to. The reasoning is that if constraints are properly identified and modeled, the system may be designed in such a way as to prevent the execution of actions that violate those constraints. This entails, above all, that workers must be make aware (through information systems and training, for example) of what those constraints are. Furthermore, if constraints are identified, then workers have the freedom (with the responsibility that goes with it) to perform their tasks in any way they find appropriate given local conditions. In other words, workers are given the freedom to adapt, so long as they respect the constraints of the system. Vicente argues that Cognitive Work Analysis – his own version of a formative approach – "is all about designing for adaptation." The Systems-Theoretical Accident Modeling and Processes, developed by Leveson (2003) is based on the same principle: "A model based on systems theory goes beyond simply blaming component failure for accidents and requires that the reasons be identified for why those failures occurred, why they led to an accident, and what system-level constraints must be imposed to prevent them or prevent hazardous system states if they do occur, potentially leading to more varied and effective measures than simply attempting to handle failures through redundancy."

Ultimately, the different approaches to studying human work are not exclusive, but complementary. There is, in particular, a strong affinity between the descriptive approach of Cognitive Systems Engineering and the formative approach of Cognitive Work Analysis (CWA). If CWA speaks of giving workers freedom to adjust as the situation requires and within the constraints of the system, it is nevertheless imperative that one knows how workers will actually adjust.

3.1.2 How to observe

Data collection in the study of work may be of one of two types: direct observation, in which the observer can see first hand the object of observation in action and indirect observation, in which the observer is removed in time and/or space from the object of observation. In this latter case, data is obtained through formal reports (documentation), interviews, memoirs, etc.

Woods & Hollnagel (2006) propose a similar classification of methods under slightly different names:

- Natural history: the observer has little opportunity to shape the conditions of observation. In principle, the observer must "wait for something to happen." The goal is to build a collection of cases that reveal something about how the system operates. Natural history is appropriate for "discovery," when knowledge about the system is scarce or when the research questions have not been addressed before. Direct observations may aided by indirect observations (e.g., interviews), as this allows for a) collecting more stories and b) gathering different views on the stories collected.

- Experiments in the field (Staged World Observations): the advantage of experiments is that they allow for greater control, on the part of the observer, of what happens. In other words, instead of "waiting for something to happen," the observer may "make something happen" and observe how the system reacts. Woods and Hollnagel (2006) call attention to the skill involved in properly designing simulations.

- Spartan lab experiments: the authors point out the role of the observer in designing spartan lab experiments. Spartan lab experiments are particularly appropriate for the validation of data and the verification of hypotheses.

A significant difficulty when looking for examples of adjustments in "normal performance" is that they may be hidden from the view of practitioners themselves. Woods & Hollnagel (2006) comment on this, saying, "... adaptations often become routinized as a standard part of a task or a role, so that, on the surface, it is difficult to see how these routines are adaptive and to what they have adapted ... the adaptations as exercised in everyday practice are not necessarily noteworthy to the practitioners themselves. Their ability to tell people directly about these processes is limited, since there is usually a significant gap between what people say they do and what they are observed to do unless special procedures are used" (p. 37). Not surprisingly, workers on board the platforms first reacted to this study saying that "they took no risk" and that "everything was safe." The notion of "routine," the word that was first used to describe the type of situation in which the study was interested, was met without enthusiasm: the workers argued that everyday was different, and that there were no routines.

Patterson, Cook, Woods, & Render (n. d.) begin by saying that "human errors" are generally approached from two different angles. The first holds the view that "e*rratic people degrade an otherwise safe system*" (p. 2, italics in the original). The second approach sees people "*as the primary source of resilience in creating safety*" (p. 2, italics in the original). The authors then proceed to explain how the resilience approach can be used to improve patient safety. For Patterson et al. (n. d.), a resilience approach is based not on finding where people made the mistakes that led to accidents, but rather on finding how people develop strategies that normally prevent accidents from taking place. In order to locate these strategies in the context of work, the authors speak of listening to "second stories." According to the authors, second stories indicate that failure (accidents) "represents *breakdowns in adaptations* directed at coping with complexity" (p. 3, italics in the original). The key, they argue, is to anticipate where such breakdowns are more likely to happen – by identifying the widening gaps between what should be happening and what is actually happening – and develop appropriate strategies to bridge such gaps. For the authors, the ability to identify and counter these gaps is found wherever people work, and it is sufficient to prevent most accident from ever occurring. It is when this ability reaches its limits that failures finally take place. Therefore, they say, it is important that the organization/system as a whole perceive the importance of this adaptation process and encourage it – hence engineering more resilience into the system. As the authors emphasize, the collection of stories is fundamental in this process. The Resilience Engineering approach, however, suggests that one should not look only for stories of failure, but also for stories of success.

3.2 Approach taken

Consistent with the research questions discussed above, a data collection method was required that allowed for the observation of adaptations. Taking note of the principle that accidents "are the result of the unexpected combinations of the variability of normal performance," the study focused on how workers handled expected, "normal" events (Cuvelier & Falzon, 2008).

Hollnagel (2004) gives a table of examples of types of failures that is illustrative of the types of events the present study was interested in:

Table 2: Types of failure and places of occurrence. Adapted from Hollnagel (2004).

Type of failure	**Place of occurrence**		
	At work	**In traffic**	**At home**
Accident	Being injured or killed	Being killed or seriously injured	Fire or water leakage
Incident	Being hit but not injured	Being hit by a vehicle	A blown fuse; breaking a window
Near miss	Something falling down close to a person	Almost colliding with a vehicle	Forgetting to lock the door

This study was interested in events that could hardly be classified as near misses. Indeed, the interest was in looking at the most common, ordinary events – events where there was, so to speak, "no failure."

Because such events are not "special" in the ordinary sense of the word, it was clear that indirect observation methods would yield little useful information. Direct observation was necessary. The arrangements made were as follows:

Offshore safety training. In order to stay offshore for the period of the study, the observer had to undergo "Basic offshore safety training". This training session was held by a private company, independent of the one that sponsored the study.

Preparation visit. A three day visit during which the researcher met several workers, presented the research project and discussed how to best conduct the observations.

Research visits for observation purposes. Five visits, ranging from nine to twelve days. During these visits, the researcher was free to observe any activity carried out on board. It was understood that all personnel on board were aware of the researcher's objectives and therefore no individual permission to use data collected was sought.

In total, five platforms were visited, but approximately 80% of the time was spent on the company's two largest platforms. Observations were of two kinds.

Direct observations: the researcher would follow a worker (or group of workers) in the execution of a job. The job was briefly explained to the researcher, who then stood back and took notes using pen and paper. When something appeared "to be happening" (often, when workers began to talk and/or point), the researcher was free to ask for clarification. It is worth noting that the researcher did not speak the workers' native language. This meant that a) it was impossible to understand their dialogues unless one of them took the time to translate, or if they switched to English and; b) there was no use in recording verbal protocols, as the researcher would have been unable to translate and interpret them. In most cases, direct observations were followed by briefings in which the workers explained to the researcher what had happened. The level of detail in such cases varied.

Indirect observations: on several occasions, at the researcher's request or spontaneously, the workers shared stories about past events which the researcher had not observed or made further remarks about earlier observations. The researcher was also allowed unrestricted access to all company documentation pertaining to the activities observed. This was only partially useful, since most documents were available only in the workers' native language. On several occasions, the researcher was granted interviews with selected workers. In these, specific topics or events were discussed, but mostly, they served to obtain different views on recorded observations. During the last visit, the workers were given the opportunity to read the stories collected and make comments. This last step is described in more detail below.

3.2.1 Data reliability

Following the advice of Lofland, Snow, Anderson & Lofland (2006), all stories collected in the first four visits were presented, in writing, to platform personnel. Given the characteristics of on-board personnel scheduling, it was not possible to present the stories to every single participant in the study. However, twelve workers did read the full document containing the stories collected and had the chance to make comments. Further analysis of the data determined that some of the stories were lacking in detail or did not add significantly to the argument of the thesis, and were thus dropped. Other stories, which were not part of that set, were included in the thesis precisely because they were thought to contribute to the argument developed, even though they were not explicitly validated by the personnel.

Comments ranged from spelling mistakes to in-depth information about specific stories. Given that platforms are confined working environments, and that most of the activities observed involved at least two workers, it was impossible to provide for complete anonymity. In most cases, but not all, workers could recognize themselves (and obviously, their colleagues) in the stories in which they took part. Several workers could also recognize stories that happened to their colleagues, since in such communities, stories can circulate quite fast. Finally, some workers indicated that they believed they knew the participants in some of the stories. No attempt was made neither to confirm nor to refute their beliefs.

In any case, the twelve workers who read the document clearly stated that the information presented was not offensive, and that no sanction for any of the actions described should be expected. They all agreed that the stories were a good representation of what takes place on board and that workers and managers alike are familiar with the issues described.

Finally, before printing and sending the manuscript to the thesis evaluation committee, a copy of the document was sent to the company's Health & Safety department. The purpose of this move was to make sure that the stories did not contain factual errors and to obtain permission to make them public. In response, the HSE department sent a number of remarks regarding the data. The permission to distribute the document was implied by the absence of opposition.

3.2.2 Ethical issues

As pointed out above, it was assumed that all personnel on board was aware of the researcher's objectives. In practice, the platform managers were told beforehand that a researcher would be on board. They then informed the senior workers. Whenever the researcher noticed that someone had not been informed about his presence, he made sure to introduce himself and the study. Verbal consent was sought for the use of stories, but no use was made of written consent forms.

It is important to point out that in such a small community, considering that the events observed often involved several people and considering that most events were in one way or another recorded (in Work Orders, Work Permits and logs), and because it was important to register the context in which actions took place, complete anonymity was an impossible goal. Nevertheless, the following measures were taken to achieve an acceptable level of anonymity:

- All names were changed. Operators have names starting with the letter A; Electricians & Instrumentation Technicians have names starting with the letter M; Mechanics have names starting with the letter R; other professionals have names starting with the letter D. Names are purposefully repeated across stories, but they may represent different workers.

- Dates and locations were either changed or suppressed. An effort was made to maintain temporal sequencing when this was considered to be an important element of the story. When necessary, the technical components involved (engines, machines, tools, etc.) were either changed or made "generic."

- All stories are told as though the researcher had witnessed their unfolding. In fact, some of them are recollections mentioned by the workers. Most often, because the same job required the participation of people located in different areas of the platform, or even on different platforms, only one point of view could be represented in the story.

In spite of the measures taken, some workers were able to recognize themselves or their colleagues. Nevertheless, during the verification step described in section 3.2.1, none of the readers indicated that they wished the stories to be changed or removed from the study. Given the nature of the study and the nature of the data collected, this was considered to be sufficient from an ethical point of view.

3.3 Life offshore

This section describes the characteristics of offshore natural gas production as a complex socio-technical system. These characteristics are presented in two sub-sections. The first one looks at the system as a whole – all of the platforms, and the onshore offices. Nevertheless, the offshore side of the organization is emphasized. The second sub-section looks exclusively at the offshore installations, including a brief summary of what a platform *does* and the organizational structure. Since the latter is used to separate the data into blocks in Chapter 4, it is recommended that the reader pays close attention to it.

3.3.1 The organization as a complex socio-technical system

In order to describe the work environment in which the situations presented in the following chapters took place, reference is made to the list of characteristics of a socio-technical system proposed by Vicente (1999) (see Chapter 2). Although an effort is make to consider the whole of the organization, this description focuses on the characteristics of the offshore work environment. Consistent with the argument presented in the preceding chapters, this description is incomplete. The objective here is to give the reader a general view of what natural gas production platforms are like as working environments.

Large spaces: the company operates over thirty platforms, including several unmanned platforms. Each platform has several kilometers of pipelines, a large number of sensors and gauges, as well as an untold number of mechanical, electric and electronic parts. Hundreds of workers, both on- and off-shore are involved in running the platforms. Helicopters and ships transport material and workers. The platforms are connected to each other, and events taking place on one platform may have a direct or indirect impact on others. The company may be considered as having a “large space.” This situation is somewhat ameliorated by two factors: a) workers are often stationed at the same platform or cluster for long periods of time, with the result that they develop in-depth knowledge about the working environment; b) the platforms tend to follow the same general design and use material from the same vendors, with the result that much of the knowledge acquired in one platform may be readily applicable to another.

Social: the company has approximately 200 full-time employees and a fluctuating number of contractors . Contractors may be permanent, semi-permanent or temporary.

Permanent contractors have long-term contracts and are generally fully integrated into platform life. This group includes the catering crew, the radio and helideck crew, and members of the logistics and construction crews.

Semi-permanent contractors are hired for large and medium projects and projects that require continuous updates and maintenance. This group includes members of the construction crew, and service providers, such as software vendor representatives.

Finally, temporary contractors come on-board for specific, short-term assignments which are not , in principle, repetitive. This group involves mostly vendor representatives who come on-board on request. The company is currently in the middle of an expansion phase, with the acquisition of assets and exploration of new fields. Consequently the number of employees, both in-house and contracted, is on the rise.

Heterogeneity: the onshore staff consists of administrative and managerial personnel. This includes secretarial staff, department managers (Production, Logistics, Health & Safety, Engineering, etc.) as well as departmental staff with qualifications in several disciplines.

The offshore staff consists mostly of operational personnel, with virtually no administrative staff present. Administrative tasks are carried out by the workers themselves, with the support of colleagues, hierarchical superiors, and onshore staff. The company management philosophy emphasizes flatness in the organizational structure. All departments are headed by a Senior, who reports directly to the Head of Mining Installation (HMI)[6], who is the highest authority aboard.

Workers come from a range of disciplines: Operators, Electricians, Instrumentation Technicians, Mechanics, Welders, Fitters, Painters, Scaffolding builders, Catering personnel, Radio operators, Medics, Helideck personnel. Notably, only the workers in the first four of those disciplines are in-house employees (Electricians and Instrumentation Technicians form a single department within the organization structure of a platform). Due to the growth history of the company, in these four disciplinesseveral workers are approaching retirement age. The company is actively recruiting workers with those qualifications, both to renew its workforce and to support new operations. With the exception of some members of the catering crew and radio/medic/helideck crews, the offshore workforce is almost exclusively male.

Distribution: onshore, the company has two offices, where administrative, managerial and support activities take place. Offshore, the company owns and operates more than 30 production platforms. The platforms are physically connected by means of a network of pipelines. Platforms can be manned or unmanned. The two largest manned platforms operated by the company can accommodate over seventy over-night personnel. Smaller platforms have a permanent crew of at least two people. Unmanned platforms are operated/supervised remotely. These platforms are manned only during scheduled or unscheduled maintenance activities. They are not equipped with long-term sleeping accommodation, but the indoor space can be used as temporary shelter.

Dynamics: natural gas is transported through pipelines from one platform to another, and from a platform to shore. Dynamics in this case refer to the amount of time that it takes for the consequences of actions taken at one end of the line to be felt at the other end. When a platform shuts down (whether as an expected event or as a result of a disturbance) and cuts the flow to the pipeline, whatever is already in the pipeline will continue to flow until the pressure in the pipeline reaches the suction pressure of

6 Not to be confused with Human-Machine Interaction.

the compressor station. The time that this will take depends on the amount of gas on the pipeline and on gas pressure. Conversely, the amount of time necessary to bring a pipeline or a process system to adequate pressure can vary significantly. Process engines (turbines, generators, pumps) can generally be started in a matter of minutes and emergency shutdown controls can bring them to a dead stop. In general, actuated valves can open or close in a few seconds.

Hazard: the major hazard associated with natural gas platforms is that of gas release followed by fire/explosion. Other hazards include the release (and potential fire/explosion or contamination of the environment) of other substances. A significant hazard is that of collision (with supply, military, fishing vessels, for example), leading to structural damage of the platform. The operation of helicopters also represents a hazard. Certain types of operations may be temporarily restricted when a vessel is stationed next to the platform, or during helicopter landing/take-off.

Coupling: gas production depends partially on electrical power for the instrumentation and supervisory systems. Some engines (notably, pumps) are also electricity-driven. However, power generators run on natural gas (fuel gas). If the fuel gas supply is cut, the generators go down. This coupling is mitigated by the availability of diesel generators that can be started automatically or manually. Helicopter and ship transportation is affected by weather conditions. Particularly on smaller platforms, scheduling changes can have a significant impact.

Automation: the level of automation in the company can be described as low to medium, depending primarily on the age of the platform and whether it was designed in-house or acquired from a competitor. The company's current philosophy emphasizes human operator control, even though some of the platforms are unmanned. A general description of the supervisory system is that it can act automatically when given set-points are reached (these actions are described in a Cause and Effect Matrix). The supervisory system does not intervene in the process between low and high set-points. Human operators must be continuously attentive to process trends (e.g., temperature raising or lowering) and react. Nevertheless, it must be pointed out that once the process is stable, little intervention is required.

Uncertainty: process data is provided by means of both analog and digital instrumentation. Episodic differences between analog and digital instrumentation values must be resolved by the Operators, often with the support of Electricians and Instrumentation (E&I) Technicians and Mechanics. The status of unmanned platforms can be monitored from the Control Room of the larger platforms.

Mediation: process data is presented mainly through computer screens in the Control Room. In the older platforms, not all information is presented to Operators in the Control Room, and Operators often must physically check (usually analog) instrumentation in loco, or in separate, unit-specific, control rooms. In one platform, for example, the only information sent to the Control Room about the compressors is a general alarm signal. Compressor control takes place in a separate room.

Disturbances: the organization as a whole is affected by the economic climate which conditions investments in expansion and maintenance, including the decision to maintain a platform in operation or to remove it from service. At the platform level, disturbances include equipment failure (although generally speaking, backups are available for all process equipment) and helicopter and shipping scheduling changes. Gas flow interruptions require prompt adjustment of flow contracts.

3.3.2 The platforms and their organizational structure

The diagram below (illustration 5) illustrates the functioning of a Natural Gas Production Platform. A photograph of a platform can be seen in illustration 7, on page 58.

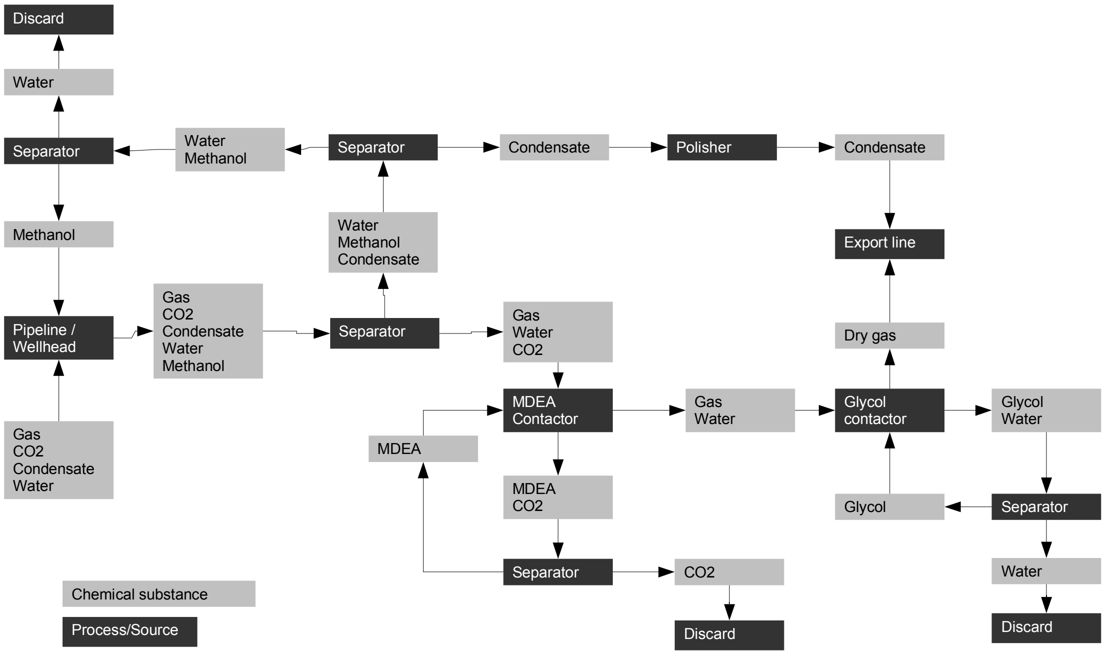

Illustration 5: Overview of the main processes taking place on a natural gas production platform.

The diagram represents a sizable platform processing a natural gas mixture containing gas, condensate, water, methanol and CO2. It represents a typical production platform with processing capabilities. The composition of the gas mixture is specific to each well, and therefore not all of the processes depicted above are carried out at all platforms. Furthermore, H2S (hydrogen sulfide), may be present in the gas mixture. In such a case it will be removed during processing. However, since none of the platforms visited in the course of this study processed H2S-rich gas, the step is not represented.

The process begins at the wellhead. The wellhead is generally located on board depending on the volumes and characteristics of the gas in the reservoir rock and the distance from the well to the nearest platform. In some cases, however, it may be more economical to install a sub-sea wellhead. Methanol is added either at the sub-sea wellhead or at the flow pipeline. Methanol prevents the formation of hydrates – ice crystals – which could clog the lines and interrupt the flow of natural gas.

Arriving at the platform, the gas passes through a separator in which the bulk of the liquids are separated from the gas. The liquids (water, methanol and condensate) are processed as follows: after an initial separation process, condensate is treated (polished), and sent to the export line. The water and methanol mixture are separated. Water is discarded, and methanol is re-injected into the well-head or stored for later use.

The gas is processed as follows: the first step is the removal of CO_2. At a contactor tower, the gas comes in contact with MDEA, a chemical substance that bonds to CO_2 molecules. The gas leaves the contactor tower with some water, and at the other end, the CO_2-rich MDEA is sent to a separator. At the separator, MDEA and CO_2 are separated. CO_2 is discarded or injected into a depleted well and MDEA is re-used.

At the second step, the CO_2-free gas, still containing some water molecules, is sent to a glycol tower. Glycol bonds to water molecules. The now dry gas leaves the tower and is sent to the export line. The glycol-rich water is submitted to a separator. Glycol is re-used and the water is discarded.

The export line sends gas and condensate to shore, where these substances are again separated and further treated, before being shipped to consumers (industrial and domestic).

The diagram above is a simplification that omits a large number of interconnected systems, such as:

Table 3: Some systems located on board of a typical natural gas production offshore installation.

Thermal oil lines	*Heat exchangers*	*Fresh water maker and fresh water lines connected to process*
Potable water	*Discharge treatment*	*Instrumentation air and work air*
Engines (pumps, compressors, turbines, generators)	*Process control (software and hardware)*	*Electricity generation and distribution*
Fuel gas	*Fire fighting engines and lines*	

These systems are not discussed because the purpose of the thesis is not to discuss the functioning of the machinery, but rather to discuss how human workers perform their activities in such an environment.

At the company where fieldwork was carried out, the platforms are organized into clusters. A cluster consists of two or more platforms under the management of a local Head of Mining Installation (HMI). The HMI is responsible for both gas production and for offshore administrative matters (e.g., day-to-day affairs on board). Under the HMI is a crew of workers, both in-house and contractors, structurally organized into departments. Each department is headed by a Senior professional. The chart below (illustration 6) represents the typical structure of a cluster.

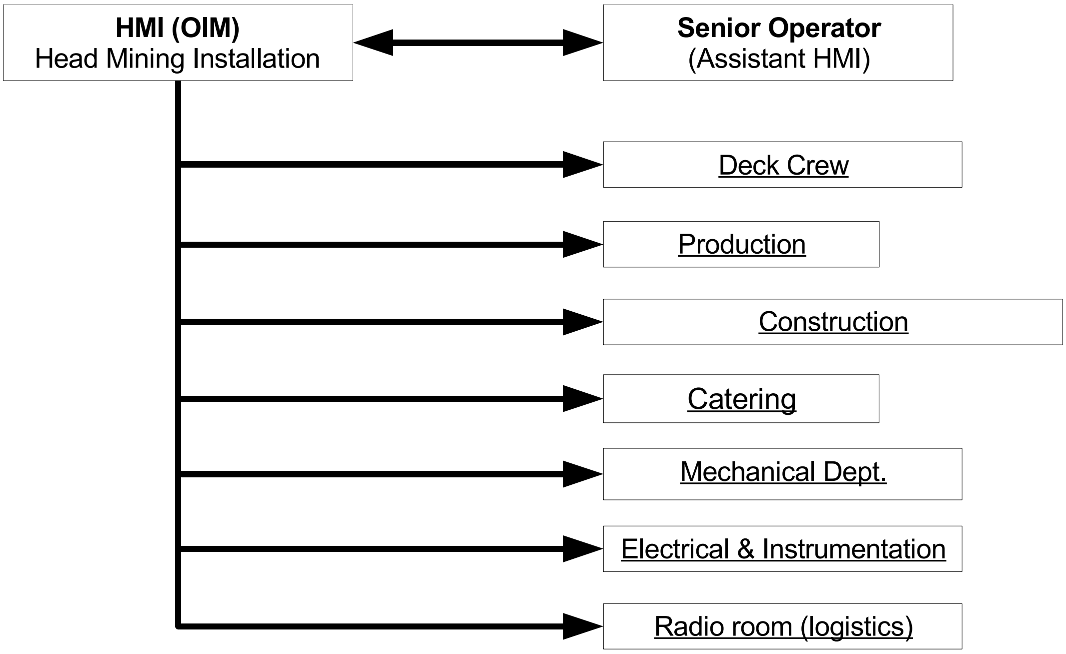

Illustration 6: Organizational chart for a cluster of platforms, showing the several departments and their hierarchical relation to the Head of Mining Installation.

Offshore workers fulfill a number of roles:

Process control (Production Department): although some platforms are unmanned, either because the processes on board do not require constant human manipulation or because the processes are remotely controlled, on other platforms, especially the larger ones, human Operators may be permanently on board. Operators supervise process flow using data that is presented by process control systems and by instrumentation mounted on process units. Operators also intervene in the process, either by computer-mediated commands or by physically manipulating valves and controls. As mentioned in section 3.3, the company where the fieldwork for this study was conducted adopts a philosophy that emphasizes the constant presence of Operators during the process.

Illustration 7: A natural gas production platform. Photo: courtesy of GDF Suez Production Nederland B.V.

Process-related maintenance (Production, Mechanical, E&I, Construction): Maintenance may be preventive or corrective. The former occurs before a breakdown and generally follows a pre-defined schedule. The latter occurs after a breakdown. Depending on the nature of the breakdown, corrective maintenance may be carried out immediately with resources readily available, or at a later time. The term process maintenance refers to the maintenance of equipment directly connected to gas processing. The company adopts a philosophy in which its technicians are expected to be familiar with the onboard equipment and to perform maintenance when required. This is in opposition to a philosophy where maintenance is carried out by vendors.

Structural maintenance (Construction and contractors): offshore platforms undergo continuous structural maintenance that is aimed at preventing corrosion and repairing damage caused by the harsh environment in which they are located. Furthermore, platforms may be subjected to capability expansion programs, which involves the installation of new equipment, and to partial/total decommissioning.

Support (Deck, Catering, Radio Room and Logistics): the deck crew works closely with the radio room in the organization of transportation and storage of material on the platform, namely, on the movement of containers to and from supply vessels and helicopter freight. The crane operator, a member of the deck crew, is responsible for crane operations on the main platforms (on smaller platforms, crane operations may be carried out by another qualified person). Medics (usually only present on the main platforms) double as radio operators. This serves two purposes: the radio operator is most busy during helicopter landing/taking off, and more or less available during the rest of the day. In addition, a serious injury may require the medic to coordinate aid with the onshore medical specialist as well as with the helicopter rescue service. Finally, the catering group is formed by a head cook (who doubles as catering manager), cooks and stewards. On smaller platforms, catering may not be available, in which case one of the other members of the crew will be responsible for food preparation, or available only at special times (e.g., during planned maintenance, when the number of people on board increases).

Other personnel: As described in section 3.3 , there is a constant flow of specialists who are not permanently attached to a cluster. This includes onshore engineers, vendor representatives (notably, process control software technicians), testing and calibration specialists, etc.

3.4 Summary

This chapter began with a discussion of existing approaches to the collection of data pertaining to the study of humans at work. The characteristics of the normative, descriptive and formative approaches, as delineated by Vicente (1999) were presented. From this discussion, it emerged that the study required a descriptive approach aimed at identifying patterns of human behavior in socio-technical systems.

It was then pointed out that data for descriptive studies may come from any of three sources (Woods & Hollnagel, 2006): natural studies, in which the researcher has the opportunity to observe workers' behavior as it takes place in the actual environment where work is performed; experiments in the field, in which the researcher deploys constructed scenarios to be played out in the actual environment; and spartan lab experiments, in which workers are removed from the actual environment of work and placed in a fully controlled setting. It was seen that while observer's control increases as one moves from natural studies to spartan lab experiments, the potential for discovery decreases. A choice was therefore made to conduct the research as a natural study.

The chapter then described the arrangements made for the study, from the process of collecting data, to checking its reliability, and discussed the ethical implications of the use of the data collected. Data was collected through unaided observations, with notebook and pen as the main tools. Very limited use was made of audio and image recorders. Even though the researcher was granted permission to use digital recording tools, they quickly proved themselves impractical due to the need for high risk work permits as well as the noise and lighting conditions aboard.

The researcher followed workers, individually or in groups, as they went about their daily activities. An effort was made to look for variety, and as a result, observations were made of Operators, Mechanics, and Electrician & Instrumentation Technicians. Interviews with other members of the offshore community, while neither presented nor discussed in this study, were nevertheless valuable to gain a better understanding of working conditions. Consistent with the notion of a natural study, no effort was made to shape the conditions of observation, and the researcher tried as much as possible to let the workers behave as they normally would. The workers had the opportunity to review and comment on the data collected, thereby providing a reliability check for the work done. At the same time , they were also questioned about the potential implications of making the data public. The same question was later raised to company management. No objection was made to the use of the data collected.

The third section of the chapter describes the natural gas production platforms as complex socio-technical systems which are characterized by the impossibility of achieving a complete understanding of their own functioning (and consistent with that assertion, the description produced is itself incomplete, but expected to suffice for the purpose of the study). This section then finishes by introducing the organizational structure of the company where the observations were made, so that the reader is able to see who's who aboard.

The incompleteness of description requires that offshore workers be capable of conducting performance adjustments that may carry significant risks for themselves, for their co-workers and for the installation itself. The workers' expertise lies in identifying when and how to adjust in such a way that work can be performed in a safe manner that simultaneously respects the production constraints to which the system is subjected. The next chapter presents a number of situations in which such adjustments were carried out.

French summary of Chapter 3

Ce chapitre commence par une discussion des approches existantes pour la collecte des données relatives à l'étude des êtres humains au travail. Les caractéristiques des approches prescriptive, descriptive et creatrice[7], délimitées par Vicente (1999), sont présentés. En vue des objectifs de l'étude, le choix a été fait d'employer une approche descriptive, visant à identifier les schémas de comportement humain dans les systèmes socio-techniques.

La première section souligne que les données des études descriptives peuvent provenir de l'une de ces trois sources (Woods & Hollnagel, 2006) : des études naturalistes dans lesquels le chercheur a la possibilité d'observer le comportement des travailleurs dans l'environnement réel où le travail est exécuté ; des expériences dans le terrain, dans lesquelles le chercheur déploie des scénarios à jouer dans l'environnement réel; et des expériences en laboratoire, dans lesquelles les travailleurs sont mis dans un environnement entièrement contrôlé. Neanmoins, tandis que la possibilité de contrôle des conditions d'étude augmentent dès que l'on passe d'une étude naturaliste à une expérience en laboratoire, le potentiel de découvertes baisse. Le choix a été fait ici d'effectuer la recherche comme une étude naturaliste.

La deuxième section de ce chapitre décrit les dispositions prises pour l'étude, depuis le processus de collecte de données jusqu'à la vérification de leur fiabilité, en passant par les implications éthiques de l'utilisation des données recueillies. Les données ont été recueillies grâce à des observations directes. Même si le chercheur a obtenu la permission d'utiliser des outils d'enregistrement numérique, ils se sont vite révélés inutilisables en raison des autorisations nécessaires et des conditions de bruit et d'éclairage à bord.

Le chercheur a suivi les travailleurs, individuellement ou en groupes, pendant qu'ils menaient leurs activités quotidiennes. Un effort de variété a été fait et, par conséquent, les observations couvrent les opérateurs, mécaniciens, et

7 Normative, descriptive and formative, in the original.

électriciens/instrumentistes. Des interviews avec d'autres membres de la communauté offshore, qui ne sont ni présentés ni examinés dans cette étude, ont été néanmoins précieux pour l'acquisition d'une meilleure compréhension des conditions de travail. Conformément à la notion d'étude naturaliste, aucun effort n'a été fait en vue de façonner les conditions d'observation, et le chercheur a essayé autant que possible de laisser les travailleurs se comporter comme ils le feraient normalement. Les travailleurs ont eu la possibilité d'examiner et de commenter sur les données collectées, ce qui a permis une vérification de la fiabilité des données. A cette occasion, ils ont également été interrogés sur les implications potentielles de la publication des donées. La même question a ensuite été posée au management de l'entreprise. Aucune objection n'a été faite à l'utilisation des données recueillies.

La troisième section du chapitre décrit les plates-formes de production de gaz naturel en tant que systèmes socio-techniques complexes caractérisés par l'impossibilité de la compréhension complète de leur propre fonctionnement (et compatible avec cette affirmation, la description faite est elle-même incomplète, mais devrait suffire à l'objectif de l'étude). Cette section se termine par l'introduction de la structure organisationnelle de l'entreprise où les observations ont été faites, afin que le lecteur soit capable de situer les acteurs présents sur le terrain.

Le caractère incomplet de la description du système exige que les travailleurs offshore soient capables de mener des ajustements qui comportent des risques importants pour eux, pour leurs collègues et pour l'installation elle-même. L'expertise des travailleurs réside dans l'identification du « quand » et de « comment » ajuster de telle sorte que le travail puisse être effectué en sécurité, tout en respectant les contraintes de production auxquelles le système est soumis. Le chapitre suivant présente des situations dans lesquelles de tels ajustements ont été effectués.

4 Performing Adjustments

This chapter presents a number of work situations the researcher observed while aboard natural gas production platforms. The situations are presented in the format of stories. The purpose of this format is to bring the reader as close as possible to the experience of the events as they unfolded. To the greatest extent possible , the stories are presented free of analysis. The choice of presenting the data as stories is one of the hallmarks of studies in Resilience Engineering, e.g. Cook (2006), da Mata, Gajewski, Hall, Lacerda, Santos, Gomes & Woods (2006), Perry, Wears & Spillane (2008), and Carvalho, dos Santos, Gomes & Borges (2008).

In telling stories, there is no attempt to judge the “correctness” of the actions performed by the workers. It is assumed as a principle that the workers involved in the events described below had no intention of compromising their personal safety, that of their colleagues, or that of the installation. Indeed, safety studies have traditionally shunned investigating events resulting from acts intended to cause damage. Whether this exclusion is justified or not will not be discussed here.

The stories presented appear quite uneventful, and have a distinct feeling of “ordinary.” One of the remarks the researcher often heard in the course of data collection was that the events in which he showed interest was: “This is normal. This is what we do.” This is precisely the point: accidents and incidents rarely come from single extraordinary events, but often from the unintended combination of many small, “normal” actions. These actions “get the job done,” but may carry small, nearly invisible risks.

In order to structure the presentation of the data collected, the stories are separated according to the main actors involved, namely the Operators (the Production department), the Mechanics, and the Electricians & Instrumentation Technicians. Each story is preceded by a brief summary that highlights its main components.

The reader is invited into the offshore world. It is recommended that the reader go through the stories with the following questions in mind: Who is doing what? Why is this being done? What may be the consequences of the actions taken? What would have been the consequences of not taking those actions? To keep these questions in mind will assist the reader in following the analysis performed in Chapters 5 and 6.

A reminder is in order: all Operators have names beginning with the letter A; all Mechanics have names beginning with the letter B; all Electricians and Instrumentation Technicians have names beginning with the letter M; all others have names beginning with the letter D. Names are intentionally repeated across stories to increase anonymity, and may not refer to the same individuals. It must also be said that because the offshore world is almost exclusively male (there were no female Operators, Mechanics or E&I Technicians aboard of any of the platforms visited), all references will be made to the masculine gender in this and in the following chapters.

4.1 Operators

4.1.1 Replacing a valve

Albert finds out that his colleague had discovered a leaking valve. The colleague determined that the valve should be replaced and that the job should be carried out by the Construction Department. Albert decides that this is a job that he can do himself.

I am walking with Albert. During this walk, Albert tries to explain to me that in his opinion, a good Operator must possess two skills:

- to evaluate a situation and to determine when to take immediate action and when to wait for further developments before taking action.
- to have the initiative to do what needs to be done.

He takes me to a unit, where three vessels, A1, A2 and B are located. The two A vessels perform the exact same function, and vessel B performs a different one. The

A vessels work in a rotation system, and are not designed to be used at the same time. Vessel B, on the other hand, is used permanently (although the system is so designed that any and all of the vessels can be bypassed). On each vessel is mounted a safety valve that opens automatically should the pressure inside the vessel exceed a threshold. Illustration 8 shows the configuration of those vessels before Albert's intervention.

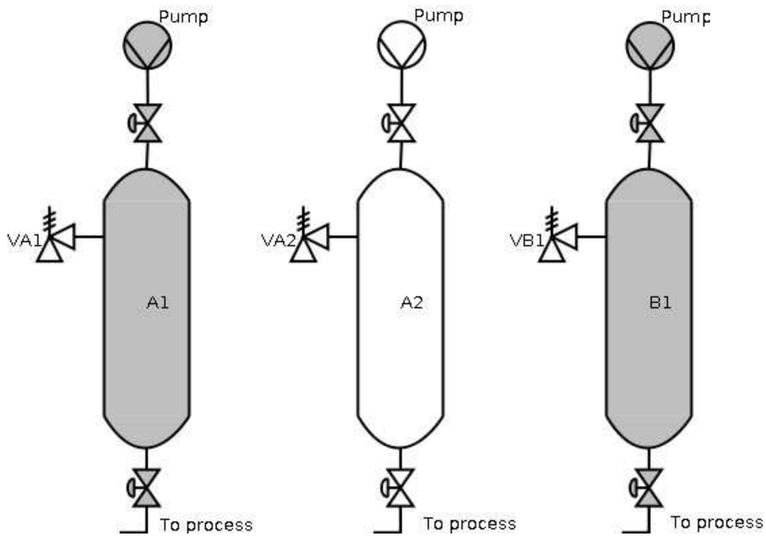

Illustration 8: Configuration of the vessels before Albert's intervention. Safety valve is mounted on the left side of each vessel. Vessel A2 is empty. Safety valve VB1 leaks.

Albert tells me that a few days ago, a colleague noticed that the safety valve on vessel B was leaking. According to Albert, the leak was not serious but the valve should be replaced. Albert's colleague's reaction was to make a formal request (a Work Order) to the Construction Department, asking for a replacement valve to be installed.

When Albert learned about the leaking valve, however, he had a different idea. The safety valves on the three vessels are identical, and only one of the A vessels is in use at any one time (in this case, A1 was in use and A2 was on stand-by). Albert contacted the Construction Department and asked for their permission to solve the problem: he would remove the defective safety valve from vessel B, then remove the safety valve on vessel A2 and install it on vessel B. The Construction Department immediately accepted the suggestion. Albert did the job. The result is presented in illustration 9.

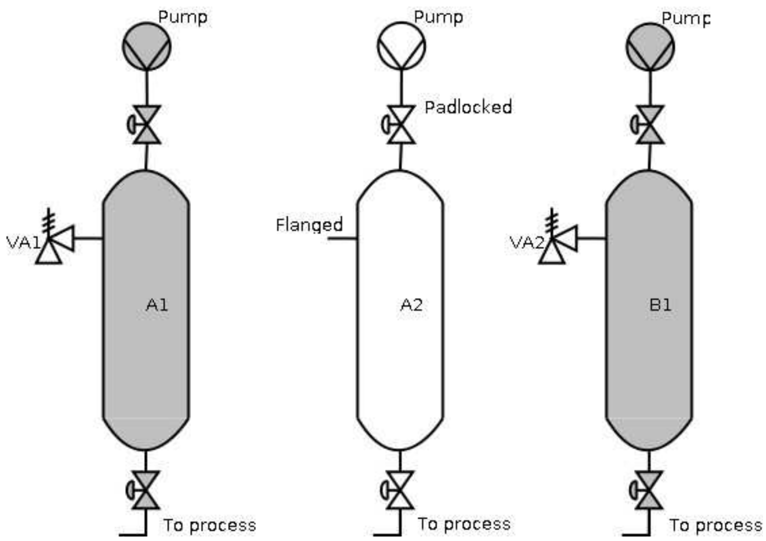

Illustration 9: Vessels after Albert's intervention. Vessel A2 was padlocked and in place of a safety valve, has a flanged end. Mounted on vessel B1 is the safety valve taken from vessel A2.

I asked him about vessel A2, which was now without a safety valve: "What if you need to switch from vessel A1 to A2?" In effect, Albert used a padlock to block vessel A2 (the use of padlocks for this purpose is controlled by a procedure), with a note about the missing safety valve. Albert nevertheless points out: "officially, this was a job for the Construction Department, it is their responsibility to perform this type of job. But if I see something that I can fix, then I would rather just go and do it myself, instead of giving the job to someone else.[8]"

4.1.2 Measuring radioactivity

Alfred is called to measure the level of radioactivity on a vessel that has been removed from the line and that will be sent to shore. Alfred does not request a Work Permit to operate the measuring instrument, but carries out the job nevertheless.

8 Throughout the thesis, reference will be made to workers' comments. Because very limited use of audio recording was made during data collection, in most cases the quotes are not literal, but constructs based on the researcher's understanding of their words. All possible efforts were made to ensure that my choice of wording accurately represents the meaning of their comments.

Normally Occurring Radioactive Material (NORM) is found in minute quantities inside the vessels and pipelines in which natural gas flows. The amount of NORM found in an isolated piece of pipeline, for example, is usually very small, but its cumulative nature is cause for concern. For this reason, whenever a vessel or pipeline is open, a qualified radiation expert must make sure that the level of radiation is below a certain threshold.

All material that has been in contact with gas is potentially contaminated, and must therefore be checked before it is sent to shore. In practice, this rule has been extended to mean that all equipment that could have potentially been in contact with gas must be NORM-inspected. This includes equipment that has never been used. The workers reported a few cases of equipment delivered out of specification, and therefore not even taken out of the shop, that had to be checked. This, some workers say, only serves to create additional paperwork. Although I did not have the opportunity to ask the question, I wonder whether in those cases the equipment was really checked.

A vessel is going to be replaced. The new vessel is on site, ready to be installed, and the crew has just removed the old one from the line. It is lying on the deck. Before it is taken anywhere (it will be sent to shore later on), Alfred comes with the radiation detection instrument to make sure it is safe for handling. A photo of a radiation detection instrument of the type used by Alfred is seen in illustration 10. The instrument is not explosion-proof (non-EX, as he tells me), and therefore its use aboard must be preceded by the delivery of a High Risk Work Permit.

When I come to the site with Alfred, this is the third time he has measured the radiation level on the vessel. The previous two times, the level was found to be too high, and the crew had been busy cleaning the vessel. Now, Alfred reads the level and determines the vessel has been sufficiently decontaminated, and can therefore be taken away.

Illustration 10: A hand-held radiation gauge of the type used offshore.

Back in the Control Room, Alfred tells me that he did not apply for a Work Permit for the job. Alfred's understanding is that radiation measurement is part of his normal duties as Operator, and normal duties do not require work permits. In any event, he adds a second later, he has a Work Permit for another crew working on an unrelated job, but using a similar instrument (in terms of risk). Instead of asking for another permit, he can simply work within the scope of the active permit. This is facilitated, I understand, by the fact that apart from the "permit holder" (the person leading the job described in the Work Permit), members of the crew are not mentioned by name. In practice, a Work Permit issued for a crew of three people means "the permit holder plus any other two workers." Alfred admits he is taking a risk, but adds that he would not be a good Operator if he were not able to know what was safe and what was unsafe to do on board.

4.1.3 Filling a water tank

Andrew is overseeing the refilling of the main water tanks on board. The control panel indicates that the tank has been filled to 100%, but Andrews does not ask the boat to stop pumping. The tank is intentionally overfilled.

I am in the Control Room with Andrew. He is looking attentively at the computer screen that indicates the rising level of a water tank that is being filled up (see illustration 11). Soon the computer indicates the tank has been filled to 100% capacity, but Andrew does not react. When the computer indicates the tank has been filled to 103%, he finally asks the supply boat to close the flow line.

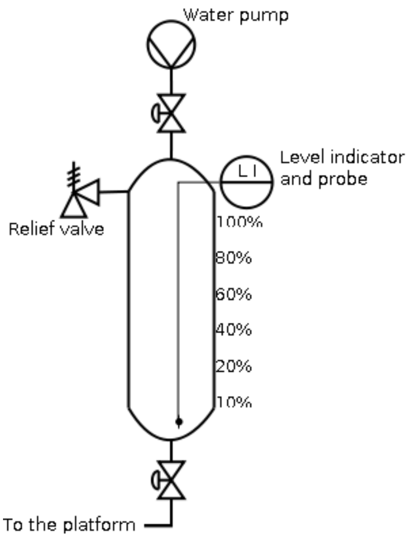

Illustration 11: A water tank. Notice relief valve mounted above the 100% mark.

I find that very strange, and ask him, “How come you filled a tank beyond 100%? Is that even possible?” Andrew explains to me that there are two factors to consider. First, he is not sure that the level indicator is accurate. He cannot guarantee that 100% really means 100%. Second, the 100% figure only means that the tank is filled to the set capacity, not to full capacity. He then adds, “well, we can never have too much water on board, right?” Albert, who is nearby and overhears our conversation, says that in the past, supply boats have been delayed by bad weather, and the platform had to be partially evacuated by helicopter because there was not enough water on board.

4.1.4 Checking the level in an oil container

Albert comes upon a tank that should be full. Looking at the sight glass, he is unable to determine whether the tank is full or completely empty. He tries a number of things before he is finally able to assert that the tank is, in fact, full.

It is early in the evening, and I am following Albert, who is walking around the plant, "doing a round," as he usually does when he begins his shift. The round is a visual (and in some cases, tactile) inspection of the status of the platform. During the round, an Operator checks the values on meters and gauges, looks for leaks or other signs of problems, verifies that work done during the day or during the previous shift has been completed and that the site is in proper condition, etc.

Albert looks at a sight glass (a photo of a sight glass can be seen as illustration 12) and notices that it appears to be completely empty. The sight glass indicates the level of lube oil for an engine. The engine is not running, but is considered to be in a state of readiness, which means it could be started up at any time. Albert's first reaction is to confirm his initial perception. Using a flashlight, he tries to look at the sight glass from a different angle, but because the sight glass has only a front view, he is unable neither to confirm nor to reject the impression that the sight glass is empty. He tries to bleed the sight glass, that is, to open the tap underneath it and drain it, but the lube oil is a high viscosity liquid that is even more viscous in the ambient temperature, and nothing is coming out. I sense in his gestures a feeling of urgency. He then opens the oil container, with the purpose of sticking a rod into it to verify whether there was any oil in the container. However, the top opening of the container is internally protected by a mesh (to prevent impurities from falling into the container and clogging it), so he cannot pursue this course of action. Again using the flashlight, he tries to look inside the tank, but he is still unable to determine the level of oil in the container. Albert then takes another look at the sight glass, and this time he is able to spot a small air bubble, which indicates that the sight glass – and by inference, the container – is full.

Illustration 12: A sight glass. The horizontal line indicates the interface, in this case, of condensate (top) and water (bottom). Photo: courtesy of GDF Suez Production Nederland B.V.

At the end of the round, Albert and I go back to the Control Room and he reports the event to one of the other Operators. This Operator remarks that someone in the previous shift must have overfilled the container, therefore overfilling the sight glass as well, but did not update the Operations Log – indeed, there was no record of the tank being filled in the past few days. Albert, who spotted the problem, turns to me and explains, “I know that the container is leaking and that we cannot stop the leak, but I checked yesterday and it was full, and there was no way it could have leaked so much in a matter of hours. One of the Operators in the previous shift must have overfilled it to make up for the leak.” Looking through a sight glass, an overfilled tank looks very much like an empty one.

4.1.5 Making a change to the plant

Increasing the efficiency of a process requires a physical change in the structure of the plant. Alfred believes he knows how to do it, and decides to experiment by installing temporary piping. The experiment appears to work, and what is supposed to be just a temporary situation suddenly becomes a permanent one.

On this platform, substances Alpha+Beta are mixed with substance Gamma at an early stage of the process. These three substances are then submitted to a Process P1, in which Alpha is separated, while Beta and Gamma bond. Beta and Gamma are then separated through Process P2. Gamma can then be re-used. However, due to the plant design, not all of the Beta+Gamma bond is submitted to Process P2. This was a undesirable situation, since a certain amount of substance Gamma was continually lost. Illustration 13 depicts the situation prior to any intervention.

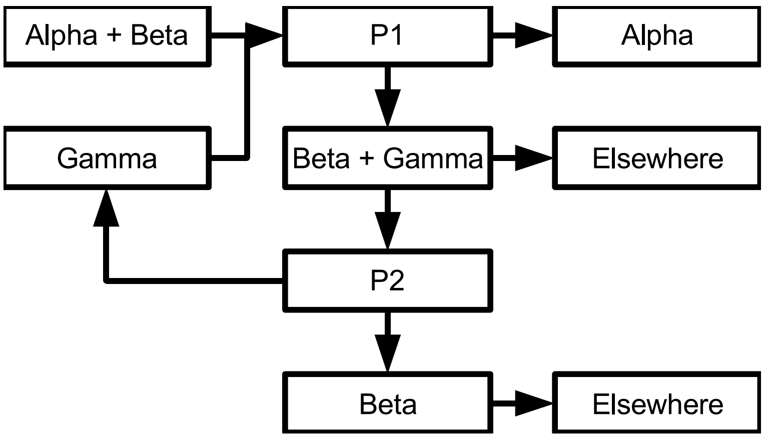

Illustration 13: Simplified diagram of the original process. Notice some of the bond Beta+Gamma does not go to process P2.

Alfred recognized the problem and wondered whether it would be possible to route all of the Beta+Gamma mixture to P2. In order to do so, Alfred first checked whether a connection would be feasible and then consulted his immediate superior about the plan. With his superior's approval, Alfred installed a temporary tubular connection, so that all Beta+Gamma mixture flowed to P2. Process P2 was then monitored to check whether its output remained within the specifications. Illustration 14 depicts the situation following Alfred's intervention.

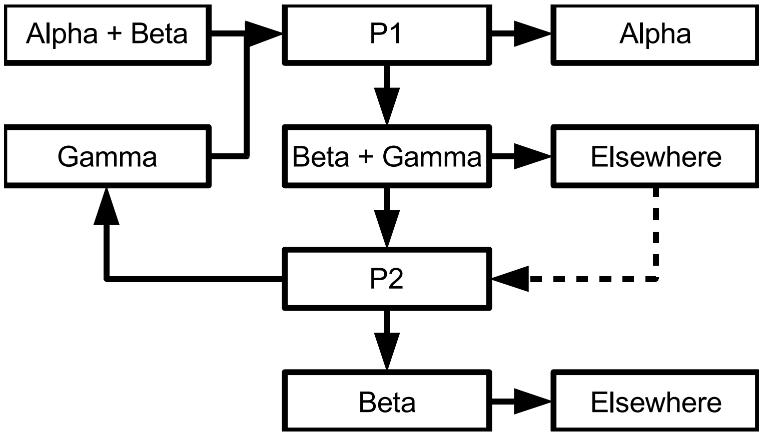

Illustration 14: Simplified diagram of the process after Alfred's intervention. Notice that now all Beta+Gamma goes through process P2 (dotted line).

At this point, Alfred collected a Plant Change Proposal form, filled it in with the details of his test, and handed it to his superior. He then removed the temporary connection. When Alfred's shift ended, the information was transmitted to the incoming crew. The new crew saw the value of Alfred's idea, but considered that further testing was necessary. This crew then devised another type of connection, of a more permanent nature.

This new structure was mentioned to Alfred's crew when it came back on board, but it was not officially reported through the Work Order system. In effect, a plant change had just taken place but no record of it – other than a written note from one crew to the other – existed. In order to create such a record, it was decided to create a Temporary Repair Work Order, to which amended drawings depicting the current (changed) configuration of the plant were attached.

4.1.6 Replacing a tubing

Albert must perform a "double block and bleed" before a worker begins to install tubing on a vessel. Albert knows that one of the valves is leaking, but believes the situation is safe. He explains the problem to the worker, who agrees to carry out the job.

I am walking in the process area with Albert. We stop in front of a large vessel, and pointing down, he tells me that the small pipe (a "tubing") that connects the vessel's drain valve to the closed drain system has been removed and must be replaced (as shown in illustration 15). The next morning, when the construction worker arrives, Albert tells him to take all measurements, prepare all the material and collect the tools needed ahead of starting the job. Turning to me, he says that the job requires that he puts the vessel's level transmitter on override mode to prevent an automatic system response. In override mode, the system ignores the fact that the vessel is empty. Since he does not want the detector to be on override for longer than necessary, he reminds the worker to be prepared.

A few hours later, the worker comes back and tells him that he is ready. The three of us walk together to the vessel. Albert puts the level switch on override mode, closes the upstream valve, and lets the fluid run through the downstream valve. Then he closes the downstream valve and opens the drain valve. When he closes the drain valve, the space between the two valves is empty, creating a safety buffer. He also opens a small vent valve between the two closed valves, completing a safety procedure called a "double block and bleed."

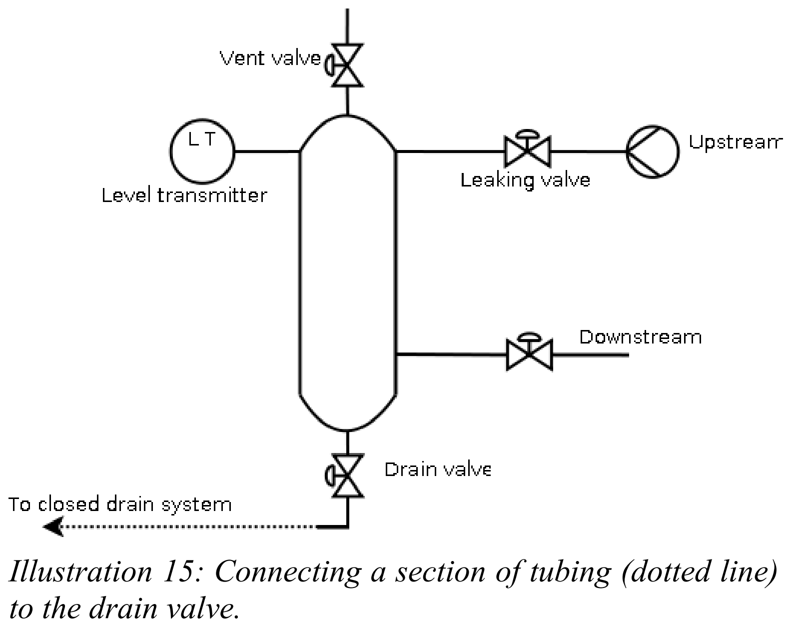

Illustration 15: Connecting a section of tubing (dotted line) to the drain valve.

The “double block and bleed” guarantees that in case of failure or otherwise unexpected opening of the upstream valve, the worker will still be protected by the closed drain valve, with the vent valve getting rid of excessive pressure. The other scenario, a failure of the downstream valve, would not represent an immediate risk except that of a return flow. In any case, the worker would still be protected by the closed drain valve.

However, what Albert tells me is that the upstream valve is quite old, and is known not to provide a complete seal. In other words, it leaks. The “double block and bleed”, in this particular case, reduces the risk of an accident, but does not eliminate it entirely. He briefs the construction worker, and explains to him what the situation is. They come to an agreement that the work can still be performed. Albert explains, “I told him what the problem is, and I know his style of working. So I know he usually works safe and fast. I will also remain here while he works, to keep an eye on it.”

I ask Albert if the worker could have refused to work in that situation, and he tells me that, “of course, no one is forced to work in unsafe conditions. In practice, it is a good question, because I don’t know how often someone would refuse to work.” Although there are specific rules about this type of work, he says, “people in the office onshore do not like to hear it, but what the paper says and what we have to do sometimes do not match.”

4.1.7 Servicing an engine

A construction job and a maintenance job scheduled for two platforms meant that one of them would be offline for four days. The conflict was noticed and the job on one of the platforms was re-scheduled to an earlier date. The workers were not informed about the change until the afternoon before they were expected to start working.

Platform Sierra and Platform Tango are part of a network of platforms so designed that all gas produced by Tango flows through Sierra before going to shore. In practice, this means that disruptions in Platform Sierra, including planned disruptions, have an impact on Platform Tango's ability to produce and send gas to shore.

A construction job was scheduled to take place on Platform Tango on Monday and Tuesday. Maintenance of an engine on Platform Sierra was scheduled for Wednesday and Thursday. As with most work that takes place offshore, both tasks were planned several months in advance, so that all material and tools could be acquired and shipped to the platforms. In addition, as per the contract, disruption in production must be approved by clients at least fourteen days in advance.

Although activities that impact on other platforms are usually coordinated, one important fact was overlooked: the original schedule meant that Platform Tango would not be able to produce for four days in a row. About two weeks before the jobs were scheduled to take place, the problem was identified. After some discussion, it was decided that Platform Sierra would change the scheduled maintenance job to Monday and Tuesday, so that both platforms would be disconnected from the network at the same time. The clients were then informed of the change.

The Operators and Technicians aboard Platform Sierra were not immediately notified of this change. On Sunday afternoon, the platform manager called the Operators and Technicians who would be performing the maintenance job to his room and asked whether everything was ready for the next morning. This is when they learned of the change. Since all the material and tools needed for the job were already on board, the Operators and Technicians simply shifted whatever they had planned to do on Monday and Tuesday to the following days and performed the maintenance job instead. When I asked whether that sudden change had had any impacts, they responded that schedule changes were a common situation in offshore work, and that therefore they were used to handle them. Consequently, they said “this is not at all a problem for us.”

However, one of the Operators later told me that he had already began working on something else when he learned of the change. What he was working on involved putting some level switches to bypass mode. He said that although he had never taken the switches out of his mind, he had not had the time to properly report on their status until several days later.

4.2 Mechanics

4.2.1 Preventive maintenance (1)

During preventive maintenance on a compressor, the team performs the tasks in an order that reduces physical discomfort. A small element of design is changed so that the work can be more easily performed.

It is time for the 4,000-hours preventive maintenance on a compressor. The job itself does not appear particularly dangerous, but it is time-consuming and involves several people from Production, Mechanics and E&I. The compressor has been turned off, its valves and electrical switches in safe position. The men are at work.

Robert tells me that the engine remains hot for a while after it is turned off. If he follows the list on the Work Order (this list just indicates the checks that must be performed for the 4,000-hour milestone), then he'd be working in the heat. However, the list is just a list of what needs to be done, not of the order in which they must happen, and Robert is free to start with a job away from the heat. The E&I guys did the same, and spent most of the first day working on the compressor's control panel.

It appears that the job is proceeding smoothly, and no problems have been found. Robert points out that this time, things are quiet on board and there is not a backlog of work to be done. In other words, he has the time to work on the compressor without other concerns. I ask him what this means in practice, and he gives me an example. He tells me that job is done a little different when one person is doing it, instead of two as now. He says, “If I'm working alone, and I'm servicing the starter engine, I'll just put in a spare, and service the engine later, when I have more time. But since we're two, and we have time, we can take it out, service it, and bring it back.” In my mind, I wonder how this is different from taking parts from another engine. I remember what an Operator had once told me about this practice: “yes, it happens, we want to get the job done and sometimes it's the fastest way, specially when it may take a month to get a spare part from shore. But I don't like it, because we lose a backup.”

On the morning of the second day, I meet Robert at the shop, and we walk together to the compressor. As we walk by it, Robert points to someone working on a corner and tells me what is happening. I do not understand what he says, so we go to the control panel room to talk. There, he explains to me that he realized yesterday that to change a filter (a job he's done several times), he had to stand in an uncomfortable position, because of the location of some tubing near the ground. So he asked a fitter to modify the piping so that the filter could be removed more easily. This, he tells me, “is not a plant change, it's just a little thing to make the job easier next time.” Illustration 16 shows a similar example of tubing placed in an inconvenient position.


Illustration 16: Tubing in the way, partially blocking view of gauges. Photo: courtesy of GDF Suez Production Nederland B.V.

While Robert continued working on the compressor, the fitter worked on the relocation of the tubing. At the end of the day, both jobs had been completed, and Robert remarked once more that in the future, servicing the engine would be easier.

4.2.2 Preventive maintenance (2)

Upon opening a housing containing an engine, Richard noticed that the hatch seal was damaged. Richard performed the scheduled preventive maintenance on the engine, and spent the rest of the day replacing the seal. He did not have the time to inspect the unit and look for other potential issues.

I am speaking to Richard, who has just come back to the shop at nearly the end of the shift. We begin to talk about the job of a Mechanic. He tells me that he always tries to do more than "the bare minimum." I ask him to explain it, and he says that when servicing an engine, he could simply do only what the servicing manual indicated, but that instead, he liked to tidy the place up, look around for other things that may require his attention, in other words, check that everything looks proper.

In fact, “going the extra mile” is not always possible, and he had an example. Earlier in the day, he had to go and perform preventive maintenance of an engine. The engine, which handled combustible material, was isolated inside a sealed housing, so that in case of a leak, the fumes would not spread to the platform deck. He was the only person involved, and spent the whole day on it.

Upon opening the housing, the Richard noticed that the hatch seal was damaged, and that in case of a leak, it might not offer adequate isolation. The seal is in that sense a safety item. Replacing it is therefore not so much a matter of “tidying up” or “making sure everything looks proper”, as it is a requirement.

Richard finished servicing the engine, went to the storage room and found a spare seal that he could use. However, close inspection revealed that the spare was also damaged, and could not be used. There were no more pre-cut spares available in the storage room. Richard decided to make a new seal using raw material he found there. The whole task took a considerable amount of time, but at the end of the day, the scheduled maintenance had been performed, and the seal had been replaced. The consequence, Richard concludes, is that “this time I was not able to do anything else. I serviced the engine, and I changed the seal. Next time I have work to do on that engine, I'll have to make sure I take a good look around.”

4.2.3 Making a plant change

Some changes had to be made to an engine. Those changes characterized what the company calls a “plant change”, and were therefore subjected to a lengthy procedure. The work was considered too important to wait for the procedure to be completed.

Ronald, one of the Mechanics, takes me to one of the decks on the platform. There are several engines on the deck, and one of them is only partially assembled. It is not yet in operation, although it will soon be. He explains to me that the set up of the engine is being changed. “This engine,” he says, “is connected to a process on the platform, and the process is changing, so the engine must change as well. We are working on it.” This is a clear case of a plant change. The work, he says, began when the materials and tools became available, and several steps of the flow diagram had been skipped. The engine was almost ready, and the proposal was still being processed. Richard, another Mechanic, adds that in this case the work was too important to wait for the appropriate paperwork to be completed. The engine is part of a plant process, and therefore related to the very core of the company's business. However, the official company policy is that no plant change work should commence before a plant change is approved.

4.2.4 Servicing a water pump

A pump must undergo periodic preventive maintenance. The next maintenance had been planned to take place on Friday. On Thursday, Ronald consults his schedule and realizes he has some free time. He decides to service the pump right away.

A water pump on this platform is part of the firefighting system. It must undergo periodic preventive maintenance to make sure that if ever needed, it will respond promptly and effectively. The next maintenance had been scheduled to take place on Friday morning. The job is relatively brief and simple, requiring only a couple of hours and the labor of a single Mechanic.

On Thursday morning, Ronald consulted his list of Work Orders, and realized that this was not a busy day. He decided therefore that he could execute the maintenance service right away. In effect, this constitutes a change in the schedule of work, but such changes are quite frequent, and to a certain extent, even expected. The situation is depicted in table 4.

Table 4: Task schedule and actual execution.

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
1	2	3	4	**5**	**6**	7
8	9	10	11	12	13	14
	Original schedule					
	Actual execution					

The next step was to request a Work Permit. Albert, the Operator in charge of processing the work permits received the request. Considering that the unit was part of the "safety system" and that it would be unavailable during maintenance, concluded that the job should be issued a "High Risk Work Permit" (HRWP).

A discussion ensued about whether the maintenance job merited a HRWP. On the one side was Albert, whose argument was that "if a component of the safety system is going to be unavailable, the risk on the platform increases, and therefore a HRWP is needed." On the other side was Ronald, who argued that "it is true that the unit will be unavailable, but should it be needed, I can quickly bring it back to operational state." Anthony, another Operator in the Control Room at the time, overheard the discussion and joined it. Anthony later explained that he sensed that the discussion was a good opportunity to have the crew talk about how Work Permits "work".

In the end, Albert was convinced that the job could be performed under a "Normal Risk Work Permit" (NRWP), which he could approve and issue without the participation of the Head of Mining Installation (HMI). The permit was issued, and the Technician was allowed to get to work. Albert, however, was only partially convinced. His understanding still was that the level of risk on board increased, and that the HRWP was more appropriate. According to Anthony, Ronald was merely trying to avoid asking for what he considered an unnecessary HRWP that would take time to obtain, since it required the signature of the HMI. Ronald himself explained that "while some of my colleagues may make the unit completely unavailable during maintenance, I know how to bring it back very quickly, and that is the way I always do this job. In my mind, there was never a question that this is a normal risk job."

4.3 Electricians and Instrumentation Technicians

4.3.1 Corrective maintenance

Soon after starting up an engine, a small gas leak was detected. The location of the leak was identified and the problem was addressed. Later on, a transmitter was found to be malfunctioning. The crew took the gauge of a stand-by engine and used it as a replacement.

On board one of the platforms are two engines of identical build which perform the same function. They were installed for an operation that is only rarely carried out, and, as a consequence, they remain switched off most of the time. Nevertheless, the engines are subjected to periodic maintenance, which includes switching them on every so often, to ensure that they remain in working condition. See illustration 17 for an overview of this configuration.

Andrew, one of the Operators, explains that "we always find a problem when we switch these engines on, because they are rarely used. It's better when an engine runs continuously." Company management devised an alternative use for one of the engines, which I will call Engine A, running it for a different purpose in the production process. A team of Engineers, Operators, Mechanics and E&I Technicians was assembled and a date was set to test whether Engine A could indeed perform that alternative function, and if so, what modifications might be needed.

On the day prior to the test, Engine A was switched on, both to make sure that it was working and to warm it up for the test on the following day. Ralph, one of the Mechanics, switched it on, apparently without any problems. Later that day, Alfred, another Operator, was doing a round inspection of the platform, and when checking Engine A, found a small gas leak, which he diagnosed as coming from a joint connecting the engine to a pressure transmitter. Transmitters are the domain of the E&I Department, and Mike was called. As he explained, "when installing a gauge, the joint must be very clean, otherwise the connection will not be proper. I removed the transmitter, and found that the joint was not clean. I cleaned it, re-installed the transmitter, and the problem disappeared.”

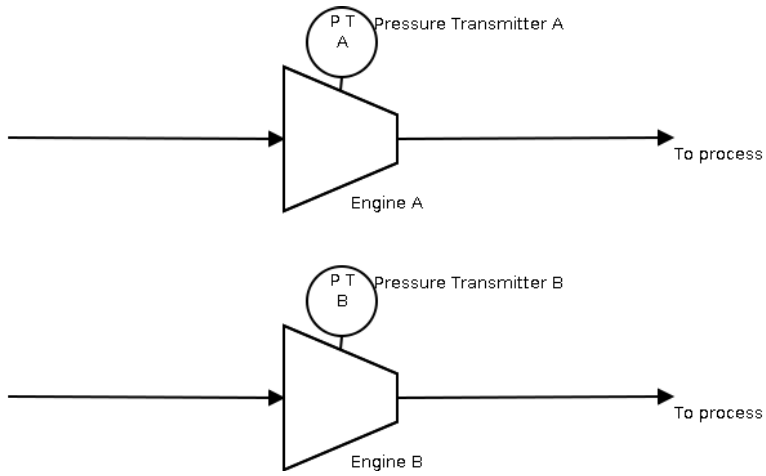

Illustration 17: The two engines prior to any intervention. Engine A is running during a test. Engine B is shut down.

On the day of the test, the transmitter malfunctioned. Mike was again called to investigate the problem. The transmitter provides information about the flow of gas, and pressure below or above given set points can trigger a shut down of the engine. It is not only an operational instrument, it is a safety-related one as well, and for both these reasons, Engine A cannot run without it. Since the test was about to begin, a quick solution had to be found.

Mike walked to the second engine, Engine B, removed its pressure gauge, and installed it on Engine A. Mike took the faulty gauge back to his shop, to inspect it and to determine whether it could be fixed. Indeed it could be fixed, and was. Later that same day, Mitt, another E&I Technician took the gauge and installed it on Engine B. The test on Engine A continued without any problems related to the pressure gauge. The result of this intervention can be seen in illustration 18.

Interestingly, when removing the pressure gauge from Engine B, Mike found that the screws used to attach it to the engine were not all of the same length. Although this appeared not to pose a significant threat, Mike made a remark that he did not like it that way. So, he changed all the screws on both gauges (engines A and B), using new screws of same length.

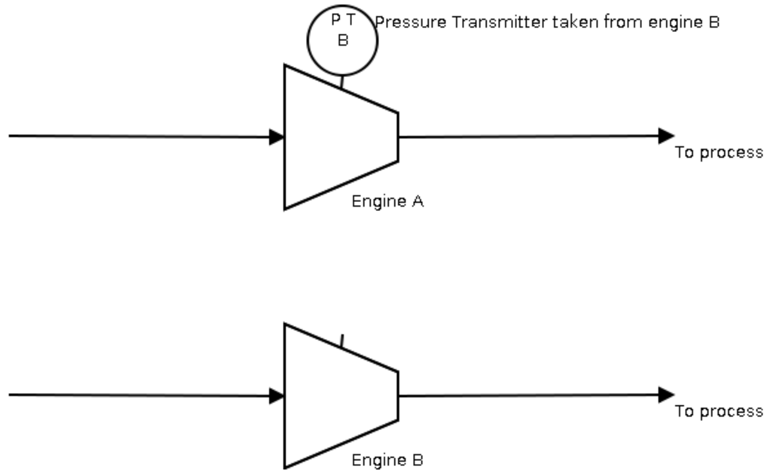

Illustration 18: The engines after intervention. Engine B's transmitter is on engine A. Later, engine A's transmitter was installer on engine B, completing the swap.

4.3.2 Calibrating a metering instrument

Due to bad weather, a person is unable to make it to the platform. The workers go on without him, with the more experienced man using this situation as an opportunity to teach the job to the other. A damaged connection joint is replaced by one taken from a unit nearby. The job is finished and they are getting ready to leave when they notice that now one of the units is missing a joint.

Daniel explained to me that the platform is equipped with a set of metering instruments that collect information about the flow of gas leaving the platform. The information is fed into a computer, which then calculates the precise amount of gas exported. These are sensitive instruments that require regular calibration. Since the company has contracts with a number of clients, calibration ensures accurate billing. To guarantee fairness, the instruments are periodically calibrated in the presence of a third-party witness.

We were waiting for the witness to arrive. The weather was bad and all flights were delayed. There was never an announcement that the flights were canceled, but by noon, Daniel realized that the witness would not come. To re-schedule the calibration in such cases is considered unnecessary. The companies involved prefer to proceed with the calibration without the witness. Daniel spoke to his superior and started to get ready to begin.

It turns out that there is an advantage to the witness's absence. Daniel takes this opportunity to teach an E&I Technician how to use the calibration device. The three of us go to the metering deck and they begin to work. The job involves disconnecting the instrument from the pipeline and connecting the calibration device, which simulates a number of flow properties, which are then picked up by the computer for comparison.

When trying to connect a small pipe to the meter, the Technician found that a connection joint was leaking. Without much deliberation, he went to another meter located a few steps away, removed its connection joint, and used it to finish the calibration. This second meter, which had already been calibrated, provided a temporary replacement joint that allowed the job to progress seamlessly.

The calibration was done. Daniel and the Technician are packing. The calibration device goes back into the box. The Technician closes one of the meters, and moves to the next. At this point, Daniel reminds him that he has not replaced the connection joint he had removed earlier. The Technician acknowledges it, and leaves the meter open. Later that day, he finds the time to go to install a new connection joint and complete the job.

4.3.3 Installing a control panel

The crew on one shift assembled a control panel. When the crew of the following shift comes on board, it notices that the new panel is different from the old one. The new panel conforms to the Technical Drawing, but the old one does not. The crew assumes the Technical Drawing is out-of-date. The new panel is modified, so that it resembles the old one. It is then installed.

A Plant Change regarding the upgrade of a control panel had been proposed and approved. The material was acquired and the new panel was assembled according to the Technical Drawings on file.

Illustration 19: The inside of a control panel. Each set of cables or pipes corresponds to an indicator on the front of the panel. Photo: courtesy of GDF Suez Production Nederland B.V.

Mark tells me that he wanted to take note of the configuration of the control panel before removing it, so that he would know how to install the new panel (illustration 19 shows the inside of a control panel). As Mark begins to take notes, he realizes that there is indeed a mismatch between the configuration of the control panel and the drawings. He finds this odd, since the workers who assembled the new panel are fully aware of the situation. He cannot explain why his colleagues did not check the drawings, but suggests that "it is easier to just follow the drawings, because it takes time to come here and check the panel, compare it to the drawings, and then figuring out why they don't match." This situation is schematically seen in illustration 20.

Mark spends some time re-assembling the new panel. His main concern is not with the Technical Drawings themselves, but with making sure that the new panel has the same configuration as the old one. He cannot be sure whether the differences are due to an error in installation, to an unreported change, or to an outdated drawing, so he must trust that by using the same configuration, the new panel will work just fine. The new panel is installed, and it indeed appears to work. He makes two copies of the drawing in which he indicates the differences he had found. One copy should be sent to the Engineering Department, but the other, he will keep in the E&I Department's files. He ends, "from experience, I know that there's a good chance I will never get an updated version of this drawing from the engineers."

Illustration 20: Simplified diagram illustrating the difference between Technical Drawing and actual situation. Note connections 2-B and 3-C.

4.3.4 Changing a light tube

The light tube on top of a pole burnt. Due to weathering of the mechanism, the electricians cannot lower the pole, but the Construction crew fixes it. While changing the light tube, the electricians find a number of problems to solve.

I meet Mark, an experienced electrician, in his shop. It is the end of his shift and he is writing in the electrician's logbook what he did today. Michael, a fellow electrician, is also in the shop, planning the work for the coming days. We review the events of the past two days.

An explosion-proof lighting fixture is mounted on top of a mast. The light tube itself is identical to those found in a household, but the fixture and the wires feature seals that prevent a potential gas leak from coming into contact with the electrically charged parts of the ensemble.

Just as with domestic lighting fixtures, in this one the light tube also burns after some time, and must be replaced by a new one. To perform what is in principle a simple operation, the mast can be lowered by removing the bolts that hold it to its base. This particular fixture is located in an area of the platform where it is very exposed to weathering, and as a result, the fixture had rusted and could no longer be removed.

Mark explains that the bolts have been in bad shape for a long time. He says that the last time he had to change the light tube, he asked the Construction team to build a scaffold, so that instead of lowering the beam to ground height, he could go up to reach the fixture. Mark says that there is an alternative: "You could simple take a ladder and rest it against the beam. Some of our colleagues would have done that."

Michael adds that using a ladder is dangerous, not only because of the height to which they would have to climb, but also due to the location of the beam. Mark and Michael agree that falling from the ladder could easily mean serious injury, and so, "although others would do it, we think it is unsafe and do not take that risk."

Mark tells me that two days ago, the lamp burned. Just as he had done the previous time, he contacted the Construction team and asked for a scaffold. Aware that the scaffolders follow a tight schedule, Mark initially scheduled the work for a couple of months later. When Mark told Daniel, the manager of the Construction team, why he needed the scaffold, Daniel understood that this was a recurring issue. The manager suggested that instead of building a scaffold, he would cut and replace the rusted bolts. What was more, Daniel would have it done right away.

This solution was promptly accepted by Mark, as it meant that in the future, he would be able to do the job by himself, without the assistance of the Construction team. Of course, it also meant that the job would be done properly, safely, and a lot sooner than planned.

Daniel's solution was straight-forward, but required a Work Permit, to be obtained from the usually busy Operators. Several hours passed before Daniel finally got the bolts removed. Mark then lowered the beam and replaced the light tube, but nothing happened. As it turns out, the problem was the starter, which was damaged and had to be replaced.

Previously, when the beam could not be lowered, the job consisted of opening the fixture, climbing the scaffold, replacing the tube and closing the fixture. With the fixture at ground level, Mark has the opportunity to inspect it, and to find out that not only the wiring connection to the fixture is not up to the required standard, it is also loose. This compromises the proofing of the fixture, and must be repaired. In addition, the wiring is old, and has suffered considerable weathering. Mark decided that it too must be replaced.

Mark removed the fixture from the beam and brought it to the shop. The fixture was quite old, and Mark had to improvise a support for the new starter that went inside it. The material for this support, Mark explains, comes from a stock of "old parts" that the electricians and other Technicians on board kept just for this type of situation. At the end of the day, the fixture was ready.

On the morning of the next day, Mark was busy replacing the wire. This required the installation of a connection box, for which a support also had to be built and put in place. Finally, just before lunch, Mark succeeded in making all the connections. The fixture was then re-attached to the mast, and the beam was raised. The job was done.

4.4 Summary

This chapter introduced several instances of offshore workers performing adjustments. Those instances were presented as stories, and the stories constitute the main source of data available for analysis. Reading the stories, it is possible to get a sense of the situations workers faced, and what course of action they ultimately decided to take. There were no acts of heroism, and there were no acts of vicious carelessness. Indeed, although in several occasions the workers acknowledged that there were safer alternatives, they did not perceive what they were doing as *unsafe* or *dangerous*. The workers who had access to the stories (see section 3.2.1) were mostly in agreement with what their colleagues had done. Occasional divergences appeared to focus on *working styles*, rather than on an absolute sense of right or wrong.

There was however a sense that things could be better. Although invariably proud of their accomplishments, of their ability to keep the platform running safely and reliably, every now and then comments surfaced to the effect that that is not the way to work, but one makes do with what one has. Remarks of this type stress that adjustments are not entirely invisible for the workers, although whether all adjustments are equally visible can be debated. Perry, Wears & Spillane (2008) argue that resilience capacity – precisely, the capacity to perform adjustments, is finite. One may argue that the visibility of adjustments is an indicator that the system is operating close to its safety limits. But merely to see something is not enough. What is seen must be put in context, must be interpreted according to a certain model of the world, so that it makes sense. The development of a framework to assist one in making such interpretations is the topic of Chapter 6.

However, before moving to the development and proposition of a coherent framework, the thesis turns to a search for the common elements underlying the stories. The focus, it should be again stressed, was not to judge the workers' actions in terms of right/wrong or safe/unsafe. It was rather to identify the general purpose of adjustments, and the factors that influenced their execution.

French summary of Chapter 4

Ce chapitre présente des situations de travail que le chercheur a observé à bord des plates-formes de production de gaz naturel. Les situations sont présentées sous la forme de récits. Le but de ce format est d'amener le lecteur aussi proche que possible de l'expérience des événements tels qu'ils se sont déroulés. En décrivant des situations, on n'est pas tenté de juger l'exactitude des actions menées par les travailleurs. On suppose en principe que les travailleurs impliqués dans les événements décrits ci-dessous n'avaient pas l'intention de compromettre leur sécurité personnelle, celle de leurs collègues, ou celle de l'installation.

Les récits présentés correspondent à des situations « ordinaires », sans incident particulier. C'est une des remarques que le chercheur a entendu pendant la collecte des données. Les événements dans lesquels il manifestait son intérêt était considérés comme normaux : « C'est normal. C'est ce que nous faisons. » De fait, les accidents et les incidents proviennent rarement des événements uniques extraordinaires, mais souvent de la combinaison involontaire de nombreuses petites actions tout à fait normales. Ce sont des actions évidemment nécessaires, du point de vue des acteurs, pour que « le travail soit fait », mais qui peuvent engendrer des risques.

Afin d'apporter une structure à cette présentation des données recueillies, les récits sont séparées selon les principaux acteurs impliqués, à savoir les opérateurs (le département de Production), les mécaniciens, les électriciens/instrumentistes. Chaque récit est précédée d'un bref résumé qui met en lumière ses principales composantes.

Il est recommandé que le lecteur lise les récits avec les questions suivantes à l'esprit : Qui fait quoi ? Pourquoi fait-on cela ? Quelles peuvent être les conséquences des mesures prises ? Quelles auraient été les conséquences de ne pas prendre ces mesures ? Garder à l'esprit ces questions aidera le lecteur à suivre l'analyse effectuée dans les chapitres 5 et 6. En lisant les récits, il est possible d'avoir une idée des situations que les travailleurs ont rencontrés, et des actions qu'ils ont finalement décidé d'entreprendre. Il n'y a eu ni d'actes d'héroïsme, ni d'actes de mépris pour la sécurité.

En effet, même si à plusieurs reprises les travailleurs reconnaissent qu'il existait des alternatives plus sûres, ils ne percevaient pas ce qu'ils faisaient comme étant dangereux. Les travailleurs qui ont eu accès aux récits (voir section 3.2) étaient pour la plupart en accord avec ce que leurs collègues avaient fait. Les divergences semblent se concentrer sur les styles de travail, plutôt que sur un sens absolu de bon ou mauvais.

Dans le chapitre 5, la thèse se tourne vers la recherche des éléments communs qui sous-tendent les histoires. Il faut encore souligner que l'accent n'est pas mis sur un jugement des actions des travailleurs en termes de vrai/faux ou de sécurité/risque. Il s'agit plutôt d'identifier les buts généraux des ajustements, et les facteurs qui ont influencé leur exécution. On observe toutefois chez les acteurs le sentiment que les choses pourraient être mieux. Bien que toujours fiers de leurs réalisations, de leur capacité de garder la plate-forme en fonctionnement de façon sûre et fiable, ils font de temps en temps le commentaire que « ce n'est pas la bonne façon de travailler, mais on fait avec ce qu'on a dans les mains. » Des remarques de ce type montrent que les ajustements ne sont pas totalement invisibles pour les travailleurs, quoique on ne sache pas si tous les ajustements sont également visibles. Perry, Wears & Spillane (2008) soutiennent que la capacité de résilience - précisément, la capacité d'effectuer des réglages, est limitée. On peut supposer que la visibilité des ajustements est un indicateur de la limite de la capacité d'ajustement. Mais voir quelque chose n'est pas suffisant. Ce qui est perçu doit être placé dans son contexte, doit être interprété selon un certain modèle, de sorte qu'il soit effectivement compris. L'élaboration d'un cadre pour aider à faire une telle interprétation est le sujet du chapitre 6.

5 Functional Synthesis

Chapter 4 presented to the reader a wide, representative sample of the activities normally carried out by the professionals aboard natural gas production platforms. This chapter then discusses those activities, and seeks to extract their most significant characteristics. In this chapter, a functional synthesis is attempted. The goal is to arrive at patterns that illustrate how the system behaves under different, particular conditions.

According to Pavlov & Obukhov (1973), a "functional synthesis reflects the quantitative characteristics of a system and their functional properties." More recently, Woods & Hollnagel (2006, p. 55) spoke of functional synthesis as the process of modeling "based on patterns that are abstracted from observation." In turn, patterns emerge as a result of "comparison and contrast across settings over time" (Woods & Hollnagel, 2006, p. 4). What Woods and Hollnagel have in mind, however, is not *quantitative* patterns, but *qualitative* ones. It is the latter that this chapter is concerned with.

Synthesis involved three steps. In the first step, the researcher returned to the stories and isolated the central issue(s) in each of them. The objective was to identify what the situation was, what made that situation problematic, and how the crew addressed the situation. In other words, how the crew adjusted.

The second step consisted of "comparing and contrasting" the adjustments made, looking for both similar and unique cases. From this step emerged a set of patterns – or themes, in the language of qualitative research (Creswell, 2007; Corbin & Strauss, 2008):

- patterns of handling the work schedule;
- patterns of risk perception;
- patterns of dealing with paperwork;

- patterns of information acquisition; and
- patterns of use of resources.

The third step consisted of discussing the patterns identified: what is their significance? In what kinds of situations are they likely to be found? What kinds of risks do they carry with them? The second and the third steps form the core of this chapter.

5.1 The work schedule

One of the most important functions in a socio-technical organization is the planning of the use of time. Time here refers to the initiation, duration, and conclusion of activities or events. The complexity of the operation of an enterprise such as offshore natural gas production requires a time management strategy that is both rigid enough to ensure that everything gets done when it needs to be done, and flexible enough to accommodate local conditions.

The organization uses a number of tools, mostly in the form of software applications, to schedule activities related to maintenance, projects and contracts across its various sites. However, these tools only provide for the rigid part of the time management strategy. They supply the workforce with an overall picture of the tasks ahead. This section discusses how workers handle the local, immediate conditions which escape the rigidity of formal schedule planning.

5.1.1 Freedom to adjust one's own schedule

Freedom is represented here by the changes that workers themselves make to handle local, immediate conditions. In practice, the schedule workers receive from the company is approximate – work as imagined (see section 2.3.1). The maintenance of a compressor, for example, may be scheduled to take two entire days. Under certain conditions, however, it may be possible to complete it in a single day. Conversely, it may take three days or more. None of these possibilities is explicitly considered in the schedule. It then becomes up to the worker(s) to resolve the gaps and conflicts that are created. This resolution may come in one of two ways: changing the way the work is done, so that it *fits the schedule*, or changing the schedule, so that it *fits the work*. It is this latter type of adjustment that this section is concerned with.

The story 4.2.2 illustrates a clear case of a scheduling gap. Ronald noticed that he had some free time in his schedule. What can he do with this time? Several possibilities exist, including “doing nothing”, but he chooses to bring forward a job scheduled for the next day. It is difficult to say with precision what motivated this choice, but the data available provides some clues:

- There are few leisure activities available. Doing nothing, in this case, could mean really nothing.

- Due to space limitations, there is little privacy on board. A worker “doing nothing” would be exposed, and vulnerable, to criticism from colleagues and a reprimand from superiors. The need to maintain discipline aboard means that workers should be always working.

- As several workers remarked, the situation on board could change quite dramatically from one moment to the next. By bringing a job forward, a worker can guarantee that at least that job will get gone, even if something unexpected comes up later during the hitch. Here, the worker must decide which job to bring forward.

- Workers are on board for fourteen days, working for twelve hours a day. They know that performance drops as the days go by. Bringing a job forward ensures that it is executed at a higher performance level.[9]

From the points above, it is reasonable to argue that adjusting one's own schedule fulfills three purposes: (1) it avoids wasting time; (2) it makes good use of one's physical and mental capacities; (3) it builds up a time buffer for later use. It is worth

9 This is, in fact, taken in consideration when making the schedule. The more demanding tasks are often scheduled for earlier in the hitch.

noticing that these three purposes are at the root of the framework developed in Chapter 6.

5.1.2 Handling a schedule change

The discussion about freedom to adjust the schedule may give the impression that schedule changes are always purposefully initiated by the workers themselves. This is certainly not the case. The story 4.1.7 illustrates what happens when change comes "from outside", leaving workers with no choice other than to accept the revised schedule and to work with it. In other words, they must change the work, so that it fits the schedule.

In that story, change was instigated by the late discovery of an error in planning, that meant a platform would be offline for four days, a clearly undesirable situation. The change was made, but apparently it was never recorded and so the Operators were unaware of it. When the change was finally communicated to the Operators, they were already busy with other activities – following their work plans.

The change meant dropping those activities and focusing all attention on the maintenance job. Flexibility here was not a choice, because disruptions in production must be communicated to clients several days in advance, lest the company be penalized. However, one of the Operators later explained that he had already begun working on something else when he learned of the change. What he was working on involved switching some level gauges to bypass mode. He said that although he had never taken the gauges out of his mind, he had not had the time to properly report on their status until several days later.

It is worth pointing out that the bypass procedure requires that a bypass is approved by the platform's HMI before the execution of the bypass. In practice, and especially when the bypass will be active for a short period of time, the HMI may be informed only verbally. In any event, the bypasses went unreported until later, when the Operator had the time to do the paperwork involved.

There is yet another type of change from outside that requires adjustment: when the work turns out to be more difficult than anticipated. This is seen clearly in 4.3.4.What started as a job that, according to Mark, should take no more than 10 minutes of one electrician's time, had already consumed an entire morning and involved (at separate times) Mark, Michael, Daniel, and another member of the Construction team. It would still take the afternoon, and the morning of the next day, to finish the job.

Let us briefly review the sequence of actions, first looking at what should have happened, under ideal conditions, and what actually took place[10]:

Lamp burnt > Corrective Maintenance Work Order (CMWO) opened to replace the tube > mast lowered > tube replaced > mast raised > CMWO closed.

The number of steps taken from the time the lamp burns is five . According to Mark, the time to complete the operation was ten minutes (this estimate probably excludes the CMWO).

Lamp burnt > operation planned for the coming months and Corrective Maintenance Work Order opened to build a scaffolding > discussion about the scaffolding and decision to replace rusted bolts > rusted bolts cut and replaced > mast lowered > tube replaced > removal of the fixture from mast > replacement of broken starter using a piece of plastic as support > replacement of the fixture onto mast > renewal of the power cable, with the installation of a connection box > mast raised > CMWO closed.

Here, the number of steps taken from the time the lamp burns is eleven – more than twice the number anticipated. The operation took more than a full day of work and even required the participation of another department.[11]

10 For ease of reading, both versions are somewhat simplified. Not included, for example, are the search for spare parts and the request of the necessary Work Permit.

11 To be precise, not over a day of continuous work. It is meant here rather that this job was their main occupation for that length of time. The reader will have noticed by now that the stream of daily work on board is fraught with interruptions and disruptions. Indeed, this story is precisely an example of that.

In neither of the two cases did the workers have a real alternative. In the first case, the production imperative meant that the workers had to figure out a way of getting the platform running, even if that meant dropping on-going tasks. In the second, there was no justification to postpone the task initiated, and the workers had to keep going until they finished it. If that meant delaying other tasks, it is sensible to assume that those were not as important or as urgent, which brings up the issue of calculating risk, which is the subject of the next section in this chapter.

5.1.3 The work schedule: summary

The management of time is an important function in socio-technical systems. Time is a limited commodity, in the sense that one cannot take an indefinite amount of it to accomplish a given task. This is especially so when one considers that socio-technical systems are made of several sub-systems, which creates a problem of coordination. The obvious consequence of that is that organizations must have a way of allocating time so that work is performed in an orderly fashion.

As shown in sections 5.1.1 and 5.1.2, offshore installations pose a certain resistance to precise planning. There is simply too much variability to be taken into account. As a result, there must be occasional give-and-take, which amounts to either *changing the schedule*, so that it meets the requirements of the task; or to *changing the way the task is performed*, so that the schedule can be maintained.

It appears that the largest threat to safety with respect to time is to have a schedule that is too tight and too rigid (tasks must be performed at very specific points in time, for very specific durations). In such a case, the workers' only possible response will be to drop other tasks to keep up with the schedule. However, unless the schedule explicitly gives the workers a ranking for tasks, workers will have to figure out what must absolutely be done and what may be left for later. Since workers have only partial knowledge about how the system works, the possibility of mis-coordination and failure increases. Nevertheless, this is the situation: workers are called upon to make such decisions, based on their own experiences and knowledge about the system, however partial and incomplete this may be.

5.2 Risk perception

What makes a task safe or unsafe? A formal risk assessment can provide a statistical point of reference regarding the probability of an event (a failure, an incident, etc.). At the ground level, however, probabilities appear to be of little value for workers. Rather, the determination of whether a certain situation is safe or unsafe becomes a matter of possibility (Clarke, 1999). This section discusses how workers concretely handle the decision to undertake a given task: first, by assessing the need to do something right away, or leaving it for later; and determining whether the conditions that make a task acceptably safe are there.

5.2.1 Fix it or leave it

Albert's decision in the event described in 4.1.1 to fix the situation immediately was at least in part influenced by a strong cultural trait of the organization, one that dictates workers should have the initiative to fix the problems they find.[12] This trait is modulated by the understanding that not all problems are equally serious. Some appear to be better left untouched, others monitored, and finally, some immediately addressed. The first class of problems is commonly seen in the Control Room, where one sees alarms that pop up and to which no one seems to pay any attention - alarms are "acknowledged" (by pushing a button), but acknowledgement appears to be motivated rather by the desire to silence the alarm than anything else.[13]

The second class of problems is illustrated by cases in which other considerations – safety, production, need of special tools or expertise, etc. - make taking immediate action an unattractive option. This appears to be a regular feature of offshore life, and examples are presented in the stories 4.1.3 (there is no perceived need to find out whether the gauge is accurate) and 4.1.6 (the valve can be fixed later).

The third category of problems comprises problems that should be solved immediately. Quite evidently, it includes emergency situations where action cannot

12 As opposed to assigning it to someone else.
13 There are however alarms which are merely "informational", and that do not, by definition, indicate any type of malfunction or failure.

be delayed, as well as situations which could, in the short term, evolve into an emergency. Consistent with company culture, this category also includes problems that, while not particularly serious or threatening, may be addressed without further delay, namely, because all the elements required are already available.

In the story 4.1.1, Albert's colleague clearly identified the leaking valve as a category two problem. It did not pose an immediate threat, and was furthermore the responsibility of another department. Albert, however, identified it as a category three problem, one that could be fixed right away because he had the knowledge, the tools and the time to do it. He also knew that leaving the task in the hands of the Construction Department meant that the valve would continue to leak, in his view unnecessarily, for some time.

Task prioritization based on an evaluation of risk is an essential skill. It appears to be particularly useful in the isolated environment of a platform, where not only are resources limited, but the very ability to muster additional resources is limited as well. The key, as one Operator once put it, is that the offshore worker must know the balance between being a cowboy (the risk-taking attitude) and a schoolgirl (the fright-flight attitude). It is noteworthy that the veteran workers often make reference to the company's old “cowboy culture” and that even though there is wide agreement that times have changed and that the level of acceptable risk has lowered markedly, one still finds occasional signs of “cowboy behavior.”

At the organization, very little formal assistance with prioritization based on risk appears to be available. Prioritization seems to take place on an entirely empirical basis, that is, based on experience – first-hand or vicarious. Although this is known to be limited as far as evaluations go, no cases were observed in which an evaluation missed the mark. The absence of such cases can be interpreted in many ways: as a delay between the actions taken (or not taken) and the results, consistent with the notion of latency; as a fortuitous choice under conditions of variable uncertainty; as a testimony to the expertise of the workforce.

5.2.2 The possibility of failure

A central feature in the story 4.1.6 is the explicit knowledge that the valve is known to be leaking. There was no mention of a leaking valve, or that a level switch would be put on override mode in the Work Permit issued for the job. When asked about this "missing information," Andrew explains that the general understanding is that "when an Operator is doing something that is directly related to his job as an Operator, he needs not fill in a Work Permit request. We would spend all day requesting permits to open and close valves." However, this rule should apply only to work that is performed by a single person, the Operator himself, and only when it does not create any additional risks. That was not the case: a double block and bleed for the purpose of construction work is not part of "normal operation," especially when one of the valves is known to be leaking.

The Operator is not concerned with how often a double-block-and-bleed fails, but with whether it will fail on this specific occasion. It is evident from the story that the Operator's view was that a possibility of failure existed. Concretely, he estimated that the possibility existed, but that it was not great – one assumes that he would not knowingly expose his colleague. Nevertheless, he was sufficiently concerned about it to stay with the Technician for the duration of the job. This did not in any way reduce the possibility of failure, but increased the possibility that, in the event of failure, an immediate response would be available.

Safe or unsafe? The job was executed and nothing untoward took place. When discussing this and other stories with a group of Operators, the researcher suggested that they sometimes had to work in less than ideal conditions, to which one of them replied that what the researcher was saying was "an understatement." Situations where Operators must judge the risks involved in a given activity are not rare. What is apparent from this story is that the Operator did not determine the risks in a vacuum, but rather gauged them against a concrete context that involved questions about the possibility of getting the valve fixed, the urgency of the task, the experience of his colleague, and the actions that could be taken to create a countering element of safety.

5.2.3 Risk perception: summary

Risk calculation may be understood here in either of two senses. The first is that of assessing the seriousness of a given situation, and on the basis of that assessment, deciding whether immediate action is necessary, or can be included in the organization's schedule of work to be done. An important advantage of this aspect of risk calculation is the optimization of the use of the limited resources on board, ensuring that the most important issues are addressed sooner. However, one must not forget the very real possibility that a miscalculation of the risks may create or exacerbate a problem elsewhere.

The second sense in which risk calculation may be understood refers to the evaluation that workers make, before engaging in a task, of whether the local condition ensure the safety of the task. Workers aboard are very aware of the dangers of working in an offshore installation. There are frequent reminders in the form of training sessions, drills, and of course, accidents. Yet, they both expect and trust that they will be able to accomplish their tasks without anything untoward taking place. This expectation, this trust, is not blind. It is founded upon observation, practice, experience: it is a *feeling* of being in a safe position to work, closely related to the notion of situation awareness that Rajan, Wilson & Wood (2005) discuss.

5.3 Paperwork

Work aboard platforms, just as in any industrial system, is to a significant extent regulated by formal exchanges of information, in the shape of *paperwork*. Schedules, seen in the previous section, are one of the many types of paperwork. The current section is concerned two other types of paperwork: Work Permits and Plant Change Proposal forms. Vicente (2004) comments that "soft" technological elements are often ignored or given less consideration than the "hard" elements in the design of socio-technical systems. Yet, the former may have a significant impact on how work is accomplished, as will be shown.

5.3.1 Work Permits

A Work Permit is a document that states the work that will be performed, where it will take place, who will perform it, for how long, and the safety measures taken. Work Permits are widely used in the Oil & Gas industry, and since the Piper Alpha accident in 1988, much attention has been dedicated to establishing and maintaining a proper work permit system.

At the company, work permits are handled through a computer software. Workers request a permit by completing an on-line form. Once completed, the form becomes visible to an Operator-in-Charge[14], who must check that the information is correct and that safety measures indicated are adequate. The Operator-in-Charge adds to the Work Permit the safety measures that the Production Department must implement. The permit is then approved and delivered.[15]

The Work Permit regulates the flow of work on board. According to company procedure, “A work license is generally necessary for carrying out work on installations with the exception of work that forms part of normal operation activities on the installation” (GDF Suez Production Nederland B.V., 2007). Work in the kitchen, in the living quarters, on the helideck (loading and unloading helicopters), in offices, in workshops and in the Control Room, and the operation of cranes clearly fall into the “normal operations” category and are therefore excepted from the requirement.

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14 In principle, all Operators are allowed to deliver work permits. In practice, it appears that at least in the large platforms where many Operators work together, one of them is selected to handle the work permits. The expression Operator-in-Charge, however, applies best to the small platforms, where a single Operator is responsible for all activities on board. On larger platforms, the notion of Operator-in-Charge is diluted by the division of labor between Operators (field Operators and panel Operator), as well as by hierarchy: Operators, senior Operator, HMI.

15 The so-called “High Risk” permits require, in addition to the Operator-in-Charge's approval, the approval of the HMI. This will be discussed later.

For a range of other activities, including hot work (welding, grinding, etc.), painting, assembling and disassembling scaffolding structures, and performing periodic maintenance of engines, Work Permits appear to be always issued – in some cases due to regulations (e.g., a Work Permit should always be issued for high risk work[16]), and in other cases due to established practice (one of the criteria here is how the HMI likes to run the platform(s) under his authority).

The lack of a precise definition of what constitutes "normal operations" and the fact that HMIs have a leeway in deciding how the platform should be run contribute to create what workers on board, but particularly the Operators, call "the gray zone on work permits." To summarize, there are tasks for which work permits are not required, and there are tasks for which work permits are mandatory. What falls in between must be assessed by the workers in general, by the Operators in particular, and by the HMI in certain cases.

In the story 4.2.4, it is indicated that the High Risk Work Permit requires not only Albert's signature, but also the signature of the Head of Mining Installation (HMI), the highest authority on board an offshore platform. The HMI is ultimately responsible for the safety of the installation itself and of all people on board. Each individual HMI has his own "style" when it comes to work permits[17]. This includes how and when Work Permits should be requested. For example, some HMIs appear to have instructed the crew to request HRWP at least one day in advance, while others will accept them at any time of the day. According to some workers, these differences in styles has caused some workers – contractors in particular – to write down notes on how the work permits should be written and requested depending on the HMI on board.

Roger, a Mechanic, had an opinion about this particular case. He sided with the Technician, suggesting that the type of maintenance that was going to be performed

16 There are two types of Work Permit: "normal risk" applies to most work that requires a permit; "high risk" applies to work that, by its nature, increase the risk of accidents. Hot work, such as welding, is the prototypical case.

17 The implication here is that managers are also inclined to make adjustments when they see fit. The phenomenon of adjustments is not exclusive to ground-level workers. However, the data collected focuses on work performed by ground-level workers, and this issue will not be discussed further.

was simple and it did not present any immediate risks. Indeed, the Risk Assessment tool available within the Work Permit system does not mention the temporary unavailability of safety systems as a risk factor to be considered.

Alfred's situation in the story 4.1.2 was precisely that the job he had to perform fell into the "gray zone." Strictly speaking, the instrument used was not certified as explosion-proof. Therefore the job was to be considered "high risk", falling into the "permit always required" category. However, as Alfred explained, *the instrument was built to comply with the explosion-proof certificate*[18] and was therefore safe to use. Furthermore, the risk involved is indeed so small that the company is currently discussing whether a high risk permit is really necessary. According to one of the workers involved in the discussion, there is agreement that a normal risk permit should be sufficient.

The first element of the story is then that while Alfred's action not to take a high risk permit was not correct from the perspective of the existing procedure, it anticipated the company's initiative to change the procedure. The second element refers to the definition of "normal operation". Radiation measuring is a relatively routine task that involves nothing more than taking the measuring instrument to the object (pipeline section, valve, etc.), pushing a button, and writing down the figure that appears on the display. It is not difficult to see why Alfred would choose not to request a permit: asking for a permit was seen as taking as much time as it would take to simply do the work. Since Alfred himself was the Operator-in-Charge on that day, this was his call.

It is important to observe how patterns overlap: work permits serve the specific purpose of ensuring that work is carried out in a safe manner. Yet, deciding what is safe – and therefore, what requires a Work Permit – is an issue of weighing risks (a topic which was discussed in section 5.2), as well as an issue of obtaining information about the state of the system (which is the subject of section 5.4).

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18 Explosion-proof certified instruments are referred to as "EX", and non certified instruments are referred to as "non-EX."

5.3.2 Plant Changes

The company has implemented a "Plant Change Procedure," designed "to ensure that changes to existing plants are carried out in a carefully-considered and responsible manner" (GDF Suez Production Nederland B.V., 2007). This procedure, is to be followed whenever a proposed change has an effect on the overview drawings of the installation, on Piping and Instrumentation Diagrams (P&ID), or on the Cause & Effect Matrix (C&E). The two purposes of the procedure are a) to prevent changes that could have unintended (negative) consequences and b) to reduce the mismatches between the technical description of the plant and its actual configuration. The process of executing plant changes, which in the past had been a somewhat informal affair (as one worker put it, "people could go and do whatever they wanted."[19]), was eventually formalized with a written procedure, described in a flow diagram, and supported by a Plant Change Proposal form. In principle, all company employees are allowed to propose plant changes. The number of propositions received through this formal channel was so great that it was described to me at least once as "overwhelming."

The management of plant changes became difficult, with the bottleneck being, according to some workers, the onshore-based Engineering Department, tasked with handling the propositions received[20]. The company responded by setting priority criteria: safety items were to receive "top priority," production items would come next, and other changes would come last. This appears to have created a motivation to justify plant change proposals in terms of safety. In practice, plant changes are first evaluated on the criterion of whether they are a "must have" or a "nice to have".

The story 4.2.3 indicates the type of dilemma that both ground-level workers and managers confront. This dilemma involves a certain tension, because the decision to

19 It is important to point out that the assets of the company have switched hands a few times in the past 30-plus years. The workers readily acknowledge the current management's commitment to improvement in this area.

20 As a matter of fact, the proposals must be approved by the Heads of Mining Installation (both hitches), by the onshore-based Production Manager and by the onshore-based Engineering Manager before it is sent to the Engineering Department. A Project Engineer is then assigned to the Plant Change. The Project Engineer is responsible for planning and executing the Plant Change.

either stop or to carry on is severely constrained by the need to produce gas. Workers are very aware that their job is to keep gas flowing and this imperative often means that it is “acceptable” to break the rules. Indeed, although there is no disagreement that plant changes should “in principle” not be carried out before they are duly processed, they do take place in exceptional cases where safety and/or productivity are at stake. It is not always possible, according to the workers, to wait for the proposal to be fully processed, as that can take several months. Yet, at least one document issued by the company emphatically states that “it should be impossible for work on a plant change to begin before a plant change is approved.”

The story 4.3.3 shows what happens when changes are not strictly controlled. Mark's verification of the current configuration of the old panel should not be necessary. The installation of the new panel could be done simply by following the Technical Drawings. However, Mark was an E&I Technician with several years of experience in the company and he knew that although the situation had improved in recent years, many changes had never been documented and that trusting the Technical Drawings blindly was a recipe for problems in the future.

Why did Mark's colleagues assemble the new panel according to the Technical Drawings? Mark could not answer that question. What matters in this story is that Mark followed up on his intuition (others may prefer to call it experience, or hunch, see Gladwell (2007) and Klein (2004)), took notes of the situation, and began making comparisons. Once he found that there was a difference between what he was seeing and what the drawings suggested, Mark decided to ignore the drawings. The reasoning here was quite simple: if this works, why change it?

There are two features of concern in this story. At no point does Mark question why the difference existed in the first place. Instead, he simply assumed that he should re-assemble the panel. This appears to contradict the “questioning attitude” that is expected of workers, but it is a good example of taking the “path of least effort.” This was possibly the most sensible path to follow, given that he had no reason to believe that the configuration of the old panel was incorrect.

The second feature is that after he had finished the job, Mark could have then looked for more information. He did not. He made notes on the drawing he had on file, and made a copy for the engineers. One expects that the engineers would contact Mark, but Mark believes this will not happen. The conflict between what one sees and what the document describes, in this particular case, is likely to remain unresolved.

The story 4.1.5 is an excellent example of workers actively trying to improve performance – not at the individual level, but at the aggregate level of the platform. Although the loss of output was known to the employees, as well as to management, it had not been addressed. It fell to Albert to turn the situation into a "problem" in need of a solution.

Albert's proposal in effect amounted to a plant change in which two vessels would be connected and in which the amount of product flowing into Process P2 would increase. The "proper" way of proceeding, in this case, would have been to write down the proposal, obtain the approval of the HMIs, and then let the engineers take care of the rest. However, this way of proceeding appears to ignore the fact that a professional would not make unsubstantiated proposals. In other words, some sort of testing would be carried out – as the story clearly demonstrates – in order to make a pre-assessment of the change being proposed.

The story shows that such tests do take place. The issue at hand is then how tests are incorporated into the flow of work. Namely, within a few hitches what had begun as a test became a "permanent" feature of the plant. The Operators themselves were not aware of the change.

To conclude this discussion, a last point of the second story must be highlighted. Once the Operators took notice of the fact that the test had become "permanent"[21], they realized that it should be made formal. The way they chose to accomplish this was to write a "Temporary Repair Work Order", where they indicated what the situation was. However, as the name indicates, this type of work order exists to

21 By permanent, it is meant that it will remain there for a long time, possibly until either the connection to Process P2 is found to be unnecessary or it is formally approved through the normal bureaucratic procedure of plant change.

record repairs, and in this case there was no repair to be reported, since nothing was broken in the first place. This last point may sound superfluous, because it emphasizes the word Repair, to the detriment of the word Temporary. On the contrary, it illustrates precisely that, when faced with a problem, workers are likely to give new definitions, or find new uses for the resources at their disposal. Concretely, faced with the need to make a record of a plant change, the Operators made use of a Temporary Repair Work Order, discounting its primary purpose (to record repairs) and focusing on the adjective temporary, which suited the situation.

The plant change procedure was designed with two purposes in mind: (1) to ensure that changes follow a structured process of evaluation of costs and benefits; and (2) to make sure that changes are properly recorded, so that all actors can plan and carry out their tasks on the basis of up-to-date information. However, it is clear that the mechanism in place is only partially adequate. For example, testing (or trying out ideas) is an important step in implementing change that is not handled very well, as the story 4.1.5 illustrates.

5.3.3 Paperwork: summary

Paperwork is part of any modern socio-technical system. Paperwork here is understood as those formal exchanges of information through written documents – therefore including not only paper, but also electronic media. Paperwork disciplines communication, through the use of forms that pre-determine what information should be exchanged and how – that is precisely the case of work permits and plant change proposals.

However, if on the one hand the formality of paperwork is essential to discipline communication, on the other hand it also creates constraints which are often ignored during their design and implementation. The result can be dreaded bureaucracy: forms which are complicated, or that take too long to fill, documents whose sole purpose is to display someone's signature, in other words, “paperwork for the sake of paperwork.”

The consequence of such a situation is that workers will in time learn what paperwork is really essential for their jobs. The rest will be filled, if at all, just because there may be someone who checks that every box is ticked, that every page is signed, and so on. At this point, the purpose of paperwork will be lost.

Yet, paperwork will not disappear. It will continue to circulate, and it will continue to be the "official" version of what goes on. A trap becomes open: there are now at least two routes through which information circulates. There will be paperwork, incomplete, imprecise, but still formal; and there will be notes on notebooks, on sticky notes attached to computer screens, all informal, all also incomplete and imprecise. There will be confusion and misunderstanding, until an accident reveals the true state of the system, when it will then be too late.

5.4 Information acquisition

It was argued in section 5.3 that paperwork is a mechanism to ensure information is reliably transmitted across the organization. However, not all information is presented in the form of paperwork. Indeed, to control the more dynamic processes going on aboard, the workers must make use of other mechanisms. Two of these mechanisms are discussed here: the control system, and how the workers relate to it; and the information which workers obtain from "going out" and in a sense, "experiencing" the platform. This section then finishes with a brief discussion about the *assumption* of knowledge, or how workers will trust that they have information even though they have not verified it.

5.4.1 Mediated knowledge and the questioning attitude

The first and most visible issue that the stories 4.1.3 and 4.1.4 introduce is that of trust in the control system. In order to discuss this issue, one must bear in mind that the state of the plant – and of the processes sustained on board – is inferred from a large number of instruments that collect a number of parameters, such as temperature, pressure, level, flow and speed. In the older platforms, the values collected by such instruments are often displayed analogically by means of needle gauges and sight glasses, among other types of displays. In the newer platforms, the values are transmitted to digital control systems, and displayed to Operators on computer screens located in the Control Room. However, this is not always the case, and exceptions abound. As a matter of fact, the constant process of updating and upgrading of equipment means that in most of the company's platforms, analog and digital systems co-exist. The two level gauges mentioned in the stories (the water tank level and the lube oil tank level gauges) illustrate this. While the water level can be monitored from the Control Room, the lube oil level requires a visual inspection of the sight glass.

One problem Operators face when dealing with such mediated knowledge is that they must develop a certain trust in the instrumentation available. This trust, however, must never be complete. The Operator must be capable of questioning the instrumentation when it does not conform to his expectations. Nevertheless, trust is necessary, and Operators will readily acknowledge that they cannot doubt everything, all of the time.

In 4.1.3, one is presented with an interesting case of distrust that does not actually lead to questioning. The Operator declares that he is not sure that the gauge is accurate, and since water does not pose any risk, he chooses to overfill the tank. In conversations with other workers, there was much agreement in regard to the Operator's course of action. Workers were able to recall occasions where lack of water became a serious concern, and that the practice to overfill the water tanks developed over time. As for the accuracy of the gauge, one Instrumentation Technician reproached the Operator's attitude, arguing that if the gauge is suspected to be accurate, the correct way to proceed is to ask that it be fixed. One may speculate that no repair is ordered because overfilling a water tank does not pose a risk. The Operator's reasoning here, may as well be: “I do not trust this gauge, but I can afford to live with it, because there is no risk involved.”

In 4.1.4, there are two elements worth discussing. The first is the decision of an Operator to overfill the lube oil tank, with full knowledge that the tank was leaking.

In doing so, the Operator was applying the same strategy as in the story above, although here the element of distrust in the instrumentation is entirely absent. Given that the tank was known to be leaking, that the unit was located some distance from the Control Room, that level inspection required looking through a sight glass (thus no information was readily available in the Control Room), and also considering that a low level of oil could cause serious problems, the Operator appeared to have reasoned that overfilling the tank was a prudent action.

The problem, which the Operator apparently overlooked, was that overfilling the tank meant that the oil-air interface inside the sight glass disappeared. Due to the design characteristics of the sight glass, to the color of lube oil, and to the lighting conditions where it is placed, looking at the sight glass did not provide a definitive indication that the tank was full. The Operator who noticed that the tank might have been empty went through a number of moves before he could establish that the tank was indeed full. When discussing this story with other workers, on the one hand there was unanimous praise of this Operator's course of action; on the other hand, there was no condemnation of the Operator who overfilled the tank.

Gauges, sight glasses and computer screens present up-to-date information about ongoing processes to the workers. To get work done it is necessary to trust the information. It would not be possible to work if at every turn the workers questioned the values presented to them. Yet, blind trust is dangerous, and some measure of distrust is always necessary. How can workers trust and distrust the instrumentation, at the same time? The answer is partially to seek out *additional* information – clues which may serve to confirm or deny the information presented by the instruments. One of the ways of seeking for information is to “go out” and see for oneself, by performing rounds.

5.4.2 Doing Rounds

For the Operators (and for the Mechanics, in a smaller degree), to perform rounds is primarily a means of remaining connected to the physical reality of the platform. The computer screens in the Control Room display data about the status of the various processes on board, but the need still exists for Operators to go out and “get a sense” of the plant. The use of the expression “get a sense”, in this case, is quite purposeful, for the Operators indeed use their senses: while walking, they touch the pipelines and the vessels, to feel the temperature; they listen for the noise of the engines; they smell the air to detect leaks; they look at the gauges everywhere. Although some of these sense-activities are to some extent prescribed either by procedure or by the very design of the plant – the gauges whose data are not transmitted to the Control Room can only be inspected visually, for example – much expertise, developed through considerable periods of time, is required.

A particular aspect of rounds is that they lack a formal structure. This naturally excludes the periodic inspections that workers carry out (e.g., once a day, Mechanics inspect the rotating equipment and the Operators analyze samples). Indeed, it appears more appropriate to reserve the term “round” for the activity of “going out and getting a sense” of the plant. It is essentially an Operator's job, as illustrated in the story 4.1.4.

A pattern can be discerned in the conduct of rounds, at least in the larger platforms. Rounds take place around the middle of the morning, after work permits have been distributed, and late in the afternoon, around the time workers are finishing off their tasks. It is evident that in addition to inspecting the production side of the operation, rounds are also used to check up on what workers are doing outside. Rounds make the Operators visible and available to all of the workforce, thus contributing to the alleviation of any sense of isolation that workers may develop. In this regard, it is instructive to remember that one of the “contributing causes” to the Tokai-Mura (Japan) accident was that the workers were isolated in a separate building, where they had no contact with anyone else. Indeed, “they felt they were in another company” (Furuta, Sasou, Kubota, Ujita, Shuto & Yagi, 2000).

There is a final use for rounds that deserve mention: they may be used by the Operators as excuses to leave the Control Room. It is not meant by this that Operators must obtain permission to leave. However, there are times during the day –

or during the hitch – where the workload may reach a low point. To go for a round is an alternative to sitting around (notice how this may be a strategy to handle schedule gaps, as seen in section 5.1.1). There are also times when tension develops in the Control Room, and going for a round is an acceptable way to take time out.

5.4.3 The Operator must know, so he knows

In explaining his action in 4.1.2, Alfred mentioned that he had delivered a Work Permit for another group working with non-EX instruments earlier that same day. The rationale was simple to follow: if another group was already working with that type of instrument, that meant all safety measures had been taken. His bringing of another non-EX instrument to the process area did not add to the risk of an accident.

However, this explanation was not sufficient. After all, it is easy to imagine multiple scenarios where the absence of a Work Permit relative to a specific job is implicated in an accident. The Piper Alpha accident mentioned above (see 5.3.1) is one such case. Indeed, the workers at this company are familiar with the Piper Alpha case, since during recent Safety Meetings they had been shown a video documentary about it.

Alfred adds then a second layer of justification to what he did. This is justification based on expertise and knowledge. As Operator-in-Charge, Alfred knows who is doing what on board, since he himself has handed out the permits. As an experienced Operator, which he certainly is, he knows that using that particular instrument at that particular time poses very little additional risk. Finally, as he says, he knows he is taking a risk, but understands that being able to take such risks is part of what makes him an Operator.

Does Alfred realize that other workers on board follow the same reasoning? This is a difficult question to answer. In the course of many interactions with the workers, several opinions were expressed. Of particular interest to the present discussion is a dilemma: a worker cannot trust a colleague, but a worker must trust a colleague. What this means is that workers acknowledge that their colleagues may fail. The consequences of failure can affect others and therefore trust brings a risk. However, the cost of distrust is unbearable: one would be simply unable to work if he had to double-check what everyone else were doing. To make this point concrete, one of the safety measures required for the use of non-EX instruments is a prior scan of the area to ensure that it is free of combustible gas. When Alfred chooses not to take a Work Permit for his job, he is essentially trusting that the gas scan has been performed, and properly performed. The key issue here is that one must know when to trust, and when to question any form of knowledge.

5.4.4 Information acquisition: summary

Section 5.3 discussed the circulation of information as written documents. It was emphasized that the risk existed for the development of two channels of communication: a formal, and an informal one. However, it is clear that, on the one hand, not all the information that the workers use comes from paperwork. In the specific case of process control, data about the process will usually be presented through gauges and computer screens. Information may also come from taking part, directly or indirectly, in the many tasks that are carried out.

What is of particular importance in this discussion about information is the issue of trust. To what extent can workers trust the information they receive? There is here a double-bind from which it is difficult to escape. On the one hand, distrust would slow one down to the point of paralysis. On the other hand, blind trust would mean abandoning oneself to the vagaries of system performance. A compromise has to be reached. This compromise is reached in two steps. Firstly, workers will find out through experience what may be generally trusted, and what must be generally distrusted. On the basis of this distinction, they will then seek additional information whenever necessary. The obvious risk is to be wrong: to trust when one should distrust, and to find out that things are not as they should have been; or to distrust when one should trust, and in a sense, to waste time and energy unnecessarily.

5.5 Use of resources

Resources, in the sense meant here, refer to what workers use to accomplish their tasks. They include the information that comes from paperwork and from control devices, but also the tools, the materials, and the physical, as well as mental, capacities of the workers themselves. This sections discusses three issues related to the use of resources aboard. The first of these is the cannibalization, temporary or permanent, of pieces of equipment, so that their component parts may be used elsewhere. The second is the development of secret stocks of odds and ends that the workers keep, "just in case." The third issue is the mustering of human resources from other departments, whether through informal means (because after all, they form a community), or through formal ones (through the planning of tasks which require the involvement of multiple disciplines).

5.5.1 Doing it now, doing it later

Many of the engines on board a platform come in pairs, sometimes even in triplets. This design provides redundancy: one of the engines is on stand-by, and can be switched on, either manually or automatically, if the engine running breaks down. The design also increases the platform up-time, since maintenance on one engine can be performed while the other is running. Finally, the engines can be used at the same time, either resulting in increased output, or in reduced wear-and-tear, when the engines run below their maximum capacity.

Exemplified by Albert's decision to replace the leaking valve of the B vessel with the valve taken from the unused A2 vessel in story 4.1.1, taking "the fastest route" is a common strategy at a workplace that, by design, consists of several duplicate units. The purpose of units in pairs, or even in triplets, is of course not to serve as spare part repositories. Nevertheless, duplicate units are usually located near each other and use identical components. In regard to the latter, in many cases, this is the result of acquiring units from the same vendor, possibly at the same time; in other cases, it may be a design strategy aimed at standardizing the components used in the workplace, reducing the need for training in the handling of different components of the same type, as well as reducing the complexity of maintaining multiple types of spare parts, among other benefits.

These characteristics of workplace design appear to create an incentive for the use of such a strategy. During the test of an engine, a defective gauge was quickly replaced with a gauge taken from the duplicate engine at its side, thereby avoiding the expense of time required to find a suitable replacement gauge in the storage room and to calibrate it (story 4.3.1). During the calibration of a device, in another operation, a worker found that a connection joint was leaking. The backup device a few steps away provided a temporary replacement joint that allowed for the job to progress almost seamlessly. A quick and simple operation when compared to the alternative of returning to the workshop and finding a joint of the same type, not to mention the always present possibility that one might find another job waiting at the workshop, causing additional delays (story 4.3.2).

Albert made sure to padlock the A2 vessel, which now lacked a safety valve, to prevent it from being brought back into operation. The worker who had replaced the defective gauge of a running engine with the gauge of the standby engine took it to the workshop, repaired it and finally installed it on the standby engine, thereby completing the switch. Not so with the worker who had taken a connection joint from the backup device. After finishing the calibration job, he began to close the plastic housing of the two devices. At this point, a colleague reminded him that the backup device was missing a joint connection. He then decided not to close the housing. He later took a new joint from the workshop and installed it.

A contrast, and a mild warning, is provided by the story 4.3.2. The missing joint did not by itself create a hazard, but the case clearly illustrates one of the risks of the "least effort" path. This is the risk that the unit from which a component was taken may be taken to be fully assembled and operational, when it fact it is not. Another potential risk is that the component taken may not be identical to the one that must be replaced, although this situation was not observed.

5.5.2 The secret stock

In the story 4.3.4, Mark used a piece of plastic that he took from a “secret stock” of old parts that he kept for these occasions. He then crafted this piece of plastic into the appropriate format to support the new starter. It is perhaps imprecise to call this behavior “improvisation.” It is clear that such situations are expected, or workers would not go through the trouble of selecting and storing parts.

These stocks could be called “secret stocks”, but in reality they are only partially secret. The workers who engage in this know what they collect, and it appears that there is a certain amount of pride involved in being able to access the stock and “save the day.” The ground-level workers on board are aware of the existence of these stocks – and they may consult each other on what might be available. The platform managers (the HMIs) are certainly aware of the practice, since at some point they too were at the ground-level. However, from the point of view of the organization, these stocks are entirely secret, as they are not part of the company's books.

At least one Operator suggested that the practice of keeping these stocks was particular to the Electricians. He told the story of an electrician who used to keep old, discarded material in his own cabin. According to this Operator, “if you wait long enough, then of course there is a chance this material might be needed”. In the meanwhile, these parts are taking space, and every now and then, causing trouble. How so? He gives a concrete example: “sometimes we have to replace an o-ring, and we get a set of them. Now, there are some which are used once a year, and some which are used once every ten years. So you use one and you store the rest. Years later, you see that box and you say, 'ok, I have what I need in that box.' So you plan your work, you get everything ready, and when you open the box, you find that the ring you wanted isn't there, because it was used already. It's not fun when that happens. Really not fun. So I always say, throw them away. Specially on the satellites, there's no space for that sort of stuff.”

5.5.3 The fluidity of organizational structures

The platform is organized along the lines of departments, each with its own area of competence (see 4.1.1 and 4.3.4). In practice, these departments must be able to work together to make the platform run. It is clearly not enough, as many cases observed indicate, that each department do only its job. The boundary between departments is fluid and permeable. As one worker explained, "the departments and the hitches may be different, but the platform is the same."[22]

These properties are manifest both in cases where a given task involves the participation of workers coming from different departments, such as when the maintenance of a compressor requires the participation of E&I Technicians and Mechanics, and in cases where a worker performs a task that, by definition, belongs to another department, as the stories illustrate. To achieve this level of inter-departmental integration, workers must be able to understand, or at least to appreciate, what others are doing.

In the story 4.1.1, integration goes one step further in that Albert is well-aware that by giving the task of installing a valve to the Construction Department, the actual work will not be done until much later. As Albert has the knowledge and the experience necessary to perform the task himself, he is able to do the job, considerably reducing the length of time during which the valve would be leaking. Albert's colleague, however, had chosen to give the task to the Construction Department. His decision is understandable in light of the fact that he has been working with the company for less time, and his previous work experience was at a company that appeared to enforce labor division in a more strict manner. Given his experience, it was clear to Albert's colleague that the right thing to do was to hand the job over to Construction.

22 The practices observed that form the basis for the discussion presented in this section involved primarily Operators and Mechanics, or Operators and members of the Construction Department. Electrical work is subjected so a more restrictive legislation and the exchanges described here are probably less frequent between the E&I Department and the other departments on board, except in the case of double-functions.

Although friction between departments does occur, given different priorities, different expectations, differences in worldviews[23], etc., from an operational point of view the benefits of interaction appear to outweigh its disadvantages. The company itself acknowledges that interaction is good, but cautions in its procedures that workers should only attempt to do the work of other departments if they have received proper training.

Nevertheless, boundaries are important, and attempting to eliminate them is not without risk. This was made clear in discussions with several workers regarding the company's policy of “double function.” A double-function is the practice of giving a workers trained in one domain (Mechanics, for example), and training him to work in another domain (typically, Production). Most workers with double functions were E&I Technicians and Mechanics trained to work as Operators. From an organizational/corporate point of view, the use of double-function workers presents obvious advantages: a “basic team” of three people (an E&I, a Mechanic and an Operator) can be reduced to 2 people (an E&I-Operator and a Mechanic-Operator) and there is increased flexibility when it comes to dispatching workers to the various platforms. Nevertheless, there are disadvantages: a double-function worker is never an expert, because he must divide his attention between two topics. The noted consequence here is a tendency for double-function workers to learn the “tricks” of the trade without necessarily understanding why or when such tricks are admissible. Furthermore, because the primary function of a platform is to produce gas, “Production always has a priority when competing jobs come up.” In that sense, the work schedule of the E&I department and of the Mechanic department become contingent upon the needs of Production.

When describing the initiating event in story 4.3.4, Mark said that a light tube had already been changed a while ago. Back then, they asked the Construction team to

23 To illustrate how members of different departments have different worldviews, an Operator told me the following story: the air conditioning system was not working. So an Operator, a Mechanic and an electrician went to the engine room to fix the problem. The Mechanic immediately walked to the engine and took out his tools to open it; the electrician went look for blown fuses; the Operator walked to the control panel and pushed the start button. The air conditioning engine immediately switched on.

build a scaffolding, and this was done. It was not possible to ask why the permanent solution of replacing the rusted bolts was not adopted – perhaps not even considered – then. Mark also explained that some of his colleagues, facing the exactly same situation, would have opted for using a regular ladder (he later stated that he knew this had actually been done in the past), a solution that he and Michael found unsafe.

The construction of a scaffolding was not the best way to handle this job. First, it required the labor of specialized scaffolding builders – a resource that is quite limited on board. Second, it did not address the fundamental problem, which was the fact that the bolts that hold the mast in place were rusted. A scaffolding had been used before (by Mark and Michael), and so had a ladder (by other electricians). Replacing the bolts eliminated the need for those tools.

5.5.4 Use of resources: summary

Things break down. It is simple as that, and yet the consequences of that fact are very serious indeed. When something breaks, it must be repaired or replaced. The discussion above focuses on replacement. The essential problem of replacement parts is that they are limited. The organization cannot afford to have spare parts for every single piece of equipment on board each of its facilities. In practice, that would amount to (at least) duplicating the organization's assets in a warehouse, where they would sit unused until needed. Nevertheless, things break down and must be replaced. Since spare parts are needed, a stock of the most commonly used is kept at hand. For those used more rarely, it should in principle be possible to order them.

Availability is relative. In some cases, as illustrated in section 5.5.1, it is clear that retrieving spare parts from the stock room, calibrating it, testing it, etc., would have taken too long. The workers instead go for what is closer: they cannibalize a nearby piece of equipment. The advantages of this strategy include: the replacement is available right away, which eliminates the need to go to the workshop or to the storage room to look for one; the replacement is likely to be of the same type (model, size, function, etc.) as the defective component, which guarantees that it will work; and the replacement is known to be in operational condition (since backups and standbys are regularly inspected), which eliminates the need to break in the component.

Yet there are risks, which must not be ignored. They include the creation of a "latent condition", when the component taken from a unit is not put back in place after the operation, or substituted by another one; and the potential for failure, when the component taken is not an adequate substitute for the one that must be replaced.

What of secret stocks? Supporting the premise that there is a regularity of types of behavior that cuts across domains of human activity (see Chapter 1), secret stocks encounter a parallel in household behavior. Just as people at home keep odd clothing buttons, rubber bands, paper clips, etc., around, so do people at work keep damaged or out of commission equipment, leftovers from previous tasks, etc.

The behavior – and its purpose – is identical. It is difficult to imagine what risks it could pose to the common person at home. The risks that it poses for socio-technical systems are at least two: first, using the secret stock "fools" the organization into believing that the amount and quality of spare parts is adequate – if workers go around using glue or tape to keep the platform together, how is the organization to know that there is a need to buy bolts? Second, using the secret stock may lead one to assume equivalences which may not be real – if using a rubber band keeps this together, then rubber bands can keep anything together. The risk is obvious.

There is nevertheless an important advantage to the use of secret stocks which cannot be ignored: it can really get a worker out of a tight spot when going the "official route" of ordering spare parts would take too long, or when spare parts are no longer available.

Finally, a word about human cooperation. There are tasks which are *planned* to involve workers from multiple disciplines. There are other tasks, however, in which the need for some type of cooperation emerges from the local conditions. In such cases, workers will have to locate who is available to help them, and negotiate how this help may be provided. The platform, in the end, is not a *sum* of departments, but a *combination* of departments. Along these lines, one may say that workers are able, and indeed expected, to take the responsibility for tasks that are not primarily part of their competencies. This in turn allows for a re-distribution of tasks that contributes to bringing the separate departments' workloads to a certain state of equilibrium. This re-distribution may be “formal”, as in the case of double-functions, or “informal”, as when a worker from one department negotiates the workload with a worker of another.

One must however remain cautious of potential risks. Fluidity is a process of coordination, and coordination can break down. Expectations may build up regarding who does what, with the possibility that a task may not be performed at all – because someone else should have taken care of it. The “forced” fluidity that comes with double-functions oftentimes creates a conflict of priorities, which appears to be most likely resolved on the side of the Production Department. This is understandable from a corporate point of view, since Production is what generates cash flow. However, it may result in delays for the other departments, or even that other departments hurry to finish their assigned tasks on time, with the increased possibility of failure that comes with work performed in a hurry.

5.6 Summary

The reader will have noticed by now that the patterns discerned in this chapter have a considerable overlap. It was argued above that a characteristic of socio-technical systems is that its multiple parts are interconnected. To try to completely separate the many issues discussed here would result in a fragmented text that would do little to contribute to the understanding of how the system works.

This chapter presented an in-depth discussion of types of behaviors that are commonly seen in the environment of offshore work. Those types of behavior refer to certain elements of the socio-technical system, namely the temporal organization of tasks (the work schedule), the formal mechanisms of communication (paperwork), the risks involved (risk perception), the acquisition of information, and the use of resources. It must be emphasized that while the characteristics of these elements are particular to individual socio-technical systems, they are universal. This means that the issues workers have to handle, indeed the issues workers have to make adjustments to, share a common essence that cuts across work domains. The adjustments made may take different concrete forms (which may be more, or less, fitted to the systems), but they will be adjustments to problems that are, in essence, common to workers anywhere. Table 5 summarizes the discussion carried out in the current chapter, with a focus on the potential advantages and disadvantages of the behaviors adopted by the workers in the cases presented in Chapter 4.

It would appear that adjustments favor short-term advantages, rather than long-term, permanent solutions to issues. Indeed, a common theme cutting across most of the stories presented and discussed is that workers were trying to solve their immediate problems. This, however, would be to ignore that workers do plan for future contingencies, and prepare for them. The most obvious example of that is in story 4.3.4, in which a worker makes use of a “secret stock” of parts. This stock was not built overnight. It is the result of knowledge that situations in which rare spare parts are needed, arrive from time to time, and of preparation for such situations.

Table 5: A summary table for patterns identified

THEME	BEHAVIORS	ADVANTAGES	RISKS
The work schedule	Change the way the work is done to stay on schedule; Change the schedule to match the flow of work;	Breakdown of coordination is avoided by remaining on schedule; Time, energy, resources are not wasted;	Produce a breakdown of coordination if others are not properly informed of changes;
Paperwork	Ignore paperwork which is considered unnecessary or cumbersome; Do the work first, record it later;	One may get to work faster, there is no need to interrupt others to ask for permission; Guarantees that the work actually gets done;	Loss of information, creation of noise in communication;
Risk perception	Assess the urgency of a situation; Evaluate the safety of the workplace;	Allows for the setting of priorities, preventing dedication to minor tasks while leaving major ones unattended; Workers do not take "unnecessary" risks – only the amount that would be considered reasonable;	An incorrect assessment or evaluation could lead the worker to take disproportional risks; Emergence of unsafe practices because "we did this before and nothing bad happened";
Information acquisition	Questioning attitude and search for additional information; Remaining close to processes controlled; Trust in information obtained;	It is admitted that mistrust of information would lead to paralysis. Trust that information is correct allows one to "move forward"; However, mistrust allows one to detect emerging risks before it is too late;	The game of "Trust and mistrust" is played by all workers, may result in confirmation bias, or paralysis;
Use of resources	Cannibalization of pieces of equipment; Maintenance of secret stocks; Calling for assistance;	Avoids loss of time involved in ordering parts; May at least temporarily alleviate the problem of finding parts for out-of-stock or difficult to find parts; Assures all competences needed to accomplish a task are effectively involved;	Create false impression that stocks are adequate when they are not; Create the illusion of equivalence between parts which are not really equivalent; Creates coordination problems, as well as competition problems for resources that are scarce or already in use;

Chapter 4 presented a number of events in which workers had to perform certain adjustments in order to accomplish their tasks. Then, Chapter 5 discussed those events at length, with a focus on isolating and describing those adjustments in terms of their objectives, their actual performance, and their consequences. From that discussion, it is now possible to distinguish the underlying adjustment mechanisms, and propose a way of managing them. This will be the subject of Chapter 6.

French summary of Chapter 5

Le lecteur aura remarqué que les motifs (voir tableau 6) dégagés dans ce chapitre ont un chevauchement considérable. Plus haut, il a déjà été avancé qu'une des caractéristiques des systèmes socio-techniques est que ses parties multiples sont interconnectées. Essayer de séparer complètement les nombreuses questions examinées ici se traduirait par un texte fragmenté qui contribuerait peu à la compréhension de la façon dont le système fonctionne.

Ce chapitre présente une discussion approfondie des types de comportements qui sont communément observés dans l'environnement de travail à l'étranger. Ces types de comportement se réfèrent à certains éléments du système socio-technique, à savoir l'organisation temporelle des tâches (la programmation), les mécanismes formels de communication (les documents), les risques encourus (la perception du risque), l'acquisition de l'information, et l'utilisation des ressources. Il convient de souligner que, bien que les caractéristiques de ces éléments sont propres à chaque système socio-technique, les éléments eux-mêmes sont universels. Les ajustements apportés peuvent prendre différentes formes concrètes, mais ce seront des ajustements à des problèmes qui sont, en substance, communs à tous les travailleurs. Le tableau 6 résume la discussion menée dans ce chapitre, avec un accent mis sur les avantages et les inconvénients des comportements adoptés par les travailleurs dans les cas présentés dans le chapitre 4.

Il semblerait que les ajustements favorisent des avantages à court terme, mais qu'ils sont peu propices à la résolution de problèmes à long terme. En effet, un thème commun dans la plupart des histoires présentées et discutées est que les travailleurs ont essayé de résoudre leurs problèmes immédiats. Toutefois, cela reviendrait à ignorer que les travailleurs se préparent également pour les imprévus. L'exemple les plus évident se trouve dans l'histoire 4.3.4, dans laquelle un travailleur se sert d'un stock "secret" de pièces. Ce stock ne s'est pas constitué du jour au lendemain. Il est le fruit de l'expérience qu'il arrive de temps en temps des situations dans lesquelles les pièces de rechange « rares » sont nécessaires. Ce stock est un symbole de la préparation à de telles situations.

Le chapitre 4 présente un certain nombre d'événements dans lesquels les travailleurs ont effectué des ajustements afin d'accomplir leurs tâches. Le chapitre 5 discute ensuite ces événements en détail, pour décrire les ajustements observés en fonction de leurs objectifs, leurs performances réelles, et leurs conséquences. A la fin de cette discussion, il est possible de distinguer les mécanismes d'ajustement sous-jacents, et de proposer une façon de les gérer. Ce sera l'objet du chapitre 6.

Table 6: Sommaire des thèmes identifiés

MOTIF	COMPORTEMENT	AVANTAGES	INCONVENIENTS
Programmation	Modifier la manière dont le travail est fait pour rester dans les délais prévus Modifier la programmation du flux de travail	La rupture de la coordination est évitée en restant dans les délais prévus Pas de gaspillage de ressources : temps, énergie...	Produit une rupture de la coordination si les autres ne sont pas correctement informés de l'évolution du système
Formalités administratives	Ignorer les formalités qui sont considérées comme inutiles, ou encombrantes Faire le travail d'abord, en rendre compte plus tard	On peut se rendre au travail plus rapidement, il n'est pas nécessaire d'interrompre les autres pour demander une autorisation de travail Garantit que le travail est réellement fait immédiatement	La perte d'information, la création des perturbations dans la communication
Perception de risque	Évaluer l'urgence de la situation Évaluer la sécurité de l'environnement de travail	Permet la fixation des priorités, Les travailleurs ne prennent pas des risques "inutiles", ils restent dans la limite du raisonnable	Une évaluation erronée pourrait conduire le travailleur à prendre des risques disproportionnés Émergence des pratiques dangereuses parce que « nous avait déjà fait avant et rien de mal ne s'est passé »
Information	Avoir une attitude interrogative, et chercher des informations supplémentaires Rester près des processus contrôlés Avoir de la confiance dans les informations obtenues	Il est admis que la méfiance de l'information conduirait à la paralysie. Confier que l'information soit correcte permet de « faire avancer » Cependant, la méfiance permet de détecter les risques émergents avant qu'il ne soit trop tard	Le jeu de la « confiance et méfiance » est joué par tous les travailleurs, et peut entraîner un biais de confirmation, ou une paralysie
Ressources	Cannibaliser des pièces d'équipement Maintenir des stocks secrets Demander d'assistance aux collègues	Évite la perte de temps associée à la commande de pièces Atténue, au moins temporairement, le problème de trouver des pièces en rupture de stock ou difficiles à trouver Assure que toutes les compétences nécessaires pour accomplir une tâche sont effectivement impliqués	Crée une fausse impression que les stocks sont suffisants même s'ils ne le sont pas Crée l'illusion de l'équivalence entre pièces qui ne sont pas des vrais équivalentes Crée des problèmes de coordination, ainsi que des problèmes de concurrence pour les ressources qui sont rares ou déjà en circulation

6 Results – Why adjust? How to adjust?

An argument was put forward in Chapter 2, namely that the continued functioning of a socio-technical system requires that it be able to adjust its functioning to a range of conditions. In other words, that its performance be allowed to vary in order to match the natural variability of the working environment in which the system exists. In that chapter, two contrasting models were presented. The first model, which was called the "Traditional View," pictures adjustments in a rather negative light. In this view, adjustments are not only unnecessary, but also inherently dangerous to the system. Therefore, proponents of this view argue, adjustments must be constrained by the setting up of barriers that attempt to either prevent or punish the execution of adjustments.

The second model, which was called the "Resilience View," goes in the direction of the argument presented in the thesis. In this view, adjustments play a fundamental role in the functioning of socio-technical systems. Resilience Engineering is in agreement with the traditional approach in that adjustments may lead to increased risk and to resulting accidents. However, whereas the traditional approach stresses the negative effects of adjustments, Resilience Engineering stresses on the one hand the need for adjustments in socio-technical systems, and their often positive effects on the other. Nevertheless, Resilience Engineering acknowledges that adjustments are themselves limited – or *approximate*, to use the term employed by Hollnagel (2009) - and in that sense, are not sufficient to prevent failures from taking place (see section 1.2).

In Chapter 3, the method used for going about the quest for understanding adjustments was presented. The first step was to collect a number of examples of adjustments. The difficulty here is that adjustments do not generally come with an attached label. Rather, they are seen, especially by the workers themselves, as normal features of working life. Based on the notion that adjustments are part of how work is performed in socio-technical systems, this challenge was addressed by taking an interest in *normal work*, that is, in activities carried out by workers in the course of what they would see as a typical day. This choice was also motivated by the need to demonstrate that adjustments could be found even in situations where there was no discernible negative outcome, and where the work executed, in the eyes of both the workers themselves and their peers, could be considered satisfactory or adequate.

The second step consisted of transforming the examples collected into cases, or stories. It was clear from the beginning that adjustments only made sense, and therefore could only be understood, in context. A simple list of adjustments would provide insufficient information about why and how they take place. Chapter 4 consisted of a presentation of several stories that describe workers making adjustments in the course of their typical tasks. It was noted that the adjustments constituted, in effect, a balancing of the requirements of the tasks in relation to what the workers were actually able to do, given local conditions.

Chapter 5 then presented a first layer of analysis that resulted in a functional synthesis of the work performed on the platforms observed. The synthesis had as a main purpose to highlight the issues workers routinely confront when going about performing their usual tasks. Four main issues were identified. They related to the scheduling of tasks, the evaluation of risks, the role of paperwork, the acquisition of information, and to the use of resources. Actual strategies for handling those issues were highlighted, and their benefits and drawbacks were pointed out.

The current chapter presents a method for understanding adjustments in the workplace based on the data collected, and analysis conducted in the previous chapters. The purpose of the method is to supply the analyst – the designer, the ergonomist, the manager, but also the ground-level workers – with a simple tool to initiate a discussion about what actually takes place at work. The tool distinguishes between objectives, which respond to the question, "*Why adjust?*" and facilitators, which respond to the question, "*How to adjust?*".

6.1 Objectives

An objective is what the worker intends to achieve by carrying out an adjustment. There are two ways of looking at objectives. The first is to look for the specific, local issue that gives rise to the need for the adjustment, such as “the container is leaking”, or “the bolts used are not of the same diameter.” It is instantly obvious that pursuing objectives in this way would represent an endless effort, since as von Mises (1996) put it, all human action is aimed at effecting a change from an undesirable state to a desirable one – in other words, that all action is in itself an adjustment.

Another way of looking at objectives is to inquire about the course of action taken by the worker. To go back to the example of the “leaking container” just mentioned, it is relatively simple to elaborate a number of potential courses of action: the worker could ignore the leak; the worker could try to find the leak and place a bucket under it; the worker could raise an alarm; and so on. Yet, from the multiple potential courses of action, only one is actually taken. The question is: why? By looking at the data in this way, it was possible to distinguish three objectives. They are: compensation, avoidance, and maintenance. This section is concerned with describing these objectives. Table 7 below presents these objectives, as well as the elements of the system which they are intended to affect. These elements are called targets in the framework developed here, and are detailed in section 6.1.1.

It is important to recall at this point that in analyzing the data, the aim was to adopt the point of view of the actor, whether it was an individual worker or a team of workers. During data collection, it was noticed that workers would often be unable to explain precisely why they behaved in the way they did. Furthermore, workers would sometimes offer different, or even conflicting, explanations for their actions. For example, in the story 4.2.1, one worker argued that the order in which the team executed the tasks related to the maintenance of that particular engine was dictated by practice and experience. Another worker, however, emphasized that the engine itself remained hot for a while, and that therefore it was better to start by working in the Control Room, away from the heat – precisely what they had done.

Table 7: Objectives (in columns) and targets (in rows).

Targets	Avoid	Maintain / Establish	Compensate
Time	Waste of time / Inadequate timing	Time buffer	Inadequate amount of time / Inadequate timing
Human work capacity	Waste of effort / Waste of labor	Effort buffer / Labor buffer	Inadequate amount of effort / Inadequate amount of labor
Workplace	Inadequate workplace	Adequate workplace / Workplace buffer (especially space)	Inadequate workplace
Psychology	Inadequate state of mind	Adequate state of mind / State of mind buffer	Inadequate state of mind
Materials	Waste of material	Material buffer	Inadequate material availability / Inadequate material quality
Equipment / tools	Unnecessary use	Equipment / Tools buffer	Inadequate equipment / tools
Finances	Waste of financial resources	Financial buffer	Inadequate amount of financial resources
Data	---	Data buffer	Inadequate data

Analysis of the data available revealed the main objectives of adjustments: Avoidance, Maintenance, and Compensation. A detailed explanation of the meaning of each is given below.

Avoid: corresponds to the adjustments that are aimed at avoiding a situation or scenario that workers perceive to be out of step with their own goals, or with those of the organization. These adjustments are generally aimed at avoiding what workers perceive to be *wasteful*. In that sense, avoidance adjustments are not expected to take place with respect to the Information target, given that information proper cannot be wasted. With respect to the Time target , it is sensible to consider that although *timing* cannot be wasted, it can be perceived as inadequate, in which case the worker may wish to avoid executing the task. With respect to the Equipment/Tools target, one may more properly speak of unnecessary use, rather than of waste, with the reminder that the judgment of necessity is a subjective one made by the worker.

Maintain / establish: corresponds to adjustments that are aimed at maintaining or establishing a situation or scenario that workers perceive to be appropriate (in the case of maintenance) or more appropriate (in the case of establishment) in relation to a present state. Maintenance adjustments are generally aimed at maintaining or creating *buffers* in anticipation of future need. With respect to the Workplace target, one may more properly speak of maintaining or establishing an *adequate physical setting*, rather than of a buffer, although one may conceive of the need for a physical space buffer. In a similar vein, one may speak of maintaining or establishing an *adequate mental setting*, rather than a mental buffer, although one can conceive of mental buffers.

Compensate: corresponds to the adjustments that are aimed at compensating for a *inadequacy* (in terms of either amount or quality) of one or more of the factors related to the execution of the task at hand. The objective is to compensate for an inadequacy of the current state (as is the objective to avoid a situation or scenario). In this regard, it is different from "maintain / establish" objectives, which are generally aimed at future states.

6.1.1 Targets

Targets correspond to the specific characteristics of the situation which adjustments are intended to modify. The essential idea is that a worker perceives one of these targets as not matching his expectation of how the system should run. The worker is therefore motivated to change it in some way.

Time: relates to the initiation, duration, and conclusion of tasks or events. There are two meanings in which time is important in a socio-technical system. First is the issue of timing, or that a task must be initiated and/or completed at a specific *point in time*. Second is the issue that the execution of a task takes a certain *amount* of time. The difference between these two meanings of time can be illustrated with a simple hypothetical example: a Mechanic must check the oil level in an engine every first Monday of the month (*point in time*), and the check takes five minutes (*amount of time*).

Human work capacity: may also be said to have two meanings. The first, associated with the word labor, is the presence or absence of workers, where each worker has a certain capacity to perform work, or to borrow a term from physics, where each worker has a certain *potential energy*. The second meaning corresponds to the amount of energy, or *effort* required for the execution of a task. Again, an example will illustrate the difference: consider a task that consists of lifting a single box. A single worker is capable of lifting ten boxes before being completely exhausted. If a second worker is called in and the two workers together lift ten boxes, one could say that the box-lifting capacity (*potential*) doubled, but that the *effort* actually made was halved.

Workplace: corresponds to the characteristics of the location in which a task takes place. Parsons (2005) highlights four main characteristics of the workplace which affect performance: the *thermal* environment; the *lighting and visual* environment; the *noise*; and the *air quality*. Other important characteristics include *vibrations* and *pressure,* the *design of chairs and desks*, the *placing of commands*, the readability *of screens*, etc. (Moscato, 2005).

Psychology: relates both to the cognitive demands of the task upon the worker, and to the worker's appraisal of the work (Megaw, 2005). Several authors have emphasized that much of the work performed in modern socio-technical systems is mental, rather than physical (Vicente, 1999; Flach & Kuperman, 2001; Megaw, 2005). In this context, issues such as stress, information processing capacity, motivation, and attention come to the forefront. The literature on the sociology of organizations and management highlights the effects of motivation on safety and productivity (Bernoux, 1985; Livian, 2000). It also includes risk perception, which relates to the hazards or features of making decisions about problems that lead to a subjective feeling of danger or safety. Hazards are defined as “threats to people and things they value” (Mearns & Flin, 1995). The perceived level of risk has an important impact on workers' behavior, in particular through the mechanism of risk homeostasis (Trimpop, 1996). It may be argued that risk perception is an issue that should be treated separately. Indeed, this was attempted when the first version of the framework was developed, but it appeared that this separation did not contribute in a significant manner to making the framework more precise.

Materials: refers to both the *availability* and the *quality* of the material at the worker's disposal in the workplace. It comprises the consumable items such as paper, lubricant oil, bolts, lamp bulbs, and spare parts in general.

Equipment / tools: refers to both the *availability* and *quality* of the equipment and tools in the workplace. It includes the fixed equipment, such as compressors, turbines, tanks, pipelines, as well as the hardware and software of computer systems; and the mobile tools and instruments such as hand-pumps, screwdrivers, drills and radiation detectors.

Finances: refers to the *availability* of financial resources (money or other instruments) at the worker's disposal. Since none of the workers who participated in this study handled the financial aspects of the operation of the system, this factor will not be considered at length. Nevertheless, it is mentioned here because on various occasions the workers made it clear that they were aware of the impact their actions had for the financial well-being of the company, as well as because workers whose work does involve finances are not exempt from performing adjustments (see note 17 on page 106).

Data: refers to the *availability*, *relevance*, *correctness* of data required for the execution of tasks. This target comprises (a) knowledge that the worker already possesses, for example through formal training, experience, or observation; and (b) information that the worker may access, through communication with other workers, through instrumentation and information systems, as well as through guidebooks, procedures, standards and manuals. Although the literature on “data” (e.g., display ergonomics) and on “experience and skills” is different, both themes are grouped here with the specific purpose of making the framework compact and readily understandable even by non-experts.

6.2 Facilitators

Objectives are, as seen above, what workers intend to achieve when engaging in adjustments. However, in order to execute an adjustment, the workers must first consider the task which they are undertaking, and then make use of certain resources. The perceived availability, quality, and consequence of use of those resources contribute to the choice of adjustment to be executed.

This is to say that regardless of the specific, concrete form that the adjustment takes, there are conditions which either facilitate or hamper the execution of whichever course of action is chosen. These conditions may be therefore called the facilitators of adjustments. The facilitators are characteristics of the system that may enhance or hinder the possibility of performing an adjustment. In that sense, facilitators open possibilities for specific adjustments to be executed. The data suggests that facilitators can be grouped in four categories: task-related; worker-related; team-related; and organization-related. They are summarized in table 8 below, and described in detail in the following sub-sections (from 6.2.1 to 6.2.4).

Table 8: Facilitators of adjustments.

Task-related	**Worker-related**	**Team-related**	**Organization-related**
Task coherence	Awareness	Cooperativeness	Interactiveness
Sequencing	Experience	Trust	Innovativeness
Sub-tasks are optional	Responsibility		Freedom
Sub-tasks can be suspended/delayed			

It was not in the scope of the study to determine whether a worker is first motivated to make an adjustment, and then evaluates the presence or absence of the facilitators; or if the presence or absence of certain facilitators "prompt" an objective that justifies a course of action that has already been chosen. What is certain is that offshore work is quite dynamic, and that adjustments are always open to revision. Indeed, as pointed out in Chapter 5, a particular characteristic of offshore work is that it may be subject to sudden changes in orientation.

6.2.1 Task-related facilitators

Task, in the sense used here, refers to the action or series of actions executed by a worker or group of workers in order to accomplish an objective. The adjustment is merely a number of actions that become part of that task as it is carried out (see discussion on section 2.3.1 about the difference between work as imagined and work as done). Some characteristics of the task may be considered facilitators when an adjustment is needed:

Task coherence: refers to how the actions "fit together" in a coherent, continuous set. Actions that do not fit in *disturb* the flow of work. It stands to reason that adjustments are more likely to be carried out if the action or actions that comprise it are perceived not to disturb the flow of work.

Sequencing: in a task comprising many actions, there is usually an order of execution that must be respected for the task to be carried out correctly. If an adjustment requires a change in the order of execution of tasks, a perception of flexibility in the order of execution will be invoked as a facilitator.

Sub-tasks are optional: in a task comprising many actions, some actions may be perceived as "optional", whereas others will be considered to be essential for the correct execution of the task. An adjustment may involve dropping some of the actions that are normally part of the task being carried out.

Sub-tasks can be suspended/delayed: this is different from altering the order of execution (the order is not changed) and different from opting out of an action (no action is dropped). The execution of an adjustment may require that some of the actions that are normally part of a task be delayed.

6.2.2 Worker-related facilitators

Worker-related facilitators correspond to characteristics of the *individual* worker. Three main characteristics were identified: the worker's awareness of the state of the system, the worker's experience in handling the system, and finally the worker's sense of responsibility toward the the system. The reader will notice that there is a significant overlap between worker-related facilitators and the psychological targets mentioned in the discussion about objectives (see section 6.1 above).

Awareness: Rajan, Wilson & Wood (2005) speak of situation awareness as a state of knowledge comprising three levels: a) awareness of the current situation; b) understanding of what it means; c) assessment of future events. It can be summarized as a state of "knowing what is going on." Situation awareness is a facilitator in the sense that the worker will draw on his perception of the current situation in order to evaluate the consequences of performing an adjustment. The issue is not one of whether the worker *has* situation awareness (as Dekker (2005) asks, what would happen if someone *lost* situation awareness?), but rather: (a) the Operator is confident that he actually knows what the situation is; (b) whether the Operator's understanding of the situation is compatible with external reality.

Experience: refers to the worker's previous encounters with the situation that is prompting the adjustment. It is assumed that a worker who has faced, either directly or vicariously, a situation similar to the current one, will be able to draw guidance from that past experience (Klein, 2004; Gladwell, 2007). This includes the knowledge acquired by the worker by formal means (education, training sessions) as well as by informal means (sharing experience with colleagues). For the role of experience in situation recognition and response, see Crandall, Klein, & Hoffman (2006) and Nathanael & Marmaras (2008).

Sense of responsibility: refers to the level of responsibility the worker has over the success or failure of the task at hand. It is assumed that the worker is more likely to take action if he understands that he is responsible for making the necessary adjustment. Conversely, it is suggested that if the worker understands that executing the adjustment is "none of his business", he is less likely to execute it.

6.2.3 Team-related facilitators

The expression "team", as used here, refers not only to the members of a group working on the same task, but also to the members of a group who perform the same functions. In this sense, when Operators and electricians come together for a specific task, they form a team. Likewise, the ensemble of Operators aboard form a team. One can therefore speak of "task-oriented teams", which emerge from the need of several workers to come together to perform a specific task; and of "function-oriented teams", which results from the grouping of several workers with the same professional role.

Cooperativeness: refers to whether workers in a team can count on each other for support and assistance. This facilitator is important when an adjustment requires the participation or assent of several workers. In this case, the worker(s) leading the adjustment must be able to summon the necessary assistance.

Trust: workers who work together must be able to trust that all members of the team are performing their tasks to the best of their ability. The argument here is twofold. First, a worker must trust that everyone is doing their job. This is particularly important when the adjustment involves *skipping* an action, on the assumption that someone else has already, or will later, perform it. Second, a worker must trust that everyone *knows how* to do their job. The implication here is that when performing an adjustment that requires the participation of several workers, they will not need to question or second-guess the actions of their colleagues.

6.2.4 Organization-related facilitators

The term "organization", as used here, refers to the firm and to its structure. Livian (2000) points out four essential characteristics of organizations: division of labor, existence of hierarchical control, existence of official rules and procedures, and a degree of stability. These characteristics are found in the three organization-related facilitators described below.

Interactiveness: may be of two types. Vertical interactiveness occurs when workers are able to interact with higher and lower levels of the hierarchy. Horizontal interactiveness occurs when workers are allowed to navigate the organizational structure at the same level of the hierarchy. It is suggested that the quality of both types of interactiveness can facilitate adjustments, as they allow for the resources needed for the execution of adjustments to be assembled. Speaking about interactiveness across hierarchical levels depicted in an organizational chart, a manager of a nuclear power plant once explained, "those are just the reporting lines. The work gets done in the white spaces between the boxes, up, down, and sideways" (quoted in Perin, 2005).

Innovativeness: the issue here is how the organization handles change, but in particular, how the organization reacts to ideas and methods put forward by the workers themselves. Does the organization listen to the workers, does it consider the workers as experts? It is suggested that adjustments will be facilitated by a working environment in which new ideas can be discussed and implemented with ease.

Freedom: it is evident from the analysis of the data that some adjustments may deviate or violate rules (as expressed in guidebooks, manuals, procedures or instructions). It appears reasonable to argue that a permissive attitude on the part of the organization facilitates the execution of adjustments. It is important to stress, however, that the point here is not whether organizations should or should not (and to what extent) allow deviations and violations. The point is simply that adjustments that involve deviation and violation of rules will be facilitated by a permissive environment.

6.3 Applying the objectives and facilitators to a case

The previous sections have introduced a series of factors that first motivate, and then facilitate, the execution of adjustments. In this section, a case will be discussed to illustrate how those factors can be used as a framework to understand an adjustment.

The case: in the story 4.2.1, a Mechanic decides to change the position of some of the piping in the compressor area. According to the Mechanic, the change did not constitute what is formally defined as a “Plant Change”, and the task was organized locally, by talking to one of the fitters aboard. Observation of the task as it was carried out and a post-fact debriefing with the Mechanic indicates that the task was successfully executed and that it did not generate any undesirable side-effects.

To understand this adjustment, one looks first at what motivated it, using table 9 below.

Table 9: Objective at play in a concrete case, with the objective and target “establish workplace buffer” highlighted.

	Avoid	**Maintain / Establish**	**Compensate**
Time	Waste of time / Inadequate timing	Time buffer	Inadequate amount of time / Inadequate timing
Human work capacity	Waste of effort / Waste of labor	Effort buffer / Labor buffer	Inadequate amount of effort / Inadequate amount of labor
Workplace	Inadequate workplace	Adequate workplace / Workplace buffer (especially space)	Inadequate workplace
Psychology	Inadequate state of mind	Adequate state of mind / State of mind buffer	Inadequate state of mind
Materials	Waste of material	Material buffer	Inadequate material availability / Inadequate material quality
Equipment / tools	Unnecessary use	Equipment / Tools buffer	Inadequate equipment / tools
Finances	Waste of financial resources	Financial buffer	Inadequate amount of financial resources
Data	---	Data buffer	Inadequate data

The tubing is in the way, and makes access to the filter difficult. It is important to notice that the task of changing the filter *had already been performed*. Accordingly, the objective for performing this adjustment may be said to be *to establish a workplace buffer* (i.e., to clear space). The moving of the piping to a different position was done specifically so that the task could be more easily performed in the future. This is the hallmark of Maintain/Establish objectives: they are aimed at preparing the ground for a future event.

What makes it possible for the Mechanic (and the fitter) to perform this adjustment? One uses the table 10 below to highlight the facilitators that made the adjustment possible:

Table 10: Facilitators at play in a concrete case, with facilitators Task coherence, Cooperativeness, Interactiveness and Innovativeness highlighted.

Task-related	**Worker-related**	**Team-related**	**Organization-related**
Task coherence	Awareness	Cooperativeness	Interactiveness
Sequencing	Experience	Trust	Innovativeness
Sub-tasks are optional	Responsibility		Freedom
Sub-tasks can be suspended/delayed			

Four facilitators appear to be most relevant to the understanding of the adjustment: Task coherence, Cooperativeness, Interactiveness and Innovativeness. In relation to Task coherence, one notes that changing the position of the pipes did not disrupt the flow of work of the compressor maintenance task, as evidenced by the fact that the Mechanic carried on his work while the fitter made the change. It appears quite clear that the notion of Cooperation played an important role in this adjustment. As the Mechanic explained, the change was organized informally, as an agreement between himself and the fitter, who was available at the time.

On the organization side, two factors can be highlighted. Interactiveness, at the horizontal level, allows the Mechanic to speak to the fitter and to organize the task. One notes that there was no intervention of hierarchical superiors to dictate whether the task should or should not be carried out. The arrangements are made at the level of the ground workers. It seems that worker-led Innovativeness is accepted within the organization. When arguing that “it is not a plant change, it's just a little thing to make the job easier next time,” the Mechanic seems to say that in his view the organization allows him to take the initiative to make improvements to the workplace that make his own job easier.

It is worth pointing out once more that both the motivators and the facilitators are perceptions. Indeed, it is not unlikely that an organization would formally prohibit the type of innovativeness that was discussed in the previous paragraph. What matters, as far as adjusting goes, is that the worker, or workers involved believe that the organization is open to it. It must be clear that this does not mean that adjustments will not take place in an organization that is not open to it. In such a case, adjustments may still take place. However, if the framework presented here is correct, they are more likely to result in poor outcomes.

Now that the objective and the facilitators have been uncovered, it is possible to engage in a discussion about the value – both positive and negative – of this adjustment. The tubing was probably there for no particular reason. Like so many other cases, it had been installed without particular regard to how the space was used for other tasks. Repositioning it allowed for work to be performed in a simpler, more convenient manner. There is no longer a risk of hitting the tubing, and less movements are needed to reach the engine. The impact for safety and productivity, when the whole organization is considered, appears minimal.

However, for the individual worker who has to routinely perform maintenance on that engine, it makes a significant difference. Performing an adjustment that is based on the factors mentioned above allowed the Mechanic to handle the situation directly with the fitter. Even though it is unlikely that this would have happened in this particular case, the possibility existed that going through formal channels would have resulted in a delay. As one manager put it, “there are things that are must-haves; and there are things that are nice-to-haves.” Would this not fall into the nice-to-have category? There is more: the Mechanic only noticed the problem and thought of a solution as he was carrying out the maintenance job – in other words, the tubing issue was not an issue contemplated during planning.

What about the potential negative consequences, or in other words, what could have gone wrong? This is certainly the speculative part of the exercise proposed by the method. It requires a good understanding of the overall functioning of the system as well as the context of the particular situation under analysis. The following is therefore one hypothesis to be considered (among many others which could be generated).

The organization coordinates ongoing tasks through two devices: Work Orders and Work Permits. The engine was shut down for maintenance – a job which had been properly authorized by a Work Order and a Work Permit. Furthermore, Robert, the Mechanic, was himself working on the engine. The risk of the engine being switched on while the fitter was still working on the tubing was very small. However, the fitter's job was not recorded anywhere. Robert knew he was there, and presumably the fitter's supervisor was aware as well. Two – admittedly small – possibilities open up: the engine could have been switched on while the fitter was still there, perhaps causing him injury; and the absence of the fitter could have signaled that the engine was in operational condition – even if he had not actually completed the task.

6.4 The Framework

Now that all the elements of the framework have been introduced, and a concrete case has been discussed, it is possible to describe it as a method. First, the definitions will be presented, followed by a description of the series of steps to be taken when using the framework to study a concrete case of adjustment.

The definitions which the analyst should keep in mind are:

Adjustment: an action aimed at changing the state of the system. This action is performed by a human being, is intended to achieve a goal perceived as desirable, and is distinct from strict procedure compliance;

Objective: a descriptor of the objective of an adjustment. May be of three types: avoid, compensate, and maintain / establish.

Target: an element of the system upon which the actor wishes to effect a change. These elements are *time*, *human work capacity*, the *workplace*, *psychology*, *materials*, *equipment and tools*, *finances*, and *data*.

Facilitator: characteristics of the system from which the actor can draw resources to perform the adjustment.

With these definitions in mind, the analyst should then follow the six steps listed below:

1) Describe the situation *prior* to the adjustment. This description must consider the state of the relevant factors and facilitators from the point of view of the worker(s) involved in the task.

2) Using table 7, indicate which target(s) the worker(s) wished to effect change upon and what motivated the worker to effect that change.

3) Describe the concrete form that the adjustment takes, that is, what the worker(s) actually did. The point of view of the worker(s) involved should be used in this description.

4) Indicate whether the adjustment led to the intended change;

5) Describe how the facilitators contributed either to the successor to the failure of the adjustment.

6) Discuss how the adjustment impacted the safety and productivity of the system. The result of this discussion is an assessment of whether the adjustment is beneficial (in which case it should be encouraged) or detrimental (in which case, measures should be taken to prevent it from being needed).

With respect to the last step, it is important to notice that a detrimental adjustment should not be prevented by making it it more difficult , or by making it the object of sanction. Rather, the analyst should suggest measures that prevent the adjustment from being needed. This means that preventive measures should be taken to make improvements to the *target* to which the adjustment refers.

6.5 Summary

This chapter suggested that there is an alternative way of looking at adjustments. As von Mises (1996) points out, all human action is aimed toward a goal. Accordingly, this alternative view does not consider adjustments as deviations, violations or errors, but simply as actions carried out by humans. The analysis of the data collected made it possible to distinguish between three types of goals that workers try to achieve when executing adjustments: they try to *avoid* a condition or situation which they find inadequate; they try to *compensate* for a condition or situation which they find inadequate and; they try to *maintain or establish* a condition or situation which they find adequate for the future.

The conditions or situations which the adjustments are aimed at are related to *time*, *human work capacity*, the *workplace*, the *psychology* , *materials*, *equipment and tools*, *finances*, and *data*. The essence of the idea of performing adjustments is that the worker finds a situation which is different from his expectation of how the system should look with respect to the conditions listed above. The worker then performs an adjustment aimed at avoiding or compensating for those conditions, or maintaining / establishing other conditions.

The success or failure of an adjustment depends on the state of what the framework calls *facilitators*. These are characteristics of the system that are considered to have a large influence on the outcome of an adjustment. Four types of facilitators were identified in the course of the study. They relate to *the task at hand*, to the *individual worker*, to *the team*, and to *the organization*.

All of these elements were then presented as a method for assisting an analyst in the study of adjustment. Such a study, due to the characteristics of the method, could be carried out both as an *assessment*, during the design phase of the system, or as *investigation*, when it becomes necessary to understand the actual functioning of the system – preferably, before a failure takes place.

In the study of adjustments, it is only after the goal of the worker has been established that questions about whether the measures taken were justified, and how they were justified become relevant. In that sense, the need to a priori qualify an action as an error is pushed to the background. The possibility to do away with the notion of *human error*, which has so far dominated the discourse on improving safety and avoiding accidents, is an essential feature of the framework presented here.

French summary of Chapter 6

Ce chapitre suggère qu'il existe une autre façon de voir les ajustements. Comme von Mises (1996) le souligne, toute action humaine a un but. Par conséquent, ce point de vue alternatif ne prend pas en compte les ajustements comme des déviations, des violations ou des erreurs, mais simplement comme des actions menées par des acteurs humains. L'analyse des données recueillies a permis de faire la distinction entre trois types d'objectifs que les travailleurs tentent d'atteindre lorsqu'ils exécutent des ajustements : ils essaient d'éviter une condition ou une situation qu'ils trouvent mauvaise, ils tentent de compenser une condition ou une situation qu'ils trouvent mauvaise et ils essaient d'établir ou de maintenir un état ou une situation qu'ils trouvent adéquats pour l'avenir.

Les conditions ou les situations que les ajustements visent sont liées au temps, à la capacité de travail de l'homme, au lieu de travail, à l'état d'esprit, aux matériaux, à l'équipement et aux outils, aux finances et aux données. L'essence de l'idée de procéder à des ajustements, c'est que le travailleur trouve une situation concrète qui est différente de son attente, de la façon dont le système devrait être en ce qui concerne les conditions énumérées ci-dessus. Le travailleur exécute alors un ajustement pour éviter, pour compenser la différence, ou pour établir / maintenir une autre situation à son avis plus adéquate.

Le succès ou l'échec d'un ajustement dépend de l'état de certains éléments facilitateurs. Ce sont des caractéristiques du système qui sont considérés comme ayant une grande influence sur le résultat d'un ajustement. Quatre types de facilitateurs ont été identifiés dans le cadre de l'étude. Ils se rapportent à la tâche à accomplir, au travailleur, à l'équipe et à l'organisation.

De tout ce qui a été présenté ci-dessus, il est maintenant possible de construire une méthode. Premièrement, les définitions sont présentées, suivis d'une description de la série de mesures à prendre lorsqu'on utilise ce cadre dans l'étude d'un cas concret d'ajustement.

Les définitions que l'analyste doit garder à l'esprit sont :

Ajustement : une action (ou série d'actions) visant à modifier l'état du système. Cette action est menée par un operateur humain, vise à achever un objectif perçu comme souhaitable, et est différent de l'exécution stricte de la procedure ;

Objectif : un descripteur de l'objectif d'un ajustement. Peut être de trois types : eviter, compenser et maintenir/établir ;

Cible : un élément du système sur lequel l'acteur veut effectuer un changement. Ces éléments sont le temps, la capacité de travail de l'homme, le lieu de travail, l'état d'esprit, les matériaux, l'équipement et les outils, les finances et les données ;

Facilitateurs : les caractéristiques du système à partir desquelles l'acteur peut puiser des ressources pour effectuer l'ajustement.

Avec ces définitions à l'esprit, l'analyste doit suivre les 6 étapes énumérées ci-dessous :

1. Décrire la situation antérieure à l'ajustement. Cette description doit tenir compte de l'état des facteurs et des facilitateurs du point de vue du (des) travailleur(s) impliqué(s) dans la tâche ;

2. En utilisant le tableau 7, indiquer sur quelle cible le travailleur souhaite effectuer un changement et son objectif ;

3. Décrire la forme concrète de l'adaptation, c'est à dire, ce que le travailleur a fait. Le point de vue du travailleur concerné doit être utilisés dans cette description ;

4. Indiquer si l'ajustement a conduit au changement souhaité ;

5. Décrire comment l'état des facilitateurs a contribué à la réussite ou à l'échec de l'ajustement ;

6. Expliquer comment l'ajustement impacte la sécurité et la productivité du système. Le but de cette discussion est d'évaluer si l'ajustement est un bénéfice (dans ce cas, il devrait être encouragé) ou un inconvénient (dans ce cas, des mesures devraient être prises pour éviter qu'il soit nécessaire) ;

En ce qui concerne la dernière étape, il est important de noter qu'un ajustement inconvénient ne doit pas simplement être pénalisé. Avant tout, l'analyste doit proposer des mesures qui empêcheront le besoin d'un ajustement. Cela signifie que des mesures préventives devraient être prises pour apporter des améliorations au facteur auquel l'ajustement se réfère.

Une telle étude, en raison des caractéristiques de la méthode, peut être menée à la fois comme une *évaluation*, au cours de la phase de conception du système, ou au cours d'une *enquête*, quand il devient nécessaire de comprendre le fonctionnement réel du système - de préférence, avant qu'un échec se produise.

Dans l'étude des ajustements, il est nécessaire d'établir d'abord l'objectif que le travailleur visait, pour poser la question de savoir si les mesures prises étaient justifiées, et la façon dont elles étaient justifiées. En ce sens, la nécessité de qualifier a priori une action comme erreur est relégué au second-plan. La possibilité d'en finir avec la notion d'erreur humaine, qui a jusqu'à présent dominé le discours sur l'amélioration de la sécurité et la prévention des accidents, est un élément essentiel du cadre présenté ici.

7 Conclusion

Efforts to maintain or increase safety in socio-technical systems have generally focused on the prevention and punishment of deviations and violations of procedures. The argument often made is that following the rules is the best way to have work done in a productive and safe manner.

This thesis has adopted the point of view of Resilience Engineering to argue that while rule-following has a role in enhancing safety and productivity, adjustments are needed in order to come to a matching of objectives and resources. Adjustments may or may not be in agreement with existing rules, but they should not be prevented on the mere assumption that they will have negative effects for productivity and safety.

This thesis has argued that instead of taking a definitive stand for or against adjustments in the workplace, safety management must strive to understand *why* adjustments occur in the first place and *how* they come about in practice. It is through this understanding that it will be then possible to assess the potential benefits and drawbacks of adjustments.

From the observation of natural gas production platform workers as they performed their daily tasks, it was possible to compile a corpus of cases which describe several adjustments that took place in that environment. A verification step, in which the data collected was presented to the workers, indicated that the examples corresponded to typical situations that the workers routinely faced and that the cases had been properly described.

The examples were analyzed in order to identify: a) what adjustments were made; b) why the adjustments were made; and c) what made the adjustments possible. From this analysis a framework for understanding adjustments emerged. This framework consists of a two-step process. The first step consists of highlighting the objective behind the adjustment, namely, whether the adjustment had an avoidance, a compensation, or a maintenance objective. The framework also allows for the definition of *what* the adjustment was aimed at avoiding, compensating for, or maintaining, that is, the target of the adjustment.

The second step consists in highlighting the *facilitators of* the execution of an adjustment. Facilitators were grouped into four categories, namely those that are related to the task at hand, to the worker, to the team, and to the organization. It was emphasized that facilitators make adjustments possible, but they do not guarantee a desirable outcome.

The advantage of the framework that resulted from this study is that it does away entirely with the need to establish whether an action constituted a deviation or a violation. Rather, it focuses on the objective of the worker , independent of how it related to procedures or whether the adjustment was successful.

7.1 Adjustments: safe or unsafe? Productive or unproductive?

What to make of the adjustments observed? Did they contribute to safety, or did they create new and unnecessary risks? Did they contribute to making the platforms more productive, or were they, in the end, hindrances to increased production? These are questions which are difficult to answer. There is the point, already made, that none of the stories ended badly – there were no incidents, no failures to speak of. Yet, it cannot be denied that risk may increase as a result of latent conditions which adjustments create.

Indeed, to think in terms of adjustments, forces one to think of many questions regarding the value of procedural compliance, the role that sanctions and rewards may play in the management of safety, and in the trade-offs that workers execute so often. What this study shows is that adjustments are not simple phenomena of trivial consequence. They are, rather, an important feature of the functioning of socio-technical systems which must be better understood.

What over fifty days of fieldwork showed was that platforms are not ever fully operational, and never in full compliance with the formal operational rules and instructions. There is always something that is broken, always something in need of repair. There is always someone, somewhere, who for one reason or another, does not follow a procedure. Why does one not see many more accidents on platforms? One possible response is that there are so many layers of defense built into the system that the chance of a single adjustment causing a failure is very small. Another response, in line with Resilience Engineering, and with the view developed in this thesis, is that adjustments balance each other. Here, one worker finishes the job earlier than expected – he has done it many times and knows there is little risk, so he skips a few steps; there, another worker goes behind schedule – he is doing it alone, instead of with a colleague, and so takes a few extra precautions.

The role of adjustments on productivity appears to be more clear. The workers are well aware that if they have a job, it is because gas is flowing. So, to keep gas flowing is an imperative for them. There is therefore great temptation to make adjustments that will contribute to improving production. From the point of view of the organization, this is certainly a desirable state of affairs. However, if left unchecked, adjustments may lead to failures (even though none was seen). It is, as Joseph Heller called it, a C*atch-22* situation: adjustments can be good, but they can also be bad. The solution is not to try to eliminate all adjustments, but to try to ensure that they are controlled. The framework which this thesis proposes is expected to contribute to controlling them.

7.2 Uses of the framework

The research carried out in this thesis resulted in the proposition of a framework for understanding adjustments that occur in the workplace. It was not within the scope of the thesis to produce a full-fledged method for the analysis of adjustments. The framework proposed should therefore be understood as a first, tentative step towards such a method. Nevertheless, it is possible to envision a number of possibilities for the development of the framework into a usable tool. These possibilities are briefly discussed below:

- Focusing on "objectives" alone, it might be possible to identify what type of situation workers are most often confronted with. For example, if workers are constantly *compensating for lack of time*, it may be reasonable to suspect that the workload is excessive, or that procedures are cumbersome and include too many steps. In such a case, it may be desirable to consider an increase in the workforce, a reduction in the workload, or a different division of labor, among many possibilities. If workers are constantly trying to *maintain a time buffer*, it may be reasonable to assume that there is not enough predictability in the workplace. Many options for addressing such a situation could then be discussed, such as reformulating the way tasks are scheduled or assigned to workers.

- Focusing on "facilitators" alone, one could investigate how "true to fact" workers' perceptions are. For example, it could be problematic to have a situation in which workers began to make adjustments on the assumption that they have enough experience of handling a given scenario, whereas "in fact", the scenario was novel to them.

- There may be value in being able to see whether "unusual" objectives or facilitators are being invoked. For example, if most of the organization's adjustments are motivated by Compensation, and suddenly there is an increase in adjustments motivated by Avoidance, that would be a sign that something within the working environment has changed. This could then prompt an investigation into what changed and what the consequences of this change may be, both in the short and in the long term.

- There may be value in using the framework to compare sites. For example, in a distributed system such as the organization studied, with more than thirty offshore facilities, it would be useful to know whether some platforms perform more adjustments, and of what kind, so that necessary measures can be taken.

7.3 Limitations and further work

The limitations of the framework presented here are of three orders: theoretical, methodological and practical. On the theoretical side, it is worth noticing that the objectives and facilitators were derived from the analysis of cases collected in an specific setting, namely, natural gas production platforms. Although the objectives and facilitators are sufficient to explain all of the cases presented, no test was conducted to check whether they would be sufficient to explain cases outside of that work environment.

On the methodological side, as explained in Chapter 3, the cases were collected through a process of observation and note-taking, followed by the writing of descriptions which were then presented to the workers for verification. Although, as noted, the workers were of the opinion that the cases were representative of the situations that they commonly faced, some uncertainty remains regarding the completeness and the accurateness of those cases. It appears that since the examples collected represented very ordinary situations with no negative impacts, “there was not much to talk about.” Nevertheless, the observation-description method adopted had the distinctive advantage of allowing the workers to be as natural as possible. There is little reason to believe that the workers would have performed those adjustments in a different manner were there not an observer presented. Furthermore, on at least one occasion the presentation of a case to the workers was sufficient to spark a discussion about work practices and potential improvements.

On the practical side, the usability of the framework has not been assessed outside of the confines of the cases presented in this study, nor has it been tested by an independent user. In that sense, there is no information about how well this framework would perform when taken back into the field.

Further work is needed to address the limitations listed above. To address the theoretical limitations, more cases as well as cases from other work domains should be collected and analyzed. This would allow for a validation of the underlying model of adjustments (objectives and facilitators) and enlarge its scope of application.

Theoretical refinement will, as pointed out above, require more data. The observational method provides certain advantages, but is limited in terms of both the amount of data that can be gathered and the quality of that data. Methodological advancement should be in the direction of developing data collection techniques. This in turn will require specific training in *what to look for*, namely, in how to identify adjustments as they happen, so that less time is spent following workers and waiting for something to happen.

Clearly, this methodological refinement is connected to the use of the framework. It is through regular practice of the ideas put forward in the framework presented that it will be possible to find out what data collection method works best, and how data analysis could be done in a consistent manner. For example, objectives and facilitators could be turned into grids that reduce the analyst's need for subjective assessment.

7.4 Final Thoughts

This thesis has shown that it is possible both to describe and to understand normal human performance within the context of a socio-technical system without invoking judgment notions such as “error” or “deviation”. Instead, it proposes a framework that is consistent with the principle enunciated by Hollnagel (2009), which claims that “human performance is always variable and always adjusted to the conditions of work.”

Every day, newspapers and other news outlets publish information about the most recent accidents. Invariably, a human is found to be guilty – the worker who did not close a valve; the supervisor who paid lip service to the formalities of paperwork; the manager who did not provide enough training; and so on. Yet the observation of daily activities show a different story. A story in which humans must balance several, often conflicting, objectives with limited resources. To ignore this simple fact is to wish that humans behaved as machines. To acknowledge that human performance varies – and that it must indeed be variable – is to take a step towards improvement in safety as well as in productivity.

French summary of Chapter 7

Les efforts visant à maintenir ou à augmenter la sécurité dans les systèmes socio-techniques ont généralement porté sur la prévention et la répression des déviations et violations des procédures. L'argument souvent avancé est que s'en tenir à des règles est le meilleur moyen d'avoir un travail fait de manière productive et en toute sécurité. Cette thèse a adopté le point de vue de l'Ingénierie de la Résilience qui fait valoir que si les règles jouent un rôle dans le renforcement de la sécurité et de la productivité, des ajustements sont nécessaires afin de parvenir à une adéquation des objectifs et des ressources. Des ajustements peuvent être en accord ou en opposition avec les règles existantes, mais ils ne doivent pas être écartés sur la simple présomption qu'ils auront des effets négatifs sur la productivité et la sécurité.

Cette thèse a fait valoir qu'au lieu de prendre une position définitive pour ou contre les ajustements sur le lieu de travail, la gestion de la sécurité doit s'efforcer de comprendre d'une part pourquoi les ajustements se produisent et d'autre part comment ils interviennent dans la pratique. C'est grâce à cette compréhension qu'il sera possible d'évaluer les avantages et les inconvénients potentiels des ajustements.

A partir de l'observation du travail quotidien sur les plate-formes, il a été possible d'établir un corpus de cas qui décrit plusieurs types d'ajustements. Une étape de vérification, dans laquelle les données recueillies ont été présentées aux travailleurs, a montré que les exemples correspondent à des situations typiques auxquelles les travailleurs sont confrontés régulièrement et que les cas avaient été correctement décrits.

Les exemples ont été analysés dans le but d'identifier : a) quels ajustements ont été opérés ; b) pourquoi les ajustements ont été opérés, et c) ce qui a fait les ajustements possibles. De cette analyse, un cadre pour la compréhension des ajustements est apparu. Ce cadre consiste en un processus en deux étapes. La première étape consiste à mettre en évidence l'objectif derrière l'ajustement, à savoir, si l'ajustement avait pour but éviter, compenser ou établir/maintenir un état ou situation. Elle permet la définition de la cible de l'ajustement.

La deuxième étape consiste à mettre en évidence les facteurs qui facilitent l'exécution d'un ajustement. Ces facteurs ont été regroupés en quatre catégories, à savoir les facteurs qui sont liés à la tâche à accomplir, au travailleur, à l'équipe, et à l'organisation. Il a été souligné que les facilitateurs rendent possible les ajustements, mais qu'ils ne garantissent pas le résultat souhaité.

L'avantage du cadre résultant de cette étude est qu'il fait disparaître entièrement la nécessité d'établir si une action a constitué une déviation ou une violation. Au contraire, il se concentre sur l'objectif du travailleur, indépendamment de sa relation avec les procédures, ainsi que sur le fait de savoir si l'ajustement a été couronnée de succès ou non. Cette thèse montre qu'il est possible à la fois de décrire et de comprendre la performance humaine normale dans le cadre d'un système socio-technique sans faire appel à des notions telles que l' « erreur » ou la « déviation ». Au lieu de cela, elle propose un cadre qui soit compatible avec le principe énoncé par Hollnagel (2009), « human performance is always variable and always adjusted to the conditions of work. »

Chaque jour, les journaux publient des informations sur les accidents les plus récents. Invariablement, un homme est reconnu coupable - le travailleur qui n'a pas fermer une vanne, le responsable qui n'a pas respecté les formalités administratives, le dirigeant qui n'a pas organisé suffisamment de formation, et ainsi de suite. Pourtant, l'observation des activités quotidiennes montrent une toute autre histoire. Une histoire dans laquelle l'homme doit prendre en compte plusieurs objectifs, souvent contradictoires, avec des ressources limitées. Ignorer ce simple fait reviendrait à souhaiter que les humains se comportent comme des machines. Reconnaître que la performance humaine varie - et qu'elle doit en effet être variable – permet de faire un pas vers l'amélioration de la sécurité et de la productivité.

References

Ashby, W. (1957). *Introduction to cybernetics (2nd re-print)*. London: Chapman & Hall.

Bernoux, J. (1985). *La sociologie des organisations (5th ed.)*. Paris: Editions du Seuil.

Besnard, D., & Greathead, D. (2003). A cognitive approach to safe violations. In: *Cognition, Technology & Work, v. 5, n. 4*, pp. 272 - 283.

Busby, J. (2003). *Mutual misunderstandings between designers and operators of hazardous installations.* Retrieved from Health & Safety Executive (UK): http://www.hse.gov.uk/research/rrpdf/rr054.pdf

Carvalho, P., dos Santos, I., Gomes, J., Borges, M. (2008). Micro incident analysis framework to assess safety and resilience in the operation of safe critical systems: a case study in a nuclear power plant. In: *Journal of loss prevention in the process industries, n. 21*, pp. 277 - 286.

Clarke, L. (1999). *Mission improbable: using fantasy documents to tame disaster.* Chicago: University of Chicago Press.

Cook, R. (2006). Being bumpable: consequences of resource saturation and near-saturation for cognitive demands on ICU practitioners (Chapter 3). In: D. Woods and E. Hollnagel, *Joint cognitive systems - patterns in Cognitive Systems Engineering*. Boca Raton: Taylor & Francis. pp. 23 – 35.

Cook, R., & Nemeth, C. (2006). Taking things in one's stride: cognitive features of two resilient performances. In: E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering - Concepts and Precepts*. Aldershot, Burlington: Ashgate. pp. 205 – 221.

Cook, R., & O'Connor, M. (n. d.). *Thinking about accidents and systems*. Retrieved from: http://www.ctlab.org/documents/ASHP_chapter.pdf

Cooper, R., & Foster, M. (1971). Sociotechnical Systems. In: *American Psychologist, v. 26, n. 5*, pp. 467 - 474.

Corbin, J., & Strauss, A. (2008). *Basics of Qualitative Research (3rd ed.)*. Thousand Oaks, CA: Sage.

Crandall, B., Klein, G., & Hoffman, R. (2006). *Working minds: A Practitioner's Guide to Cognitive Task Analysis*. Cambridge, MA: MIT Press.

Creswell, J. (2007). *Qualitative inquiry and research design: choosing among five approaches (2nd ed.)*. Thousand Oaks: Sage.

Cuvelier, L., & Falzon, P. (2008). Methodological issues in the quest for resilience factors. In: E. Hollnagel, F. Pieri & E. Rigaud, *Proceedings of the third Resilience Engineering Symposium.* Paris: Mines ParisTech - Les Presses. pp. 59 - 65.

da Mata, T., Gajewski, D., Hall, C., Lacerda, M., Santos, A., Gomes, J., & Woods, D. (2006). Application of Resilience Engineering on safety in offshore helicopter transportation. In: Michael D. DeVore (Org.), *Proceedings of the 2006 Systems and Information Engineering Design Symposium*. Retrieved from: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4055143&isnumber=4055097 pp. 228 - 233.

Daniellou, F. (2005). The French-speaking ergonomists' approach to work activity: cross-influences of field intervention and conceptual models. In: *Theoretial Issues in Ergonomics Science, v. 6, n. 5*, pp. 405 - 427.

Daniellou, F., & Six, F. (2000). Les ergonomes, les prescripteurs et les prescriptions. In: *Actes des journées de Bordeaux sur la pratique de l'ergonomies*. Bordeaux: Université Victor Segalen Bordeaux 2.

Daniellou, F., Simard, M., & Boissières, I. (2010). *Les facteurs humains et organisationnels de la sécurité industrielle: un état de l'art*. Paris:

ICSI/FonCSI. Retrieved from: http://www.icsi-eu.org/francais/dev_cs/cahiers/CSI-FHOS-Etat-de-l-art.pdf

Dejours, C. (2007). *Le facteur humain (4th ed.)*. Paris: PUF.

Dekker, S. (2003). Failure to adapt or adaptations that fail: contrasting models on procedures and safety. In: *Applied Ergonomics, v. 34, n. 3*, pp. 233 - 238.

Dekker, S. (2005). *Ten questions about human error: a new view of human factors and system safety*. Mahwah: Lawrence Erlbaum Associates.

Dekker, S., Siegenthaler, D., & Laursen, T. (2007). Six stages to the new view on human error. In: *Safety Science Monitor, v. 11, issue 1*. Retrieved from: http://ssmon.chb.kth.se/vol11/5Dekker.pdf

Dien, Y. (1998). Safety and application of procedures, or 'how do 'they' have to use operating procedures in nuclear power plants?'. In: *Safety Science, n. 29, issue 3*, pp. 179 - 187.

Eurocontrol, 2009. A white paper on Resilience Engineering for ATM. Retrieved on April 10, 2010 from: http://www.eurocontrol.int/esp/gallery/content/public/library/A%20White%20Paper%20Resilience%20Engineering/A_White_Paper_Resilience_Engineering.pdf

Flach, J., & Kuperman, G. (2001). The human capacity for work: a (biased) historical perspective. In: P. Hancock and P. Desmond (Eds.), *Stress, workload and fatigue.* Mahwah: Lawrence Erlbaum Associates. Retrieved on April 6, 2010 from: http://books.google.com/books?id=og4VMJfq3s0C&lpg=PA429&ots=6uee7xMmB-&dq=The%20human%20capacity%20for%20work%3A%20a%20(biased)%20historical%20perspective&pg=PR4#v=onepage&q=The%20human%20capacity%20for%20work:%20a%20(biased)%20historical%20perspective&f=false

Furuta, K., Sasou, K., Kubota, R., Ujita, H., Shuto, Y., & Yagi, E. (2000). Human factor analysis of JCO criticality accident. In: *Cognition, Technology and Work, v. 2, n. 4*, pp. 182 - 203.

GDF Suez Production Nederland B.V. (2007). *Operations manual (rev. 6)*.

Gladwell, M. (2007). *Blink: the power of thinking without thinking*. New York: Back Bay.

Guérin, F., Laville, A., Daniellou, F., Duraffourg, J., & Kerguelen, A. (2006). *Comprendre le travail pour le transformer - la pratique de l'ergonomie*. Lyon: ANACT.

Hale, A., & Heijer, T. (2006). Is resilience really necessary? The case of railways. In: E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering - Concepts and Precepts*. Aldershot and Burlington: Ashgate. pp. 125 - 147.

Hale, A., & Hovden, J. (1998). Management and culture: the third age of safety. A review of approaches to organizational aspects of safety, health and environment. In: A. M. Feyer & A. Williamson (Eds.), *Occupational injury: risk, prevention and intervention*. London: Taylor & Francis.

Hansson, L., Herrera, I., Kongsvik, T., & Solberg, G. (2009). Applying the resilience concept in practice: a case study from the oil and gas industry. In: Safety, reliability and risk analysis: theory, methods and applications: proceedings of the European Safety and Reliability Conference, ESREL 2008, and 17th SRA-Europe, Valencia, Spain, September 22-25, 2008. London: Taylor & Francis. Retrieved on April 6, 2010 from http://sintef.org/project/Building%20Safety/Publications/ESREL%202008%20-%20Hansson%20Herreira%20Kongsvik%20Solberg.pdf

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. In: *Annual Review of Ecology and Systematics. v. 4*, pp. 1-23.

Hollnagel, E. (1993). *Human reliability analysis: Context and control*. London: Academic Press.

Hollnagel, E. (2002). Understanding Accidents - From Root Causes to Performance Variability. In: *2002 IEEE conference on human factors and power plants, n. 7*, Scottsdale, AZ.

Hollnagel, E. (2004). *Barriers and accident prevention*. Aldershot, Hampshire, England: Ashgate.

Hollnagel, E. (2008). Safety management-Looking back or Looking forward. In: E. Hollnagel, C. Nemeth & S. Dekker (Eds.) *Remaining sensitive to the possibility of failures*. Aldershot and Burlington: Ashgate.

Hollnagel, E. (2008b). *From FRAM (Functional Resonance Accident Model) to FRAM (Functional Resonance Analysis Method)*. Presentation at the 2nd FRAM Workshop, Mines ParisTech, Sophia Antipolis, 20 – 22 Feb., 2008.

Hollnagel, E. (2009). *The ETTO Principle: Efficiency-Thoroughness Trade-Off*. Farnham, UK and Burlington, VT: Ashgate.

Hollnagel, E., & Woods, D. (1983). Cognitive Systems Engineering: New Wine in New Bottles. In: *International Journal of Human-Computer Studies, v. 8, issue 6*. pp. 583 – 600.

Hollnagel, E., & Woods, D. (2005). *Joint Cognitive Systems - Foundations of Cognitive Systems Engineering*. CRC Taylor & Francis.

Hollnagel, E., Woods, D., & Leveson, N. (Eds). (2006). *Resilience Engineering - Concepts and precepts*. Aldershot and Burlington: Ashgate.

Hollnagel, E. (2006). Resilience - the challenge of the unstable (Chapter 1). In: E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering - Concepts and Precepts*. Aldershot and Burlington: Ashgate. pp. 125 - 147.

Klein, G. (2004). *The power of intuition*. New York: Currency/Doubleday.

Lagadec, P. (1981). *Le risque tecnologique majeur - politique, risque et processus de developpément*. Paris: Pergamon.

Laurence, D. (2005). Safety rules and regulations on mine sites - The problem and a solution. In: *Journal of safety research, v. 36, issue 1*. pp. 39 – 50.

Leplat, J. (1997). *Regards sur l'activité en situation de travail - Contribution à la psychologie ergonomique*. Paris: PUF.

Leveson, N. (2003). *Model-Based Analysis of Socio-Technical Risk.* Retrieved on Dec. 22, 2008 from: http://sunnyday.mit.edu/papers/stpa-tech-report.doc

Leveson, N., Dulac, N., Marais, K., & Carroll, J. (n. d.). *Moving Beyond Normal Accidents and High Reliability Organizations: An Alternative Approach to Safety in Complex Systems.* Retrieved on Dec. 22, 2008 from: http://sunnyday.mit.edu/papers/HRO-final.doc

Leveson, N.; Dulac, C.; Zipkin, D.; Cutcher-Gershenfeld, J.; Carroll, J.; & Barrett, B. (2006). Engineering resilience into safety-critical systems. In: E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering - Concepts and Precepts*. Aldershot and Burlington: Ashgate. pp. 95 – 123.

Livian, Y. (2000). *Introduction à l'analyse des organisations (2nd ed.)*. Paris: Economica.

Llory, M. (2001). Accidentes industriais: o custo do silêncio (2nd ed.). Rio de Janeiro: Multiação Editorial.

Lofland, J., Snow, D., Anderson, L., & Lofland, L. (2006). *Analyzing Social Settings: A guide to qualitative observation and analysis (4th ed.)*. Belmont, CA: Wadsworth/Thomson Learning.

McDonald, N. (2006). Organizational resilience and industrial risk (Chapter 11). In: E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering - Concepts and Precepts*. Aldershot and Burlington: Ashgate. pp. 155 - 180.

Mearns, K., & Flin, R. (1995). Risk perception and attitudes to safety by personnel in the offshore oil and gas industry: a review. In: *Journal of Loss Prevention in the Process Industries, v. 8, issue 5*. pp. 299-305.

Megaw, T. (2005). The definition and measurement of mental workload (Chapter 18). In: J. Wilson and N. Corlett, *Evaluation of human work (3rd ed)*. Boca Raton: Taylor & Francis. pp. 525 – 552.

Moscato, M. (2005). *Ergonomie - analyse des tâches en ergonomie*. Paris: Ellipses.

Motta, S. (2009, Nov. 11). *Lula diz que não vai 'dar chute' sobre causas do apagão*. In: O Globo Online (Blog do Noblat). Retrieved on Nov. 15, 2009 from: http://oglobo.globo.com/pais/noblat/posts/2009/11/11/lula-diz-que-nao-vai-dar-chute-sobre-causas-do-apagao-240158.asp

Nathanael, D., & Marmaras, N. (2008). On the development of work practices: a constructivist model. In: *Theoretical issues in ergonomics science, v. 9, n. 5*. pp. 359 – 382.

National Transportation Safety Board. (2000). *Natural Gas Pipeline Rupture and Subsequent Explosion - St. Cloud, Minnesota - December 11, 1998*. Retrieved from: www.ntsb.gov/Publictn/2000/PAR0001.pdf

Operador Nacional do Sistema Elétrico [ONS]. (2009, Nov. 11). *Nota à Imprensa*. Retrieved on November 15, 2009 from: http://www.ons.org.br/download/sala_imprensa/nov2009-notaimprensa.pdf

Ordoñez, R. (2009, Nov. 13). *Apagão: explicação do governo não convence especialistas, que veem falha humana*. In: O Globo Online. Retrieved on Nov. 15, 2009, from: http://oglobo.globo.com/economia/mat/2009/11/13/apagao-explicacao-do-governo-nao-convence-especialistas-que-veem-falha-humana-914738693.asp

Parsons, K. (2005). The environmental ergonomics survey (Chapter 22). In: J. Wilson and N. Corlett, *Evaluation of human work (3rd ed)*. Boca Raton: Taylor & Francis. pp. 631 – 642.

Patterson, E., Cook, R., Woods, D., Render, M. (n. d.). *Gaps and Resilience*. Retrieved on Nov. 10, 2009 from: http://www.ctlab.org/documents/heinmedv26-gaps%20and %20resilience.pdf

Pavlov, V., & Obukhov, V. (1973). Functional synthesis of systems. In: *Cybernetics and Systems Analysis, v. 9, n. 1*. pp. 35 – 44.

Perin, C. (2005). *Shouldering risks: the culture of control in the nuclear power industry*. Princeton: Princeton University Press.

Perrow, C. (1984). *Normal accidents: living with high-risk technologies*. New York: Basic Books.

Perry, S., Wears, R., & Spillance, J. (2008). When worlds collide: two medication systems in one emergency department. In: E. Hollnagel, F. Pieri and E. Rigaud, *Proceedings of the third Resilience Engineering Symposium*. Paris: Mines ParisTech - Les Presses. pp. 219 - 233.

Rabardel, P., Carlin, N., Chesnais, M., Lang, N., le Joliff, G.; & Pascal, M. (2007). *Ergonomie concepts et méthodes (5th re-print)*. Toulouse: Octares.

Rajan, J., Wilson, J., & Wood, J. (2005). Control facilities design (Chapter 14). Boca Raton: Taylor & Francis. In: J. Wilson and N. Corlett, *Evaluation of human work (3rd ed)*. Boca Raton: Taylor & Francis. pp. 389 – 425.

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. In: *Safety Science, v. 27, n. 2/3*. pp. 183 - 213.

Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, Hants, England: Ashgate.

Reiman, T. (2009). How to evaluate safety critical organizations. Slide presentation reproduced in: Organisation for Economic Co-operation and Development, Dec. 3, 2009, *Proceedings of the workshop on justifying the suitability of nuclear licensee organisational structure, resources and competencies – methods, approaches & good practices, Uppsala (Sweden), Sep. 8 – 10, 2008*. Retrieved from: http://www.nea.fr/nsd/docs/2009/csni-r2009-11.pdf

Reiman, T., & Oedewald, P. (2009). *Evaluating safety-critical organizations – emphasis on the nuclear industry*. Retrieved from: http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Sakerhet-vid-karnkraftverken/2009/SSM-Rapport-2009-12.pdf

Rodrigues, A. (2009, Nov. 11). *"Queira Deus", blecaute não acontecerá de novo, diz Lobão*. In: O Globo Online. Retrieved on November 15, 2009 from: http://oglobo.globo.com/economia/mat/2009/11/11/queira-deus-blecaute-nao-acontecera-de-novo-diz-lobao-914712120.asp

Seville, E., Brundson, D., Dantas, A., le Masurier, J., Wilkinson, S., Vargo, J. (2006). *Building organizational resilience: summary of key research findings*. Research report. Retrieved on Jan. 26, 2007 from: http://www.resorgs.org.nz/Building%20Organisational%20Resilience%20Res%20Orgs%20research%20report%202006_04.pdf

Simon, H. (1991). Bounded Rationality and Organizational Learning. In: *Organization Science 2 (1)*: pp. 125–134.

Spire, A. (2008). *Accueillir ou reconduire: enquête sur les guichets de l'immigration*. Paris: Liber/Raison d'agir.

Trimpop, R. (1996). Risk homeostasis theory: problems of the past and promises for the future. In: *Safety Science, v. 22, n. 1-3*. pp. 119 – 130.

Vicente, K. (1999). *Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work*. Mahwah, NJ: Lawrence Erlbaum Associates.

Vicente, K. (2004). *The human factor - revolutionizing the way we live with technology (Vintage Canada Ed.)*. Toronto: Vintage Canada.

von Bertalanffy, L. (2006). *General System Theory (15th paperback printing of the 1969 original)*. New York: George Braziller.

von Mises, L. (1996). Human action: A treatise on economics (4th rev. ed). San Francisco: Fox & Wilkes. Retrieved from: http://mises.org/Books/humanaction.pdf

von Mises, L., & Greaves, B. (2006). *The ultimate foundation of economic science: an essay on method*. Indianapolis: Liberty Fund.

Weick, K. (1987). Organizational culture as a source of high reliability. In: *Californa Management Review, v. 29, issue 2*. pp. 112 - 129.

Wiener, N. (1988). *The human use of human beings - cybernetics and society (re-print of 1954 ed.)*. New York: Da Capo Press.

Wiener, N. (2007). *Cybernetics or control and communication in the animal and the machine*. Whitefish, MT: Kessinger Publishing.

Woods, D. (2006). Essential characteristics of resilience (Chapter 2). In: E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering - Concepts and Precepts*. Aldershot and Burlington: Ashgate. pp. 21 – 34.

Woods, D., & Cook, R. (1999). *The new look at error, safety, and failure: a primer for health care*. Retrieved from: http://csel.eng.ohio-state.edu/woods/error/NewLook_primer.pdf

Woods, D., & Cook, R. (2001). From counting failures to anticipating risks: possible futures for patient safety. In: L. Zipperer & S. Cushman (Eds.), *Lessons in* *patient safety: a primer*. Chicago, IL: National Patient Safety Foundation. Retrieved from: http://csel.eng.ohio-state.edu/woods/error/future_pat_saf.pdf . pp. 89 - 97.

Woods, D., & Cook, R. (2003). Mistaking error. In: M. J. Hatlie and B. J. Young (Eds.) *Patient Safety Handbook*, Jones and Bartlett, in press. Retrieved on Nov. 30, 2009 from: http://csel.eng.ohio-state.edu/woods/error/mistaking_error.pdf

Woods, D., & Hollnagel, E. (2006). *Joint Cognitive Systems - Patterns in Cognitive Systems Engineering*. Boca Raton, FL: CRC Taylor & Francis.

Woods, D.; Hollnagel, E. (2006b). Prologue: Resilience Engineering Concepts. In: E. Hollnagel, D. Woods & N. Leveson (Eds.), *Resilience Engineering - Concepts and Precepts*. Aldershot and Burlington: Ashgate. pp. 1 – 6.

Woods, D., Cook, R. (n. d.). *Perspectives on Human Error: Hindsight Biases and Local Rationality*. Retrieved from: http://www.nifc.gov/safety/investigation_guide/Guest%20Speakers%20Presentations/Mike%20Johns/Articles%20cited%20in%20What%20Was%20He%20Thinking/Perspectives%20on%20Human%20Error.pdf

PRODUCTIVITE ET SECURITE: AJUSTEMENTS AU TRAVAIL DANS LES SYSTEMES SOCIO-TECHNIQUES

Résume : La thèse présente les conclusions d'une étude sur les ajustements de la performance réalisés par des opérateurs dans le cadre des travaux de routine. Les résultats se présentent sous la forme d'une théorie et une méthode. Les ajustements sont les modifications apportées au flux naturel du travail pour éviter une situation considérée comme indésirable, pour compenser un manque temporaire de ressources, d'équipement, et de temps, ou pour établir ou maintenir le contrôle sur le fonctionnement d'un système socio-technique. La thèse décrit un certain nombre d'événements dans lesquels de tels ajustements ont eu lieu, et identifie les raisons des ajustements et leurs conséquences tant pour la sécurité que pour la productivité. L'identification de ces deux éléments dirige la recherche vers le développement d'une classification des ajustements en termes de conditions de travail, d'objectifs fondamentaux, et des effets observables. Cette classification peut être utilisée par toute personne intéresse par le maintien d'un juste équilibre entre la sécurité et la productivité, en indiquant les pratiques qui doivent être facilitées et améliorées, et celles qui devraient être réduites ou totalement évitées. La thèse s'appuie sur des données obtenues à partir de l'observation de diverses activités menées à bord de plates-formes de production de gaz naturel en mer du Nord. L'utilisation de la classification est décrite comme une méthode pour comprendre les ajustements de performances. Les recherches futures devrait aller dans le sens d'un affinage de la classification proposée ici, ainsi que dans le développement de méthodes pour appuyer la gestion des ajustements de performances.

Mots-clés : sécurité, ajustement, performance, travail, résilience

PRODUCTIVITY AND SAFETY: ADJUSTMENTS AT WORK IN SOCIO-TECHNICAL SYSTEM

Abstract: The thesis presents the findings from a study of the adjustments of performance conducted by human operators in the course of routine work. The findings are in the form of a comprehensive theory and a method. The adjustments are the changes to the natural flow of work, to avoid a situation considered undesirable, to compensate for a temporary lack of resources, equipment, and time, or to maintain or restore control over the operation of a socio-technical system. The thesis describes a number of events in which such adjustments occurred, and identifies the reasons behind the adjustments and their consequences for both safety and productivity. The identification of these two elements leads the research toward the development of a classification of adjustments in terms of their work conditions, their underlying motivations, and their observable effects. This classification may be used by anyone concerned with maintaining a proper balance between safety and productivity, by indicating which practices should be facilitated and improved upon, and which should be reduced or altogether avoided. The thesis uses data obtained from observation of various activities carried out aboard natural gas production platforms in the North Sea. The use of the classification is described as a method for gauging performance adjustments. Future research based on this study should go in the direction of refining the classification proposed here, as well as in the development of methods to support the management of performance adjustments.

Keywords: safety, adjustment, performance, work, resilience

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