VIGILANCE AND TRANSFORMATION

Corporal Presence and Responsibility in the Operation of Technological Apparatus

Francis Chateauraynaud
EHESS

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Summary
A description of the constraints on human agents in the operation of technological apparatus enables the author to illuminate two dimensions generally overlooked in the paradigms of action: attention-vigilance and the capacity to adapt with time. These essential capacities, without which there could be no responsible agent, determine the human agent's level of control, allowing for both routine and the invention of practical solutions in critical situations. Based on the comparison of three areas of activity (nuclear, civil aviation and road transport) in which the question of risk is central to the conception and organization of technological devices, this article shows how decisions in the workplace need to come to terms with constraints of presence and responsibility.

This article[1] addresses the question of professional responsibility with regard to acts of attention and verification accomplished in work situations. It aims to complete analyses based on the imputation of responsibility in firms or by the courts. The importance of phenomena such as "lack of attention" or "error of perception" suggests a move towards the kind of argument used in recent years in descriptions of liability suits[2]. If it is to be realistic, the follow-up to these analyses must include the corporal practices which are part of the networks of conventions and technological objects engaged in the professional environment. This level of description implies the development of a *sociology of perception* which recognizes the importance of interactions between people and things. It enables us to pose clearly the question of practical modalities of integration of the perceptual level of human activities and of debatable or normative aspects. How can we compare corporal practices related to concrete activities, and sets of rules, norms or conventions to which the actors refer, without re-creating a simplistic opposition between "empiricism" and "formalism", "informal practices" and "formal procedures", "tacit behaviour" and "public justification"? We can neither assume that the actors merely apply the rules, nor suppose that they constantly renegotiate the nature of constraints during the interaction[3].

In so-called "ordinary" activities, agents do not improvise for or against rules or instructions - as in the case of workers who cheat to cope with the unbearable pace imposed on them by supervisors and to gain some leeway -; they *literally improvise within the rules and thus help to amend or transform them.* Procedures in themselves require virtuosity if they are to be applied "in context". Moreover, they serve as a support or way out, enabling workers to benefit from automatisms (both physical and mental), detect singularities, create room for manoeuvre, or create a cooperative base for collective action[4]. But the rules and procedures have to be recognized by the agents as being adequate. When this is not the case, the regime of fraud sets in and takes advantage of the conflict between formal and informal, or of the antinomy of a judgement based on legal or quasi-legal rules and the complicity of a small community of operators[5].

By using the formal/informal dichotomy at an analytical level, does one not, in a sense, reproduce a trial between two opposing parties? The first camp will try to reveal irregularities and set them right by means of stricter rules, while the second will transform illicit attitudes into normal and legitimate ones. To avoid this dilemma, a comfortable solution would consist of relativizing everything, based on a model of *strategic* action.

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[1] This text is a revised version of an article entitled *"Improviser dans les règles - Engagements du corps et responsabilités dans les techniques de pilotage"* in *Normes, normes juridiques, normes pénales - Pour une sociologie des frontières*. Paris, L'Harmattan, 1997. I am indebted to Dominique Cardon for his helpful suggestions on this second version.

[2] Within the framework of studies on forms of justification (Boltanski and Thévenot, 1991), we analysed the imputation of professional responsibility as revealing practical tools and organizational methods used in work. Both the accusation and the defence base their arguments on a play of obligations, constraints and leeway, and thus contribute to clarifying the faculties attributed to human actors. The notion of "fault" implies both a legitimate expectation of behaviour and a freedom of action in context, since it would not be possible to attribute a fault to someone who could not act otherwise (see Chateauraynaud, 1991).

[3] On this point see L. Suchman, 1993.

[4] For example, one of the ways of avoiding the dilemma of following the rule and making a mistake, consists of creating intermediate rules at the team level, which are used as an interface between individual conduct and organizational constraints. On the construction of agents' autonomy through teamwork, see Tersac, 1992.

But such an approach would also imply reduced practical efficiency or skilfulness of agents, conceived as alternatives to the evidence and rhetoric of power. For example, the focus of interest would not be the fact that an aeroplane can take off and land, but rather the power play between the pilots, on the one hand, and their company, the manufacturers, other professionals, etc., on the other. In this context, the definition of competence would be determined not on the basis of practical activities, but in relation to a game of strategy in which each actor's power depends on the areas of uncertainty, uncontrollable by others, that s/he controls[6].

Cognitive ergonomics and the sociology of work have together recently helped to challenge the classical opposition between "prescribed work" and "real work". We are now able to describe more precisely the cognitive adjustments through which rules or prescriptions are engaged in the course of the action[7]. But it seems that many analyses remain prisoners of the idea of a "situation", denoted, for example, by the use of notions such as "situated action" - which spawns a burdensome ghost: an action which is not situated. We can go a little further by recognizing, among the essential competencies of our actors, a dual capacity for transformation and vigilance. This accounts for the flexibility or practical adaptability generally associated with the "human factor" by conceiving of it, no longer in relation to a given situation, but in *time*, from the point of view of a faculty for *regulating improvization* or, in other words, *learning*.

The three examples very briefly presented below, concern the control room in a nuclear power plant, civil aviation and road transport. Our material is very different in each case:
- In the case of the nuclear plant, the material derives from a survey conducted in 1992 and 1993, in the framework of research carried out with the Human Factor Group of the Power Production Division at EDF[8] (Chateauraynaud and Conein, 1993).
- The case of air traffic navigation draws upon the analysis of controversies related to accidents, and the examination of a series of ergonomic studies of cockpits.
- The case of road traffic may seem more anecdotal but does warrant some attention. It draws on the study of the conflict concerning heavy-duty vehicles and the introduction of driving licences with a penalty point system (1992), and on the ethnographic observation of the driving of cars in everyday conditions.

The composition of this corpus makes it suitable for relating an analysis in terms of dispute or attribution of responsibility, to an approach in terms of the sociology of perception. It also allows us to compare cases with a series of common properties - e.g. the importance of physical control of the apparatus, constant adaptation to changes of state, repeated switching between quasi-sleep-inducing phases and tricky phases demanding an extremely high level of concentration and coordination, the relative solitude of pilots and the very general nature of the rules and norms framing their activity - or cases with specific properties - e.g. the control room in the

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[5] See Dodier, 1993; 1995.
[6] See Friedberg, 1993.
[7] Cognitive ergonomics on the west coast of the United States (Norman, Hutchins) has shown - particularly on the question of the relationship with automatism - how actions are neither the step-by-step execution of plans formalized in advance, nor based on a series of uncertain *bricolage* which will be justified afterwards. They take place through the appropriate use of benchmarks available in the environment of the action, for the instruction here is merely a resource among others (like a road map which enables one regularly to check one's position).

nuclear plant is directly connected to the notion of "major risk", making the idea of "routine" and of "improvization" suspect and open to criticism; the professional activity of truck drivers takes place directly in a public space and is constantly confronted with rules and positions which are foreign to it; air navigation has other characteristics, such as the high level of qualification of pilots and the implacable nature of any take-off (once in the air, one has to be able to land). Consequently, we cannot settle for a scale of complexity or risk which *a priori* compares simple situations (X taking her car and driving out of Paris) with highly complex ones (the functioning of a nuclear power plant). Driving a car, for example, is carried out in an "open environment", creates a form of complexity which differs from the operation of machines in a "closed environment" and is, to date, the most dangerous activity.

Monitoring in the control room of a nuclear plant

The purpose of observations in the control room of a nuclear plant (900 MW unit) was to describe, as precisely as possible - using task descriptions in ergonomics -, the techniques used by operators and especially the negotiation of sharing between automatic regulation and manual intervention. The method consisted of asking the operators to treat us as novices to whom they had to teach the monitoring procedures described in texts called "operation sheets"[9]. Most of our observations - particularly those which were filmed - concerned Jean, an experienced operator who soon appeared to be one of those who most efficiently mastered the regulation of the "delta-I" in units 1 and 2 of the plant.

Regulation of the delta-I is an essential operation in the functioning of the process of nuclear reaction during the power variations made by a unit (when the reactor is started up or stopped, or upon demand). The purpose is to maintain the right proportions of water and boron in the reactor. Any reduction in the power causes an increase in xenon, a neutron-absorbing element, which tends to set the delta-I off course[10]. Of importance here is the value of the delta-I, represented by a point on the monitoring screen, called VOTAN. When the xenon curve rises, this has to be compensated for by the addition of water (dilution). When, on the contrary, the power increases and the xenon level drops, it is necessary to add boron (boration). The level of the boron concentration is calibrated and represented on abacuses.

Because the reaction time is not immediate and therefore not linear, this operation requires real time monitoring by the operators. It may happen that they see the point going off course, but experience difficulty getting it back within the limits beyond which pre-alarms are set off. Although these alarms hinder the functioning of the plant, they have no direct impact on safety. Regulation of the delta-I, which requires a particularly high level of attention, is a task which cannot be shared. The operator must constantly have her/his hand on the boration monitoring panel, while simultaneously manipulating the VOTAN buttons and connecting the movement of the

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[8] *Electricité de France*

[9] In fact it was the operators who drew up the operation sheets in question, based on standard instructions corresponding to the norms defined jointly by the operating company, the central services and suppliers.

[10] In more technically precise terms, although less accessible to the layman, the delta-I, which is adjusted in relation to the proportions of water and boron injected into the core of the reactor, corresponds to the ratio of the "high flow" and the "low flow".

point to an assessment of the state of the facility and subsequent developments. A signal from the CIME[11] can adjust the plan of action by requesting a reduction or increase in the power level, depending on the needs of the electricity supply network. Without going into a more detailed technical description of the dilution/boration process, we shall mention four main features:

- In theory, a mathematical formula is used to determine the quantity of water or boron to inject into the circuit. In reality, the operator works in short spurts of activity, with intervals of a few minutes or hours, to control the movements of the point in time. The aim is not mechanically to follow an instruction, but harmoniously to incorporate a regulation constraint into a long process. However, in certain critical circumstances - which depend on the state of the fuel (start, middle or end of life), the relation between the primary circuit (reactor) and the secondary circuit (turbines), the simultaneous application of periodic tests on safety circuits or the quantity of water previously injected - the point tends to drift off course. In such cases the operator's eyes have to be "glued to it". The action in "short spurts" enables her/him to spread out the work evenly and to avoid being surprised by an untimely digression of the delta-I. The calculation corresponding to the procedure is materialized by a small calculator casually placed on the control room desk. The operator uses it to make estimations, but never takes out the delta-I regulation instructions. Thus, boration seems not to be an isolated task, an order to execute immediately, but a series of acts deployed over time and intended to accompany a process of transformation (a change of state in the monitoring parameters).
- When the operator glances at the VOTAN, s/he systematically puts her/his hand on the boration monitoring panel and taps or turns the buttons which adjust the screen in relation to the time that has passed. S/he simultaneously glances around at the alarm panel situated on the opposite side of the control room, and at the positions of the clusters of different groups in the core. The clusters appear on an analogue panel situated immediately beneath the screen displaying the value of power produced (in megawatts). Jean showed us several times that by playing on the insertion of "grey groups" in the core, one can avoid injecting too much water. This limits the amount of waste produced by the unit and thereby gives these short, barely visible, interventions an ecological dimension[12]. From a formal point of view - which is that of the task definition -, one could consider all these interactions to be useless. However, *they are a sign of the operator's presence* and constitute *the indispensable sensorial relay of a logic of vigilance* which acts on a multiplicity of temporal modalities: waiting, reconstitution of the previous curve, intense presence in contact with the point, anticipation of future variations, etc.
- The operator listens intently throughout the shift even if s/he is doing something else (filing instructions, taking a quick look at championship results or inquiring by telephone about maintenance work on a control box). The activation of most of the alarms or pre-alarms is identified directly by the sound and, as in medical emergencies, queues are created without any interruption of presence or vigilance[13].

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[11] *Centre Inter-régional de Mouvements d'Energie,* responsible for the distribution of electricity.

[12] In 1985 tests by FRAMATOME on a small boration automat, showed that the quantity of water injected was consistently greater than with an experienced operator. The automat monitored like a novice who mechanically applies the formula, alternating the injection of water and boron to constantly reposition the point.

[13] This observation corresponds to what I. Joseph shows in the case of the RER (Parisian express suburban underground) (Joseph, 1994). Managers and other normalizers naturally tried to abolish what to them seemed to be "lost time" or "excessive reaction time". J. Theureau, in his critique of the inadequacy of most ergonomic coding systems, writes: "A pattern of behaviour is baptized 'strategy'; a relative fixing of the gaze in a direction is called 'taking information'; a pause in motory activity, for example, when the operator sits down, is called a

- When a critical situation starts to emerge and the agents identify a possible evolution towards a pre-incidental scenario, there is an activation of the network of actors present who, until then, were virtually invisible: dialogue between operators; calling the auxiliary operators, the shift supervisor or, if necessary, the reactor safety engineer. Digressions of the delta-I which have no immediate consequences on the safety of the facility do not trigger off the same reactions. The collective coordination of activities is not a constant preoccupation; it depends on very particular configurations. The work collective is reconstituted either during team meetings organized by the shift supervisor, or for the purpose of undertaking a series of agreed interventions, or else for dealing with difficult situations. Periodic tests create particular constraints since they imply interaction between the operating and maintenance teams intervening in other buildings (generally, this involves several comparisons of information to check the state of control boxes or safety circuits).

In the case of the delta-I, the operator assumes full individual responsibility. As the extracts of the following interviews show, the operator experiences the "digression" of "his" point intensely, although from the outside nothing suggests a critical situation. That is why design engineers have often wanted to make the boration process completely automatic, whereas, according to the operators, this is impossible.

Pierre - That's where the problem lies: if one day they have that automated, will the operator be able to replace the automaton, in other words, to calculate the boron concentration adjustment, the flow of water and boron? Here we do it every day. ... with CASOAR, the CIME would calculate the power. It would say: [name of plant] 2, we'll put it at 500. When we do that, when we put the power at 500, we're obliged to launch dilution-boration processes to monitor the differences in flow, the dI, and that would then be done automatically ... the delta-I; we do it intuitively... There's no law telling us exactly what to do...

Jean - It's experience... You can't put it any other way... I spent almost a year on it, I was glued to it all the time... Well, you realize that there are points you have to watch constantly and it's written nowhere, you have to follow it. You know that once you get to a low level, there are three and a half hours of monitoring ahead of you and you can't take your eyes off it, you can't let it go off course, you've got to watch a point straight away and not move from it, but that's intuition, experience. I had problems with digressions in the beginning, I couldn't cope, I was really stressed at the time because the thing went off course, the delta-I moved off to the right, I keyed in 3%, I tried a whole lot of solutions to get it to stop and to move back. ...

Pierre - The CASOAR system can be good but it mustn't be continuous... For a whole week you switch to automatic and then perhaps you go back to manual... Finally being able to switch off CASOAR. For the network it may be better to have CASOAR for more flexible operation of the network, to switch units ...

'pause', etc. Correlation is established between such 'strategies', 'taking of information' or 'pauses' and other observations. Explanations are formulated or only sugggested, based on this correlation which may have practical consequences. For example, if an organization engineer learns from a recent study on a furnace that such 'pauses' occupy 40 percent of work time, he will, of course, try to reduce them, whereas they are often an

Comments

On several occasions the CIME, the distributor representing the electricity network, considered installing an automaton for the remote regulation of power, with a view to optimizing the functioning of the network. This was to be achieved by means of a system called CASOAR.

From a logical standpoint, the "intuition" is tainted with "subjectivity". Now, one of the aims of the survey was precisely - at least in the minds of some of the sponsors - to give a more explicit form to the operators' know-how.

"Glued to it" is a linguistic sign of the physical engagement of the operator who compensates for the absence of a precise instruction on how to monitor the point and keep it within a predetermined frame.

The learning process, which has allowed the level of flexibility attained by the operator, has been difficult. The operator physically experienced the critical configurations in which he could "crash" the system.

CASOAR is coherent from the point of view of the electricity network but not of the operators. Symmetrical automation would consist of alternating periods of automatic and manual monitoring. In other words, as D. Norman (1990) put it, symmetrical automation is necessarily oriented towards the human agent.

Thus, for the operators, complete automation of the regulation of the delta-I in the case of power variations requested by CIME, does not seem reasonable. They nevertheless recognize that, in certain areas and certain states of the plant, a dilution/boration automat could be introduced. We could interpret this as a purely defensive logic of professional know-how. Take the following on-the-spot conversation between operators, which directly connects the themes of the operator's capacity for awareness and attention, the switch between manual and automatic, and the imputation of responsibility. The operators refer mainly to the famous steam generators, placed at the interface of the primary and secondary circuits and because of their intermediate situation, are particularly subject to a variety of disturbances and failures.

Eric - ... I've experienced the new regulation of the grey groups that I didn't know before. I leave it in automatic more often than the other operators because I trust the automat more, because I didn't have previous experience in regulation and they switch to manual because they're experienced. I'm not so good at it ... I only know what I've learned in books ... that means by extrapolation that an operator who only knows the automatic system will never be good at it ... He has the knowledge but he'll never be as reactive ... we've had operators who'd monitored fuel boilers and they often switched to manual. When we had problems with the SG we anticipated the movement of water in the SG, thanks to our knowledge of traditional methods. Here it's nuclear but the

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opportunity for considerable perceptive and cognitive activity which is vitally important to the monitoring process (Theureau, 1992).

effects of subsidence or expansion, depending on the volume of cold or hot water injected into the SG is physically the same thing ... this didn't prevent us from having a lot of emergency shutdowns [ES] but did anyone count all those we didn't have? ... Then another generation of operators came along who were reluctant to switch to manual, who waited till the phenomenon got out of hand, so that switching to manual was ineffective ... now, that was never taken into account ... I've never read anything saying: the SGs were taken over at the right time because there was a switch to manual ... you can't say which part is related to automatisms and which is related to informal knowledge where it's the guy who knows ... if we had a paper saying there were so many ESs because of the regulation, and so many ESs were avoided because of a switch to manual, perhaps one could distinguish between the two ... How often have you felt like taking over manually at full power? ... Have you already done it?

Yves - No but if it happened to me I'd do it, no problem ... I prefer taking the risk of sending in a lot of cold water and getting subsidence rather than having an ES ...

Eric - What I've noticed is that if it works too well, those operators who've never switched to manual on SGs will do it but they'll bungle it... They'll definitely have subsidence ...

Yves - Anyway, when you switch to manual you'd better know what you're doing because here they won't let you get away with it either ... It's a detail but it's important ... It's better to have an ES on automatic than to have it because you switched to manual, because with automatic it's always imputable to a faulty transistor. If you have it on manual, it'll be 100% your fault ...

Eric - No but forgetting about all that ...

Yves - What d'you mean "All that"! Hey man, that's what explains why we're reluctant to switch to manual ...

Eric - No but if things develop badly ...

Yves - Yes but developments, they also do what they want with it ...

Eric - The guy who switches to manual and saves the SG won't get a medal ...

Yves - He's just done his job ... But if ever he has an ES he can be sure of being reprimanded.

Yves - But sometimes they'll go and check if you didn't switch to manual too soon, and if the automat had done it's job properly whether it would have saved the situation ... If fact with the automat we've got even less right to make a mistake ...

Jean - But normally we shouldn't make mistakes anymore ...

Comment:

The problem of the human/automat balance is posed not in abstract terms but in relation to practical experience. Thus, switching to manual implies experience in this respect and practice in hand-to-hand interaction with the system.

The operators base their decisions on past experience. If they are used to the automatic mode they are reluctant to switch to manual. In this respect, they note the differences of behaviour between the generations, but try to hand down to their younger colleagues as many tried and tested techniques as possible.

As soon as there is dysfunctioning or an untimely shutdown, the question of responsibility is raised. But all ESs (Emergency Shutdowns) cannot be imputed to the operators. To euphemize these shutdowns - particularly vis-à-vis the outside world - the official term given to them is Automatic Reactor Shutdowns.

According to these arguments - which are critical of the management - the switch to manual is never encouraged. It is a stopgap measure tolerated by the hierarchy which does not consider it as a principle of professional excellence. We see here how the vigilant attention of the operator is linked to responsibility and, gradually, to the defence of the occupation.

An ES is an admission of failure which also has the drawback of engaging a public space since there is necessarily a relation to and involvement of a host of actors (one cannot stop a nuclear reactor without explaining oneself to the hierarchy). The pressure to justify this act may be so great, for the operators, that they may try to "hide" mistakes (e.g. in early 1997 in the Paluel nuclear plant).

Summarizing the status granted to the "human factor", the operators indicate that "with manual you don't have the right to make a mistake".

Switching to manual engages responsibility directly. If there is no balance, permitting quick changes that ensure a degree of reversibility, the operators lose flexibility and tend to rely on instructions.

We note, in passing, that in *L'Etat providence*, F. Ewald (1986) asserts that the development of the logic of risk, associated with the growing complexity of productive activities, is accompanied by a generalization of the "right to make mistakes" and the abolition of "fault". This version of responsibility is obviously not shared by nuclear operators.

The talk here, in a situation marked by the presence of outside observers with an ambiguous status (working for the central services), armed with a tape recorder and camera, reveals connections which apparently are not made in this form during ordinary activities. Not only do the operators not usually discuss the subject of automation, but the question of *responsibility* as presented to us at the end of the sequence is typical of a re-reading of

actions from the point of view of *forced justification*. This clearly indicates that, in certain critical configurations, the activity may be thwarted or suspended by reference to this type of constraint. When this constraint is activated, the agent can no longer manage her/his relations with the environment in a natural mode. The presence of an automaton contributes towards the emergence of this type of tension because it normalizes, in a sense, the sequences of the action. Those operators who perceive or anticipate a fault are faced with the choice of leaving it or intervening. But on whose behalf do they intervene? The installation of an automaton forces the agents to redefine their know-how or, at least, to clarify its resources so as to justify their interventions. The setting up of procedures for learning, based on feedback, normally creates an intermediate space between the isolated management of failures or uncertainty and the direct imputation of responsibility[14].

In the course of ordinary activities, the decisions made by the agents and the way in which they try to find a balance between manual monitoring and recourse to automats, depends as much on "folds" (plis) that have developed, as on justificatory reasoning. But "folds" are not simply "habits". They create resources or room for manoeuvre. For the agents, "being good at it" means both inhabiting the working space with their own bodies and developing a form of virtuosity gained through practice. It is through a constant perceptual effort that they manage to acquire the keen vigilance which cannot be equalled by routine surveillance by automats or regulators, nor by the information readings imposed by safety and operational requirements, nor by the strict monitoring of procedures. The know-how they defend is not incompatible with these modes of action; on the contrary, it organizes the modalities of the shifting or switching between a multiplicity of regimes.

The pilot, the automat and the joystick

R. Amalberti, specialist in aeronautic ergonomics, has shown that despite technological advances, "human errors" have not decreased. According to a report drawn up in 1989, they account for close to 88 percent of all serious accidents in civil engineering (Amalberti, 1991). The incompressibility of human errors is reflected in the stabilization of the frequency of accidents for a given number of hours' flight. The logical consequence is an absolute increase in the number of accidents, due to the constant increase in air traffic. Sadly, current figures confirm this. Manufacturers have tried to deal with the problem by increasing automatization in the cockpit. In other words, "the risk is treated by excluding the operator from the manual loop of piloting or, more exactly, giving her/him a different role: that of controlling the systems" (*Ibid:* 7-8). Yet automatization has been the object of extensive criticism, which is what we shall consider here.

Apart from the fairly classical analysis in terms of a "loss of competence", we find an argument based on the idea of unintentional effects of bad representations of the systems, resulting from a lack of understanding of the

[14] The attention focused on the human factor, particularly since the Three Mile Island accident in the United States in 1979, has led to the creation of multiple forms for expression for operators, enabling them to break out of their isolation and to learn continually, especially through the collective analysis of ways of dealing with incidents. In recent years it has been towards maintenance workers that efforts to increase the visibility of procedures and modes of coordination have been directed. On this point, see the report by C. Birraux, 1997.

internal functioning of the automats. The conclusion is that errors are simply shifted[15]. A more severe argument is based on the observation of a total imbalance between underload and overload of activity. This critique may be expressed directly in the problematic of attention-vigilance under consideration here. Automatic systems make the intervention of an operator even more essential in cases of breakdown or failure. However, when pilots are used to relying on these systems, they get out of the habit of concentrating and lack practice in dealing with critical situations. Thus, the problem of automatization is confronted with the question of relations between perceptual capacity and normative expectations of behaviour: can agents be expected to control a machine which, most of the time, does not require their engagement in order to function[16]?

This tension largely explains the strategies developed by agents to regain a "hold" (*prise*)[17], and the temptation they have, in some cases, to literally switch off the system in order to put themselves to the test. A case in point is the Habsheim accident (Airbus A320, June 1988) where huge demands were made on the pilot, due to the exceptional nature of the situation[18] - the air show afforded the opportunity to show his mastery of the aircraft and the manoeuvrability of the machine. With the agreement of his co-pilot, he switched off the computer and went over to manual piloting, but flew too low and too slowly to have the time to clear the trees. In defence, the pilots blamed the computer, which had remained partly connected without their knowledge. They accused it - wrongly, according to the judgement pronounced nine years later - of faulty transmission of fuel towards the reactors.

Yet most of the "derived holds" (*prises dérivées*) invented by agents are not so radically opposed to the regular functioning of the system. It is within the loops regulated by set procedures that the agents organize their relationship with the system[19]. That is why, in most cases of reconstruction of an accident, it is very difficult to distinguish between human error and technical failure. To use Bruno Latour's metaphor, we are clearly dealing

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[15] See E.L. Wiener (1988), who considers the conditions of the emergence of harmonious interfaces between pilots and automats, without adopting the viewpoint of pilots who - as we have seen in numerous conflicts - argue in defence of their profession. See also the very detailed observations of A. Gras *et alii* (1991).

[16] If it is badly designed, automatization involves the risk of mental isolation of the operator (Norman, 1989), who has very little control over the system. To construct this argument, critical ergonomists refer to a phase of less automatization in which operators learn to master the system through direct contact with the most essential elements of the task. This direct contact enables them to go back and forth, without cognitive tension, between the signs and references provided by the state of the system, and the reasoning and interpretations required by the realization of the task. Bad automatization thus appears to be a system where humans lose all possibility of control and are reduced to a supervisory role, but where their interpretative faculties and their capacity for improvization cannot be activated in the event of their having to take over (Rasmussen 1986). On the redistribution of know-how and the competencies related to new forms of computer aided production, see also M. Stroovbants (1993).

[17] The author introduces here the notion of a *prise* or "hold", where the subject may "have a hold over" and/or "be afforded a hold". [Transl.]

[18] See Chateauraynaud, 1991.

[19] Bessy and Chateauraynaud (1995: 231-319) have attempted to theorize the notion of a *prise* as it is used here, in the sense of a hold. The authors conceive of the *prise* as the organization of the encounter between *plis* (folds) - of the body, of matter - and *repères* - signs, marks, forms of inscription and representation that can be used to make an object or complex configuration calculable. The movement of the *prise* can thus be described as a dialectical relationship between *repères* and *plis*, between representations and perceptions, reasoning and actions on matter. In this way we recognize what ordinary judgement aims at when it talks of *avoir prise sur* (having a hold over) someone or something or *donner prise à* (laying oneself open to) someone or something. We shall revert to the conceptual framework of the *prise* in the last two points of the article.

with hybrid creatures, compound assemblies in which human and non-human capacities are mixed. An accident attests to the failure of their association (Latour, 1991). Seeking causes most often leads to the exposure of a multiplicity of factors which, in a chain reaction, caused the failure of the entire system of piloting and protection[20]. In the case of the Mont Sainte-Odile accident (Airbus A320, Air Inter, 20 January 1992), the legal experts estimated that the aeroplane's approach was "compromised by an accumulation of errors". Having observed "ergonomic defects" in the cockpit, the experts noted that the aircrew consisted of two pilots who had qualified recently to fly an A320 (which, in their minds, meant an obvious lack of experience, measurable in hours of flight), as well as bad radar positioning for the initial approach, a bad choice of approach procedure, making it possible to avoid waiting but also making it impossible to stagger deceleration and, lastly, a "dysfunctioning of the crew" which allegedly did not comply with "procedures of mutual control". The report notes, moreover, a series of dysfunctions in the air traffic control at Entzheim, as well as the absence of a ground alarm.

Unlike the cruising phase, during which pilots can easily rely on automatic piloting instruments, take-off and landing involves the intervention of numerous actors and resources which must necessarily be well coordinated. In these phases, interactions are multiplied between pilots, external sources of information and automatic systems of the aircraft, changing modalities to suit the configurations (queues, quantity of kerosene, weather conditions, air currents, etc.). The dysfunctioning of a source of information transmits the tension to other elements in the socio-technological network. To avoid confusion, the pilots have to be able to distribute their acts of verification and attention, without focusing entirely on the problem. In these circumstances everything is decisive: an appropriate conception of distributed information in the cockpit will allow for a rapid grasp and good feedback; physical control of the situation will enable the pilot to clear an autonomous area of calculation or reasoning to solve the problem at hand, based on sound rules; good coordination between the members of the crew will depend on tacit understanding, linked to a common perception of the situation, attested by habitual acts or positions[21]. By thus considering the chain of resources involved in piloting, one departs from the simplistic opposition - that makes headline news - between human error and technical failure. The loss of control can be analysed in a more refined manner, as a broadening of the gap separating the most stable references - which no longer serve their purpose - and the state of those concerned who suddenly have no alternative but to act "in the folds". The pilots, left to themselves, faced with their instruments and having become, in a sense, pure sensorial devices, engage in a hand-to-hand struggle where they rely on the "folds" gained through experience (whether these are called habits, reflexes, tendencies, skills, sensations or whatever). The strength of the image of a joystick thus becomes meaningful. A clear illustration is the case of a pilot who managed to control and land his aircraft after both reactors had failed, because he was also an expert glider. This type of ability was

[20] On the question of a division between imputation and causality in the analysis of industrial injury, see N. Dodier (1994).

[21] Analyses of cockpit voice recordings show that conversations are unintelligible for an outside listener. The crew communicate mostly through shared signs and references in their working environment (which they do not need to constantly indicate by ostensive procedures) and tacit knowledge of each other's "folds" or, in other words, ways of working. This knowledge enables them to rapidly assess an abnormal state of uncertainty, nervousness or preoccupation.

certainly not focused on in the normative frame defined by procedures, including emergency procedures. (We do not, however, know whether recruitment prerequisites now include excellent gliding skills.)

The engagement of the body allows for the creation of the "ultimate holds", or possibilities to act, without panicking - like when one manages to spin a car around. This is possible only if there has been *constant creation or testing of "derived holds", secondary aptitudes* playing on an intimate experience - although one that can be shared with peers - with the machine. That is where the pilots' sense of responsibility comes into play. They do not use their "derived" techniques against the machine, but in the leeway it allows. This helps us to understand the implications of pilots' arguments against processes of automation and/or normalization. Such arguments, which emerged when pilots challenged the automation installed on Airbuses by engineers, resembles those of operators in nuclear power plants: "if we get used to switching to automatic, we get out of practice and can't cope when we have to, and we get blamed for that".

Aviation is one of the fields thoroughly explored by E. Hutchins (1989; 1994). He takes the example of the accident of a KLM Boeing 747 in September 1977, in which 580 people died. The captain thought the Pan Am plane he crashed into had left the main runway. The co-pilot, who was relatively inexperienced, was not able to contradict his chief since he received no decisive information from the control tower (the runway was under a cloud of mist). The attempted take-off was done blindly, without any perceptual assurance and no possibility of comparing information sources. The pilot constructed an interpretation that nothing contradicted (in other words, it was pure inference). But the mistake lies in the absence of verification based on "shared holds". What interests Hutchins in this type of disaster, are the conditions of the shift of cognitive procedures implemented by individual agents for interpreting situations, to the collective cognitive aptitude which emerges from interactions within the complete group of protagonists. In particular, the participants have to share a series of common constraints on the validation or invalidation of hypotheses (the aeroplane cannot be on the runway and no longer on it; there must be a way of checking). The interpretations of each one must, he writes, *"be adjusted to the state of the world"*. This adjustment is impossible without the mediation of *common perceptions*, since the actors have no guarantee *a priori* of the way in which others apprehend the state of the world. The responsibility for cohesion of the network therefore lies with the instruments involved in the communication of these states of the world. A socially organized network has a series of protocols for the authentication of agents (persons and technological objects) and the states of these agents. It is, however, powerless when these protocols are deactivated or produce misleading information (hence, the constant need to check control instruments).

The idea that information and responsibilities are distributed between a multiplicity of agents is not incompatible with a model of perception/attention based on individual agents. On the contrary, the network may, when circumstances require it, intensify the pressure on the agents to avoid the torpor produced by routine. It may force them to test whether their perceptions are effectively shared, so that there is agreement on interpretations - sometimes one has to check that one is talking about the same thing[22]. This constraint is not without consequences for our model of responsibility: *the responsibility of all the actors can be clearly established from*

[22] See E. Hutchins, 1989 and D. Norman, 1989.

the holds they had and failed to use in the situation. The agents' mode of engagement and the type of holds they have, thus contain a form of normativity which is never totally formalized in the written rules or procedures, yet which in practice acts as a constraint.

One could say that, basically, all these problems relate to the selection of agents. In fact, the piloting of complex systems has for a long time been connected to particularly drastic recruitment and evaluation procedures (much appreciated by industrial psychologists and certain strands of the cognitive sciences)[23]. In both the nuclear and civil aviation fields, tests on simulators are carried out regularly and are decisive. The purpose is not only to test "reflexes", but also to initiate the agents, cut off from their familiar environments, into new forms of moving between mental schemas, sensor-motory devices, and controls[24]. The exercise on a simulator consists of leading the agents into situations of rupture, both to test their emotional reactions[25] and to revive the perception/reasoning dynamic which tends to be dulled by routine. But, like all training or testing apparatus, simulation places the agents in the grips of judgement and evaluation, creating numerous inhibitions[26]. That is why the agents try *to develop their "own holds" in real situations by creating a space for variation around the most stable procedures.* Thus, they have a true sense of responsibility without needing to reason as if they were in court. Even if errors present the negative side of the perceptual work carried out by the agents to manage their relationship with the system, they are a perpetual source of innovation and learning, providing pilots with a stock of *significant experiences*.

Another important feature from the point of view of work organization is the isolation of the agents through whom the entire process, lasting at least several hours, passes. The pilot is the obligatory point of passage of the whole organization: it relies entirely on her/him coping, through the series of *small gestures which place the apparatus in a state of continual variation around points of equilibrium*. The "rest of the world" is present through multiple channels of communication, but from a distance. The interlocutors are not in physical contact with the machine; they move in a purely informational world, in which they have access to the situation through artefacts and representations. Hence, the key importance of communication procedures and problems of ambiguity and misunderstanding. The act which consists of switching off and knowingly leaving the framework of procedures may sometimes be interpreted as a gesture of protest, an appeal to the work collective which has become, so to speak, anonymous and abstract.

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[23] For a more general approach to the question of recruitment, see F. Eymard-Duvernay and E. Marchall, 1997.
[24] We know that major transport corporations (mainly rail and air transport) were pioneers in the development of research on man/machine interfaces.
[25] Piloting in complex environments is thus very often associated with very specific states of "stress"; see D. Lhuillier and T. Grosdeva (1992).
[26] The stress caused by tests leads agents to rely on their most significant experiences. Amalberti takes the example of the "gust of wind" test. A situation, in which there is a sudden gust of wind at takeoff, was presented to about 30 pilots, ten of whom were American. Half of the American pilots immediately recognized the origin of the incident and kept the situation under control. The score was far lower among the French pilots who thought of other types of failure. This was because the American pilots had very often experienced gusts of wind. Amalberti's analysis: "Incidents are associated with the schemas in the pilot's memory, in an order which reflects the risk perceived by him, depending on his own past experience". Since it is impossible to review the entire corpus of known incidents, the pilots take the risk of coding incidents in terms of their own experience.

The road - conflict and controversy

In July 1992, after a law was passed instituting driving licences with a penalty point system, violent conflict broke out in France, in which the most conspicuous protagonists were truck drivers. Their demands for an exceptional status were based on the specific constraints of the occupation. They argued that the difficulties of driving heavy-duty vehicles exposed them, more than other road users, to possible violation of traffic rules. But what the drivers were attacking above all, was the gloomy picture of road use explicitly painted by the law which made no distinction between "Sunday drivers" and "tarmac professionals". Because heavy-duty vehicles are largely responsible for lethal accidents, truck drivers are generally considered, *a priori*, as "roadhogs" who are over-confident about their driving[27]. To this first accusation was added that of "road rage": for the average road user constantly feels that truck drivers' behaviour is "aggressive" and that they suffer from a form of "civic immaturity" (since personal and commercial interests take precedence over safety and respect for others). Thus, the terms of the debate seemed to crystallize around moral arguments.

The truck drivers' argument in their own defence was based on their difficult working conditions and on delivery constraints which led them beyond breaking point (of humans and equipment). Thus, compulsory schedules and itineraries, a disregard of regulatory resting time, and the absence of technical control were related to "collective fraud" considered necessary and admitted to by over 60 percent of the drivers (according to statistics compiled during controls), in which employers and workers, often tacitly, shared responsibility. Since most lethal accidents are related to fatigue (there is, so to speak, no longer a driver on board) or to faulty brakes, this type of constraint seems to seal fate. In the days following each new disaster, the controversy is revived and brings into question the state of legislation and the system of prevention or sanctions concerning road transport, as if no improvements had been made. This was seen, for example, with the "crazy truck" in Andorra (9 dead and 15 seriously injured on 6 December 1994). The driver of the vehicle, of which the roadworthiness test was eight months overdue, ignored two signs prohibiting heavy-duty vehicles in the town centre. While the driver considers himself a "murderer", the accident revived the controversy on the responsibility of heavy-duty vehicles and the ineffectiveness of legal and regulatory systems. The following article by M. Laronche, entitled "Shared responsibility" (*Le Monde*, 9/12/1994), is fairly typical of the terms of the debate:

> It's true that trucks kill fewer people, in absolute terms, than cars. But, because they are on the roads far more, they are more often involved in serious accidents. Company managers are the main culprits responsible for the unbearable pace imposed on truck drivers. It is unacceptable that the Andorra truck did not undergo its annual roadworthiness test on time, especially since its brakes seem to have been faulty. It is equally unacceptable that trucks do not use alternative routes. The drivers also have their share of responsibility, as do the authorities, despite the efforts that have been made. The backing down of Pierre Bérégovoy's government during the road transport conflict in the summer of 1992 is significant.

[27] On the "representations" of sanctions and infrastructure concerning road transport, see J.-M. Renouard (1997).

This case shows how, in practice, a system of perfectly codified and logically coherent rules proves to be inapplicable and exists in conjunction with perfectly standard irregularities which serve as "practical norms" for the agents concerned. Unlike the safety devices regularly set up in high-risk industries or civil aviation - environments which have developed standards in which "lay persons" have no say - systems for controlling road transport are directly based on suspicion and fraud. Moreover, as everyone knows, systems of control produce people who cheat and who know exactly how to beat the system. The tachograph, better known as "the informer", is an obvious example. It is constantly tinkered with by agents who, reduced to a state of nature, in a sense, by the set of constraints weighing on their work, spend their time cheating.

We therefore have a situation which is symmetrical to the one described above. It is no longer a question of building up a position of control within a technological system of which the rules and standards are recognized and directly installed in the monitoring instruments, but of bridging the huge gap separating the driver, faced with her/his solitude, and the law, which lacks the required material relays. To avoid cumulative fatigue, ensure that the brakes are checked regularly, and avoid fatal competition with private cars, truck drivers should be connected to remote monitoring systems. This implies finding instruments capable, in one way or another, of helping drivers out of their isolation, out of the repeated hand-to-hand struggle with the machine which progressively creates a quasi-hallucinatory relationship with the outside world - something which may explain the extreme violence of the conflicts[28].

Unlike the case of nuclear power plants or civil aviation, the problem is less one of avoiding over-automatization and the quasi-eviction of human agents, than of finding a way of providing trucks with suitable intermediaries[29]. To be effective, the legal and regulatory standards must be materialized in practical terms. This is what is allowed, for example, by the improvement of roads and the erection of more appropriate road signs and signals which have helped to provide the actors with intermediate forms aimed at both the experience of driving and rules governing judgement. But is it possible completely to normalize the perception of the road and the anticipation of danger? The penalty point system conflict was, from this point of view, a source of innovation. Through their protest movement, the truck drivers were able to bring into public view an experience of the road and a sense of responsibility that had been denied them. Moreover, several firms reported on new systems of training drivers and new incentives for regular check-ups and cautious behaviour.

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[28] The CB makes communication possible with other agents and introduces directly into driving, a system of remote location. However, it also serves to avoid controls, just as ordinary citizens flash their headlights to warn oncoming traffic.

[29] The manual/automatic debate is not entirely absent in the case of road transport, but here the attachment to a manual "hold" is often deconstructed as if it were a matter of belief or collective imagination. According to J.-M. Normand, "the results of all inquiries show that the automatic gear box is viewed with extreme distaste by the Latins who are convinced that it would kill the pleasure of driving and transform them into passive drivers, who would feel belittled - perhaps even emasculated! - and incapable of having fun with their cars" (*Le Monde*, 14/02/1995). Here we clearly have the equivalent of the joystick. But why oppose the manual and automatic modes as two social choices? Could one not conceive of mixed systems as on certain American cars? Most importantly, drivers must be able to distribute their "holds" so as to become part of their vehicle. Now, with the exception of a few fundamental studies on visual perception of the road environment (Dubois, 1993), the

The lack of impact, so often observed, that legal systems have on real practices, is not foreign to the political philosophy underlying road safety legislation. By opposing individuals, who can be influenced by psychological means which endow them with dangerousness rather than a faculty for vigilance, and by confronting them with legal requirements, an immense discrepancy is created, coupled with a de-realization of the ordinary experience of driving which forms an intense corporal experience, exercised in an open and complex environment. No driver can introduce her/himself "normally" into the traffic by adopting the Kantian attitude of a moral subject deciding to apply the rules because they are just. Every driver has the disturbing daily experience of claiming to control her/his vehicle, to know the risks, to judge the mistakes of other drivers, to break the rules or make mistakes - convinced of being in the right - to adapt to customs - such as flashing one's headlights to warn on-coming traffic of radar - and, finally, to shout when s/he is a simple pedestrian, cyclist or ordinary citizen, inclined to denounce a delinquent category which s/he is not even sure of belonging to or not. One thing is, however, certain: people drive very badly when they are put in the position of impartial spectators.

It remains the case that the first rule that all drivers share is "to be careful". Now, being careful behind the wheel soon appears to be a complex activity far removed from rhetoric and the laws of argument. It implies agents capable of engaging their bodies in operations which are, to say the least, complex. Any situation of learning these corporal techniques, which later become so "obvious" with routine, is there to remind us: there is nothing "trivial" about engaging one's body in an action. Moreover, this is not reduced to the alternative of reasoning and sensation. The following example was taken from a small base of direct observations:

One Friday evening at about 7 p.m., while talking to me about the French University crisis, Richard P. starts to cross the chaotic intersection situated at the Place Voltaire in the 11th district in Paris. Strangely laid out, in the form of a double X, this intersection has a system of traffic-lights that is particularly difficult to understand. Yet Richard moves ahead unhesitatingly. His right foot constantly moves back and forth between the accelerator and the brake, while his left foot stays on the clutch. He constantly turns his head, looking around attentively, while continuing his discussion about problems concerning the recruitment of lecturing researchers. A multitude of aggressive sounds fill the air on the virtually saturated Place. A few invincible vehicles manage to thread their way through the traffic at a good speed. Vigilance has to be at its maximum. Our driver keeps his hand on the gear lever, which seems to indicate a level of concentration or nervousness that is higher than usual. The position of the passenger-observer is somewhat uncomfortable: I reduce his visibility and Richard has to lean over several times, although he does so very naturally. We mange to get out of the intersection by going through a red light. Richard then starts to argue in self-defence after seeing the face of his (not entirely neutral) passenger-observer: "this system of lights is impossible to understand! That's why there are always traffic jams here. I wonder what the traffic authorities have between their ears!" (we note that it was because of this remark, that we decided to record the scene which would otherwise have been forgotten soon afterwards).

In this commonplace sequence, the driver is able to coordinate his diverse actions without panicking or losing concentration, and without dealing with it all through a centralized algorithm. He delegates operations to his

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dominant analysis of driving is still based on a psycho-sociological trend incapable of escaping the opposition

limbs which are in direct contact with the vehicle, and uses his sight and hearing simultaneously to adjust his driving to the turbulent state of the environment. This does not prevent him from continuing his discussion and maintaining a "normal" communicative relationship. To be sure, the motory activity can attain this level of efficiency only because of a long period of learning and adjustment of the driver's body to his vehicle. A change of vehicle or environment would require the partial renegotiation of this adjustment. However, in the passenger's seat one does not have the same "holds" as the driver: one functions far more by way of representations which, in some cases, enable one to see and to over-evaluate dangers which the driver has perfectly anticipated or controlled. Sometimes passengers will even go through the motions of braking by pressing on an imaginary pedal.

Being attentive: between slack perception and cognitive tension

What is an error of inattention? Or rather, what is the attention normally expected of people in certain situations? The rule and the attention can connect only through the way in which the body is connected to the machine. Inattention seems to be related to a bad distribution of vigilance, itself due to a state of preoccupation or to the senses being captured by an outside phenomenon which diverts the person's attention. In short, inattention results from the agent being prompted by the simple opposition, prevalent in sociological models, between an internal state and an external situation. We can thus defend the following hypothesis: it is because s/he is split between thoughts or calculations, based on representations, and sensations or gestures binding her/him to the objects present, that the agent commits the ergonomic *lapsus* called error or inattention. "Normal attention" can then be placed in an intermediate zone capable of linking up "representations" (of a procedure, state of the world, intentions of other actors, etc.) and engagements of the body. For clarity, we shall briefly identify several forms of attention:

- *Attention as a process of concentration and closure of engagement around an object.* In this sense, being attentive means being intensely focused on an object by eliminating sources of outside noise. In this model, the swing from one centre of interest towards another is commanded by a calculation or reasoning or a rational evaluation (possibly of a marginal nature). Now, this model of concentration is probably relevant for chess players, but proves to be inadequate for understanding the ability of human actors to deal with a multiplicity of centres of attention by managing their engagements through a distribution of their perception. The use of calculation based on mental representation is soon cumbersome in the situation since it implies smoothly transmitting heterogeneous information towards a single centre of calculation (the agent's mental load is at its peak).

- *Floating attention:* nothing really maintains the agent's attention: it is constantly distracted and dispersed. This is particularly well described by I. Joseph (1994) in his article devoted to the central control cabin of Line A of the RER (Parisian inter-urban express underground). Having one's "ears open" is also a good example of

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between economic stakes and libidinal drives.

floating attention as a means for capturing information through "weak links", and for contributing marginally to the regulation of a collective of people and things.

- *Attention based on an economy of perception:* the agent focuses on a set of objects by distributing her/his sensorial capacities so as not to lose "sight" (or smell or sound or feeling, etc.) of changes in states or processes occurring simultaneously and for a variable length of time. Only the engagement of the sensorium allows such a performance. The tension is at its peak at the points of contact, but the "mind" may, so to speak, be "free" or "available" for anticipation or verification of a secondary level. Calculation is not excluded, but at the most it reveals relevant signs in the environment. This ease of coordination often fills the uninitiated observer with silent admiration and creates a climate of "confidence". It is not unrelated to the *faculty of presence* highlighted by Chinese philosophy and described by F. Julien (1992), the model of *attention/vigilance* developed by Varela (1993) to bridge the gap between the lived experience and cognitivist apprehension, or the *"generalized wakefulness"* described by F. Roustang (1994) to explain mechanisms of hypnosis[30]. This third type of attention - which implies that the other two are extremes - enables one to understand both the modalities of practical organization employed by the agents, and possible difficulties of translation in the form of rules - or of arguments in the case of failure or dispute[31].

Relations between phenomena of situated attention and constraints of presence contained - usually implicitly - in the rules, can be clarified more easily if one introduces, on the side of attention, the complementary attitude constituted by *verification*. Acts of verification are, by definition, reflexive: they originate in an intention to verify and, as with inference, the possibility of discovering an error or a state that is incompatible with the action or the reasoning in question is assumed. They thus imply a critical attitude vis-à-vis beings and machines. Phenomenology, then ethnomethodology, have shown that one cannot spend one's time checking everything without becoming mad[32]. The act of verification consists of applying rules or norms of evaluation, with the observed discrepancy or fault being, by definition, already integrated into the system of management of the machine. That is why many incidents reported in nuclear power plants are, in reality, mere discrepancies or deficiencies compared to normalised technical safety specifications. There was not necessarily an incident

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[30] "The trance, the conscious forgetting of what is accomplished", writes Roustang, "gives driving a flexibility and precision it would not have if the driver had explicit knowledge of the succession of his gestures. Thus, it is no longer the aware, limited wakefulness which perceives the multitude of stimuli required for a well integrated action, but a wakefulness which is both fully aware of the slightest variations in the environment and unaware because it does not have to be explicit" (Roustang, 1994: 73).

[31] The highway code is filled with driving rules which imply acts of attention/vigilance, e.g. overtaking or change of direction are accompanied by rules which engage notions of "visibility", "anticipation" or "understanding" of the behaviour of the vehicle ahead or behind. Now, in practice, one discovers that one has to learn to look back without losing sight of the vehicle ahead, to turn one's head without really turning it, etc. All these movements cannot translate directly into a language of constraints without seeming to produce contradictory injunctions. What is implicit in each rule, is that one has to inhabit one's vehicle completely, to distribute centres of attention without unnecessary contraction, and to melt into the traffic without calculating between each gesture or waiting to make decisions.

[32] Obsessional neurosis takes shape precisely around this tension. There are drivers who stop every 100 kilometres to check whether everything is in order, or hypochondriacs who take their pulse or blood pressure every fifteen minutes. Logically, we have no grounds to oppose these people's acts; it is simply that they lack the faculty to let themselves go in the obviousness of the sensible world with trust in the unobtrusive operators who function through the body and its different forms of memory.

preceding the coding. *In verification, it is the coding which constructs the event*. On the other hand, attention does not imply, above all, formalized rules of expertise, but a perceptual capacity in which there is "common sense", that is to say, *a presence, a certain state of awareness* enabling one to integrate what is new, strange or incongruous and to get it to work. This attitude of presence is less easy to describe in the paradigm of "action" because it is on a more primordial level which escapes closure on intentions and situations. It is even owing to the phenomenon of permanent attention that one can conceive of our actors adequately switching or changing their "style" or "regime of action"[33].

Attention and verification enter into a dialectic relationship to form what is called vigilance. The discovery of a fault or of an event produces an enhanced state of attention which, in turn, produces acts of verification. The torments of verification in its complex relations with attention are developed at length by James Reason in his book *L'Erreur Humaine* devoted to human error (Reason, 1993)[34]. To account for errors with serious consequences such as that of Challenger, Chernobyl or the Herald of Free Enterprise, Reason readily uses examples from daily life, particularly to highlight the effects of excessive familiarity or conflicting rules. His typologies lead to the distinction of three major sources of faults or errors:
- *alterity or strangeness of a situation:* not having been able to develop a hold, one is unable to cope; one "folds" (adapts), in a balance of power.
- *conflict between rules, injunctions or devices* which may also be expressed in the form of faulty coordination between diverse actors, each of whom is turned in on their machines without managing to cooperate.
- *excessive familiarity* (one no longer pays attention).

We can see more clearly now how our examples enable us to reconsider the sociology of responsibility that was based on a model of argumentation or justification. In it responsibility had two main forms: *statutory responsibility* (defined by an organization and consolidated by a formal engagement) and *responsibility as the result of a process of imputation* through the confrontation of events and of a network of relevant obligations[35].

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[33] Attention is closely linked to detail which is not pre-constituted as a reference or as a relevant indication in the area of calculation that defines the situation and on which either distractions or a change in the modality of interaction can be based (on this point see: Piette, 1996).

[34] While Reason has attributed a particularly important role to attention, J. Rasmussen (1986) has also treated the subject, distinguishing three levels of competence which endow humans with clear superiority as compared to any automatic device: the *level of habits* (skill-based behaviour) which allows the natural development of a perceptive capacity (perception of detailed modifications outside of all explicit calculation); the *level of reasoning* based on rules covering the field of action (rule-based behaviour) with possibilities for constant verification of assumptions; and, lastly, the less stable level of *general knowledge* or, in other words, common sense (knowledge-based behaviour) which, because non-specific, may prove to be relevant for cases not treated by the formalism of the system. That is the dynamic between these three levels which make the human operator superior, *in fine*, to any automatic system necessarily functioning in a closed world, based on a closed set of parameters that are correctly described and incorporated in the machine.

[35] Our first model was based on a *mechanism of accusation/defence* (in the sense of McEvoy, 1995): X accuses Y, basing his accusation on a convention binding Y to a device D which, by extension, concerns X. By accusing Y, X simultaneously produces his defence. To defend himself, Y must at least accuse X of an error of qualification (X is mistaking the person, the rule or the device, etc.), show that D was not in the expected state or that the situation relates to another device D, thus implying, where relevant, another agent Z, etc. In so doing - through and for their arguments -, the protagonists in the dispute cover a network of rules and conventions. If they do not reach agreement on the relevant rules and conventions, X and Y may refer the matter to a third party

This model may thus be completed by looking at the holds available practically to people for acting in their world and asserting themselves as fully responsible agents.

As P. Ricoeur emphasizes, there can be no human action without the notion of responsibility: "what we then have to think about" writes Ricœur, "are phenomena such as initiative and intervention, where the agent is caught unawares, interfering in the course of the world - an interference which effectively causes changes in the world" (Ricœur, 1995: 56). Of course, with Ricœur, this regime of responsibility in actuality is quickly related to a logic of judgement through a vocabulary of intentions. Yet it can remain separate from judgement, as in the creative act described by Deleuze, based on Nietzsche, in which the true engagement relates less to a (moral) obligation than to a (vital) combat. *Being responsible here means being aware, present in the world and accepting one's participation in the course of things*. One is called on by the task and one feels responsible - which explains certain phenomena of "guilt" based on no form of (moral or legal) obligation. Mere presence, participating in the course of things is given significance (as shown by the guilt feeling which develops from the mere fact of having been there and not having done anything).

This essential form of taking responsibility does not have to be heroic. It may be born silently through the production of a form of "regularity". We note that the notion of "regularity" may itself be broken down into several different notions, including that of "stability" and "normality" - which is often implied when one says that someone "is responsible" (s/he is stable and/or behaves normally). Related to the mute participation in the course of things, to a constant engagement to accompany it with one's presence, this responsibility rests on a continuous *perceptual effort* which, once again, is neither the mechanical application of incorporated schemas nor the local and perpetual invention of contingent significations. For, far from being the immediate response to a local situation, perception is *a long-term activity which transforms*. This dimension takes us away from the paradigm of "action" which tends to enclose sociology into micro-situations, and to reduce humans to the state of situated agents without any past, future or faculty to shape time, and without any history. As soon as we reintroduce time and duration as key dimensions in human activities, we have to revise our conceptual apparatus[36]. Duration changes the logical status of most categories of analysis; for example, intuition can be defined positively as a *perception which lasts* beyond the context in which it takes shape, but which *has not yet found its space of calculation*. It is for this reason that intuition can be neither true nor false as long as it has not been able to provide a hold for a representation which detaches it from the blocks of sensations it has to have survived - even if for a few moments only - and which allows inference.

Towards a sociology of transformation

(authority, judge, expert, mediator, etc.). The testing of conventions may thus produce new ones by concatenation or extrapolation of existing conventions.

[36] Most pragmatic sociology lacks a clarification of the concepts of time used. This clarification can be outlined by means of the modal approach proposed by R. Duval in *Temps et vigilance* (1990). Duval makes this modal thinking possible by *linking the duration offered, with the unit of time determined by the type of object or action aimed at by the persons.* His book thus opens onto the diversity of concepts of time by allowing one to conceive very different temporal phenomena such as a "lapse of time", "urgency", "a countdown", "a delay", "waiting", "forecasting", as well as "a project", "forgetfulness", "disappearance", "evanescence", "boredom", "impatience", "a return" etc.

The examples developed in this text clearly show the time dimension of the harnessing of information: agents have constantly to memorize former states - with the help, where relevant, of external memories[37] - and concurrently anticipate future states (for example, in the nuclear case, an increase in power after a decrease or a periodic test). The connection of the two operations implies a form of lasting presence which tolerates neither distraction nor the switching between separate centres of attention. There is a common base, a continuity which links the different centres and into which the agent must fit.

With this type of description, we are moving towards an approach to monitoring which gives an essential place to the perceptual work through which the *corporal space* and the *work space* are adjusted. These are the two decisive mediators between representation through the rules and the physical state of the environment. Clearly, this type of approach is opposed to the mentalist models in which the agent memorizes and anticipates because s/he incorporates all of the most probable scenarios[38]. But it is also opposed to the excessive transfer of competence towards the outside world. The idea of perceptual work, which is neither the product of *direct perception* based on a pre-established harmony with the environment, nor the mere projection of *mental structures* rooted in "cultural arbitrariness" or - a more updated version - "networked arbitrariness", is far closer to a *phenomenology of presence in the world*. It relates to the art of embracing the propensity of things, of letting the transformations underway happen and monitoring them more closely, without saturating the situation with elements of representations and calculations[39]. This faculty can be deployed only because perception is not subjected to a single centre of calculation, localized in the brain and controllable by a simple system of injunctions. *Perception is constantly in motion*. Only instruments tend to set perception (especially vision). That is why one must never rely exclusively on an instrument for evaluating the state of the world.

We consider it relevant to mention the phenomenological assumptions of our argument. Whereas Husserl tends to exclude movement from his phenomenology, always taking an object as given, Merleau-Ponty is probably the one who went furthest in the formulation of the problem posed by perception, for Western philosophy[40]. He

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[37] Sometimes operators have to invent, from scratch, forms of inscription or tracing. For example, in the nuclear plant control room, they added a small three-sided device enabling them to know whether the line (the pipes) was already filled with water, boron or a mixture of the two. This information is not taken into account whatsoever by the system, which traces only the movement of the point and not the nature of the substances added. Now, the lack of information on the latter could modify secondary calculations. This aid was based on an experience of common sense which avoids multiple interpretative uncertainties and detours: someone has put water or boron in the circuit and any new addition has to take this into account.

[38] This hypothesis is expressed in various forms: "mental models", "scripts" or "prototypical scenes" (see: Schank, 1977).

[39] We find a good representation of this art of leaving significations to emerge, very close to the quest for the pure gesture developed in Zen, in two books by F. Julien devoted to the ancestral Chinese conception of effectiveness (1992; 1996).

[40] Among the multiple formulations, take this one from *L'oeil et l'esprit* where Merleau-Ponty, basing his argument on P. Klee, writes: "There is that which hits the eye from the front - the frontal properties of the visible - but also that which hits it from below - the profound postural latency where the body gets up to see -, and there is that which hits the vision from under it - all the phenomena of flight, swimming, movement, etc. in which it participates, no longer in the weightiness of its origins, but in free accomplishments" (Merleau-Ponty, 1964: 86). On the relations between touch and sight, and presence and distance, the reader is also referred to M. Dufrenne (1991).

often takes the example of the vehicle or the musical instrument, to show acts of grasping through which the body and the object mutually adjust to each other to open up to multiple experiences and transformations. With Merleau-Ponty perception, even at a distance, as in the case of a gaze, always has a tactile dimension and merges with movement (Merleau-Ponty: 1945).

The perception in question here clearly contrasts with the mechanical repetition of operations or gestures which deaden sensorial resources (creating mental exhaustion, fatigue, a secondary state, alienation, mental automatisms or unconscious gestures). The use of sensations for forging situated percepts implies an opening up and therefore an understanding of the processes underway. That is the condition *sine qua non* of the gradual installation of *relevant holds* on a device. To perceive the folds and transform them into references, one has to allow for the penetration of the phenomena, properties and bodies. The hold is neither the pure repetition of a gesture acquired by habit (*habitus*) nor the pure local and occasional invention of a point of passage (*kaïros*). Itself undergoing transformation through the movement of bodies in space (here in the work space), it binds repetition to difference and is a question of differential calculation[41]. That is why experienced operators are able to work on small differences, at levels of detail inaccessible to novices or to outside observers who remain fixed on more superficial representations.

Our actors' faculty of adaptation is not the result of the opportunistic use of local holds, but of the constant improvement of their perceptual faculties. As a veritable vehicle of experience, perceptual work is no more "a-social" - as biological or psychological reductions led us to believe - than over-determined by "the social". By making the body act at the intersections between the individual and the collective, it relies on regularities and is organized around fixed points provided by the environment - which it thus helps to reinforce - but constantly opens up onto new experiences. While regularities allow economic coordination with other beings, based on the folds developed together[42], the holds of the different protagonists communicate only because of a constant tension between problems and regularities[43]. This work of perception, at the level of things, often marked by silence, is no less constituent of the social link than are institutions or forms of collective expression. For there is production of a self-organized world which cannot be represented in the form of a "system" because it is constantly undergoing transformation. But this "world" is not, for all that, indescribable or ineffable. It gradually creates its language (one merely has to think of all the worlds of signs, linguistic or other, invented by the pooling of conditions, professions or corporal practices). This world that has gradually become common, through a series of trials, may be at the basis of "behavioural norms" which, in the case of dispute or disaster,

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[41] One could say, at a stretch, that the hold produces order in the fold by putting the small folds, the folds in the folds (i.e. the details or secondary properties) first. On this faculty of derivation, see Deleuze, 1988.

[42] See the text by Livet which distinguishes between action by several agents, action together, and common action (Livet, 1991).

[43] To be shared, perception implies a basis, continuity, a sort of perpetual return, close to forgetfulness (one is no longer paying attention but it is nevertheless there, that world that has become familiar, habitual, constantly within reach of one's senses, obvious, unquestionable), and protrusions, discontinuities, singularities, sometimes next to nothing which stands out and attracts one's attention (but which is already absent, imperceptible, which requires the test to be launched again in order to be captured). The advantage of the notion of a fold for conceptualizing perception lies in its faculty to refer to both rupture and continuity (see our comments on Deleuze in Bessy and Chateauraynaud, 1995).

rub shoulders with deficient rules or representations, to criticize or support them and, in any case, actively transform the meaning[44].

This model of self-organization is supported in approaches such as those of F. Varela (1993). According to him, taking shape is based on emerging processes, and conscious access to these processes implies a complete presence based on a principle of "enaction" or, in other words, a process of attention/vigilance which allows one to be completely present in the world to benefit from structuring interactions. This argument can be toned down by pointing out the actors' faculty to use the inverse mechanism: they may start with a system of constraint or representation, itself objectivized in plans, procedures, instruments and collectives, and put it to the test of variation, sounding the resources of the environment to produce derived holds.

In the argumentation model, the protagonists plunge the situations into more abstract entities and relations: principles, rules, categories, topoï. In the perceptual engagement in contact with things (pleonasm because perception is above all of a tactile order[45]), it is the folds which predominate. But how does one go from one world to another? Is it not in the nature of disasters and disagreements to force the actors to renegotiate passages between representations and experiences? We therefore have to work on the elaboration of a third model capable of formalizing, at least partially, the modalities of a passage between the two preceding models. We could call this the *understanding* or the *common hold* model. It would have the property of not disconnecting argumentative processes and the operations of qualification underlying them, from the experiences truly experienced by our protagonists. This model of understanding leads one to conceive practice as an art of variation, an inexhaustible source of regulatory improvisation.

This approach to vigilance and transformation of which human operators are capable is attended by a critical point of view of the political motives of certain cognitive conceptions. Certain theories do tend too readily to dispossess human agents of their responsibility and experience, and to attribute everything to the properties of the environment or the constraints of a "situated action". Have we not witnessed the setting up of a model of competence which celebrates constant situated adaptation and flexibility, and in which the capacity for transformation with time is no longer valid (even being denounced as a an outdated view of work)? There is certainly reason enough to question the connections being spun between neo-cognitivist celebration of the "flexibility of the human operator", and the development of new modes of domination which reduce professional competence to the state of pure capacity to adapt, to the great pleasure of designers of technological objects and artefacts.

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[44] We find here the well-known contrast between rule and regularity highlighted by Wittgenstein (1961) and found in Hart (1988). The TGV (bullet train) has the rule of being on time but is so often late that passengers incorporate this regularity into their calculation. There is not, strictly speaking, a conflict of rules since the folds which are formed, a priori, unintentionally, do not constitute a competing rule. Moreover, the SNCF (French railways) keeps apologizing for the delays. The rule, in the moral or legal sense, is bound to intention and reflexivity. It is, as D. Dennet (1990) would say, an intentional device. Regularity happens through repetition; it can do without intentionality and tolerate an infinity of variations around fixed points.

[45] Touch occupies a median place in the cartography of the senses because it is directed both outwards and inwards, and serves both as a mediating barrier and an instrument of direct perception. On this point, apart from the writings of Merleau-Ponty, Dufrenne and Gil cited above, see Anzieu (1985).

REFERENCES

AMALBERTI, R. (1991): *Sécurité des vols et automatisation des cockpits*. Paris, Draft.

ANZIEU, D. (1985): *Me Moi-peau*. Paris, Dunod.

BESSY, C., CHATEAURAYNAUD, F. (1995): *Experts et faussaires - Pour une sociologie de la perception*. Paris, Métailié.

BIRRAUX, C. (1997): *Contrôle de la sûreté et de la sécurité des installations nucléaires*. Office parlementaire d'évaluation des choix scientifiques et technologiques; Assemblé Nationale - Sénat. April 1997.

BOLTANSKI, L., THEVENOT, T.L. (1991): *De la justification*. Paris, Gallimard.

CHATEAURAYNAUD, F., CONEIN, B. (1993): "Les relations entre agents humains et automates sur site nucléaire - Le cas des séquences de dilution-borication", Paris, convention EDF/DOXA, July.

CHATEAURAYNAUD, F. (1991): *La Faute professionnelle - Une sociologie des conflits de responsabilité*. Paris, Métailié.

DENNETT, D. (1990): *La Stratégie de l'interprète - Le sens commun et l'univers quotidien*. Paris, Gallimard.

DODIER, N. (1993): "Les arènes des habiletés techniques" in *Les Objets dans l'action. De la maison au laboratoire, Raisons pratiques*. Paris, EHESS, n° 4, pp.115-140.

_ (1994): "Causes et mises en cause - Innovation socio-technique et jugement moral face aux accidents du travail", *Revue française de sociologie*, XXXV, pp.251-281.

_ (1995): *Les Hommes et les Machines - La conscience collective dans les sociétés technicisées.* Paris, Métailié.

DUBOIS, D. (Ed.) (1993): *Sémantique et cognition - Catégories, prototypes, typicalité.* Éd. du CNRS.

DUFRENNE, M. (1991): *L'œil et l'oreille*. Paris, Jean-Michel Place.

DUVAL, R. (1990): *Temps et vigilance*. Paris, Vrin.

EYMARD-DUVERNAY, F., MARCHAL, E. (1997): *Façons de recruter - Le jugement des compétences sur le marché du travail*. Paris, Métailié.

FRIEDBERG, E. (1993): *Le Pouvoir et la Règle - Dynamique de l'action organisée*. Paris, Seuil.

GIL, F. (1993): *Traité de l'évidence*. Grenoble, J. Millon.

GRAS, A., MORICOT, C., POIROT-DELPECH, S., SCARDIGLI, V. (1991): *Le Pilote, le contrôleur et l'automate*. Paris, Éditions de l'Iris.

HART, H.L.A. (1988): *Le Concept de droit*. Bruxelles, Facultés universitaires Saint-Louis.

HUTCHINS, E. (1989): "A Cultural View on Distributed Cognition", Proceedings of the Cognitive Science Society, Annual Meeting. Ann Arbor, Lawrence Erlbaum.

_ (1989): "L'organisation sociale de la cognition distributée", Draft, University of California in San Diego, La Jolla.

- (1994): "Comment le 'cockpit' se souvient de ses vitesses", in *Sociologie du travail*, n° 4, pp.451-473.

JONAS, H. (1990): *Le Principe responsabilité*. Paris, Cerf.

JOSEPH, I. (1994): "Attention distributée et attention focalisée - Les protocoles de la coopération au PCC de la ligne A du RER", *Sociologie du travail*, n° 4, pp.563-585.

JULLIEN, F. (1992): *La Propension des choses - Histoire de l'efficacité en Chine*. Paris, Seuil.

_ (1996): *Traité de l'efficacité*. Paris, Grasset.

LATOUR, B. (1991): *Nous n'avons jamais été modernes*. Paris, La Découverte.

LHUILLIER, D., GROSDEVA, T. (1992): "Stress et conduite de système complexe", *Le Travail humain*, n° 2.

LIVET, P. (1991): *Les Catégories de l'action collective.* Rapports et documents du CREA. February.

MC EVOY, S. (1995): *L'invention défensive - Pragmatique, droit, argumentation*. Paris, Métailié.

MERLEAU-PONTY, M. (1945): *Phénoménologie de la perception*. Paris, Gallimard.

- (1964): *L'Œil et l'Esprit*. Paris, Gallimard.

NORMAN, D. (1989): "Design considerations for reducing error in high-risk situations", Draft. University of California in San Diego, La Jolla.

- (1990): "The 'Problem' with automation: Inappropriate feedback and interaction, not 'over-automation' ". Draft. University of California in San Diego, La Jolla.

PIETTE, A. (1996). *Ethnographie de l'action - L'observation des détails.* Paris, Métaillié.

RASMUSSEN, J. (1986): *Information Processing and Human-Machine Interaction*. North Holland.

REASON, J. (1993): *L'Erreur humaine*. Paris, Puf.

RENOUARD, J.M. (1997): "Les Représentations de la circulation, des infractions et des sanctions chez les conducteurs condamnés" in *Normes, Normes juridiques, Normes pénales - Pour une sociologie des frontières*. Paris, L'Harmattan, pp.199-210.

RICŒUR, P. (1995): "Le concept de responsabilité - Essai d'analyse sémantique" in *Le Juste*. Paris, éd. Esprit.

ROUSTANG, F. (1994): *Qu'est-ce que l'hypnose?*. Paris, Minuit.

SCHANK, R., ABELSON, R. (1977): *Scripts, Plans, Goals and Understanding*. Hillsdale, N.J. Lawrence Erlbaum.

SIMONDON, G. (1958): *Du mode d'existence des objets techniques*. Paris, Aubier-Montaigne.

STROOBANTS, M. (1993): *Savoir-faire et compétences au travail - Une Sociologie de la fabrication des aptitudes*. Bruxelles, Éditions de l'Université de Bruxelles.

SUCHMAN, L. (1987): *Plans and Situated Actions - The Problem of Human-machine Communication*. Cambridge, Cambridge University Press.

TERSAC (DE), G. (1992): *L'autonomie dans le travail*. Paris, PUF.

THEUREAU, J. (1992): *Le cours d'action: analyse sémio-logique - Essai d'une anthropologie cognitive située*. Peter Lang, Berne.

VARELA, F. (with E. ROSCH and E. THOMPSON) (1993): *L'Inscription corporelle de l'esprit*. Paris, Seuil.

WIENER, E.L. (1988): "Cockpit Automation", in *Human Factors in Aviation*. Academic Press Inc., pp.433-460.

WITTGENSTEIN, L. (1961): *Investigations philosophiques*. Paris, Gallimard.