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Team Coordination in Extreme Environments

Work practices and technological uses under uncertainty

Cécile Godé

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Introduction

In recent years, the nature of coordination and the managerial devices developed to help businesses cope with challenges have been the subject of numerous empirical analyses. Whether they are confronted with problems related to extended supply chain restructuring [JAR 12], work-integration of geographically-dispersed project teams [SRI 11], building collective intelligence [ZAR 06, LEN 09] or putting together various competencies (for example [FAR 06, MEL 10]) organizations need to know how to support the coordination of teams that evolve in highly changing, uncertain and risky contexts [AUB 10].

This work endeavors to answer the following general question: how do we coordinate teams in extreme environments? Beyond an analysis of coordination "in the field", it aims at offering managers active ways in which to implement devices that facilitate coordination within teams.

I.1. Coordination and team: proposed definitions

The coordination of various tasks evokes a founding question of management theories and is a major concern for organizations, whether public or private. As Fayol said, coordination is one of the five key principles of management, because "to coordinate is to harmonize all the activities of an organization so as to facilitate its working and success" [FAY 49].

The literature provides many definitions of coordination, focusing either on task integration – where converging efforts achieve coherence of dispersed activities – or on the interrelation of activities, that is to say the capacity to smoothly run a set of interlinked activities.

Considering these definitions, Alsène and Pichault [ALS 07] propose the following synthesis: coordination is a process whereby dispersed activities are arranged so as to generate collective coherence of work. As used here, collective coherence of work relates to the processes: (1) resource and task allocation (allocate workforce and material means, divide up tasks and work, etc.; (2) harmonization of activities (align and/or standardize actions so that everyone works toward the same direction); and (3) orchestration of activities (arrangement in which individual efforts complement each other and yield effective results).

This work focuses on coordination at team level. In project-based structures, which predominate in today's organizations, work groups and their performance are a central concern for the management [SAL 08]. According to Langevin [LAN 04], "a team is a group with social identity, composed of interdependent and co-responsible individuals who gather together to carry out an activity". Teams combine sets of specific competences, experiences and expertise [COH 97] which, if effectively distributed, can contribute to achieving results. The organization into teams facilitates transversality, making it easier to react and adapt to various pressures from the environment [MOH 92, LAN 04]. But work, competences and people require coordination. This is the challenge of this work: to study and comprehend how teams are coordinated within what we call an "extreme environment".

I.2. Team coordination in the extreme environment: a major challenge for the company

Companies operate today in an extreme environment, namely a context simultaneously marked by high levels of uncertainty, change and risk. They are faced with great competition, strong pressure to innovate and complex interdependencies that force them to implement adequate team management processes and tools. Their personnel employability is thus managed from the standpoint of distributing competencies and expertise. Their teams are temporary, with members joining or leaving according to project needs.

It is under these conditions that coordination has become a major concern. The main challenge is to develop and maintain work groups that are able to successfully complete complex projects. Teams need to be able to follow the procedures and norms in force, while remaining flexible and resourceful when faced with unexpected situations.

To reach objectives and successfully complete projects, teams need to develop work practices and learning attitudes with multiple dimensions: technical (know how to bring a solution to the problem posed), human (know how to combine various competencies for the benefit of a common goal) and collective (know how to build the collective competences and intelligence needed to work toward the same goal). How do they manage to coordinate when faced with such requirements? What work practices and technological uses do they develop in order to be effective? How do they collectively adapt when faced with multiple changes? How do they learn to coordinate and what roles can managers play in this process? This work provides some answers to these various questions.

In order to achieve this, it relies on many cases and illustrations from the military domain. These cases come predominantly from the French Air Forces, and more marginally from the French Army and French Navy. To the extent that French forces engage regularly alongside American forces, some experiences are also mentioned. French Defense personnel is presently 265,853 full time equivalents (Draft Finance Bill, 2015), managed according to a priority payroll control objective, in compliance with military programming. The 2014–2019 Military Programming Law stipulates an overall cut of 34,000 jobs over this period. The Defense budget is maintained at 31.4 billion euros, excluding pensions (Draft Finance Bill, 2015), taking into account important structural savings measures. In this highly constrained transformation context, French military forces have to cope with high deployment requirements (according to the strategic priorities stated by the White Paper on Defense and National Security, 2013): on April 20 2015, over 7,000 troops were engaged in operations abroad, particularly in the Sahel-Sahara strip, in the Central African Republic, in Lebanon and Iraq (Ministry of Defense).

Drawing on the experience of military combat forces may seem at a first reading an atypical approach to a study of coordination that aims to identify concrete paths for businesses to follow. However, as Scarborough mentioned in 1993, “the military has much to offer private business in areas of vulnerability to competition" [SCA 93]. The military world is in effect a natural laboratory where task team coordination practices can be studied. The logic is more visible when actors are pushed to the limit. Furthermore, the paroxystic and, in a certain way, exemplary character of military environments is revealing of more classical work situations and permits us to reflect on how to transfer the observed coordination practices to companies.

I.3. Plan of the work

The present work is structured around four main chapters.

Chapter 1, entitled "Extreme Environment and Management Situations", endeavors to provide a precise definition of the nature of the extreme environment in which today's companies evolve. It offers a characterization of various management situations that are part of the extreme environment (routine, unexpected and crisis situations). Special attention is given here to the main challenge for teams in terms of coordination: knowing how to manage the shifts between standardized situations, governed by rigor and procedures, and unexpected events, which require flexibility and adaptation.

Chapter 2, "Team Coordination: What the Theory of Organizations has to Say", develops the two main perspectives on coordination according to the management science literature: the classical – or contingency – view and the "practice-based" view (practice-based coordination). Though they are often considered antagonistic, we will notice that these perspectives are complementary rather than opposed. The "practical" view notably allows us to go beyond certain limitations of classical theories, particularly when it comes to understanding team coordination in the extreme environment.

Chapter 3, "Coordination Practices in Extreme Environment: Communication, Reflexivity and Socialization", is entirely dedicated to the illustration and comprehension of coordination practices implemented by teams on the ground. This third empirical chapter, gives illustrations that have emerged from the routine work of French Air Force crews. These illustrations highlight three main types of coordination practices: communication, reflexive and socialization practices. It is a combination of these practices that allows crews to manage the shift between routine and unexpected events and to cope with constraints and opportunities in the extreme environment.

Finally, Chapter 4, “Can Coordination in the Extreme Environment be Learned? A Management Approach”, asks the following question: what role can managers play in guiding and supporting team coordination? When devising managerial action, several entry points are of interest: teams’ and their members’ knowledge and expertise, how they use and share them, as well as the role played by the company in order to facilitate these approaches. In this respect, this last chapter ponders first the knowledge and competencies that teams develop for coordination in the extreme environment. It then proposes managerial routes and methods that facilitate the acquisition of such knowledge and competencies: implementing a system for immediate feedback collection, fostering professional communities and taking full advantage of decision support systems.

1

Extreme Environment and Management Situations

This chapter endeavors to provide a precise definition of what is meant by "extreme environment". An analysis of management science literature reveals in effect a recent trend toward a better comprehension and deeper integration of the role played by such contexts in managerial dynamics. Even so, the works on the subject remain heterogeneous. They resort to, and even amalgamate, various notions such as uncertainty [WEI 07], volatility [BOU 89, WIR 07], surprise [CUN 06], extreme situations [LIE 09] or crisis [ROU 07, RER 09], struggling to provide a rigorous and commonly accepted definition of what an extreme environment is.

The developments that follow propose a general characterization of the extreme environment, and proceed with a clarification of the nature of various management situations that are part of it.

1.1. The extreme environment: what is it about?

An environment qualifies as extreme if it is simultaneously marked by evolutivity, uncertainty and risk [GOD 15, BOU 12, AUB 10]. These three criteria clarify, respectively, the nature of changes the participants are faced with, their probability of occurrence and impact:

– The nature of changes relates to the notion of evolutivity. It emphasizes the rapid, dynamic and discontinuous aspects of the changes that individuals experience (for example, [BOU 89] and [WIR 07]), while stressing dynamic differences in comparison with the previous operating mode. The pace of

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change differs depending on situation. Some situations involve real-time pressure and urgent implementation of collective action [KLE 06]; others, on the contrary, do not require immediate action, thus allowing participants more time for decision-making (they can, for example, take the time to meet and discuss the event that is a matter of concern for them).

– The probability of occurrence of change is characterized by the uncertainty criterion. Uncertainty suggests that a situation can be more or less expected (and therefore more or less "foreseeable"), depending on the predictability level at the respective moment and on the event modes. Some situations may well emerge in a totally unpredictable manner, to the great surprise of participants who need to rapidly adapt [CUN 06, WEI 07].

– Finally, the impact of change can be assessed depending on the type of risk the participants are exposed to [LIE 09]. Understood as potential damage inherent to a situation, risk can be physical, media-related, symbolic, financial, legal, material, etc. Risk affects the organization, its groups and members.

There are numerous work environments where teams operate under extreme conditions. In the public sector, this is, for example, the case in emergency medicine, internal security or the military organizations this work focuses on. Companies in the private sector may be under similar constraints. For example, teams of market traders make decisions in situations marked by the volatility of the markets they operate in, the uncertainty related to when and how the market values evolve and the risks, mainly financial and legal, incurred by the investment bank on behalf of which they operate.

Drawing on examples from the military, Table 1.1 illustrates the three characteristics of an extreme environment.

1.2. Various management situations in the extreme environment

The extreme environment consists of various management situations: routine, unexpected and crisis situations. They form an articulate continuum and the main challenge for teams is to control the shift from one situation to the next.

Three criteria of change in the extreme environment	Examples from the military environment
Evolutivity Nature of change	Weather conditions, tactical context, quantity and quality of enemy armament, and reliability of tactical information
Uncertainty Probability of occurrence of change	Bird strike, engine stop, armament failure, radio/communication system failure and enemy attacks
Risk Impact of change	Vital, material, media, political, budgetary, symbolic, etc.

Table 1.1. *Characteristics of the extreme environment: illustrations*

1.2.1. *Routine activities, unexpected events and crises: a typology of management situations in the extreme environment*

A management situation gathers "participants […] who must accomplish, in a determined time, a collective action leading to a result submitted to an external evaluation" [GIR 11]. It is defined through continuous group interactions within a specific space–time context. As mentioned by Journé and Raulet-Croset [JOU 08], emphasis is being placed on the collective, spatial and diachronic dimensions of the situation, while stressing results and performance. The management situation relies on the interactionist (for example, [GID 84]) and pragmatist (for example, [DEW 38]) approaches, according to which the emergent nature of a situation is the result of subjective participant interpretations [JOU 08].

As represented in Figure 1.1, the extreme environment consists of three distinct management situations:

– Routine situations relate to a repetitive and standardized team operating model [FEL 03, WEI 07].

– Unexpected situations refer to unexpected events or sequences of events that take participants by surprise and force them to adapt and react [WEI 07].

– Finally, crisis evokes a rare emergency situation that exceeds the capacities of participants and structures (for example, [LAG 91]).

Evolutivity, uncertainty and risk criteria weigh differently, depending on the management situation that teams are faced with.

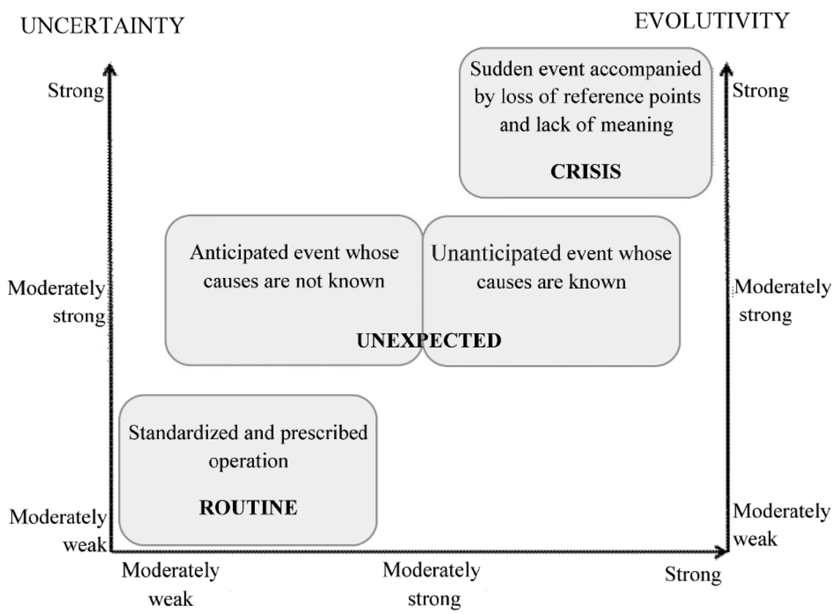

Figure 1.1. *The three management situations in the extreme environment*

1.2.2. *Routine, crisis and unexpected situations: a characterization*

1.2.2.1. *Routine situations*

In the extreme environment, teams' work has a strong routine dimension. Routines refer to operating guides and procedures (for example, [CYE 63]), stable activities rooted in repetition (for example, [NEL 82]) or more precisely to a "repetitive, recognizable pattern of interdependent actions carried out by multiple actors" [FEL 03].

As Feldman and Pentland [FEL 03] show, routines have a double aspect: ostensive and performative. The ostensive aspect refers to the "abstract" and structured nature of routines, providing rules and procedures that participants follow. In its turn, the performative aspect represents the manner in which routines are implemented by the same participants in a given context. The authors stress the existence of a recursive relation between ostensive routines, which "objectively" guide and standardize the action, and performative routines, which leave room for the interpretation of these standards in their daily implementation. This way, routines simultaneously constrain and enable action.

Thus, groups that operate in the extreme environment are subject to formal operation routines, most often of a (public or private) administrative nature. This leads to high standardization of work procedures by defining, setting limits to, and rigorously prescribing individual and collective actions [ROC 87]. These routines are nevertheless likely to evolve in time, according to their implementation and circumstances. They play a major role in ensuring the safety of operations, as well as follow-up and control. In this sense, they are necessary for the smooth operation of teams in an extreme environment.

A good illustration of the role played by routines is the functioning of military teams, either in military operations or during training. Let us take the example of *Close Air Support* missions – aerial support of special forces operating deep behind enemy lines – conducted by fighter crews of the French Air Force on the theater of operation. When on mission, crews follow highly prescriptive engagement rules, which limit their action patterns and processes. These refer to flight manuals and check-lists of detailed and precise operating procedures (flight planning, Close Air Support Card, etc.) that they rigorously apply in various stages during the mission. Within this formal regulatory framework, various execution stages of the mission are standardized. This is how a pilot having operated in Afghanistan defines the term: "Standardized? It means a stereotyped and routine response to an operational situation". For navigating crews, standardization does not only refer to procedures. These crews also use a common language, which was published in NATO documentation and which they call code words. *Push when ready, Continue, Investigate or Abort* are the code words easily understandable by the team members, which facilitate concise and rapid communication, while significantly reducing the risk of misinterpretation. Finally, the automation of behaviors is equally noticeable. Back from Afghanistan, a member of a fighter crew explains: "Automatisms are habits […]. We internalize typical action patterns that evoke positions and maneuvers and allow us to more effectively build an image of the airspace". Automatisms gain time, reduce verbal exchanges and facilitate work, irrespective of team composition. The development and acquisition of automatisms can be observed within groups of experts from other fields, such as the crews of civilian aircraft (for example, [HUT 95]) or nuclear plant control room teams (for examples, see [JOU 05]).

Thus, operating in extreme environment does not at all mean that the respective actors are perpetually faced with unexpected situations and surprise. A significant part of their activities is governed by routine action patterns, guides of conduct that are known in advance and most often become automated due to exercises and training. These routines are, however, not rigidly fixed, since their performative dimension can lead to their gradual evolution. They allow teams to effectively solve predictable problems, that is to say problems whose probability of occurrence has been anticipated and whose causes are known well before the problem emerges. Therefore, the degree of evolutivity, uncertainty and risk in a routine situation is relatively low.

1.2.2.2. *Unexpected situations*

The second situation constitutive for an extreme environment refers to the emergence and development of unexpected events or sequences of events. Consequences are most often controlled by the implementation of specific management processes, but may also have dramatic outcomes.

Revisiting the works of Cunha *et al.* [CUN 06], it is possible to distinguish two types of unexpected situation, depending on their nature and origin (Table 1.2). The first type refers to an unexpected situation that was anticipated, but whose causes remain unknown to the teams; the second type refers to an unexpected situation that was not anticipated, but whose causes are known.

Let us now elaborate on the two types of unexpected situations presented in Table 1.2.

<table>
<tr><td>Nature</td><td>Origin</td><td>Examples</td><td>Management processes</td></tr>
<tr><td>Anticipated
The probability of occurrence of the event has been assessed and taken into account
Training, rehearsals, exercises, etc., have allowed actors to assimilate the event-processing procedures</td><td>Unknown cause
String of failures at all levels (individual, team, organization, regulatory authorities, etc.)
Complexity</td><td>Air France Flight 447
Reason's Swiss Cheese model</td><td rowspan="2">Collective meaning reconstruction (collective discussions)
Consensual decision
Actions: return to processing procedures, task distribution</td></tr>
<tr><td>Not anticipated
The probability of occurrence of the event has been neither assessed nor taken into account</td><td>Known cause
Group destructuring
Leadership weakness
Sudden evolution of tactical and operational conditions</td><td>Mann Gulch fire
Transall C-160 flight</td></tr>
</table>

Table 1.2. *Two types of unexpected situation*

An unexpected situation can occur when the event, though anticipated, and taken into account by processing procedures assimilated by the team, is part of a complex and iterative process that makes it difficult to identify causes. Let us consider the example of the Air France 447 Rio–Paris accident in June 2009: the aircraft crashes into the Atlantic Ocean after being stalled for 3 min and 30 s. The three pilots in the cockpit are experienced, together having over 20,000 flight hours. They had trained on stalls (low altitude) in a simulator several times. Nevertheless, that night weather conditions were rather mediocre (however, not exceptional) and the problems multiplied during the flight [BUR 12]. In particular, the automatic pilot shutoff produced real surprise in the cockpit. Emotions and confusion intensified when they realized that airspeed indicators were inaccurate (the Pitot tubes were blocked by ice) and the after stall alarm went off twice. According to the BEA report, the AF-447 crew went was not able to identify the causes of airspeed drop and various alarms and messages. Moreover, they added to the complexity of the situation through persistent attempts to pull up (maintain an ascending path), which stalled the aircraft. Thus, despite the high level of expertise of the pilots in the cockpit, their training on stalls and their mastering of procedures applicable for recovering from stall, the crew failed to understand the “why” of the situation. They failed to make sense of its causes.

In military aeronautics, Reason’s Swiss cheese model [REA 90] is often referred to when analyzing incidents and accidents. This model shows that there are latent failures spanning all levels (individual, team, organization, etc.) and an accident occurs when all these failures are aligned. Reason stresses the complexity of causes of an unexpected situation. These causes emerge from a string of failures whose interpretation will serve the groups in making sense of the event. This first type of unexpected situation is, therefore, part of a process of high complexity which makes it difficult, if not impossible, to identify its causes and comprehend its magnitude.

An unexpected situation can also occur when the causes of the problem are known, but its occurrence has not been anticipated by the actors. It is, for example, the case, described by Weick [WEI 93], of a team of firefighters who, in 1949, were parachuted over an ordinary forest fire area in Mann Gulch (Montana) and lost 13 of its members. The team had in effect wrongly analyzed the fire expansion and was rapidly encircled. This case highlights a destructuring problem that leads to the emergence of an unexpected situation: the loss of leadership. In effect, the leader’s position, which had until then been beyond questioning, is challenged when he orders his crew to throw away tools to facilitate escape. As Weick writes: “A fire crew that retreats from a fire should find its identity and morale strained. If the retreating people are then also told to discard the very things that are their reason for being there in the first place, then the moment quickly turns existential. If I am no longer a firefighter, then who am I? With the fire bearing down, the only possible answer becomes, An endangered person in a world where it is every man for himself” [WEI 93].

The order to leave the tools behind is indirectly a signal for crew “disintegration”, and thus the leader loses legitimacy. The crew stops listening or following him, despite the fact that he has the solution for group survival. The fact that material environment and the constituent “objects” (tools, bodies, body language, esthetics, etc.) allow a group to identify as a team of experts has already been shown in the specialist literature [BAR 13, CAR 13, HAW 15]. In this example, the unexpected incident – loss of leadership – was never judged as probable by the group leader, not even when his orders lead, by way of consequence, to the very destructuring of the group.

Let us continue with an illustration from the military, an extract from interviews conducted with members of Transall C-160 crews (tactical and cargo transport military aircraft) of the French Air Force. Many unexpected situations arise in the tactical transport field. During action, changes compared to what was anticipated and planned for frequently occur. In particular, tactical and/or operational conditions often evolve between briefing (conducted just before take-off) and fly-over of the landing area. For example, one pilot says that once above the place where he was supposed to take on troops, the crew noticed that the ground was on fire. It was purposely set on fire in order to force the plane to divert. Given this unexpected incident, the crew had a discussion aimed at reaching an agreement on "what to do". Once the decision was made, the captain validated it and each member of the team implemented it based on automated task allocation. In this example, the unexpected incident – landing area on fire – had not been considered by the crew during briefing. However, the crew very rapidly grasped the causes: a significant evolution of tactical conditions due to the enemy forces trying to generate a diversion.

Generally speaking, when confronted with unexpected situations, teams need to know how to make or give sense to changes that have occurred in the action environment. This collective sense-making goes through common discussion. Even if very short, it generates the atmosphere needed to reach an agreement on "what to do" and to subsequently implement the processing procedures and the adapted task allocation. Unexpected incidents thus require teams to rapidly make and implement decisions in order to be able to achieve their initial objectives. In an extreme environment, there is a strong probability that unexpected situations arise (high evolutivity and uncertainty). Risk level is directly correlated to the collective sense-making process, either through the anticipation of the cause of the unexpected situation, or through the anticipation of its occurrence.

1.2.2.3. *Crisis situations*

The third and last management situation constitutive of the extreme environment is crisis. It is in effect noticeable that routines and the actors' capacity to adapt may not be sufficient when the problems they are confronting are not anticipated and have unknown causes. Crisis differs from an unexpected situation to the extent that it is characterized by an exceptional and rare event. As noted by Roux-Dufort and Ramboatiana [ROU 08], this event occurs suddenly and develops rapidly, in parallel with a significant flow of information, both in terms of quantity (volume of available information) and quality (multiplicity of sources of information and heterogeneity of content).

A crisis is thus a "high turbulence process that affects an organization" [LAG 84]. Lagadec distinguishes three dimensions of this "high turbulence":

– wave-like unfurling: crisis submerges teams and renders regular management tools useless, even counterproductive [LAG 84]. It overwhelms the capacity of actors and structures [LAG 91];

– things are thrown out of order: routine action and operational patterns become helpless and even aggravating factors during crisis [LAG 84];

– the break: the key goals and missions of the team and/or of the organization are called into question and have to be reconsidered [LAG 84]. Crisis can, therefore, significantly destabilize the very foundations of the system, threatening to bring the teams' reference universe to disintegration [LAG 91].

For work groups, a crisis situation is similar to facing a black hole: the event is stunning and they can easily find themselves pulled in and overwhelmed. Literature notes the existence of a "cycle of incompetence". It is a sequence of behaviors that are part of an event(s) perception process that is out of phase with the reality of facts [ROU 08, ROU 09]. What is stressed here is the actors' difficulty or lack of capacity to grasp the event as it is effectively unfolding. This form of disconnect between perception and reality may aggravate the crisis situation, by triggering bad decision-making and adding to tensions [ROU 08].

In the defense environment, a crisis situation needs to be approached from two different perspectives:

– On the one hand, military crews, all armed forces taken together, can be instrumental to crisis management. For example, in 2004, the Staff of French Armed Forces established the operations planning and execution center (Center de Planification et de Conduite des Opérations, CPCO). Among its various missions, the CPCO is responsible for: (1) upstream crisis intervention, by devising warning indicators of potential crises; (2) during crisis intervention by proposing an adapted military component and/or by arming the interministry emergency committees; and finally (3) after the crisis intervention by deciding on how the Armed Forces can contribute to the exiting crisis [TEU 07].

– On the other hand, the Armed Forces can be themselves subject to crisis. This situation differs significantly from the former, to the extent that they have to interpret, analyze and manage a "highly turbulent" event that directly affects them. This has, for example, been the case for military forces at the Canadian Forces Valcartier, near Quebec. Studies conducted in 2001 revealed trichloroethylene contamination of the soil underneath the base. These carcinogenic substances had polluted the water wells of a neighboring town, being a serious threat for the population. The base's environment committee was quickly overwhelmed by the media storm which rendered it unresponsive. The image of the base and its military personnel was strongly undermined by this environmental and media crisis, which called into question their competences in terms of environmental and crisis management [BOI 05].

As this last illustration reveals, for the teams that manage and go through it, a crisis situation is a great challenge, particularly in terms of stress and frustration. Crisis often leads to breakdown [ROU 08]: of the decision-making process, of behavior in human relations and, finally, of regulations, due to inadequacy of routines and standard operating patterns.

Operating in an extreme environment can thus expose teams to crisis situations. Under these circumstances, they undergo radical changes (evolutivity), experience difficulties in anticipating events (uncertainty), particularly because their perceptions contribute to aggravating or improving the events, and finally they take significant risks (media-related, legal, symbolic, vital, etc.) whose impact may last. For this reason, crisis situations require the implementation of specific managerial processes.

Finally, an essential point is worth stressing: evolving in an extreme environment does not mean that organizations will necessarily and regularly be confronted with crisis. On the contrary, when they pay stronger attention and are vigilant with respect to procedures, error detection and proactive watch, they are identified as highly reliable and are not under a higher crisis threat than other structures evolving in more "classical" contexts [CAR 02, WEI 06].

This work will not focus on crisis management modes and tools, which have been described and analyzed by specialized authors.

1.3. Coordination in the extreme environment: shifting from one management situation to another

As characterized and illustrated above, the extreme environment consists of a set of management situations. These situations are constitutive of a continuum that goes from routine situations, providing recurrent and standardized patterns, to crisis situations, in which actors face serious breakdown. Between these two positions of the continuum, teams need to be able to manage unexpected situations (Figure 1.2).

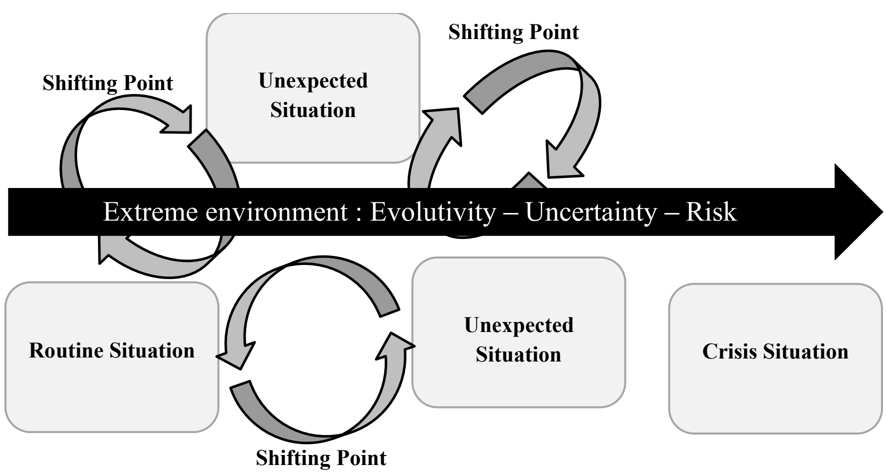

Figure 1.2. *Extreme environment: a continuum of management situations*

As shown in Figure 1.2, one of the major challenges that work groups evolving in the extreme environment are faced with is present at the level of the “shifting points” between routine and unexpected situations. As we have seen, there is a high probability of occurrence of such shifts in an extreme environment. Teams have to cope with sudden tensions and it is dependent on their capacity to manage the passage from one situation to the next that the mission or the project, and more generally, the organization’s performance, relies. These tensions come into play in particular when shifting from standardized situations, governed by rigor and procedures, to an unexpected event, whose effective management requires flexibility, adaptation and often creativity.

Chapter 4 addresses the acquisition of collective competences that allow a team to manage the shift from one situation to next, as well as the tools that management can provide the teams with to facilitate the shift.

Chapter 2 delves into the concept of coordination. In particular, it stresses the limits of classical theories in their approach to team coordination in an extreme environment and proposes a more appropriate perspective: “practice-based” coordination.

2

Team Coordination: What the Theory of Organizations has to Say

The coordination of various tasks to be completed by teams evokes a founding question of management theories and is a major concern for organizations [MIN 78]. The matter of interest is how a work group comes to allocate resources and tasks, to harmonize actions and orchestrate activities in order to advance toward "collective coherence in the accomplished work" [ALS 07]. Team coordination also refers to the general question of management of interactions between people and activities.

This chapter presents the two main perspectives on coordination in the management science literature: the classical – or contingent – view and the practice-based coordination view. Though often considered antagonistic, we will see that these two perspectives are complementary rather than opposed. The "practical" view notably allows us to go beyond certain limitations of classical theories, particularly when it comes to understanding team coordination in the extreme environment.

2.1. Classical theories of coordination

Classical theories of coordination refer to the contingency view, which is still dominant today. As we will see, this view is rooted in the works of major authors in the field of theory of organizations and offers rigorous analysis of various mechanisms, modes and tools needed for team coordination. Nevertheless, it does not bring complete satisfaction when applied to the study of how teams manage the frequent shifts between routine and unexpected situations.

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2.1.1. *Predetermined coordination*

2.1.1.1. *Contingent view on coordination*

There are many authors who reflect on "how" activities and people are coordinated within teams. They have developed a set of typologies that identify the most appropriate coordination mechanisms with regard to action contexts. For the proponents of this (still) dominant contingency view (for example, [MAR 58, LAW 67, THO 67, VAN 76] and [MIN 78]), the choice of mechanisms is a matter of "adjustment – or furthermore of strategic alignment" [PIC 02] in relation with the contextual constraints and opportunities, external and/or internal.

This perspective synthetically identifies two main contingency factors that affect coordination: the level of interdependency between parties [THO 67, CHE 83, MAL 94, CRO 97, GIT 02] on one hand, and the degree of environmental uncertainty [MAR 58, GAL 73, VAN 76, GUP 94], on the other hand. Teams and organizations are called upon to develop their coordination mechanisms in relation to these contingency elements. According to Okhuysen and Bechky [OKH 09], certain contributions are integrated into contingency effects by acting at the level of operating work stations and modes (for example, [TAY 16] and [CHA 62]), while others focus more on the conception of management systems dedicated to structures, roles and rules (for example, [FAY 49, THO 67] and [MIN 78]). Despite these divergences, all the authors agree on the following principle: whether operational or structural, the arrangements are conceived in order to process a volume of information corresponding to the number and complexity of tasks to be accomplished.

This is how March and Simon [MAR 58] have come to consider the plan an effective formal coordination mechanism when the organization operates in a routine context, where information is redundant and reliable, while retroaction would prove more adapted to unexpected and sudden situations. Thompson [THO 67] considers that, faced with high uncertainty, teams are coordinated effectively when they use flexible mechanisms, such as mutual adjustment and informal interactions. Along the same lines, Mintzberg [MIN 78] defends the idea of a continuum between five mechanisms of coordination, where increasing complexity of the situations induces "relaxation" of coordination mechanisms (from formal mechanisms, such as direct supervision, to more informal mechanisms, such as mutual adjustment).

The contingent approach thus considers that formal and informal coordination mechanisms coexist in organizations. The teams either substitute one for the other, or they superimpose them, depending on their needs. Substitution refers to the use of one mechanism instead of another, while superimposition refers to a form of mechanism accumulation, which the teams will use as a source of appropriate elements, according to the situation [GOD 14]. The major contribution of the contingent approach lies, therefore, in the differentiation of coordination mechanisms and the analysis of how they are used by the actors.

2.1.1.2. *Mechanisms, means and tools of coordination*

The question of the nature and aims of coordination mechanisms remains open in the contingent literature. As noted by Alsène and Pichault [ALS 07], there is a tendency to qualify the set of coordination elements mobilized to coordinate tasks and people within organization and teams as "mechanisms".

Even so, there are significant differences between the elements of coordination. A thorough review of the literature makes a distinction: the actors use at the same time mechanisms, means and tools of coordination in their daily activities (Table 2.1).

Coordination mechanisms are those typically referred to by contingency theories, namely as the "most basic elements […] that hold organizations together" [MIN 78]. Mutual adjustment, considered a process of informal communication between actors [MIN 78], differs from relational coordination [GIT 02] to the extent that the latter focuses more on the role played by social networks in support of coordination. In this context, Gittell [GIT 02] takes into consideration both the informal dimension of interactions and the power of social relations and networks [GRA 85].

The means of coordination refer to devices that individuals use to reach their objectives. They diverge from the tools, which are instruments of coordination, namely the support available for implementing and facilitating coordination. In the contingency view, the tools refer to formal and informal artifacts that support coordination. In this context, information and communication technology (ICT) plays a central role.

Elements of coordination	Among the most representative
Mechanisms of coordination	– Standardization of methods [THO 67, MIN 78] – Standardization of results [GAL 73, MIN 78] – Standardization of qualifications [MIN 78] – Standardization of norms [MIN 78] – Mutual adjustment [MIN 78] and relational coordination [GIT 02] – Direct supervision [MIN 78]
Means of coordination	– Line of hierarchy [FAY 49] and authority [BRA 89] – Plan [MAR 58, THO 67] – Rules and procedures [THO 67] – Routines, automatisms and pace [BOU 10] – Meetings [THO 67, VAN 76] and direct contacts – Culture and cultural values – Social networks [GRA 85] – Trust [BRA 89] – Learning processes (e.g. experience feedback [GOD 15])
Tools of coordination	– Technological artifacts (TIC, SAD, etc.) – Operating guides and reports – Code language – Dialogue – Face-to-face discussion

Table 2.1. *Examples of coordination elements indicated by classical literature*

The contributions rooted in the classical perspective approach technologies as technical and computer tools in the service of mechanisms and means of coordination already existing in the organization [CAB 99]. The contingency factors most frequently stressed are the degree of task interdependence, the size of teams and the volatility of the action context. These factors would permit management authorities to identify the type of technologies to implement [KIM 88, KEL 94], depending on their functionalities and expected effects.

In this context, the concept of *fit* – alignment or adequacy – between organizational context and technological artifact is frequently mentioned in literature [KIM 88, KEL 94, SHE 04, KOT 08]. For the most part, the theories of *fit* [GOO 95a, GOO 95b, JUN 08, GEB 09] explore the adequacy of technology, the task completed by the user and the context in which the task is executed in order to improve individual and collective work performances [GOD 13]. The answers to the question of "how" technologies contribute to proper team coordination propose measurements of how activity is affected by volume, quality and modes of information transmission. The contingency factors retained are task predictability, analyzability and coupling [KIM 88, KEL 94], group size [KIM 88, KIM 90], frequency of internal and external changes as well as the more or less routine nature of the task to be executed [KEL 94, SHE 04, CHE 08].

Rich as it may be, we have to admit that contingency literature offers few ideas for understanding how teams are concretely coordinated in a given situation. The works describe a range of coordination elements that need to be identified beforehand and implemented in order to adapt the work modes and/or the structures to contingency factors. These contingency factors determine which elements of coordination are most appropriate. In this context, actors intervene in the downstream coordination: they are approached as simple "users" of mechanisms, means and tools provided to them by the organization.

2.1.2. *The limited contribution of classical theories to the analysis of team coordination in the extreme environment*

2.1.2.1. *The notion of coordination solution*

Relying on this knowledge base, Alsène and Pichault [ALS 07] propose the notion of "coordination solutions" in an attempt to account for how individuals work together (implement coordination mechanisms, means and tools). The authors perceive the coordination solution in terms of a "prescription proposed to (or imposed on) a group of employees, which tends to create coherence of their efforts". Their nature depends on the work situations the teams are confronted with.

Alsène and Pichault [ALS 07] identify 11 work situations. For example, shift work describes a case of one or several employees who take over from one or several other employees; concurrent work corresponds to a situation where several employees participate simultaneously, but each on his or her own, to produce a collective output; or team work refers to the case of several employees working simultaneously, in a collective manner, to produce a collective output.

Each of these work situations has a typical corresponding coordination solution. As a result of research conducted in four large industrial companies, the authors have listed 15 solutions. For example, “operating procedures to follow” refers to a solution where actors have to use certain procedures known to all in order to complete their tasks; “assignments to take on” refers to cases where employees are asked to change their area of responsibility and/or to complete tasks pertaining to another job; “mandates to accomplish” denotes a coordination solution where individuals carry out an activity that does not officially belong among their tasks, but is part of their area of competences.

Using the notion of coordination solution, Alsène and Pichault [ALS 07] question some of the foundations of contingency theories, notably the idea developed by Mintzberg [MIN 79] according to which every organizational configuration corresponds to a coordination mechanism that dominates the mobilized continuum. The authors then demonstrate that approaching coordination at the level of work situation instead of that of structure broadens the analysis perspectives. In this case, the various work situations coexisting in the organization refer to 15 coordination solutions implemented by the actors, a fact that invalidates the principle of dominant mechanism.

However, the discussion around coordination “solutions” cannot solve the problem of limitations of contingency theories when the subject being studied is coordination in the extreme environment. In effect, in such a context teams navigate continuously between routine situations, marked by standardization and formalism, and unexpected situations that require flexibility and responsiveness. The pace of changes is high and random. In these conditions, to predetermine and impose coordination mechanisms or solutions becomes a complex, even counterproductive issue. As we will see further on, teams do not follow a logic of substitution or superimposition of coordination mechanisms or solutions designed upstream by the management [GOD 14]. They “produce” coordination on a daily basis.

2.1.2.2. *Limitations of the classical perspective of coordination*

There are four main limitations of the classical perspective on coordination [BOU 11]:

– First, contingency theories are part of a post-Coasian representation, wherein the company is viewed as an information processor [COH 99]. This view is based on the idea of an environment that, even if marked by complexity, remains predictable enough to make possible the upstream designation and implementation of coordination mechanisms or solutions best adapted to various contingency factors. Alsène and Pichault [ALS 07] do not escape this first critique. As they qualify the coordination solutions as "prescriptions", they implicitly relate them to a *top-down* view of coordination, where the manager and/or the organization have the capacity and means to identify upstream problems and advance to (or impose on) employees the effective solutions.

But, the passage from the industrial paradigm to the knowledge-based economy has radically changed work situations and organizational processes [PES 02]. Due to the complexity of action contexts, the upstream process whereby effective mechanisms or solutions are identified may become very expensive, if not impossible. Moreover, these mechanisms or solutions may emerge simultaneously with the development of the problem to be solved. The process through which coordination solutions are constructed may, therefore, prove to be *bottom-up* rather than *top-down*. In this context, it is very difficult to achieve preidentification of interdependences between work situations and coordination solutions, mechanisms, means and tools;

– Second, the contingent perspective relies essentially on a "design" view of coordination [OKH 09], the envisaged coordination mechanisms referring to various arrangements: either at the level of structural devices to be implemented, such as activity planning (mechanistic system) in a slow evolving context; or at the level of forming transversal groups (organic structure) that aim to facilitate lateral exchanges in a more unstable context. Under these circumstances, coordination is approached at too aggregated a level to allow for comprehension of the phenomenon in all its complexity, and the hidden part of the iceberg remains unknown;

– Third, the contingent models do not take into account the time dimension of coordination. It is not approached in terms of process, but only in terms of content (mechanisms, means and tools). The diachronic aspect of coordination is essential for understanding changes that organizations go through and the actors' capacity to adapt [BOU 10, BOU 12, NIZ 12, GOD 14]. Team coordination is a continuous and situated process: continuous because the search for coordination takes place in real and historic time, stressing the irreversible and uncertain dimension of time (in [BER 46] Bergson speaks of "continuous creation of unforeseeable novelty"); situated because it evokes a social construct which emanates from interactions and interdependences between competences, expertise and specific knowledge [BEC 06, XIA 07, RIC 08] within a given context [FAR 06];

– Finally, the level of granularity retained by the contingency theories is adequate at the scale of the organization or work unit. For example, they refer to large organization samples. This is the case for the contribution of Burns and Stalker [BUR 61] which studies around 20 cases of British companies in order to distinguish between mechanistic and organic structures. However, such analyses do not allow for an examination of how coordination is produced at the level of actors' play and interactions, or for the opening of "this black box that contingency theorists are rather inclined to keep closed" [NIZ 12]. As these two authors note, the examination of individual and collective actions of individuals involved in coordination is possible only if we concentrate on microsociological situations. This research path looks then particularly attractive.

2.2. "Practice-based" coordination: putting back actors at the center of coordination

Since the middle of 2000, works dedicated to "practice-based" coordination are being developed (see in particular [FAR 06, BEC 06, KEL 06, RIC 08, JAR 12] and [BRU 13]). For the most part, they attempt to answer the question of "how" team coordination is produced in concrete terms, on a daily basis. It is an approach to coordination starting from individuals' actions on the ground, followed by their articulation to work structures and modes.

2.2.1. *The "practice" turn in management science*

2.2.1.1. *Drawing inspiration from contemporary sociology*

Though recent, the practice turn in management science enjoys growing success. A good illustration is the strategy as a practice trend, which has become well known over the last 15 years (see, for example, [WHI 06] and [JAR 07]). But as Whittington [WHI 06] stresses, strategy is not the only specialist area influenced by the practice turn. For example, contributions of Orlikowski and Yates [ORL 94] and Orlikowski [ORL 00] to the management of information systems, those of Brown and Duguid [BRO 91] or Wenger [WEN 00] to the understanding of organizational learning dynamics or the works of Brownlie and Heweren [BRO 11] in marketing show that the practice-based approach is a source of inspiration for many specialized areas of management.

This practice turn is naturally rooted in contemporary sociological theories [GHE 06]. In particular, the close intertwining of field, habitus and practice concepts is in Bourdieu's view one of the main sociological bases of this approach. Starting from a critique of intellectualist models, Bourdieu develops a sociology of action leading to the approach of practice as "the dialectic of the opus operatum and the modus operandi, of the objectified products and the incorporated products of historical practices; of structures and habitus" [BOU 80]. Practices are thus dispositions to act that one is not conscious of. They are the product of habitus, in the sense of a directory of "principles of generation" [BOU 80], of "durable, transposable dispositions" [BOU 80] acquired through early and adult life experiences. Habitus in its turn is part of one or several fields, which are spheres of social life organized over time. Practices develop in and through action, under the influence of habitus. This consideration leads Bourdieu to the introduction of the social agent. The social agent's actions "are both inwardly and outwardly directed" [BON 97]. According to Bourdieu, social action reflects social structures; structures have a primacy over action.

The contributions of Giddens [GID 84], and his concepts of action and structure, are also frequently quoted by authors who share the practice-based approach, particularly in the field of management of information systems. In parallel with the works of Bourdieu, Giddens develops his theory of structuration insisting more on the dialectical dynamics of social structures and action. Here, Giddens prefers the term "actor" instead of that of social agent used by Bourdieu. Giddens's actor is competent, capable of controlling and directing his or her actions. Controlled actions are for him or her a source of new knowledge that he or she takes into account in order to act. The action–actor link is considered recursive, namely based on a circular dynamics that involves repetitive process.

The second key concept of Giddens's thought is that of structure. Structure evokes a virtual order consisting of a set of rules and resources that actors use in their actions. Thus, they participate in a recursive manner in the development of a social system (for example, a society or an organization).

Here, recursivity characterizes retroactions between structure (consisting of rules and resources) and actions: structure directs (controls) action just as much as action acts on structure. Structure represents the means and result of the action it recursively organizes at the same time [ROJ 00]. Giddens uses the term "duality of structure" [GID 84] to describe this phenomenon of mutual transformation of structure and action. It produces and reproduces the structural properties of the social system: certain structural properties rely on rules that can contribute to sense-making. When these rules constitute shared interpretative diagrams that permit actors to communicate, Giddens speaks of structures of signification. Other structural properties govern the power relations between actors. The author qualifies them as structures of domination. Finally, certain structural properties consist of norms, moral codes, conventions that embody the established order at a given moment in the evolution of the social system. Giddens then speaks of structures of legitimation.

Through actions and interactions, the structures of signification, domination and legitimation become institutionalized to the extent that they enter a process of structuration and become durable. For this reason, they affect at their turn the actors' actions and interactions, either as constraints or as "empowering" factors.

2.2.1.2. *From practice to practices*

The practice-based approach refers to the analysis of microactions through which actors organize activity [SCH 01, ORL 02, GHE 06]. It therefore offers the opportunity to grasp the continuous and situated character of coordination. Such a perspective leads the researcher to explore "the internal life" [GOL 06] of management situations, to understand how coordination is concretely produced when actors work in a routine environment and are suddenly confronted with unexpected situations. Thus, the level of analysis proposed by the practical perspective is microscopic. This leads in particular to an examination of individual and collective modes of action, interdependences and technological uses. In this last case, we will see hereafter that uses are practices. Uses translate the paths of users' appropriation of technologies; they represent the way in which users implement them ("enact" them).

The authors who adopt the practice-based approach insist that microactions cannot be approached independently of the social foundations they are shaped by. Thus, they distinguish practice – or praxis – from practices (for example, [REC 02, WHI 06] and [JAR 07]). "The practice" describes the interdependences between individual actions, the flow of activities in situation [JAR 07], as well as the institutional environment in which they are expressed. In that respect, practice is "a mode, relatively stable in time and socially recognized, of ordering heterogeneous items into a coherent set" [GHE 06].

As for "the practices", they refer to a "routinized type of behavior which consists of several elements, interconnected to each other: forms of bodily activities, forms of mental activities, 'things' and their use, know how, states of emotion and motivational knowledge" [REC 02]. Practices thus refer to the actors' way of doing things in the situation. They represent organized (or more precisely "organizing") actions that are part of a context of specific social relations, rules of behavior and ways of doing things. In this respect, practices partake of the achievement of objectives that give them meaning. They are "intrinsically connected to 'doing' because they provide the behavioral, cognitive, procedural, discursive and physical resources through which multiple actors are able to interact in order to socially accomplish collective activity" [JAR 07].

2.2.2. *What contribution does the practical perspective bring to the study of team coordination?*

Adopting a practice-based approach when exploring team coordination can open new analysis perspectives. While it facilitates the examination of the production of coordination in a situation, it directs research to the underlying processes rather than to its content. Thus, it permits us to decode microprocesses of coordination [JAR 12], such as the logic of actors, their relations with artifacts (in particular technological artifacts), the collective dynamics as well as their recursive effects on social and organizational structures. In this way, the practice-based approach stresses the material, time, collective (and/or social) and contextualized dimension of the production of coordination.

The articles by Faraj and Xiao [FAR 06] and Xiao *et al*. [XIA 07] represent a major contribution to this research perspective. In their attempt to answer the question of how hospital teams are coordinated, the authors spent several months studying the team coordination practices in a North

American medical trauma center [FAR 06]. These teams have a general objective: to stabilize the patient. The authors note that in 90% of the cases, coordination relies on the articulation of expertise and specializations of medical doctors and nurses (they then refer to expertise practices), circumscribed by treatment protocols and paths. In this respect, teams evolve in routine situations, such as those previously described. These refer to standard rules and procedures that facilitate rapid "provision" of knowledge and competences to and from the team members; moreover, these expertise practices facilitate the development of shared cognition and common mental patterns needed for joint sense-making.

Nevertheless, in 10% of the cases, teams are confronted with unexpected situations that require them to react and adapt to a deviation from the usual trajectory. In order to coordinate when faced with such unexpected situations, teams develop coordination practices that rely on dialogue and contradictory debate (the authors then speak of dialogic practices), which can lead to protocol breakdown or evolution. These practices are situated and specific responses, which are adapted to cases that cannot be effectively managed by pursuing the standard treatment trajectory. Faraj and Xiao note the role played by what they call "epistemic contestation" [FAR 06]: as the opinions expressed in relation to a case may differ, the quality of coordination and the final result rely on the term members' capacity to listen.

"Epistemic contestation" may take various forms of expression depending on the organizational environment. In one of her articles, Bechky [BEC 06] describes, for example, how, on film sets, practices based on coworkers joking and teasing each other carry messages that are essential for good team coordination. They permit us to make certain protests and critiques while preserving relations and individual roles. Bechky [BEC 06] notes that these practices also contribute to the strengthening and distancing of the role structure.

Thus, according to authors who share the practical view, coordination refers to a set of enacted (or produced) and situated practices rather than to structural arrangements fixed at the organization level. It relies on a "bricolage" process [WEI 93] aimed at assembling competences and knowledge, relational modes and situated resources, depending on the problems and needs at the given moment. More generally, by observing coordination "in the making", such a perspective can lead to opening the black box that contingency has left closed, bringing up to date a set of coordination practices (expertise, protocol, debate, friendly mockery, jokes, etc.) that teams assemble in order to harmonize their activities. This more open theoretical framework, while recognizing the role played by coordination at the level of organizational structures, reveals the importance of practices resulting from daily "bricolage" and adjusted to situations experienced by the teams.

The question to be examined now is that of the nature and categorization of these practices. As we have seen, in the extreme environment teams are continuously managing the shift between routine and unexpected situations. This capacity is crucial for preserving a good level of coordination and performance. Chapter 3 examines various types of coordination practices that may facilitate this team work.

3

Coordination Practices in the Extreme Environment: Communication, Reflexivity and Socialization

What are the main categories of coordination practices produced and implemented by teams in the extreme environment? How do these practices articulate one to the other? By taking an empirical inductive approach, this chapter endeavors to answer these two key questions.

The cases developed are based on the daily work of French Air Forces. Relying on these cases, three main types of coordination practices will be highlighted: communication, reflexive and socialization practices. A combination of these practices provides teams with the capacity to manage shifts between routine and unexpected situations and to adjust according to context and event-related constraints and opportunities.

3.1. Communication practices

In the extreme environment, where volatility, uncertainty and significant risk coexist, actors are in search of updated knowledge referring to the specifics of their task in the team, and to the means to implement in order to complete these tasks. From this point of view, they need to be able to rely on communication practices that permit us to sort out pertinent from less pertinent information when in action. The analysis of the following cases will provide an opportunity to stress the role played by shared languages (verbal, pictorial or body languages) and paths of information and communications technology (ICT) uses. These communication practices

Team Coordination in Extreme Environments: *Work Practices and Technological Uses under Uncertainty,* First Edition. Cécile Godé.

foster mutual understanding of activities among team members: actors refer to them when developing their actions and managing interactions.

3.1.1. *Shared languages: code words, diagrams and body expressions*

3.1.1.1. *Close air support operations in Afghanistan: the code words*

NATO military forces within the Afghan theater (2001–2014) would describe the combat operations there as “asymmetric”, in the sense that forces in the field were highly dissimilar. The coalition armed forces had access to resources (technologies, weapons and logistic capacities) that conferred them an objective advantage over Taliban forces. Even so, the physical characteristics of the ground, the presence of combat forces among civilian populations and the geographic dispersion of units posed real problems. Despite the means of communication deployed, they were confronted with difficulties in information gathering and reliability. Moreover, the tactical situation evolved according to nonlinear dynamics, shaped by unforeseen contingences that were therefore by definition difficult to anticipate.

It is under these circumstances that the French Air Force intervened to support special forces operating deep in the territory. These combat forces considered a situation as routine when the mission was carried out as planned (briefed) before departure and the activity breakdown followed the usual formal standards. It is worth noting that air or land forces missions in all theaters are always carefully prepared based on intelligence provided by a group of experts (among them intelligence officers). For example, the air force fighter crews brief their missions just before take-off. They describe all flight phases, security procedures and finish with what they call *what-ifs*. This last stage raises the question of what should be done (what procedures should be applied) in the case of a system operation problem during flight, such as an engine failure.

Despite rigorous preparation, combat forces may face situations that were not briefed or were briefed during the *what-if* stages, for example, but whose probability of occurrence was low. In Afghanistan, it was not possible to plan for everything, since ground targets were scattered and moving fast. These unexpected situations generated partial or total breakdown of plans of the air force crews and Special Forces on the ground, increasing the mission's complexity. The task breakdown was then called into question and combat forces needed to rapidly make sense of the situation in order for coordination to evolve. Under these circumstances, common language played a key role.

Let us consider the example of close air support (CAS) missions undertaken daily within the Afghan theater for nearly 13 years (in particular by Mirage 2000D fighter-bomber aircraft). These tactical missions were launched when forces on the ground asked for air support, either because they were facing immediate danger or because they had identified a target to be destroyed. CAS involved three main actors. The first two were the fighter crew: the pilot, who concentrated on flying the aircraft, strictly speaking, and fired gun(s); and the navigator, who was in charge of medium- and long-term tasks (electronic threat monitoring, radio frequency tuning, preparation and weapon guidance). The last actor was the forward air controller (FAC). As a member of a Special Force unit deployed on the ground, his role was to accurately guide the bomber aircraft so that it could deliver weapons while avoiding fratricide firing risks and collateral damage.

When the fighter crew was above the target area, it got in contact with the FAC. He then provided the pilot with all available information on the objective, based on a standardized information card called *CAS Card*, which contains in particular an operation check-list named *9 line* (Figure 3.1). The 9 line consists of several "lines" of instructions and data that indicate geographic coordinates, objective entry and exit point, timing, etc., as well as various procedures to implement for mission execution. Once in contact with the aircraft, the FAC provided a real-time description of the environment in order to gradually lead the pilot to visually and unambiguously identify the target. As stated in 9 line, the description should inform the crew of the number of targets to be eliminated, their nature, level of protection and evolution.

As illustrated by the *Control the attack* section in Figure 3.1, war fighters used a common language, published in NATO documentation, which they usually call code words. *Push when ready*, *Continue* and *Abort* were all code words easily understandable by the crew members and the FAC, which facilitated communication, while significantly reducing the risk of misinterpretation. As a pilot noted: "These code words are rich with meaning. They are the basis of a common language, no need for interpretation or reasoning. For example [in an air defense situation], with

Investigate one has to identify. It is a fact known from the start that a particular interception is conducted in order to observe and identify. There is no ambiguity. Code words are a real philosophy of communication".

[…] **Arrival of air support, CAS check-in**

a. Pilot call sign / mission number
b. Number and type of aircraft
c. Position and altitude
d. Ordinance
e. Time on station
f. Abort code

Create 9 line

g. Line 6: Target location
   i. 6 digit grid with ***GRID ZONE DESIGNATOR (NU 123 456)***
h. Line 4: Target elevation
   i. Elevation from map in feet. ***(METERS x 3.3) = FEET***
i. Line 8: Friendly location
   i. From the target, cardinal direction and distance in meters from the target ***(NW 1200)***
j. Line 1: IP/BP
   i. IP: An identifiable geographic point for CAS aircraft for the final portion of attack
      1. ***NORMALLY 5-15 NAUTICAL MILES*** […]
k. Line 2: Heading
   i. Straight line magnetic direction from IP to target
   ii. ***Subtract GM angle when converting grid to magnetic heading***
   iii. Offset left or right to restrict pilot for final coordination of the attack
l. Line 3: Distance
   i. Fixed wing: IP to target in nautical miles, express to nearest tenth of a mile […]
m. Line 5: Target description
   i. How many? What is the target? Degree of protection? What is the target doing? […]

Brief the attack […]

n. **DO NOT SAY**: line numbers, headers, or units of measure (exception line 9 "EGRESS")
o. After line 9, send remarks (Final attack heading, laser target line, Gun target line)
p. If pilot copies all information, understands all instructions, pilot reads back line 4 and line 6
q. Give pilot a **"TOT"** or **"TTT"** or **"Push when ready"**

Control the attack r. Pilot radio calls i. ***PUSHING*** – Moving from control point to an IP or BP ii. ***IP INBOUND*** – Pilot is at designated IP iii. ***IN THE POP*** or – Pilot is approaching and looking for the target iv. ***IN + DIRECTION or HEADING / WINGS LEVEL*** – Pilot is pointing at target, requesting to drop ordnance v. ***CONTACT*** – Pilot "sees" a reference point designated by ground controller vi. ***VISUAL***– Pilot "sees" friendly location vii. ***TALLY***– Pilot "sees" a target s. FAC radio calls i. ***PUSH WHEN READY*** – Tells pilot to start attack when ready ii. ***CONTINUE*** – Continue with attack, do not release ordnance iii. ***ABORT*** – Do not continue with attack, do not release ordnance iv. ***(Pilot Call Sign) CLEARED HOT*** – Authorized to release ordnance on this pass […]
Assess the damage t. Surveillance of target u. Number of personnel or equipment destroyed

Figure 3.1. *Close air support basic 9 line (source: http://www.imef.usmc.mil/staffsections/CAST/_Handouts/CAS%20Student%209-Line%20Handout.doc)*

In Afghanistan, with one code word war fighters could concisely and rapidly exchange a significant amount of information. Everyone knew and had assimilated the code words. They contributed significantly to reducing comprehension problems, such as the risk of communication overload, for crews and controllers on the ground.

3.1.1.2. *Aerobatic performances of the French Air Forces Aerobatic Team and Patrouille de France: diagrams and body expressions*

Coded and shared languages are also used by more atypical structures of the French Air Forces, such as the display teams. There are two specific squadrons: the Air Force Aerobatic Team (AFAT) and the Patrouille de France (PAF). Their main mission is to present their program during military and civil aviation meetings: it is qualified as "free integral" for the AFAT pilots, and consists of a sequence of free aerobatic figures (except for security rules, they are not subject to any other rules), while the PAF performs synchronized aerobatics in eight-plane formation (Figures 3.2(a) and (b)). It is worth noting that AFAT also participates in national and international competitions where for several years it has won important prizes (world champion in particular).

a) b)

Figure 3.2. *Performance by the pilots of AFAT (source: http://spottingaviation. forumactif.com/t3398p280-mna-rochefort-28-29-mai-2011) and PAF (source: www.blog.francetvinfo.fr)*

Display team members coordinate in an extreme environment: the situation may very rapidly shift due to unstable weather conditions, for example; there is high uncertainty as to the extent that unexpected events can occur, such as a bird strike, a mechanical problem or a radio communication failure; finally, the flight programs presented involve significant levels of risk: there is physical risk, as pilots' life and health may be endangered, but there is equally a more symbolic risk, as the teams' prestige and reputation are at stake.

The pilots of display teams share a common language, just as those of the operational forces do. Beyond its verbal nature, this one is striking due to its pictorial and bodily dimensions. Members of the two teams first take advantage of schematization and drawing. For this purpose, the PAF uses a magnetic whiteboard and magnets in the shape of Alpha Jet (the fighter aircraft that PAF flies). They move the magnets on the whiteboard to symbolize the acrobatics, and write the technical elements required for the successful execution of the planned figures. AFAT members share a language that borrows from both the general aeronautics vocabulary and a code specific to aerobatics: the Aresti key (Figure 3.3). Published by the Fédération Aéronautique International (FAI), this code associates code words with simple diagrams that describe nine families of classical aerobatics figures. The diagrams consist of curved lines, straight lines and geometric elements representing the maneuvers to be performed by the pilot.

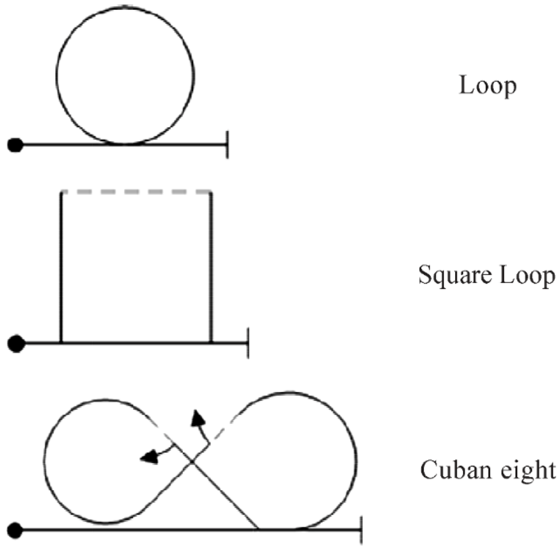

Figure 3.3. *Example of aerobatic figures diagrammed according to the Aresti code (source: www.equipedevoltige.org)*

Complementary to this shared pictorial language, and for coordination purposes, display team members develop practices based on body communication, appealing to sensations. Before each flight, pilots mime the aerobatic figures to be performed (Figures 3.4(a) and (b)); they "experience" the figures with their bodies before performing them with their aircraft. Members of PAF call this mental and body imagery "the music". During briefing meetings, pilots simulate together the flight program, in a rhythm imposed by the leader's voice. Sitting on chairs, most of them with eyes shut, the pilots express their future flight maneuvers with their hands, fingers, legs and head. The actors' gestures are always the same, perfectly automated. For the AFAT, the exercise is substantially similar, except that only one pilot mimes the flight while his or her teammates, often present, are observing him or her. Furthermore, the pilot is outdoors (on the tarmac) and performs the body movements while inside a square marked on the ground (representing 1 cubic kilometer volume, called the *Box*, in which his or her competition flight will evolve).

a) b)

Figure 3.4. *Body language of AFAT (source: http://www.equipedevoltige.org EPAA@2010) and PAF (source: http://www.aerobuzz.fr) pilots*

3.1.1.3. *Shared languages: when faced with unexpected situations, automatisms improve comprehension and save time*

In unexpected situations, teams' and their members' responsiveness and capacity to adapt prove to be crucial. When tension is high, everyone needs to work toward the overall coherence required to complete the mission within a very short time. To this end, the various types of language described above represent automated communication standards used by the actors. To the extent that they help save time, their role is crucial. More precisely, on one hand these languages facilitate communication between team members. Each code, either verbal, pictorial or bodily, is known by everybody and allows for rapid transmission of clear and straightforward messages. This significantly reduces interpretation errors. Actors understand each other without ambiguity. On the other hand, shared languages reduce the load of coordination and help free time for completing other less "routine" tasks that become a priority when unexpected situations occur.

Faced with the unexpected, actors take advantage of this time gain to reach agreement on the situation and on the adequate solutions for reaching objectives. There is a tendency to avoid code words and adopt more familiar language. A pilot shared with us: "In the combat theater, stress levels can be very high. In some situations survival instinct takes over. In such moments the important thing is to communicate, language doesn't matter, even if everyone understands code language and we need to do our best to preserve it as long as possible." Discussions may refer to the tactics to implement to deter the enemy (very low altitude flights, for example, also called *show of force*, were regularly used in Afghanistan) or the opportunity to fire weapons in a legitimate self-defense situation. A navigator remembers: "Last year I had a case when we decided not to fire weapons. […] We had the rules of engagement, what we could see below… The two of us discussed the opportunity to fire weapons. We agreed. And even if we didn't, we would have discussed it longer. I think the decision would have been still a No, because generally when one doesn't agree the decision is No". Thus, natural language is adopted not because it is more effective than code languages, but because the war fighters are under such levels of tension and stress that they unconsciously activate deeply rooted patterns of action and communication. Through dialogue, they gradually move toward consensus on the processes to be implemented in order to coordinate when faced with the unexpected.

These shared languages help actors better comprehend messages and save time that can be dedicated to sense-making during unforeseen events. These results are made possible because, through training and operations, the acquisition of these languages by the team members reaches the level of automatism.

3.1.2. *Technological uses: improving communication through information sources and flow*

ICT also contributes to improving communication within teams. According to the classical view, this effect is seemingly linked to the technical characteristics of ICT, which directly impact the conditions in which information and knowledge are collected, exchanged and stored [ZAC 99]. According to this view, ICT are approached as mere technical means at the service of preexisting modes of communication [CAB 99], referring to a contingent perspective that gives little satisfaction when dealing with coordination in the extreme environment.

Because they transform the conditions in which information and knowledge are used, technologies are intrinsically linked to their (practical) uses: technical characteristics, the programming of the technological tool and the context in which it operates are inextricably linked to the social and structural effects (as defined by Giddens) of its uses [ORL 07]. Within this framework of analysis, ICT uses can be thought of as socially and materially entangled in the social systems, teams and organization structures (the specialist literature mentions a sociomaterial approach). The materiality of the technological artifact crystallizes a set of tangible resources that offer users the possibility to advance their practices and innovate the ways in which they are used [LEO 08]. The nature of tasks, the social interactions and the team roles may be modified, thus leading to a redefinition of social and organizational structures [ORL 07, ORL 08].

The following case illustrates the types of uses developed by American military teams following massive introduction of the so-called "network-centric" technologies [GOD 10]. The Iraq and Afghanistan conflicts have in effect been marked by the deployment of a doctrine qualified as *network-centric warfare*, defining the changes and principles of action associated with the ICT introduction for military operations management. The ICT interactivity potential has been massively exploited by the engaged armies to facilitate communication between units and to optimize commands and operations management.

Among the technologies deployed within the combat theater, tactical Internet has played a major role, strengthening the network-centric organization of NATO forces. Tactical Internet – a set of technologies such as the synchronous (text-chat and instant messaging, videoconference, satellite radio, etc.) and asynchronous (e-mail) communication systems as well as decision support technologies (evolutive databases, tactical navigation support and simulation systems) – has given access to a significant volume of information and has encouraged team work around a common view of operations. The following illustration focuses on one of the components of tactical Internet: text-chat. Text-chat is a real-time communication system that allows users to have a written and interactive conversation, through interposed keyboards. Messages are managed by Internet Relay Chat (IRC), a system that involves a protocol and a network of servers dedicated to this type of communication. The US Navy and the US Special Forces, in particular, have used text-chat during their offensive and defensive operations in the Afghan territory between 2002 and 2007. The analysis of results reveals the gradual production of innovative uses around communication, allowing significant improvement in the decision and coordination capacities of the military teams.

3.1.2.1. *Multiplication of sources of information*

An essential technical characteristic of text-chat is the multiplicity of sources of information available to users. On the Afghan theater, text-chat was configured to facilitate simultaneous creation and management of a multiplicity of dialogue spaces (*chat-rooms*). The users could thus conduct several conversations simultaneously, irrespective of the geographic and tactical location of their interlocutors. Within the same space, they participated in various dialogues, created collective dialogue spaces that facilitated group interaction and used private spaces to facilitate person-to-person exchanges (*instant messaging*). Most of the individual and collective dialogue spaces were secure, so users did not have to worry about espionage and piracy risks.

Naval Air Forces were familiar with the technical specificities of text-chat – during the operations in Afghanistan, each expert contributed on average to six dialogue spaces simultaneously– and they learned to exploit them. It is worth noting, for example, that users organized extended interest communities (navy, air and land forces) around the activities of most critical importance during offensive phases, namely meteorology, intelligence, logistics, air traffic control, oceanography and target designation. Each expert was actively involved in the dialogue with his or her community, while attentively following the neighboring conversations. Thus, users integrated in real time the new data and information exchanged in other spaces and which had a potential to affect their own planning.

Instant messaging, called *whispering* in the US Navy, has been used to conduct person-to-person dialogue. This additional activity allowed the user to search for information that was critical for the proper execution of a military operation, while avoiding overloading the collective conversation within the community. One expert got in contact with another by creating a dedicated personal space, obtained the requested information and then got back to the collective space to contribute to the conversation.

These text-chat uses facilitated the articulation of various communication practices (whispering and collective) starting from spaces organized as communities of interest, significantly improving coordination within and between teams of the coalition armies. This has been all the more true in the mission preparation phases. According to an intelligence officer: “Having a real-time dialogue with units of experts of the operational groups has simply allowed the tactical level to rapidly benefit from the analyses provided at our level".

Before text-chat was implemented, the preferred communication technology was radio. The reception quality was not always guaranteed and users were frequently faced with difficulties in comprehending the oral messages (often due to limited vocabulary, accent problems, etc.). The act of radio communication could prove very time- and energy-consuming, reducing the drive to interact spontaneously and on a large scale. One of the text-chat contributions was to reduce noise during communication, allowing for text-based information exchange, which was more easily exploitable, particularly when the exchange involved multiple channels. An officer assigned to Task Force 50 (a US Navy combat group deployed at South of Afghanistan) noted: "Chat was awesome. Chat [was] like getting twenty new radios and being able to work them all at once".

Thus, the very fact of using radio to transmit a piece of information or a directive came to have a particular meaning: it was a sign of a high-degree urgency or risk of unexpected event, when operators had no time to write and were forced to organize the mission through oral communication ("by voice"). Most of the time, users exploited text-chat and radio simultaneously. To the extent that each technology served well-defined objectives, it was not something that was forced on them, but something they had chosen.

Practices associated with the multiplication of sources of information were beneficial not only in the operation preparation phase, but also in their tactical execution. NATO Special Forces have developed communication practices for combat conducted deep in the territory. The situation differed in terms of bandwidth capacity, which was very low on the ground. War fighters found a way to bypass these limitations by connecting their laptops through the satellite connection for voice and text data transmission. Due to this "bricolage" [CIB 93], they could receive and send messages that were less elaborate than those exchanged within the professional communities in the preparation phases, but were accurate enough to allow for direct dialogue with the headquarters. The special units deployed in the Afghan villages developed interesting practices starting from this improvised text-chat. As they were positioned in proximity to the attack area, they first received a vocal message through the satellite radio requesting them to connect to their laptops. A precise order was sent asking them to go near a village where wanted individuals were hiding. The commando team confirmed good receipt of the order, and then opened a dialogue space with headquarters to discuss tactical details and ways to execute the mission. Complementary to this information, war fighters got used to opening other spaces that allowed them to collect tactical data from various sources. For example, the reconnaissance drones flying above these areas were displaying data from the ground (images, geographic coordinates, etc.) concerning the real-time evolution of the situation. The information essential to the offensive was very rapidly collected without the risk of misinterpretation. Once the mission was completed, a status report (number of prisoners, weapons found and intelligence gathered) was sent to headquarters, which then asked for details, if needed. The use of text-chat enacted by the Special Forces has significantly shortened the decision-making process. The capacity to follow the troops' evolution in quasi-real time and to have access to continuously updated information has increased the responsiveness of headquarters, through reassignment of missions to those who were able to best respond to the needs on the ground.

3.1.2.2. *Permanence of the flow of communication and persistence of information*

In Afghanistan, text-chat was configured to allow for the reception and transmission of messages 24 hours a day. The permanence of the flow of communication was essential in the theater of operations, as missions had to be planned and executed anytime, by day or night. War fighters thus considered text-chat as one of the most reliable tools for command and execution: when the deployed units got so deep that they could not be reached by voice or when bandwidth capacities were not sufficient, text-chat became the only means of communication permanently available.

Little by little, the users took ownership of the capacity of permanence of technology and developed adapted communication practices: operators were still expecting to find an interlocutor to start a dialogue with. This expectation being shared by everyone, war fighters spent more and more time in front of their screens – up to 7 hours a day on average in the case of certain officers in charge of operating American aircraft carriers and destroyers during the first months of the war in Afghanistan. They were thus making sure they would never miss information that was important for the evolution of tactical plans. This behavior has led to a significant increase in the speed of mission planning and execution. As users exploited the permanence attached to text-chat more, their exchanges became more intense and strategic, and the incentive to stay in front of the screen grew stronger.

As an illustration, Task Force 50 implemented a planning and execution platform for Navy and Navy Air Force operations, named the *Knowledge Wall*. This platform provided access to various ICTs such as e-mail, Internet portal and evolutive databases. The additional information and knowledge thus collected have allowed an unprecedented level of precision to be reached in the analysis and processing of information for decision purposes. An air defense liaison officer aboard the *USS Princeton* noted: "The power of the system [Knowledge Wall] was in harnessing information from multiple sources, fusing it into a consistent, user-friendly format, and instantaneously disseminating that information back to war fighters and decision-makers".

The Knowledge Wall and the radio constituted a portfolio of information and communication tools based on which the Special Forces developed communication practices that were adapted to the situations they faced. Mediated interactions effectively replaced face-to-face interactions, partly because individuals knew each other and shared standard action patterns, and because the time allocated to decision-making was very brief and they were not able to meet whenever they needed to. Face-to-face meetings continued to have an important role during more routine phases, such as mission debriefing, when actors could afford to take the time to comment and debate on their actions.

This articulation of technologies and uses has generated a debate about the problems of information overload. In effect, during real-time dialogues and information reception, the users had to pay continuous attention to be able to follow the evolution of the situation and to make sure they did not miss essential data. They then had difficulties determining when to stop collecting information and start focusing exclusively on mission execution. Furthermore, the multiplication of dialogue spaces tended to generate a surge in the volume of information to be urgently processed. There were times when users were flooded with information and had difficulties making a priority-based selection. Experimental researches conducted in the United States have revealed the difficulties in managing information flow [SCO 06] in the theater of operations. They have notably shown that in unexpected situations, where urgency and stress reach high levels, text-chat users tended to focus exclusively on the system interface. They were completely focused on processing demands and following dialogues, even as the instructor was trying to remind them of their main mission. Users learned with experience, however, how to take ownership of technologies and succeeded in giving them meaning in their specific work environment.

In this case, the American Navy forces have requested that text-chat be configured to show a guiding thread of conversations conducted in various dialogue spaces. A time-marking system has then been developed, giving authorized personnel access to a real history of conversations. As one user said: "The chat is better because it gives history, and you can watch things unfold in near-real time". Special Forces also added a search engine to the system, and this allowed them to rapidly find, among multiple open or stored dialogue spaces, the fragments of conversations that helped them in dealing with such and such problem.

These additional capacities to store and search information conferred persistence to dialogue spaces. Users have also developed asynchronous communication practices, which were not initially planned for. Persistence of information has been considered an additional material feature of the permanence of flows and multiplicity of sources. Taken together, these features reduce communication costs and improve the coordination of teams in command and tactical situations.

3.1.2.3. *ICT uses: combined communication practices*

The examination of text-chat uses enacted in the theater of operations confirms the existence of links between the technical features of the tool, in particular its programming modes, and the context within which it is used. Actors have developed communication practices by articulating the interactive features offered by text-chat (synchronous communication) with the integrative decision-support features (history of conversations and databases). The sociomaterial characteristics of permanence and persistence attached to the tool have allowed for the articulation of these practices. For its part, the multiplication of sources of information has facilitated access to a broader variety of internal (such as logistics, ammunition, friends' and enemies' positions) and external (such as weather conditions, topographic elements and physical characteristics of the ground) knowledge. Without the multiplication of these sources, it is unlikely that users would have been able to implement uses that allowed them to exploit the variety of information and knowledge needed to conduct operations. In particular, the permanence of the flows of communication and the persistence of information were revealed and afterward reinforced through individual and collective practices aimed at integrating communication (interactive process) and decision-support (integrative process) functions into the daily uses of text-chat.

The case also shows that uses, as sources of communication improvement, combine with each other. These “combinations of uses” refer to a logic of assembly of the social–material features attached to a technological tool. These features are not perfectly embodied in the design of technology, as there is no upstream possibility for the designer to envisage the diversity of future uses. Some of these are enacted *in situ* by users during their interaction with technology in concrete work situations, between routine and unexpected situations, for example when creating a search engine that allows for useful information to be found rapidly: thus, text-chat supports the transmission of explicit knowledge within expert teams and communities. It is also the case when individuals go further into the interactive properties of text-chat associated with the permanence of information channels and the multiplicity of sources, in order to improve communication and team coordination during the mission planning phases. Here, text-chat supports the transmission of experience and the sharing of more tacit knowledge among actors.

When unforeseen situations require the accomplishment of new tasks, technological uses and their combinations improve the dynamics of coordination. Field results are a good illustration, as they refer to the actors’ capacity to get involved in multiple opportunities for horizontal communication. Collective procedures for problem resolution are thus being reinforced. Decision structures are more decentralized and hierarchical authorities can concentrate on key decision-making phases. The new communication practices also have a tendency to modify the temporality of the relations among actors and to improve their awareness of the shared situation.

3.1.3. *Communication practices: a synthesis*

The examination of communication practices based on military illustrations highlights the crucial role they play in team coordination in the extreme environment. Practices based on common languages first improve the transmission and comprehension of messages exchanged by the actors, thus reducing the risk of misinterpretation. This is because through training and missions they become automatisms. The time they help gain can be used for the analysis of unexpected situations and collective sense-making. Finally, combined technological uses stimulate the emergence of innovative communication practices, adapted to the constraints and opportunities of the action environment (Table 3.1).

Shared languages	Code words, diagrams and drawings, gestures and body expressions
Combined technological uses	Individual and collective exchanges, explicit and experiential knowledge, real-time information, history of information exchanges

Table 3.1. *Communication practices*

3.2. Reflexive practices

The study of team coordination in the extreme environment reveals the existence of a second category of practices: reflexive practices. Reflexivity evokes an individual or collective capacity to call into question interpretations and completed actions. It is a matter of standing back and examining successes and failures in order to identify the best ways of individual and collective functioning and find effective problem resolution processes. Reflexive practices are thus based on calling into question, debate and consensual search for solutions.

In the military, reflexive practices develop mainly during debriefing sessions [GOD 12a]. The following case proposes to describe debriefing as it is conducted by the French Air Forces squadrons (taking all fields together: fighter forces, transportation and presentation).

3.2.1. *Briefing–debriefing in the French Air Forces squadrons*

A working day in a squadron always starts with a general briefing of 30 min attended by all the pilots, navigators and trainees who have one or more flights scheduled. After this general briefing, the navigating personnel divides into patrols or crews of two to four members who participate in a briefing dedicated to the flight(s) they are assigned to. Immediately after the flight, they get together for the mission debriefing which lasts between 40 and 45 min.

Debriefing sessions are very formal and follow standardized procedures (NATO manual). They consist of taking in reverse order the points discussed during the briefing, with a stress on flight security. Certain fighter squadrons have flight reconstruction systems that digitize the aircraft flight path. As regards the display teams such as the PAF and the AFAT, they are always accompanied by a cameraman who films the flights and then provides the pilots with the digitized videotape. Thus, pilots have access to a clear representation of the training and exercises performed during flight and are able to accurately evaluate the quality of the mission. Each flight comes under scrutiny, particular attention being given to inappropriate actions (errors), their causes and the solutions that might be implemented. Errors that occurred during flight may be considered serious or less serious. An error can, for example, relate to a breach of flight security rules (always covered during the briefing), such as low altitude flight over a residential area; but it can also be a pilot's error that may endanger his/her or his/her teammate's aircraft and lead to an incident or accident. These are highly tense moments during debriefing, as the critique, usually severe and abrupt, is public. Finally, trainee pilots are under additional pressure, as they are evaluated by their trainer, who issues a formal progress report.

3.2.2. *Reflexive practices in debriefing sessions*

3.2.2.1. *Learning from errors, by experimentation and from others*

When asked "what are in your opinion the main objectives of briefing–debriefing?", all the personnel interviewed answered: to facilitate learning and individual progress on one hand, and to permit collective improvement, on the other hand.

Pilots are systematically evaluated by their colleagues and/or hierarchy (in the case of trainee pilots) and can be disciplined in case of failure (bad decision, breach of flight security procedures, etc.). As a fighter pilot states: "The main interest of debriefing is to improve. Debriefing provides the opportunity to analyze what was done effectively or ineffectively and to find solutions to what was perhaps done less effectively during flight, through dispassionate analysis of what happened, so that solutions are readily available next time". Each member of the navigating personnel agrees on this elementary function of debriefing and considers that error detection and correction are the best ways to progress and become successful.

While trainee pilots are particularly concerned, seniors are also interested in this process. They willingly admit that even the most experienced and talented pilots are no less exposed to error and may benefit from peers' comments and remarks. Several interviewees noted that critical examination of the actions during flight was the very essence of debriefing. One of them explained: "Debriefing focuses essentially on finding out what happened during mission. Precisely. Why? Because during flight things go too fast. One needs to trace back, almost like a historian, what has really happened and then understand why it happened that way in order to learn and eventually progress". This error detection and correction approach presupposes actors sharing a certain number of prerequisites, in particular: observing others' errors is an opportunity for self-correction and the presence of other colleagues during debriefing not only guarantees all the errors are spotted, but also permits us to envisage a complete panel of solutions/corrections.

Sharing these prerequisites facilitates the implementation of a constructive process, through which one's own practices improve due to others' critiques and comments. This learning from error process is based on daily experimentation. As one of the display teams' pilots states: "What we do is pure flight, and sensations are essential. In the case of a problem, you don't search a database to find the answer! Theoretical knowledge is good… but it has no value unless it is put into practice". The error correction approach, either for errors during flight or for those on the ground (for mechanics), is marked by the experiential nature of the knowledge it transmits. The display squadrons push this logic of experimentation to the extreme, bringing their bodies into it. As we have previously mentioned, pilots rehearse their flight before taking command of their aircraft. Keeping their eyes shut, they express with their hands and bodies the sequence of figures and aerobatic maneuvers they will present during the show. This "music" (for PAF) translates each of the technical gestures learned, criticized and learned once again during the debriefing sessions. It is also a moment of deep concentration that acts as a catalyst for emotions – such as stress – and permits the bodily and sensory preparation of the pilots for flight.

Debriefing also contributes to team progress. In effect, pilots and navigators insist that error detection/confrontation and the capacity to learn lessons at an individual level reflect on the group. Whether they are navigating personnel or not (for example, mechanics), the essential thing is that they participate in mission preparation and execution. A transport pilot explains: "The ultimate goal is to progress, get better. And I say get better in this impersonal manner because it concerns everyone, all the participants: controllers, pilots, navigators, crews, mechanics. All the actors involved in the mission have the same goal: progress. Debriefing should lead to individual or group learning so that next time the machine becomes even more successful. I use the term machine in the broad sense, as a complex system of all the individuals". Each mission is an opportunity to learn and experiment. As they agree to work in a constructive criticism mode, all personnel members approach debriefing as a multilevel learning process that contributes to the progress of the person both as an individual and as a member of a team. A fighter pilot insists: "Debriefing permits us to once again prepare to perform as we should next time. It is part of a whole process. So debriefing as such… We shouldn't take it out of context. We are working within this logic of success: we have to learn the lessons that will permit us to be successful, both as a group and as individuals. The lessons learnt during debriefing will strengthen both our global and individual knowledge. It is not an exercise in style, we are learning to be present at the right moment, when the day will come".

According to the personnel interviewed, this shared view on error as an opportunity for individual and collective learning relies on a principle that was institutionalized within the French Air Force: error is not punished. Since 2006, it has been officially enforced by the French Air Force Chief of Staff: "We should agree to systematically account for our errors, to comment on and inform our peers about all the near-miss incidents on the ground or during flight, all those events that 'nearly happened'. Our whole community should be able to take advantage, for learning purposes, of all our experiences, disagreeable as they may be" (source: French Ministry of Defense). Within this framework, pilots engage *a posteriori* in institutionalized learning practices, governed by the rules of transparency and error recognition.

3.2.2.2. *Artifacts for confronting one's errors and interacting with others*

The analysis of data highlights the role played by technologies. For example, the use of flight reconstruction systems by fighter squadrons permits pilots to be systematically and objectively confronted with reality: watching the flight recording helps them accurately represent the mission unfolding and the eventual failures. Other squadrons, such as the display teams, have a cameraman at their disposal who films each of the flights and then makes them available to the pilots: “Once he gets off his aircraft, the pilot can watch the recording of the entire flight. During the flight, I [another pilot from the team] am next to the cameraman and all the comments and critiques that I make are recorded. When the pilot finishes his flight, he listens to these comments, while watching the film. He scrutinizes his performance, notices his errors, but he needs to be equally aware of what he did well. He needs to understand why he was successful with that figure or why he failed it. He needs to be aware of his state of mind during those moments”. The facts are clear, transparency is the rule and each participant needs to be ready to accept full responsibility for his (or her) errors.

In this respect, technologies have to a certain extent revolutionized the briefing–debriefing procedures in as much as, before their introduction, some experienced pilots may have been inclined to underestimate the importance of their errors. A navigator from a transport squadron indicates: “In the past, it was very easy for a senior [pilot] to say that he had done this or that, that he was in the best position etc. And in the end, even though he may have had his doubts, the young trainee took the senior’s word as a reference, because he was the strongest, or at least he spoke the loudest. But the reconstruction system provided all those people with an opportunity to call themselves into question. And this is a good thing”. Allowing pilots and navigators to examine the objective flight data, flight reconstruction systems and films facilitate control and confront them with reality. As a fighter pilot explains, everyone, when confronted with his or her flight, needs to be able to precisely describe the problems he or she faced, to explain the reasons that led him or her to make the error and to derive from the incident the lessons for his or her next flight. The pilot states: “We all know, even those of us [who are] more experienced, that errors are nothing else but opportunities to learn. As far as I’m concerned, the moments that have most strongly marked my professional life were those when I made mistakes that I was sharply made aware of during debriefing, videotapes being there! I have not repeated those errors since then, and they marked me to the point where I still think about them”.

One of the French Air Forces display teams in 2012 implemented a camera device in the cockpit of its aircraft. It is usually directed toward the pilot’s legs and/or hands. The objective is to access how things are done in a situation. All the pilots are present during viewing so that they can observe technical errors, sources of problems (even incident/accident) during flight and good gesture and visual practices, which are sources of success. It is a group debriefing on one pilot's performance. As one of the pilots explains: "When watching these internal films, we notice the way in which he [the colleague] flies. For example, the visual circuit is very important in aerobatics, and often pilots do not know where to look. There is a delay in the visual circuit, which leads to the wrong activation of their movements, in a hasty manner. Having one or two seconds advance over their visual circuit would be enough for them to see the objective coming and to activate with more liveliness. With the internal camera, one can understand why anticipation is wrongly operated".

Video-based debriefing is deliberately directed toward team progression not only in technical terms, but also in collective terms. It is a matter of building synergy in the group, facilitating mutual learning through others' practices. One of the pilots interviewed insists: "Criticism may sometimes be heavy during the debriefing of the internal video, but we need to know how to encourage ourselves. Everything must be done in a constructive spirit. If this is not the case, then it's useless, the group is no good and the results are worthless". It is a matter of sharing know-how and being willing to ensure the team evolves as a whole. The pilot adds: "The group relies on a somewhat particular type of equilibrium: there is a very individualistic spirit of competition, and each of us wants to be the best. Then there is a team spirit, which is essential to survival in the squadron, in the team. It is in this sense that the [internal] video plays its role. It shows one's know-how and it helps communicate one's 'tricks' and continue to progress as a group. The dissemination of practices, ways to succeed in performing such and such figure, the errors to avoid… all these are balanced during the video debriefing".

3.2.2.3. *Adopting a critical stance*

The great majority of the interviewees think that debriefing sessions rely on and enhance personal qualities and attitudes. The most frequently named were modesty and calling oneself into question. Pilots and navigators define modesty as a capacity to admit one's errors and assume full responsibility: "Being alone in the aircraft is one thing, debriefing in front of the other pilots, peers, even in front of the squadron when there are concerns related to flight security is something else. It means assuming responsibility in front of everyone. One has to take responsibility. We need to debrief in order to progress and it is also a means to remain modest in one's work". As a pilot of one of the display teams notes, modesty is certainly a personal predisposition, but it can also be acquired during debriefings: "They say that the first year is the toughest, because we are effectively 'torn apart': there is a lot of criticism, but it is constructive, as the aim is to become aware of our errors and to progress. All this may sometimes be too intense because obviously not all our flights are perfect, far from it!".

Modesty is closely linked to calling oneself into question. A former leader of the PAF explains: "Debriefing is directly associated with self-analysis. It is crucial for a leader to be able to admit his errors and call himself into question. When I saw that for three flights in a row my inside right [first year in the Patrouille, evolving on the leader's right side] did not manage to execute such and such figure, I said to myself that I was to blame too, simply because I served as a point of reference to him! What did this mean? I needed to permanently call myself into question. Being a leader doesn't mean that you know everything. On the contrary, you discover quite a lot of things. Even when you have a certain background, real experience, you have to be able to analyze and call yourself into question". Debriefing sessions imply that navigating personnel is able to admit errors and to assume responsibility so that he or she avoids repeating them during future flights.

3.2.3. *Reflexive practices: a synthesis*

To coordinate in an extreme environment, teams need to be reflexive. This means that their members are able to question their actions and call themselves into question when faced with individual and collective errors committed during mission and project execution.

During dedicated sessions (such as debriefing for military teams), individuals examine what happens (or what happened), why it happens (or happened) and draw lessons in terms of individual progress, collective performance and evolution of their functioning modes. The learning cycle thus depends on the capacity of actors, teams and organizations to continuously advance in the execution of future projects, starting from the analysis of past experiences and errors (Table 3.2). The role of the organization should not be neglected: it is in a position to support and even to institutionalize, as in the above-mentioned case (error is not punished in the French Air Force), reflexive practices developed by the teams.

Learning	Starting from: one's own and others' errors, others' success and know-how, one's own and others' experiences
Technological and video artifacts uses	Confrontation with errors, critical and constructive discussions
Critical individual and collective stances	Modesty, calling into question, accountability

Table 3.2. *Reflexive practices*

3.3. Socialization practices

The third and last category of coordination practices developed by teams in the extreme environment relates to the socialization process. It is a noticeable fact that actors have a need to interact, exchange and more generally get to know and trust each other in order to be able to effectively manage the shift between unexpected and routine situations. In the French Air Force squadrons, such processes emerge and unfold mainly in a dedicated space: the squadron bar.

3.3.1. *The squadron bar: where common knowledge is built*

The squadron bar is intended to be a welcoming and friendly space (Figures 3.5(a) and (b)). It is often decorated with items that reflect squadron life: models, sketches and/or drawings of the main aircraft and its technical evolutions, books or magazines about the squadron, its history and news, squadron patches and other patches left by visiting pilots, photos of the teams in theaters of operations, during demonstrations or training, etc.

a) b)

Figure 3.5. *Example of a squadron bar in Cambrai, Air Base 103 Cambrai-Epinoy (source: www.aviation-illustree.forumactif.com)*

The squadron bar is often seen as an opportunity to socialize by the more senior personnel (pilots, navigators and mechanics), and as a means to integrate the professional community and the teams by the junior personnel. In the morning, during coffee time, or in the evening, after the missions, they freely discuss their day, the pressure they felt, the situations they have experienced and solutions they found to avoid or solve problems. These discussions frequently have a humorous tone: little mockeries, jokes and familiarities are the main carriers of the messages exchanged by team members. The atmosphere is relaxed, friendly. As a mechanic of the AFAT states: “We need to find opportunities to discuss in a more relaxed, less formal way [than during the debriefing sessions]. The squadron bar is essential as a friendly space for discussion and debriefing. We still discuss the mission, but differently, sharing experiences and taking a step back from what has just happened. It is an opportunity to know each other beyond our technical capacities and expertise, to better understand each other’s personality, attitudes. It is also an opportunity to build a team spirit”. The squadron bar is, therefore, a space where team members get together and discuss their recent experiences – things that happened during the latest performance and need to share with the others so that overall performance improves – as well as past experiences – individual or collective anecdotes that remind team members to avoid committing the same errors. The dynamics of the informal exchange of experiences generates results that are all the more interesting if all professions and specializations have access to these spaces. Team performance is the result of proper integration of knowledge and expertise brought by all team members. Group consensus results from the inclusion of various points of view, experiences and perspectives.

These discussions and exchanges of experiences contribute to the progressive building of a common knowledge stock that permits individuals to gain shared comprehension of the foundations and practices of the profession. A transport pilot explains: “I think that the squadron bar contributes to collecting knowledge, old stories, comments. There is a way of doing things. In aeronautics, even in the military, there is a global way. And this is so complex that one has only a vague idea at the beginning. So it is worth being at the bar and finding out what happened from people who were there. Who landed in such and such areas. One learns about the missiles, a way of doing things. A sense of break in order to land. There are no limits”.

The French Air Force personnel seek to develop common knowledge as they are aware that it is the basis of all collective work in unexpected situations. As a navigator notes: "There is however one *sine qua non* condition for effectiveness, especially when managing extreme cases; it is the mutual knowledge within crews". Mutual knowledge refers not only to reciprocal knowledge of team members, but also to tacit knowledge referring to the capacity of the team to manage the shift between routine and unforeseen situations. In order to develop this type of knowledge, personnel feels the need to get together and interact. A FAC notes: "Interpersonal skills are part of the profession. You must be curious to go and see the pilots, to know their procedures in order to be in line with what they are doing and effectively meet their needs".

3.3.2. *Cohesive activities that convey team values and build mutual trust*

These informal discussions at the squadron bar sustain a structured and democratic system based on which participants share and disseminate the team values and, in a broader sense, those of the squadron. These values are first acquired during the initial training, before assimilation in operational squadrons, and end up becoming second nature for the navigating personnel. In particular, they produce "facilitating" collective devices such as social control, mutual trust and cohesion. A fighter pilot notes: "The squadron bar also offers the opportunity to build trust. Someone may be a very good professional, but behave deplorably on the ground, not knowing how to behave though he feels in his place during flight… Such a person does not have what it takes to be a good pilot. This is where education and growth play their part. It is a whole. In its area of responsibility, debriefing means preparing coffee in the morning, knowing how to listen etc. It is professional and extra-professional progress".

Team values are also disseminated through traditions. The latter embody the feeling of being part of a squadron, while participating in building a unique team and advancing in the same direction. One pilot from PAF explains: "Cohesion is for me the keystone of collective synergy and trust. And traditions play an important role. The aim is to bring people together. And bring them to identify with those common values and principles. This is the role of traditions that were passed on to us by our elders. Traditions spice up the team spirit and consequently reinforce synergy. There are little traditions throughout the year. For example, the loop of eight jets [when the eight pilots of the PAF synchronize to perform a loop]: the first successful loop of eight is the moment when the three pilots having most recently joined the PAF receive their badge. In general, this is also the moment when they have their helmets painted".

In the squadrons, besides tradition-related entertainment, there are also other so-called "cohesive" activities. In this context, sports play a central role. Basketball and football matches, muscle-building sessions, trips to the mountains for skiing (for example, PAF annually organizes a week of skiing for its members) or hiking are all opportunities to get to know each other outside of the professional environment. The objective is to facilitate gradual building of trust among actors.

It is worth noting that in the extreme environment, where actors may be under high levels of tension and stress, mutual trust is essential: everyone's survival depends on everyone else's quality of work. There is no place for doubting others' competences, as all teammates need to fully focus on task execution and progress. One pilot notes: "Trust guarantees mutual protection". Another one goes even further, referring to collective performance: "With Captain X in charge, we will fly and be effective. What makes this result possible? The fact that we have known each other for quite some time. We have mutual knowledge and we trust each other". Mutual trust acts as a catalyst for emotions and stress within teams. This required trust develops and perpetuates partly through the texture of social relations built by the actors. The navigating personnel cultivate these relations. Aviation culture (for example, flying two-seat fighter jets such as Mirage 2000, or tactical transport aircraft with two-to-four-member crews) and the habits of living in a squadron are privileged ways for building and strengthening mutual trust. A navigator states: "Squadron is a tribe. Trust is part of our culture".

Moreover, when military teams leave for the theater of operations, they are most often already "constituted" meaning that they will always work together: team composition will not change during the mission. A pilot explains: "When we leave in constituted detachment, the patrols [two fighter jets] are made and the pair is never mixed". This contributes to building trust as everyone sets to know and appreciate the other's way of doing things, his or her reactivity, capacity to adapt and make decisions. For example, referring to the relations between FACs and Mirage 2000D crews in Afghanistan, a controller notes: “The fact that FACs are in the proximity of squadrons is essential. It helps them cover their aviation culture gaps. Moreover, crews have an opportunity to trust the FAC”.

3.3.3. *Socialization practices: a synthesis*

To be able to manage sudden shifts to unexpected situations, teams need to know and trust each other. To this end, they develop socialization practices of various natures (Table 3.3).

The illustrations show in particular the central role played by spaces dedicated to socialization. They are shelters where close relationships between the actors are gradually built, in an atmosphere of proximity and familiarity. Taking ownership of these spaces (for example, through arrangement and decoration) is part of the teams’ participation in building common knowledge and trust. Moreover, team values are disseminated through everyone’s involvement in cohesion activities, such as sports and other activities related to traditions and collective history.

Taking ownership of spaces	Dedicated spaces, decorations and arrangement, regular presence
Open discussions	Mockeries and jokes, “talk straight”, stories and exchanges of experiences
Commitment and perpetuation of team values	Individual and team sports, respect of traditions, team outings

Table 3.3. *Socialization practices*

3.4. Coordination in the extreme environment: articulation of communication, reflexive and socialization practices

In a rapidly changing context, where the probability of occurrence of an unforeseen event is strong and the risk to life is high, actors are in search of updated knowledge related to the specificity of their tasks within the team, on one hand, and the means to accomplish them, on the other hand. Opening new analysis perspectives, and complementing the more structural view of contingency theories, the practice-based approach offers elements enabling us to understand how teams cope with these challenges. By facilitating the examination of in-situation production of coordination, this approach permits the discovery of a set of practices and uses that the actors build and develop on a daily basis in order to stay successful when faced with unexpected situations.

The examination of military cases first permits us to highlight the role played by communication in coordination. The practices of common languages and innovative technological uses permit us to sort out pertinent from less pertinent information when in action. Being based on a set of code words, diagrams and modes of body expression, languages evoke many common references for the teams to rely on for comprehension and exchange. They translate modes of expression and automated reasoning that are shared by all the team members: a set of technical, identity-related (languages make sense within the team and more broadly within the professional community) and social (activated to manage actors' interactions) references. The combined uses of technologies made available to the actors in turn facilitate the adequacy between the technical capabilities offered by the tools and users' needs in the field. In this sense, communication practices permit individuals to save time they can dedicate to sense-making and finding solutions to more complex, because unexpected, problems. They also facilitate collective rooting by feeding the identity and social dimension of the group.

Reflexive practices represent ways to learn from individual and collective errors and calling into question common action patterns. These practices unfold in time: frequent iterations on team errors and successes encourage the adoption of a sustainable critical stance, which can even be institutionalized, as in the above-mentioned case of the French Air Force. More precisely, the calling into question of team modes of functioning and individual stances stimulates the emergence of long-lasting values at the group and organization level. In that respect, reflexive practices play a key role in coordination: on the one hand, they lead the actors to reflect on the approach of this and that situation, and on the sense they give to it; on the other hand, they direct them toward problem-solving methods that are based on calling into question, debate and seeking consensus.

Finally, socialization practices highlight the importance of human relations, cohesive activities and traditions for coordination in extreme environment. Proximity is essential to the extent that it allows the actors to assimilate and perpetuate team values. These aspects are closely linked to reflexive practices. In effect, the learning processes implemented by the actors, admitting one's errors and learning the lessons applicable on average/in the long term, may exert high social pressure. In this context, they are not viable unless the team has a constructive approach. It has nothing to do with accusing an individual, excluding him/her or neglecting collective responsibilities; on the contrary, it is about generating an internal dynamics capable of sustaining reflexive practices. From this perspective, spaces dedicated to connecting team members are a guarantee of successful integration of experiential knowledge into a common knowledge, and gradual building of mutual trust.

Team coordination in the extreme environment is based on the articulation of communication, reflexive and socialization practices (Figure 3.6). It is in this articulation that a team's capacity to manage frequent shifts between routine and unexpected situations resides: it facilitates the production of consensual interpretation of situations, by making and preserving sense.

These results contradict others that claim in particular that standardization and automation of communication practices are sufficient for coordination. It is in particular the case of professional works and norms that insist on the individuals' capacity to achieve a collective result on the basis of highly standardized actions/reactions. For example, the contributions of Hutchins [HUT 95], Hutchins and Klausen [HUT 96] and Hutchins and Palen [HUT 97] on crew coordination during flight on commercial airliners seek to demonstrate that an automated structure such as the cockpit "system" is in itself supporting coordination between pilots. Their interactions being highly standardized, pilots use highly predictable action patterns, multiple tasks being thus automated. According to the authors, these elements favor a level of interchangeability of crew members, who would have no need to know each other to be able to coordinate, the knowledge of the cockpit "system" functioning being sufficient [HUT 96].

While our field results confirm the standardized and automated nature of certain communication practices, they tend to invalidate the idea of interchangeability as applicable to coordination in the extreme environment. In such circumstances, teams are faced with unexpected situations whose causes are often exogenous to the "system" itself. They have to adapt in real time. The fact that they know and trust each other and that they are used to critical reasoning, calling into question their perceptions and problem-solving modes, allows them to save precious time to interpret the situation, give it sense and explore new solutions. The actors rely to the same extent on emotional and social bonds developed in time, as on the formal framework within which activities are carried out and on "system"-distributed knowledge. Could it be that the crew of Rio–Paris flight lacked this dimension? The question is open to debate.

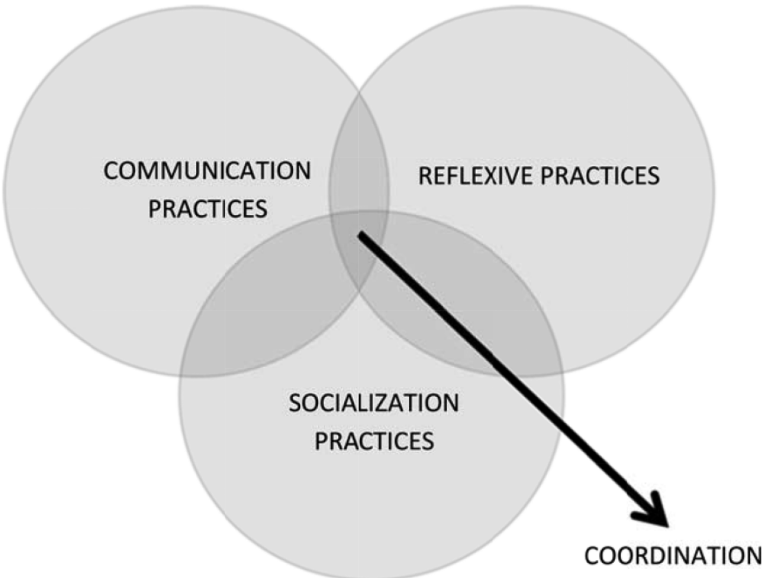

Figure 3.6. *Articulation of team coordination practices in the extreme environment*

Team coordination in the extreme environment thus requires the implementation of conditions that contribute to the building and sustaining of three categories of coordination practices and their articulation. Chapter 4 examines the following question: what managerial conditions should be provided to support team coordination? How can decision-makers be guided in adopting directions and making managerial choices?

4

Can Coordination in Extreme Environments be Learned? A Managerial Approach

Adopting a practical approach in order to analyze team coordination in extreme environments opens up promising research. It offers the chance to discover the "implicit" side of the phenomenon, by examining the players' actions under the pressure of the changes, uncertainties and risks they are exposed to. Furthermore, viewing team coordination as a set of practices emerging *in situ* makes it a phenomenon, which is, in principle, difficult to implement. Coordination is thus no longer predetermined; it is shaped during action, in the continuous construction of the players' practices and ways.

Under these circumstances, adopting a practical approach to understand the coordination as it is "being made" involves thinking about its implementation differently. It leads to the search for answers to the two following questions: can coordination in extreme environments be learned? And what roles can the managers play in order to guide and support their teams in the development of their coordination?

The different case studies presented here describe an emerging coordination, closely tied to the players and their context: team coordination results from a process of experimentation, which makes sense through the players' past and present actions.

Team Coordination in Extreme Environments: *Work Practices and Technological Uses under Uncertainty,* First Edition. Cécile Godé.

For this reason, the knowledge and expertise that the team and its members possess, the way in which they utilize and circulate them and the part the organization plays in encouraging these approaches stand out as interesting entry points for conceiving the managerial action.

Thus, it is not simply a question of tackling the research of the operational and managerial dimension in terms of hierarchically-imposed directives; it involves further identifying what Orlikowski defines as enabling conditions [ORL 02], which are likely to support and sustain the development of coordination in extreme environments. The manager in this case plays the role of a facilitator for the collective action, which involves a firm understanding on his part of field practices developed by the players.

This final chapter examines first the knowledge and skills that teams develop in order to coordinate themselves in extreme environments. It continues by proposing managerial avenues and methods aiming to encourage its acquisition: putting in place an immediate feedback system, encouraging the emergence of professional communities and exploiting the benefits of decision support systems (DSS).

4.1. Necessary individual and collective skills for coordination in an extreme environment

How do teams manage to build and rebuild meaning, to decide and act collectively, even though they regularly question the relevance of their own guidelines in handling the switch between routine and unexpected situations? What are the knowledge and skills they exploit in order to coordinate themselves in extreme environments? This questioning helps first in identifying the skills developed by the teams when they develop coordination in extreme environments.

4.1.1. *From theoretical to practical knowledge: practices, knowledge and skills*

The practical approach fosters a deep interest in how we develop knowledge and its emergence: it is at the heart of a number of works based on this approach (for example, [GHE 99, ORL 02, GHE 06, TSO 01, TSO 05, YAN 09]). It offers a substantially different understanding, however, of the knowledge put forward in a number of now classic contributions known as knowledge management.

McInerney and Day [MCI 07] distinguish between the two schools of thought when talking about knowledge as an artifact on the one hand, and knowledge as a process on the other hand. The former refers to the classic knowledge management literature. The key contributions by Nonaka [NON 94], Nonaka and Takeuchi [NON 95] and Nonaka *et al*. [NON 08] structure this research stream by focusing on the organizational aspect of knowledge and the importance of modeling the dynamics of knowledge creation.

For example, the socialization, externalization, combination, internalization (SECI) model demonstrates that knowledge is progressively created from the combination of implicit and explicit knowledge. As specified by the authors, the creation of knowledge rests on the interaction between implicit and explicit knowledge through a continuous back-and-forth movement between objective and subjective [NON 08]. McInerney and Day [MCI 07] refer to knowledge as an artifact to the extent where knowledge is approached as a resource needing to be managed. Models and tools are developed in order to create, obtain, diffuse and transform it. Gherardi [GHE 99] talks about "learning in the face of problems": when faced with an anticipated and clearly-defined problem, the teams create new knowledge tailored to answer the problem. Knowledge is seen as a resource in the service of the process of problem-solving.

The second point introduced by McInerney and Day [MCI 07] is that of knowledge as a process. It focuses on describing the process of the creation of knowledge, more than that of knowledge objects and their use in an organization. In opposition to this first approach, Gherardi talks about "learning in the face of mystery" [GHE 99]. Evolving in an uncertain environment, the organizations, and the teams that comprise them, form part of a constant approach to preparing and anticipating unforeseen and future problems. Knowledge cannot and must not be spread in a predetermined direction; it contributes daily to the collective abilities to adapt and solve problem: "Knowledge is both social and material. It is always unstable and precarious, located in time and space (local knowledge), embedded in practices and dis-embedded (theoretical knowledge)" [GHE 99].

As a process, knowledge must be created in the act; it is closely connected to the actors' concrete daily practices.

Orlikowski [ORL 02] supports the idea of the inseparability between knowledge and practice, favoring the term "knowing" to "knowledge": it is a question of emphasizing that knowledge implies the actors' commitment to action. As outlined by Schön [SCH 93], "our knowing is in our action".

In this respect, the practices and technological applications refer both to the "knowing", and to the ability to put this knowing into action, as skills. "Intrinsically connected to 'doing'" [JAR 07] and to the actors' "ways of doing", the practices refer to the question of the implementation of knowledge in any situation. Adopting a practical approach in order to analyze coordination in extreme environments thus raises the question of the obtainment of individual and collective knowledge necessary to manage the switch between routine and unexpected situations.

4.1.2. *Skills needed for coordination in extreme environments: the example of tactical airlifter crews*

The following case study is taken from an applied study to the benefit of the staff of the French Air Force [BAR 10a, BAR 10b]. It primarily allowed the examination of the individual and collective skills developed by the crew in order to coordinate with each other in extreme environments. In the following, we focus on the Transall C-160 crews, which is one of the most famous tactical transportation aircraft in the French Air Force.

4.1.2.1. *Tactical transportation missions and crew*

The collective aspect of the transportation professions is crucial to the fulfillment of the different types of missions that are carried out. The crew members refer to a crew "synergy": every member possesses specific skills, all the while sharing a common language, common knowledge and common values. The transportation crew thus capitalizes on the individuals' technical and human skills and expertise, while developing a collective skill set (the "synergy", which is highly valued by the crew).

The missions they accomplish directly condition the nature and diversity of the Transall flight crews' skills. These can be of essentially two different types, and can be accomplished during the same trip:

– *Logistical missions* concern the transportation of materials or men to and from sites where risk is insignificant. The preparation of logistical missions is linked to the optimization of the load (freight or staff) relative to the airlift's capacity and to the traveling distance. It is a question of seeking a balance between the fuel charge, the airlift's load capacity, the traveling distance, the mission's duration, the aviation regulations and the load's composition standards.

– *Tactical missions* are based primarily on the crew's ability to handle the unexpected. They concern the transportation of materials or men to and from hostile sites. The flight profile's creation is an important part of any tactical mission's preparation, and is determined by the risks involved (ground-to-air and air-to-air). Tactical missions are at the heart of the C160 Transall flight crews' career.

A Transall aircraft's crew consists of four individuals, each possessing areas of expertise in a particular area of specialty (Figure 4.1).

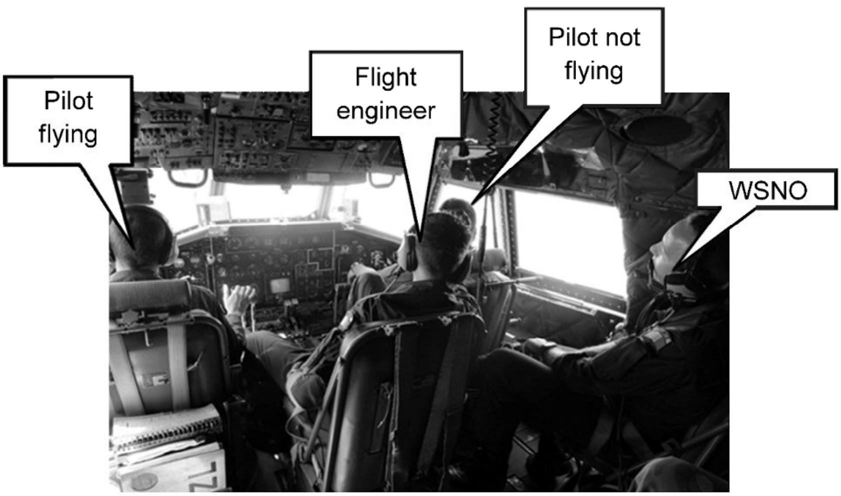

Figure 4.1. *Crew on a Transall C-160 type aircraft (source: www.defense.gouv.fr)*

The crew is made up of two pilots, one weapons system navigational officer (WSNO) specializing in navigation and the use of the defensive aid system (both of which are fundamental tasks during the tactical stages of the mission) and other a flight engineer specializing in the mechanics of the aircraft.

The four crew members complement each other with respect to the tasks that need to be carried out and the manner in which they apprehend events, particularly in temporal terms (the pilots focusing mainly on the short term and the navigational officer more on the mid and long term). The crew's work, therefore, rests on a combination of skills' both specialized and shared, distributed collaboratively. Transportation missions require good management of the interdependencies between each member's area of specialty and a good coordination of each of their action and responsibility areas.

4.1.2.2. *Transportation crews' individual skills: technical, relational and situational*

What is the nature and quality of the knowledge and skills developed by crews in their continuous search for coordination? The observation of the practices of coordination in real situations (that is during real flights) and a number of interviews with navigational personnel have allowed us to distinguish three different categories of individual skills [BAR 10b] held by each member of the Air Force's Transall transportation crews (Table 4.1).

	Technical skills Expertise relating to embedded systems and the aircraft's use	**Relational skills** Expertise in relating with other crew members	**Situational skills** Expertise in adapting and deciding in an operational environment (knowing what to do)
Pilot flying – left side	Piloting Mastery of the standardized language (actions check-lists) Mastery of crew communication (code words, actions check-lists)	Knowing how to be autonomous, while integrating oneself into the crew and team work	Taking initiatives – being a source of proposals

Navigational engineer	Operating the aircraft: a very fine understanding of the aircraft's mechanics and machine management Detecting and managing in-flight failures Knowing how to devise a mechanical review Check-lists' mastery	Orienting the work of the engineers on the ground Managing the relationships with engineers on the ground Being the intermediary between the cockpit and the hold mechanic Acting as technical advisor to the aircraft commander	Taking a critical approach to the situation: detachment from the piloting tasks and the weapons system management – technical and mechanical detachment Knowing how to detect problems and propose/discuss a solution (technical advisor to the aircraft commander)
Pilot not flying – right side	Managing radio communication Knowledge of entering air traffic Mastery of the standardized language (actions check-lists) Mastery of crew communication (code words, actions check-lists)	Sharing his experience with the pilot flying and the rest of the crew Participating in team dialogue	Taking a critical approach to the situation: detachment from the piloting tasks – developing a big picture view Offering the aircraft commander alternatives
Weapons System Navigational Officer (WSNO)	Navigation management (for example: regulation knowledge, ability to work with maps) Weapons system management (for example: defensive aid system) Threat management Mastery the standardized language (actions check-lists)	Interacting with the flying pilot, mainly articulating short- and mid-term actions during flight (for example: reminding the pilot of the mission's tempo, objectives and its progress in the mid- to long-term)	Choosing and applying tactics adapted for the context of the action Knowing to anticipate (time management) Taking a critical approach to the situation, detachment from the piloting tasks

`	Mastery of crew communication (code words, actions check-lists)	Participating in team dialogue	Offering the aircraft commander alternatives
Aircraft commander (pilot not flying or WSNO)	Managing the mission's technical and logistical aspects (preparation and conduct) Managing the mission on a broad plan Coordinating the "client's" needs according to the aircraft's technical capacities	Knowing how to create, nurture and restore the crew's synergy and mutual trust Managing stress within the crew – knowing how to manage concerns and stress Showing empathy Ability to take decisions Ability to delegate efficiently Leadership: ability to secure his or her team's support – commanding respect Hearing and taking criticism into account Knowing how to work with joint task forces as well as internationally	Taking a critical approach to unforeseen situations Ability to take a final decision relating to the necessary action(s) Knowing how to cope and find a solution – adapting to the action Adapting to different military and/or national cultures

Table 4.1. *Classification of individual coordination skills for members of a Transall C-160 crew*

The technical, relational and situational skills rest on solid knowledge. They are acquired and perfected through experience, from a process of learning through action, interaction (learning through "doing") and by trial and error. Beyond its military application, this classification can be thought of in the following way:

– First, the players develop "technical" skills. These relate to a "know-how" specific to an area of expertise and the use of resources and technologies for said area. They constitute the core of the activity. The knowledge of rules, procedures and action–reaction sequences (behaviors) that frame the activities represents, for instance, the necessary technical skills leading to the good coordination of activities and men. The actors appropriate these skills and internalize them throughout their experiences. They become automatisms, allowing them to efficiently manage routine situations and save time, which will then be used for other urgent tasks during unforeseen situations.

– Subsequently, the relational skills [PER 02] or *savoir-être*, appear as key. They are articulated through the management of social interactions and the actors' ability to integrate the others' needs and demands relating to the decision process. In this respect, relational skills are linked to the individual's emotional and social skills [RIG 07]. The former enable the management of emotionalism and stress related to unexpected situations. In particular, they enable the management of body language, of knowing how to send (encode) non-verbal messages, as well as receive them (decode). As for the latter, social skills are mainly directed toward the individuals' ability to communicate verbally with others, to relate a situation (sequence, respect the order of events and give it meaning) in a suitable way in the eyes of the interlocutor.

It is also a question of knowing how to listen to others and encouraging discussion. Relational skills, therefore, appeal to the crew members' social intelligence, their knowledge of social conventions and their ability to build relationships based on trust.

– Finally, favoring adaptation during action, situational skills or "knowing what to do" (or "*savoir quoi faire*") translate an individual's ability to adapt to the demands and constraints of the environment in order to make appropriate decisions.

They refer to managing the switch between routine and unexpected situations, resting primarily on the actor's ability to analyze information, interpret the situation, managing ambiguity and quickly finding solutions to apply to a situation which has upset the initial plans as a whole. This type of skill refers to the understanding of the action's context and logic, to intuition and common sense. Situational skills also refer to the crew members' reflexive skills [COL 06, TSO 05, YAN 09], that is their ability to think about their actions retrospectively (taking a step back) in order for the elements of the action that have not yet been uncovered to emerge and adapt, and evolve their behavior accordingly. In this respect, reflexive skills are the foundation for the practices bearing the same name that crews develop during debriefing sessions (as seen in Chapter 3).

In extreme environments, the actors' ability to coordinate themselves rests on a sequence of know-how, *savoir-être* and knowing what to do, that they weigh in relation to the management of situations they must face and the aims they pursue.

For instance, in the case of the coordination between fighter pilots and Special Forces in Afghanistan, described in the Chapters 1 and 3, the procedures, standard modes of communication (code words) and other automatisms acquire a key significance when crews manage routine situations. These coordination elements are principally exploited – acted upon – from technical know-how internalized by the actors during their training and operational experience. When an unforeseen situation arises, frequently provoking surprise and necessitating an adjustment to usual baselines, the *savoir-faire* becomes background to social skills and knowing what to do.

The actors communicate in order to give meaning to the new situation that they are experiencing: they talk about what they are going through, debate and agree on a solution in order to coordinate themselves. By doing so, they rely on their relational skills, in order to be as critical and open in the discussion as possible, and about their "*savoir quoi faire*": what decision to take? How to achieve the objectives when the initial plans are no longer adapted to them? What analogies can they make with previous experiences?

The team mates also employ their technical, relational and situational skills when interacting with technology, revealing uses that were not initially conceptualized by the maker. The case of text-chat, used by NATO military teams in Afghanistan (as seen in Chapter 3), can be seen in terms of skills. Indeed, the virtuous effects associated with combinatory uses can only be fully effective if the players are capable of engaging in multiple opportunities for vertical/horizontal and individual/collective communication. In this context, the users' technical skills, namely their mastery of the system's properties, are insufficient. They must know how to communicate with the teams scattered around the mission area, as well as knowing how to best exploit the information they have gathered in order to make the relevant decisions.

4.1.2.3. *Collective skills and intelligence in tactical transportation crews*

Technical, relational and situational skills are only fully developed within a collective: the coordination within the teams in extreme environments rests on a prominently collective aspect, which cannot be reduced to the simple combination of individual skills.

Collective skills can be defined as the "set of the participants' individual skills in addition to an indefinable component, specific to the group, stemming from its own synergy and dynamics" [DEJ 98]. Representing certain "shared and complementary knowledge and implicit *savoir-faire* (...) that participate in a collective's repeated and accepted ability to produce common results or co-construct solutions" [MIC 05], the collective skills provide teams with a greater capacity to solve problems that they would not be able to treat individually [WIT 00]. They are, by nature, established, namely tied to a context and anchored within a collective. Thus, if collective skills do not exist without individual skills, the former transcend the latter and participate in the team's performance [RET 09]. The notion of collective skills poses the question of a recursive relationship between the individual and the collective inside the learning loop, as well as that of social (relational, cultural, social identification, etc.), cognitive [RET 05] and sensory processes implemented during their development.

Furthermore, the extreme nature of the environment puts the collective at the heart of the coordination, highlighting the crucial role played by synergy and mutual trust specific to the team and essential for suitable decision-making. The ability to solve a problem and coordinate actions in a diffused work environment calls for a minimal versatility on the part of the team's members. This versatility favors the self-control of actions undertaken by others (pledge of security) and calls for a certain number of shared operational models and common values.

With the Transall C-160 experts, the crew's composition and the distribution of skills within the crew play an essential role in coordination [BAR 10b]. These two aspects touch upon the determining factors of collective skills development. Furthermore, a crew's collective skills involve a multicultural aspect that is all at once interdepartmental, international and interarmy. The ability to work with other armies and other organizations (for example, non-governmental organizations), or even with other countries, constitutes a skill in its own right. Finally, the collective skills that emerge from the complementarity and synergy of individual knowledge distributed within the crew involve the implementation of appropriate methods and processes and are notably different from individual-learning methods. The crew members receive a common theoretical and practical education that allows them to develop a shared knowledge. They also belong to squadrons marked by common work values and traditions that transcend the individual aspects in order to cultivate the "collective meaning" and synergy. This common knowledge base is considered to be a prerequisite for crew work, as outlined when interviewing the members that comprise it.

Individual and collective skills therefore allow the teams to coordinate with each other in extreme environments: they acquire the technical, relational and situational *savoir faire*, as well as the essential component the Air Force teams refer to as "synergy", that collective skill that allows them to work together, in the same direction. The management of the sudden switches between routine and unexpected situations is determined by the teams' ability to distribute individual skills, and to then exploit them "together", in order to find solutions and take the decisions best suited to the events at hand.

The question of the notion of skills operationalization, mainly the notion of collective skills, thus comes forward: how can the manager, and, more generally, the organization act? What conditions can managers implement in order to favor the acquisition of individual and collective skills necessary to coordination in extreme environments? How to encourage the team members to get involved in collaborative work?

Such a questioning points us back to the questions raised by the collective intelligence literature (for example, [ZAR 06, OLF 07, LEN 09]). Collective intelligence represents a tool that allows the development of emulation, adaptability and creativity within a team, in order to guarantee the implementation of its decisions [ZAR 06]. The following sections will describe three avenues for managerial action, aiming to generate and sustain this so-called collective intelligence within the teams: the first two (feedback and professional community) have an impact on the process of learning and the creation of collective knowledge, and the third avenue examines the effect of information systems and the technologies that comprise them (DSS) on the teams' creativity and adaptability.

4.2. Setting up a process of "immediate" feedback: the case of the Air Force's Aerobatic Team

The process of feedback consists of "using the development of a real event as an opportunity to collect the individual experience of various players and gather it in the form of a collective experience. [It...] must allow us to capture the representation of the situations' dynamics in order to better understand past accidents and encourage the sharing of the acquired experience" [WYB 01]. This definition places an emphasis on the two consecutive stages when approaching the process of feedback: it is first necessary to identify the "real event" from which the players will then manage to construct a collective experience. The event is generally an incident or accident (or even a major catastrophe), which significantly disrupted the normal functioning of the organization. The teams can thus learn from the multitude of methodologies and existing feedback processes, describing the process of experience collection and analysis. Frequently elaborated from the perspective of technical and quantitative engineer sciences, they lead organizations to implement new rules and operating procedures in order to avoid the accident from ever repeating itself. Despite the effects of inertia often associated with the different structures involved in the analysis of experience, this first stage seems to be well controlled by teams nowadays.

The second stage concerns the capitalization on and sharing of individual experience in order to favor its distribution at the work collective level. It rests largely upon qualitative approaches, looking to integrate human and organizational aspects in the management of accidents inside the learning loop. In most cases, however, the teams, prompted by the organization, limit themselves to simply creating a database aiming to codify and capitalize on their experiences in order to then support the decision-making process. Despite this, the "codifying everything" approach is often poorly suited to the experiential nature of the knowledge gathered, in the sense that the actors then do not have access to its procedural and contextual dimensions [BES 98, GRI 06]. A subpar use of this type of tool is often observed, as the gathered knowledge rapidly becomes obsolete.

In this context, the appropriation of individual experiences by the collective is, if not nonexistent, at the very least insufficient to produce a "dynamic representation of the situations" and develop the collective experience and intelligence referred to by Wybo and his co-authors in their definition [WYB 01].

This limitation can seemingly be exceeded if the second stage of the feedback process is tackled not as a simple capitalization on experience but as an opportunity to develop the necessary collective skills for coordination in extreme environments.

The feedback process thus becomes a tool in the service of the teams: it encourages collective intelligence while acting upon the communication, reflexive and socialization practices.

4.2.1. *"Immediate" feedback processes within the Air Force's Aerobatic Team*

In the last 15 years, a growing number of authors (for example, [BAI 99, DAR 05, RON 06, VAS 07, BRO 09, MEL 11, GOD 12a]) have taken an interest in a particular form of feedback, anchored in a short (right after the action), or even very short (during action) time-frame: the so-called "immediate" or short-loop feedback process.

4.2.1.1. *The "immediate" feedback process*

The "immediate" feedback process can be defined as the systematic and repeated evaluation of the actions that contribute (or have contributed) to the completion of a collaborative project, as well as that of the team members' observations and interpretations.

From formal and informal discussions, the team members are encouraged to discover independently what is happening (or what has happened), why it is happening (or has happened) and to see what lessons can be learned in terms of individual progress and collective performance.

The "immediate" feedback process, occurring during or right after the action, helps the actors reconstruct the live situations step by step, be they routine or unforeseen, as well as the management modes that were applied to them. They can thus easily identify the individual and/or collective mistakes that were made, discuss the different options they could have chosen, focus on the lessons learned and implement them during the next stage. The learning loop, therefore, rests on the ability to learn together, during and from the action. It feeds the collective skills and helps teams progress in the completion of their missions by revealing complementarities and synergies taken from the analysis of errors [RON 06].

The military environment is familiar with the short-loop feedback process. Indeed, armed forces have been practicing it for decades, only considering the mission finished once it has been debriefed. This is indeed the case of the Air Force's Aerobatic Team, on which we will now focus.

4.2.1.2. *Air Force's Aerobatic Team: who is it?*

The AFAT is located on air base 701 in Salon-de-Provence, France. It consists of six pilots, six mechanics, two operations agents and two cameramen. Apart from the fact that the pilots benefited from aerobatic flights during their initial training, every team member has a background in fighter aviation and has solid operational experience from his or her original career. Nowadays, the team consists of newly-arrived pilots, possessing experience in national and/or international aerobatic flight competitions, as well as older pilots, who have earned their experience throughout the years spent in the AFAT. The aircraft commander is one of the six pilots. The rest are likely to take over "supplementary" activities (for example, external communication and events planning), undertaking these in addition to their piloting tasks. Working closely with the pilots, the mechanics' responsibilities include the implementation and maintenance of the AFAT's three Extra 300 aircraft.

As briefly mentioned in Chapter 3, the Aerobatic Team must carry out two missions. First, it intervenes in military and civilian aerial meetings. The meetings mainly take place during the summer season, the winter season being set aside for training. The meetings allow the general public to be introduced to the field of aerobatic flight and to convey a positive image of the French Air Force. As explained by a pilot: “During an aerial meeting, we are putting on a show. We need to act as artists, trying to arouse emotions”. Moreover, the excellent quality of the maneuvers being presented guarantees to leave a good impression, which then benefits the aerobatic flight community at large. These performances, therefore, involve the team as an entity, each flight crystallizing a collective know-how.

The AFAT also participates in national and international competitions. In the last few years, the team has achieved the best possible results. It has in fact won the gold medal in the Unlimited World Championships (the highest category) in 2009, 2013 and 2015. In the individual categories, the first place was also awarded to AFAT pilots. The results for the 2010 and 2014 European Championships confirm once again the high level of excellence, as the team won a gold medal. During the competitions, the pilots execute mandatory programs (known to the pilots, made available to them several months before the competitions, and unknown, where the requested maneuvers are unveiled a few hours before the flight) and freestyle, judged by a panel of 10 judges. The different programs are executed in a space of 1 km^3 called the box, and symbolized on the ground by marks (Figure 4.2). The judges rate the execution of maneuvers and sequences with marks out of 10, the applied coefficients being directly correlated to the proposed level of difficulty. The pilot’s ability to develop inside his box (without leaving its limits and respecting the flight safety regulations) is also rated. The competition is also marked by individual dynamics, as pointed out by a pilot: “Aerobatics is an individual sport. People are not selected for their ability to be nice, but for their competitor skills. That means everyone is fighting for the top spot”. The selection and training of military pilots is carried out by the federal trainer, under the authority of the French Aeronautical Federation’s National Technical Director (the AFAT’s aircraft commander also participates in the pilot’s selection). The federal trainer himself is a former military and world champion.

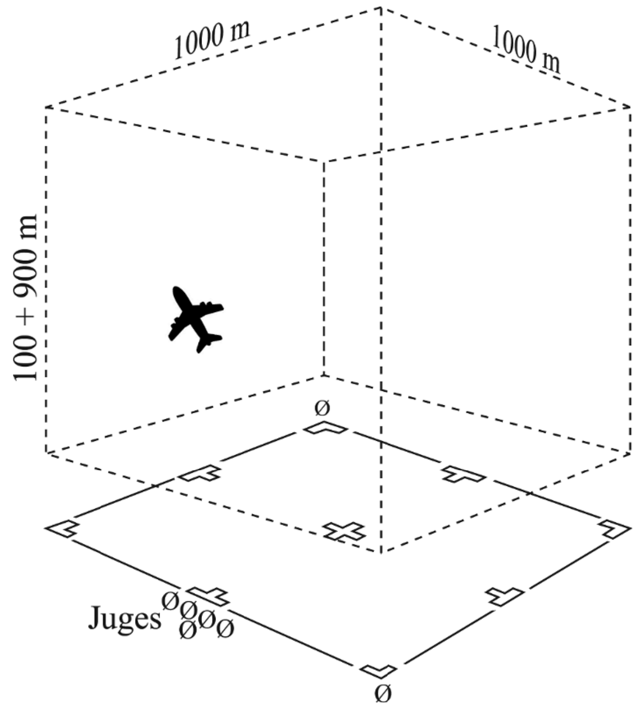

Figure 4.2. *Aerobatic team member's competition space: the "box" (source: www.equipedevoltige.org)*

Good coordination within the AFAT rests on its members' ability to collectively generate meaning from the two types of missions they must carry out. As pointed out by Alsène and Pichault [ALS 07], this collective construction (the authors refer to this as the search for coherence) highlights both the importance of the orchestration of activities (organizing resources and individual efforts) and their harmonization (each team member shares the same representation of his environment and agrees on the means necessary to accomplish the objective). At the AFAT's level, it becomes a question of managing the logistical aspects of the presentation and competition activities (personnel allocation, aircraft availability, pilots' and mechanics' workload management, time schedule planning, etc.) and a question of integrating its members' knowledge and skills so that each one develops in the same direction and contributes to the excellence of meetings and competition results.

4.2.1.3. *"Immediate" feedback in order to build and cement the collective*

When answering the question: "What does the feedback process naturally mean for you?", the AFAT's members being interviewed all converge toward the same answer: the transfer of *savoir-être* and "*savoir quoi faire*" (knowing what to do). A pilot states: "We do not talk about theoretical knowledge here. We discuss sensations, 'steering buttocks' as we're used to saying". Another specifies: "This is pure piloting, where sensations are essential. For instance, if you want to know where to put your foot to trigger a figure, you won't find the answer in a database! Theoretical knowledge is good, but has no value if it is not put into practice".

Marked by the experiential nature of the knowledge it can transmit, the feedback process in the AFAT rests on specific practices. First, the transfer of knowledge is mainly accomplished from informal discussions and dialogues, one-to-one and as a group: "You cannot find experience in a textbook, it is transmitted orally and it is lived". These exchanges involve the pilot and the trainer in all the competition flights, the pilots and mechanics when it concerns flight meetings. A pilot explains: "The feedback process is mainly word-of-mouth amongst ourselves. I sincerely think the most efficient feedback process is done between men. Paper, video,... those only represent tools that allow for only a partial transmission of the knowledge we acquire year after year".

The feedback process's "oral tradition" is made possible first due to the use of common languages, as previously discussed. Whether it be the Aresti code (diagrammatic transcription of aerobatic maneuvers) or body language or expressions, these shared languages, far from hindering informal discussion between members, facilitate it by allowing them to get straight to the point without needing long introductory descriptions. A pilot states: "Within the team we all talk the same language, certainly because we share aerobatic's language and knowledge (military and civilian). I believe that is the reason why giving feedback is done naturally and quickly between members".

It also appears that the sharing spaces, such as the squadron bar, favor this informal feedback process more than others. The AFAT members meet there in order to continue sharing their experiences, recent or otherwise. A mechanic recounts: “We always meet here in the same space, in the morning or in the evening. And a lot of things are said in the café. For example, when we come back from a meeting, us mechanics who have gone with the pilots start talking to the other ones (the ones that stayed) in an informal way: you need to use this setting for this pilot in order to avoid aggravating his tendonitis, etc.”. Pilots, mechanics and administrative personnel know they will meet daily at the squadron bar and take advantage of the opportunity to chat. The mechanic continues: “In the squadron break room, a lot of problems are solved. It allows us to communicate with the right people, while discussing with them. Which is why having spaces where people meet and communicate freely is essential!”.

The feedback process within the AFAT is particularly “immediate”. One of the interviewed pilots explains: “The transmission is fairly immediate. We perform short flights, of about 15 min, and give feedback either during or right after the flight.” In the first instance, a second aerobat (either one of the pilots or the trainer), located in a central position, that is a place where he will have a good field of vision of the maneuver taking place. A cameraman routinely accompanies him in order to film the flight. The person in the central position has radio contact with the flying pilot, and is thus able to offer his comments (and criticism) as it happens.

Another pilot explains: “Aerobatic pilots need to hear their trainer’s voice punctuating the maneuvers, severely criticizing what they are doing, all in real time. It allows us to immediately put the feedback into practice, to repeat the maneuvers, over and over...”.

The person in central position can also record his comments as voice-over, which will accompany the flight’s video. This is the second type of immediate feedback: right after landing, the pilot enters a small projection room where he inspects his flight along with his colleagues. As made clear by the trainer, the pilot is no longer in the action phase, he is in a reflexivity phase: “I record my comments as a voice-over, which the pilot will only hear once the flight has finished and is watching the video of his flight. He will scrutinize his performance, observing any errors he will have made, as well as recognizing what he has done right. Why he succeeded this maneuver and why he failed that one are answers he must obtain, with my help or that of a colleague if necessary. He must take a step back in order to apprehend his state of mind during the flight's key moments; he must learn to know himself in order to progress. It involves self-criticism and the acceptance of the others' (constructive!) criticism".

These informal and "immediate" feedback processes constitute a key source of cohesion within a team, torn between its objective of demonstrating a collective *savoir-faire* during meetings, and collective and individual results during competitions. Under these circumstances, it is in the interest of the pilots to invest in the feedback process, in order to benefit, and have others benefit, from their own knowledge in order to progress. However, the competitions are naturally marked by more individual dynamics: "People are not selected for their ability to be nice, but for their competitor skills. That means everyone is fighting for the top spot. Even if nowadays we are world champions in the team rankings, we all focus on individual rankings. The team rankings are a consequence of our individual know-how, not an end in itself".

Military pilots are now among the best aerobat in the world and directly compete against each other. They could consequently perceive the feedback process as a potential danger, as it encourages the spreading of knowledge that is crucial in order to win. One of the pilots rejects this idea: "A flying pilot who keeps all the information for himself, that could be conceived if he is in the running for first place. In my case, I am currently in the leading position, and of course I feel threatened! It is an unstable balance. But withholding information, hiding stuff... That's not how we want to win. I want to keep giving and receiving feedback". In consequence, beyond just a process of knowledge transmission, the feedback process is seen as a way of raising the contestants' level, a source of emulation and a way of always facing people better than themselves.

Thus, between meetings and competitions, the members of the aerobatic team constantly alternate between collaborative and near competitive interactions. The coexistence of supposedly opposite attitudes seems to be made possible due to the experience of giving and receiving feedback. Indeed, the practice of sharing experiences evokes a process of intermediation, a sort of bridge between the competitor attitude on one hand and the presenter on the other hand: "The collective is actually built around a quite unusual balance: the competitive spirit, very individualistic, that leads us to want to defeat everyone. Then there is the team spirit, which is essential to the survival of the AFAT, which must show its know-how and communicate in order to continue to exist. By broadcasting the videos of the flights, the way in which we succeeded this or that maneuver, the mistakes to avoid, the feedback process helps us measure all that out" (from an interview).

Furthermore, by facilitating social interactions, the feedback process creates cohesion, bonds a team. One of the pilots explains: "The feedback process plays a part in the team's cohesion. First because we see the way in which others work, their level of expertise, and that builds confidence. Also, because it allows us to get to know the others beyond their technical abilities and expertise. The feedback process allows us to approach them differently, better understand their personality, their attitudes".

The trainer explains: "The human environment is paramount and the team is interesting when the members get along and complement each other. Members must be united and they build this cohesion mainly by sharing their professional experiences. For example the pilots meet often to watch their colleagues' videos. This is a group debriefing of an individual's performance. Sometimes the criticism is harsh, but they must also know how to encourage themselves. Everything must be done in a constructive spirit. It is pointless otherwise, the collective will be poor and so will the results".

4.2.2. *"Immediate" feedback: a method of collective skills and intelligence acquisition*

The "immediate" feedback process provides the collective with skills to act, coordinate and adapt articulation in extreme environments. It represents a mode of managerial action allowing articulation of the practices of coordination identified and described in Chapter 3.

First, based on eminently reflexive practices and processes, "immediate" feedback nurtures the collective's ability to criticize the way it functions, create a consensual interpretation of a situation and maintain meaning. Throughout the confrontation of individual representations and the sharing of singular experiences, the team members progressively devise a "common baseline" [RET 05], which they refer to in order to achieve their missions: they agree on what should be done in order to accomplish their objectives and implement the required measures. Their conflicting viewpoints and constructive criticism significantly contribute to good coordination within the teams.

Second, the communication practices around their common languages allow the team members to free some cognitive load and save time during their explanations. Informal communication, which is quick and efficient, is made possible due to the repeated reference to standardized languages (for example, the Aresti Code). These also favor a collective foothold while sustaining the identity and social aspects of the group: integration within the group is necessarily accomplished through the acquisition and use of these languages.

Finally, the "immediate" feedback process spurs the players on to "subjective commitment" [RET 05]: they get involved in socialization practices and approach problem-solving in a collaborative way. This last characteristic plays a key role in extreme environments: the good coordination of teams rests on the members' ability to quickly find solutions together. By involving themselves in their collective lives, caring about each other and wanting to get to know them, the actors progressively build the mutual trust and knowledge, which will favor the team's "synergy" in the face of unexpected situations.

It becomes apparent that the "immediate" feedback process fits into and nurtures both action-based learning and an experience accumulation dynamic at the collective level. The analysis of the AFAT highlights the existence of different temporalities that overlap with each other during the implementation of the feedback process, where diachrony and synchrony coexist. This articulation of different temporalities is accomplished in the following way: iterations within the team, performed during or right after the action, favor the accumulation of experience-based knowledge and collaborative skills in the long term. In this context, feedback does not operate linearly and sequentially on collective skills; instead it adheres to tangled temporal structures, which interact with each other. On a daily basis, the team members both co-construct and commit to these temporal processes. Thus, the collective skills develop from the actors' simultaneous engagement in the short-term and long-term time structures.

The exploitation of these feedback temporalities is made possible due to the specific structuring of roles, based on intermediate management. The manager must know how to mobilize and unify the actors as a collective entity, without suppressing any individual skills. It is a question of managing the interactions between actors and articulating their practices (communicative, reflexive and social) with the organization's aims, while adopting a proactive stance. For instance, in the case of small team, informal debriefing, an integral part of the immediate feedback process, plays a key role. In particular, it nurtures socialization and reflexivity among the members, of which we have previously outlined the key role in coordination in extreme environments. This highlights the importance of managerial stimulation to create the conditions for the emergence of these practices, as the actors' willingness on the field does not always suffice. They need their manager's support in their efforts; the manager must know to encourage them to interact and share on a cohesive basis, for example by encouraging them to regularly share feedback by planning the team's time schedules and/or by suggesting and preparing spaces where they can relax and share experiences. The absence or the lack of these types of incitation can lead to a lack of coordination.

4.3. Deploying decision support systems: the example of LINK 16 in air forces

Coordinating teams in extreme environments requires thought in terms of decisional collective skills. These are applied mainly when the teams are confronted with unexpected situations and must act rapidly outside of or adapt their usual frameworks. The team members must then "know what to do" (individual situational skills) together (synergy and collective intelligence) in order to agree on a solution that will be suited to the context. The creativity of the process and the decisional result thus reveals itself to be essential.

The information systems and technologies that comprise them can play an interesting role in supporting teams in their creative resolution of problems with which they are confronted. The DSS can "generate new courses of action and produce new and useful ideas" [WIE 98]. This last section illustrates the DSS's contributions to the collective creative process [GOD 12b].

4.3.1. *Creativity and network-centric decision support system*

Generally, creativity is defined as the production of ideas, goods, services and/or processes, that are new and add value to the organization [AMA 88, WOO 93]. It can refer either to skills (individual or collective), or a cognitive process, its result and environment:

– The actors' creativity depends mainly on their character traits, skills and particular aptitudes. Csikszentmihalyi [CSI 96] insists mostly on the combination of imagination and the meaning of realities, as well as on the ability to persevere in the study of a subject. This permanent attention, which recalls the actors' daily approach to "immediate" feedback, allows the actors to exploit each element they live in order to construct new ideas. From a collective point of view, creativity is considered through the dynamics of the sharing of knowledge and experiences within and among teams (which can potentially take place, as we will see in the following section, within professional communities).

– Creativity then refers to the complex cognitive process tied to individuals' skills, to available information, and to the combination of the two. The founding works of Wallas [WAL 26] identify four stages preceding the process of creativity: the preparation stage, during which the experiences, knowledge and contextual information are gathered; the incubation stage consisting of the combination, in the form of the association of ideas, of the whole of these elements; the illumination stage, during which the ideas flow finally, the verification stage, during which these new ideas are tested against reality. Analogical reasoning, based on the confrontation of sources of inspiration, thus finds itself at the center of this process of the emergence of new ideas.

– Creativity can also be considered as a result. In this context, a creative solution rests on a process and/or a product that has not yet been explored and/or developed by the actors, and that adds value both at team level and organization level [SEI 10].

– Finally, creativity is closely tied to the environment where the teams develop, which includes the resources available to them, the degree of autonomy they benefit from and the way in which their members communicate [AMA 88].

4.3.1.2. *Network-centric decision-support systems*

In the last 20 years or so, the work in information systems management has questioned the contribution of DSS to decisional creativity, be it individual or collective [FOR 07]. Such systems permit us to see the bigger picture regarding the problems to be solved, exploring new points of view and implementing original decisions, adapted to different situations.

This is the case for a particular type of DSS, the network-centric DSS. These provide users with the precise visualization of a situation while (1) integrating geographical data, (2) manipulating data in the form of layers (each layer gathering a particular type of player) and (3) allowing the drill-down (possibility of zooming into a particular element's characteristics and zooming out to a global view). Resting on a structured network, the network-centric DSSs regularly and closely collect and spread available data, updated in near real time. They retrieve, organize and analyze the data in order to provide decision-makers with a representation of the problem they need to solve, namely (1) a graphical visualization of the elements of interest associated with the problem and (2) links between these elements.

Network-centric DSSs are particularly well adapted to (individual and collective) decision-making in extreme environments. They provide a global view of the action's environment all the while allowing for a manipulation of the data. These technical characteristics allow the decision-makers to access a situational awareness [END 00], to devote their attention to construct meaning, and then develop and stabilize their understanding of what must be done. In this way, network-centric DSSs support the so-called naturalist or intuitive decision-making [KLE 98]: inscribed in an initial reconnaissance process, the intuitive decision is taken by the experts mobilizing their past experiences in order to manage the situations they experience. Far from comparing various options with each other (analytical and satisfying decision process), they work analogically in order to adjust their decisions to the uniqueness of the problems they must solve. In this context, the "intuitive" decision-makers do not need a system capable of generating options from which they can choose (model-oriented DSS), rather, they need access to a rigorous representation of their environment of action (data-oriented DSS), which allows them to give meaning to the situation [LEB 06].

Where does creativity come into play in the naturalist decisional processes supported by network-centric DSSs? The following section aims to suggest answers while describing the creative uses of a military system that equips the French Air Force Rafale fighter planes: LINK 16.

4.3.2. *LINK 16's creative uses, developed by the Rafale fighter planes' crews*

4.3.2.1. *LINK 16: a description*

From 2006, France has progressively equipped its Air Force with American Joint Tactical Information Distribution System (JTIDS) technology. Also known as LINK 16, this system has been implemented on board the versatile fighter plane Rafale, the command and control aircraft Airborne Warning and Control System (AWACS) and several Mirage 2000Ds. We will focus mainly on LINK 16 equipping Rafale.

Resting on a highly secure reticulated structure (encryption system), LINK 16 supports the tactical data exchange necessary to (aerial, terrestrial and marine) military teams' coordination, particularly fighter crews consisting of a pilot and a navigator. The data collected by the various sensors spread over the combat zone (human and technological) are fused by LINK 16, which elaborates a coherent graphical and updated representation of the field situation. This representation is broadcast to the different players involved in the operation, such as the high command and Reachback (the Pentagon in the United States or the Operation Planning and Command Center in France), the tactical command centers located on base (that is the terrestrial, aerial or marine zones where the military operations take place) or the teams involved in the missions. A staff officer explains: "Tactical information can be relayed thanks to the linking of data, which allows us to communicate in digital form any flight information, to the ground, to another vector such as AWACS or to other Rafales". Teams can be both LINK 16 users and "sensors" (as they also collect information), to the extent where the data collected during their missions contribute to the tactical representation's update.

The tactical data being exchanged and exploited by the pilots using LINK 16 can include enemy and friendly forces' positions, fuel levels, available weapons, meteorological conditions, target coordinates, emergency airfields and tanker aircraft positions (Figure 4.3). LINK 16 also provides them with communication capabilities via a common language (code words and J-series data) that facilitates their coordination in any situation.

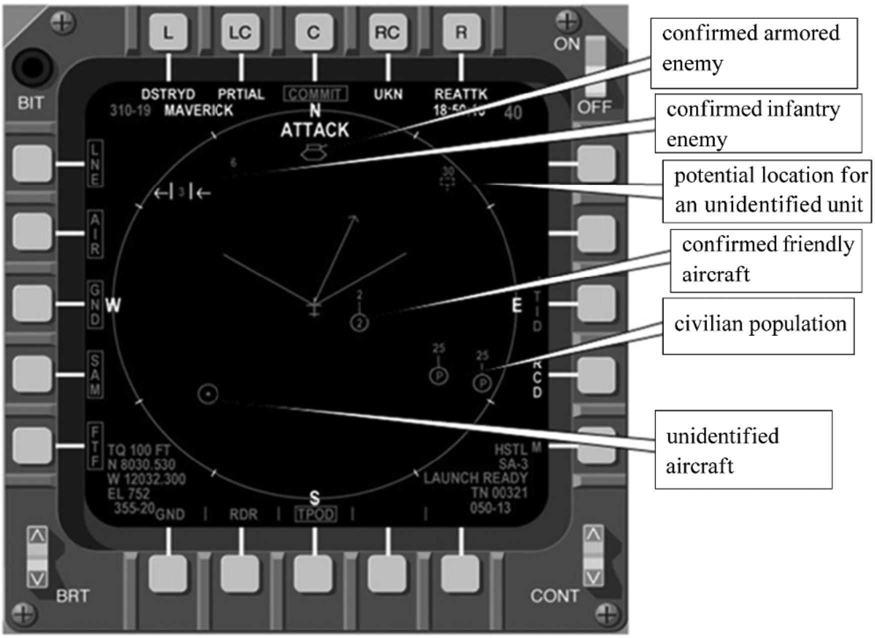

Figure 4.3. *Example of a tactical representation provided by LINK 16 to a Rafale crew (or pilot)*

All of these services allow users to improve their grasp of the situation. As they specify during interviews, LINK 16 facilitates simultaneous acquisitions:

1) The perception of environmental elements in a volume of space and time: "The first thing we share is each participant's position and that of enemy forces, because when you know where each player is at any point in time, coordination becomes easier" (a Rafale pilot).

2) An understanding of their significance: "With LINK 16, we permanently know where friends are, where enemies are, and we get a global view of the situation" (a Rafale pilot).

3) The ability to anticipate their own evolution: “For example, LINK 16 shows us tankers, which allows us to graphically see in our zone if a tanker is about to go back because it is already supplying another patrol, so we adapt ourselves. We are always one step ahead” (a Rafale navigator).

LINK 16 offers an unprecedented serenity and comfort, both in terms of apprehension of the environment surrounding the action and reactivity in the face of threats. In order to illustrate this, a pilot explains: “LINK 16 provides information updated by various sensors. This results in increased comfort, as the friendly and enemy positions are known and the tactical situation thus easily and instantaneously shared between members”. These general observations naturally lead us to question ourselves about the creative implications of such a system. What are the effects of LINK 16 on the user crews’ creativity?

4.3.2.2. *During flight: creativity in the process of elaborating aerial tactics*

LINK 16 improves crews’ abilities to detect and implement using available opportunities during flight. By providing pilots and navigators with tactical information in near real time, LINK 16 allows them to gain an unprecedented grasp of the situation. A pilot uses the following metaphor: “Imagine you are in total darkness, in an area you don’t know, and are made to run and all you have is a torch to see what’s in front of you. With LINK 16, it’s as if someone turned on the light inside the room before you started running. All of a sudden you understand what you need to do and how to do it”. Regarding any unforeseen situations of a tactical nature (for example, unexpectedly detecting an enemy aircraft, a commando unit suddenly being trapped and needing assistance, etc), crews can manage them in real time. A navigator specifies: “Between what was planned and what you actually live during flight, things can be potentially very different. The unexpected is discovered in the moment, and we need to know how to adapt in real time”. Without LINK 16, these situations become more difficult to manage, as the crews do not benefit from as fine and updated a tactical representation. A Rafale pilot recounts: “Data-linking is a huge revolution. In big COMAO [Composite Air Operation – a set of devices having different capabilities and missions but needing to work together], those that had LINK 16 didn’t talk, they didn’t need to: they saw everything, while the ones that didn’t were constantly requesting information: ‘request picture, request picture!’”.

Furthermore, without LINK 16, crews would take off with a potentially very imprecise representation of the action's environment and of the problems they would be facing. It all depends on the quantity and reliability of the information collected beforehand. On a base such as Afghanistan, for example, where the theater's physical characteristics and the presence of combatants among the civilian population made the acquisition of information particularly difficult, it was not unusual for pilots to take off with a rough knowledge of threats and upcoming enemy tactics. A Mirage 2000D navigator assigned in Afghanistan, unequipped with LINK 16, explains the conditions under which his bombardment missions were carried out: "During CAS [Close Air Support] we don't always have an objective. You need to take your own side's position, the collateral positions and the environment into account. You have drones, FAC [Forward Air Controllers – ground-based personnel indicating targets to aircrafts] if it's dark or if you need to create a show of force or if you're in the mountains or under layers… And none of that is planned". Without LINK 16, crews thus devote a big part of their cognitive resources to tracking and identifying risk, as well as anticipating enemy maneuvers, on the ground or in the air. All piloting tasks, as well as environment management and rapid three-dimensional evolution, are of course added to this mental burden. As explained by a Rafale pilot: "Those without LINK 16 are constantly mentally calculating. You need to understand them. They calculate, they calculate... That takes time!".

With LINK 16, the cognitive load dedicated to treating information is considerably lightened: "With LINK 16, you can use more of your mental abilities, you are significantly less overloaded". The visual representation offered on screens relieves crews of cumbersome calculations: symbols and colors are unambiguous and facilitate the situation's understanding. A patrol leader explains: "For instance, I will look at the symbols and quickly see if my crewmen targeting correctly". Furthermore, the fact that the data about the theater are updated in real time saves the crews from a laborious mental construction regarding the action's environment. A pilot states: "With LINK 16, you no longer need to construct a mental representation of the tactical situation. The system does that for you! As such, you can focus a lot of your mental abilities on the tactical plan, and are not as overloaded". The Mission Commander on AWACS insists: "With Rafale and LINK 16, information management tasks have significantly diminished, a few of them now being carried out by the system. Because of this, AWACS crews can be more focused on the actual aerial space control missions".

It is in this context that an improvement on flexibility supported by the system can be observed. This comes to light in the adjustment of tactics during action in relation to the environment's characteristics. A pilot explains: "When situations are complex, human judgment becomes paramount and is what allows good decisions to be taken. LINK 16 helps us understand what is happening and adapt to that". In this case, tactical opportunities are more numerous: choreography as was imagined during the briefing stage can be readjusted *in situ* by the crews, and more specifically by the formation leader in charge of mission management. One of them explains: "We have the possibility of using radio to a much lesser degree [...], we have the possibility of using our weapons thanks to LINK 16 [...], information can be filtered during transmission/reception. You can also type things in by hand with LINK 16's free text [on the Mirage aircrafts], which means we can now give indications or whatever else". The time saved due to the system is allocated to analyzing the situation and adjusting tactics.

This does not mean that the actors find themselves in a situation of complete improvisation, in the sense that they have considered a set of scenarios during the preparation phase and the appropriate responses to implement. A pilot explains: "We are not reinventing the wheel. The basic tactics are always the same. Where we are going further with Rafale, is with the linking of tactical data and all the possibilities for tactical refinement it offers!". In addition, crews evolve in a highly regulated and constrained environment. When they find themselves on an outdoors operation base, for instance, the rules of engagement, determined by the political sphere, precisely stipulate how much flexibility they have. Finally, readjustment is done under the supervision of a leader, who continually updates the symbols and colors on the pilots' screens. A crew member explains: "I shot and it suits him [his leader] somewhat... and if it suits him and I haven't he'll place a pointer on the target". In other terms, each pilot and navigator is creative in relation to his level of responsibility (which is directly correlated with his level of qualification), of which he is aware and accepts without condition. Under these circumstances, a synergetic and harmonious *in situ* reorganization of the formation is observed.

4.3.2.3. *On the ground: creativity during scenarios' preparation*

Mission preparation is primarily developed during briefing, right before flight. The crews are informed of the theater's characteristics and potential danger, and tackle tactical questioning, the method of progression as well as each of their roles. They also agree on the elements of communication (code words), and the frequency at which they will be used. It is a question of organizing the mission's progress, with the leader as an orchestra conductor. The leader makes sure that everyone knows what to expect, what to do and under what conditions.

As suggested by the data collected from Mirage 2000D pilots and navigators who are not equipped with LINK 16, any unexpected situations are only evoked from a technical point of view. With LINK 16, due to the acquisition of a precise and updated representation of the tactical situation, the process of anticipating unforeseen situations during the mission's preparation stage improves, particularly from the implementation of increasingly sophisticated scenarios. A pilot illustrates: "The problem with aerial combat is that if you can see an enemy aircraft, they can see you too. With LINK 16, you don't always need a visual. You can send a plane that will lure the target while another, who will have turned everything off and become undetectable, waits for it in an ambush. Obviously these new possibilities are taken into account during briefing!".

The leader can thus afford to imagine critical and complex situations (larger enemy numbers than previously expected, failing ground defense systems, etc.) and prepare his crews to face them by considering the appropriate response. The actors project themselves into these situations even more easily if the risk of friendly fire, collateral damage, collision, etc., is considerably reduced, if it has been discussed during the briefing: LINK 16 allows a better sharing of the tactical situation, thus contributing to limiting the risk of firing errors, collateral damage and friendly fire. This way, pilots are no longer compelled to limit themselves to technical problems during a briefing, in the sense that they know they can rely on a system that will provide them with reliable and appropriate information for dealing with the criticality of the situations.

A pilot insists: "LINK 16 opens up a lot of doors, in the sense of what can be done with it! It has revolutionized the way in which you use a fighter plane". Another emphasizes: "LINK 16 offers new opportunities for the aerial tactics that need to be implemented [...] it impacts the game plan, that is, the way in which the mission will be carried out in relation to the situation's evolution. And LINK 16 gives us a lot of new possibilities. If I turn off my radar, for instance, my enemy can no longer detect me. I become inconspicuous, whereas I can see everything on a 360-degree radius. I could come up from behind for example. In fact, it opens up huge doors, and this is only the beginning!".

By coming up with original tactical scenarios, crews also heighten their vigilance before a mission. They mentally construct the way in which the planned scenarios will be visually presented by the system (generic symbols showing positions, colors, etc). A pilot explains: "With LINK 16, I know I'll get a global view, but what is most important is that I will build a mental diagram of what we are going to do and what the others (the enemy) will do". As a result, the stress load associated with the management of unexpected situations is diminished. In order to explain the decrease in stress, a navigator describes the following: "We go on a planned mission and, all at once, our chain of command considers that we need to make an urgent strike on a certain spot. Once it has the coordinates, it sends them to C2 [Command and Control], which sends them back by LINK 16 and, bam! A target will appear visually on the screen!".

Likewise, after a mission, during debriefing, LINK 16 is used in addition to other mission progress playback systems. A navigator outlines: "During the debriefing, because we have recorded all our displays, we can see exactly what our shooting times were, as well as distances, for example. We report all the data on conventional debriefing systems and get a very clear vision of what happened." Thus, the pilots analyze all the opportunities taken during the mission, the tactics implemented, and the potential errors that were made. These discussions contribute to and enrich the common knowledge base.

LINK 16 thus offers its users the possibility of expressing their creativity in the construction of mission scenarios by improving the representation of events that can happen during flight, and by growing the field of responses that must be implemented in order to face them. In this case, the briefing's orchestration is built from a more open and complete script than ever before.

4.3.3. *Network-centric decision support systems in support of crews' creativity*

The analysis of LINK 16 helps refine our understanding of the role played by network-centric DSS on creativity's all four dimensions (individual/team, cognitive process, result/product/service and environment).

The system allows for a reduced cognitive charge for the players and teams in the extreme environment. Because of this, they have more time and resources available to imagine new avenues in their missions' predefined frameworks.

Back in the field, the flight crews' (pilots and navigators) characteristics have a strong impact. Indeed, they all have a high level of technical abilities, coupled with a decided taste for exceeding limits.

Without these characteristics, the workload, which is not managed by the system and which the pilots must process themselves, would be too much to bear and would not leave them with the possibility of deciding creatively, that is enriching tactics decided in advance.

LINK 16, while improving information display and organization during the creative process's preparatory stage, contributes to enriching the possibilities for action, and thus the opportunities to elaborate more creative maneuvers. By offering a new workspace, LINK 16 becomes a source of inspiration during the generative stage: players can imagine new action processes and collectively simulate the results before they are even implemented. As a result, even if the crews do not use the actual network on which the system rests during the action's preparation stage, they project the benefits to construct new action processes. During the mission, the DSS also supports exploratory work since, by freeing their cognitive abilities, it allows the teams to put their representations through a field test and elaborate maneuvers destined to adapt themselves to complex situations. The individuals are creative because they can rely on processes both prior (inspiration and simulation) and contributing to the action (experimentation and adjustment).

A DSS such as LINK 16 considerably improves decisional performance both on an individual and collective level. Indeed, by exploring the scope of creative liberty offered by the system (before/after action process), the teams are capable of carrying out their missions more efficiently. The increase in their capacity for anticipation improves their coordination by favoring a reduction in the surprise effect: indeed, the system allows the teams (1) to consider a large set of unexpected situations and (2) to free the cognitive space they will need in order to manage the switch between routine and unforeseen situations.

Deciding and coordinating oneself in extreme environments implies knowing how to articulate significant and compulsory action constraints (rules, procedures, etc.) all the while knowing how to adjust to continuous change. While literature tends to consider that DSS should favor the absence of constraints, in order to unleash the creativity of the spirit, it can be observed, on the contrary, that the implementation of new constraints (while LINK 16 is indeed a flexible DSS, its data collection and spreading possibilities follow a strict structure, set by the characteristics of its use) leads to a redefinition of the workspace which favors the emergence of new action processes.

The users' creativity in extreme environments is thus expressed within a context that is defined both by its limiting aspect and enabling capacities.

On a more detailed level, it is the system of iterations between the representation of the mission's elements, the opportunity taking and the scenarios' enhancement, which is at the root of creativity. By offering the teams a display of the problem's elements and the links between those elements, the network-centric DSS allows:

– an improvement in the understanding of the situation, and a presentation of most of the parameters the teams will need in order to act efficiently, since the system offers additional information they will be able to associate with experiences and knowledge they already have;

– experimentation with new maneuvers, a more refined adjustment of action tactics and taking opportunities that present themselves, thus favoring a synergetic and harmonious reorganization of decisions. This opens up the possibility of looking for the best ways to adjust to the situation, or even experimenting with planned scenarios;

– imagining solutions more sophisticated and complex than before.

In terms of creativity, DSS plays the role of the inspiration source, allowing the teams to approach the situation in an original manner, and imagine varied solutions and motions.

Thus, even if the system's primary purpose is not to favor creativity, it does so. This constitutes a major result: first, a network-centric system offers both a global view of the stakeholders and a handling flexibility allowing the user to imagine original combinations.

Second, the system is integrated into a global organizational procedure, which includes moments of interactions and reflexive discussion. These moments appear necessary to the crystallization of ideas and therefore to the emergence of creativity.

The case previously described finally allows us to highlight creativity's collective aspect, which is clearly shown here. In this way, each mission can be conceived as an original collective creation. By drawing a parallel with music, it can be noted that teams cannot only choose between a large number of songs, but they also have the possibility of improvising around a score, all the while under the control of the team manager (or patrol leader in our case). With support from the network-centric DSS, teams, having a high level of expertise and regularly sharing common experiences in highly limited environments, elaborate scenarios together. They perform them *in situ* and adapt them to their environment.

4.4. Encouraging the emergence of professional communities: the case of Air Force Knowledge Now

Military teams perform operational functions that are clearly defined and directly related to their intervention environment (for example, anti-missile defense for the Navy, mild infantry operations for the Army and aerial defense operations for the Air Force). Their members are experts, in charge of developing and implementing skills (individual and collective) specific to the necessary operational and support functions for performing defense missions. They develop action principles and techniques, which determine and structure the division of work and the execution of tasks.

In order to finalize their objectives, the military teams can form professional communities. This is particularly the case in the United States, where the Department of Defense (DoD) supports the emergence of these kinds of collaborative spaces, in a budgetary, technological and (for the contributors) time management sense.

How can the participation of military teams in the different existing professional communities improve coordination in extreme environments? How do the players, by contributing to the heated discussions within these communities, improve their ability to manage the switch between the routine and the unexpected?

4.4.1. *Professional communities in a military environment: between hierarchical communities and community of practice*

At first glance, professional communities refer to what Cohendet and Llerena [COH 03] call hierarchical communities. These refer to the traditional functional groups that comprise the organization: more oriented toward action than toward knowledge, they are made up of individuals with homogeneous and complementary qualifications and knowledge. They develop their specialization by field or area of expertise. These types of communities do not leave much space for autonomy. The activity's specifications and their control are formally defined and interactions between members are dominated by the vertical relationship to hierarchy.

Within hierarchical communities, however, identity and values relating to belonging to a group are of little importance. The strict codification of tasks, the specification of positions and the presence of hierarchy supposedly ensure the principles of cohesion. These elements bring to light the diverging aspects with professional communities such as they exist in a military environment.

Professional communities are indeed marked by cultural values and a strong identity [WIL 99]. Composed of intangible (for example, individual and collective postures and cohesive values) and tangible (for example, languages and traditions) cultural elements [SCH 92], the identity and cultural values translate representations of what things are and must be [HAN 06, RAV 06], they crystallize the meaning of collective action [FIO 91].

Indeed, identity and cultural values are the foundation of the ability of the professional communities members to define themselves as part of a collective [COR 03]. They are revealed as particularly important in military operations, where values of belonging to a group constitute the guarantee of its success. These cultural characteristics recall without contest what Brown and Duguid [BRO 91], Orr [ORR 96] and Wenger [WEN 98] write about communities of practice, when they consider identity as a determining element in its members' feeling of belonging and cohesion.

The comparison cannot be pushed further, however, as the communities of practice evoke mainly informal and autonomous groups, of which the members are voluntarily engaged in the sharing of knowledge, in order to evolve their skills in a practical manner.

Professional communities appear more as hybrid communities, borrowing the functional nature from hierarchical communities and the identity aspect from communities of practice. Teams will indeed share their experiences relating to the "career" problems they face, as well as the resolution procedures they implement. The exchange of knowledge between experts equally represents the possibility for spreading cultural values and identities that characterize them.

4.4.2. *The Air Force Knowledge Now online platform*

In 1999, the Knowledge Management Center of Excellence put into place an Internet-based collaborative technological structure, the aim of which was to promote the sharing of knowledge and skills between the teams of experts that comprise the different US Air Force units. This structure is named the AFKN. The AFKN, therefore, is not a professional community as such, rather an information system that supports and centralizes existing professional communities.

As a centralizing platform, the AFKN was quickly adopted by the contributors to the 12,000 professional communities it was composed of in 2008 [LAW 08]. In 2009, the structure counted over 320,000 members. Its average growth is 1,000 new members and 100 new communities each week [MAY 09]. The "career" fields involved in the communities are diverse, ranging, for instance, from upstream/downstream logistics to the technological transformation of the Air Forces, to public finance management [ROD 04]. Thus, a large number of functional specialties are represented within AFKN: mechanics, piloting, support, intelligence, etc. The AFKN has also opened itself up to other forces, such as the US Army.

4.4.2.1. *AFKN's goals*

The AFKN was born from the willingness to centralize the lessons learned from the multiple experiences of teams of all specialties. Its two main goals can be summarized as follows:

– On the one hand, capitalize on the experts' "field" knowledge. Firstly, it is a question of reducing the time spent on searching for solutions, which will already have been implemented by other practitioners faced with similar problems. Secondly, it is about avoiding the same mistakes that have been made in the past, by spreading lessons learned during the feedback process.

For example, a US Air Force gunsmith assigned in Africa may find himself facing logistical difficulties that he has never faced before. Through the AFKN platform, he can (virtually) meet other gunsmiths who have already found themselves in his situation and will be able to quickly provide concrete response elements that answer his problems [MAY 09]. The AFKN developers have in fact quickly identified the platform's opportunities for capitalization, notably regarding to good practices resulting from feedback processes [AIR 07].

– On the other hand, reinforce a general strategy for knowledge management, notably centered on knowledge creation. From their sharing of experiences, the professional communities' members discuss certain complex problems they may have faced or that they expect may occur, and together work toward their resolution. In this context, the confrontation of "set" experiences and good practices favors the production of new knowledge and feeds the dynamics of innovation: from the explanation of individual and collective experiences and contradictory debates, individuals bring forward aspects that are not explicit to the problem and together construct innovative resolution processes.

The AFKN thus finds itself at the center of mechanisms for (1) identifying potential problems, (2) partial or total resolution of these problems, (3) capitalization and spreading of the best practices arising from experience, and (4) principally the innovation of processes. As Randy Adkins, who is at the head of the AFKN project, explains: "no matter what situation you find yourself in, you can bet someone, somewhere has been in similar situations".

4.4.2.2. *AFKN's technological architecture: the importance of collaborative tools*

From the beginning of 2002, the AFKN platform has taken advantage of the opportunities offered by 2.0 web tools. These have been introduced in order to foster horizontal interactions between players and encourage the contributors to build a common base of experiential knowledge [LAW 08]. The main collaborative technologies at their disposal are:

– Blogs and forums that facilitate involvement in group discussions; built around specific subjects, project ideas, innovations, etc. Social media, such as Twitter, Youtube and Facebook, as well as social business networks, such as Microsoft SharePoint, are also suggested to the contributors and largely used by them.

– A Wiki that puts at each AFKN community's disposal an experiential knowledge base, as well as online help, built from contributions to the platform and composed around articles, glossaries, forum exchanges, etc.

– A system allowing for the depositing of documents relating to ongoing projects, the tracking of their evolution and progress, and intervention through the possibility of adding items and knowledge updates relating to any field.

– Questionnaires, which help inform about a set of quantitative investigations and studies, which are useful to both the managers and contributors.

Thus, AFKN's architecture is built to not only encourage the exchange of experiences and good practices between experts with the same "career", but also to allow them to be spread more broadly. Indeed, these collaborative technologies are meant to favor the horizontal flow of knowledge and allow the contributors to transcend the frontiers of their own areas of expertise and the teams that comprise them. This willingness to extend the capitalization on and the sharing of experiential knowledge to the whole of the US Air Force feeds the continuous expansion of a database of good practices, the spreading of the organization's cultural values and mainly stimulates the innovation of processes (particularly in terms of problem resolution).

Beyond its web 2.0 architecture, AFKN's success can be explained by the respect of the internal operating modes of the communities that make it up. In no way do the platform's administrators and developers intervene on the nature of the relationships entertained by the different communities' members or on the constitution of said communities. It is more a question of putting a set of technologies at the members' disposal, which favor the establishment of relationships between communities, teams and their members. In fact, in this context, we call them virtual professional communities, in the sense that the relationships and potential collaborations between members are only expressed in a mediated way.

4.4.3. *Beyond team frontiers: professional communities favoring experience sharing and organizational culture*

Professional communities are tools in the service of team coordination in extreme environments for the following reasons:

– They favor the spreading of experiences and field knowledge beyond team frontiers. We have noticed the importance of the feedback process, particularly "immediate" or short-loop feedback allowing team members to share good practices and avoid making the same mistakes of the past. However, as efficient as that is, such a learning process is only effective within a collective that implements it. The merits of professional communities rest on the opportunities for extended exchange, between members of different teams of the same career, or even of different specialties when projects and questions relate to interdisciplinary areas. Thus, the feedback process developed within professional communities allows teams to adhere to a process of knowledge creation larger than that constructed within isolated collectives.

– Being built around web 2.0 technology, professional communities encourage geographically scattered players to collaborate with each other. This collaboration, even if virtual, develops in order to expend the common knowledge base and collective innovation abilities.

– Finally, professional communities also play a role in spreading the beliefs and cultural values of the organization as a whole. It has been noted that teams are strongly shaped by their own identity and cohesive values.

These must, however, stay in tune with the organization's culture, in a more global way. As Schein states [SCH 92], culture represents the organization's communal view, which is based on a homogeneous and stable interpretation framework. It is composed of a set of intangible elements (the author refers to "hidden levels of culture") anchored in the organization's history, tradition and habits. The organizational culture is anchored in the teams' more "local" values, embodied in the artifacts, work practices, relational practices, etc. (Schein calls them "visible levels of culture").

The culture of the Organizations of Defense is built around the expression of a State responsibility: the military serves the nation by keeping order and/or maintaining peace.

The military person is above all a combat professional and his or her skills are given meaning during commitment operations. Sourbier-Pinter [SOU 01] views the development of an Army career through the three tenets every military person is bound to:

– a professional commitment based on moral rules, acquired in training during the daily practice of the profession;

– respect of discipline based on the military chief's abilities to assemble and federate;

– finally, making loyalty a sense of duty and altruism a priority [TRA 00].

These reference values form a base commonly shared by all military forces in the Army. They represent the foundation of military culture. They evoke a first level of culture, the "hidden levels of culture" referred to by Schein [SCH 92]. Each Army as well as each structure and team within it incorporate their own values of identity and cohesion. Professional communities thus play the role of spreading the first level's cultural values and guaranteeing that they tie in with "local" values.

4.5. Summary: coordination in extreme environments and managerial actions

The answer to the question "can coordination in extreme environments be learned?" is yes, under certain conditions. Yes, in the sense that good coordination demands the teams acquire specific individual skills as well as collective skills and intelligence. Nevertheless, there are some requirements to be meet. Managers (intermediate and strategic) have a central role to play in enabling teams to coordinate: they must facilitate their management of the switch between the routine and the unexpected by giving teams the tools and conditions tailored to their needs. Table 4.2 summarizes the managerial actions that are can be implemented to support teams in their coordination efforts in extreme environments.

Examples of managerial actions	Intervention level	Tools and processes	Expected results
"Immediate" feedback process Debriefing	Team	Managing the time dedicated to collaborative work Activity restitution technologies/techniques Spaces for socializing	Collective skills and intelligence
Introduction of a network-centric decision support system	Team	DSS Managing the time dedicated to collaborative work	Decisional creativity
Professional communities	Organization	Centralizing the community platform Free sharing of experts' experiences and knowledge Web 2.0 technology	Sharing of experiences and of good practices beyond team frontiers Spreading organizational culture

Table 4.2. *Managerial actions to improve coordination in the extreme environment*

Conclusion

In order to meet demands in terms of performance, change management and innovation, businesses are increasingly organized around project teams. These teams must plan to meet high demands, mainly linked to the reduction in *time to market*, shrinking budgets and strong constraints in terms of supply management. They suffer a high failure rate, mainly linked to coordination faults: collective skills and intelligence are difficult to build in a context in which career plans and individual expertise are emphasized, frequently to the detriment of the construction of a collective [FRO 15].

By asking the question "how can teams coordinate themselves in extreme environments?", this book has aimed to offer businesses insight into now to improve coordination within their teams. It has, therefore, offered a thorough analysis of coordination practices developed by military personnel when they are subjected to the pressures of uncertainty, change and risks (which characterize extreme environments), emphasizing the main challenge that teams must face: managing the sudden switch between a routine operation and the different unexpected situations likely to call their standard action modes into question. They succeed by articulating communication reflexivity and socialization practices that they develop and shape according to their cultural values and the context's demands.

Based on these observations, this book has suggested three concrete avenues through which managers facilitate coordination within teams in extreme environments: putting an "immediate" feedback process into place so as to favor the emergence of collective skills and encourage can to act together actors to meet shared goal, exploit the opportunities offered by

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decision support systems, particularly in terms of collective creativity; and finally, support the work done by professional communities by building a dedicated digital architecture and offering collaborative tools.

In order to develop more flexible work collectives that are capable of managing the unexpected and reaching a high level of performance, businesses have everything to gain from studying military experiences. They can seek inspiration from their successes, and transpose, and adapt, the devices and good practices deployed by armies in order to support coordination in their project teams.

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