A SYSTEMS APPROACH
TO
HUMAN FACTORS AND EXPERT DECISION-MAKING
WITHIN CANADIAN AVALANCHE PHENOMENA

By

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Summary of Key Conclusions for Research Participants, January 2005

In summary, the following key conclusions can be drawn from the results of this study:

A. The Foundation of Avalanche Judgment and Decision-Making Expertise

1. Experience, knowledge and skills, and relevant information formed the foundation supporting avalanche experts' judgments and decision-making.
2. Information relevant to the human, physical and environmental systems was critical for sound avalanche judgments and decision actions.
3. Participants accumulated avalanche knowledge and experience temporally over years, and spatially, in different geographic regions and snow climates.
4. As avalanche experts gained knowledge and experience, they developed more expansive mental models (internal representations of the avalanche domain).
5. Detailed mental models enabled these avalanche experts to make sense of their experiences, and the situations and conditions they strived to interpret.
6. These avalanche experts had developed fine perceptual skills that enabled them to recognize subtle cues, and form meaningful patterns within and between the human, physical and environmental systems of influence.

B. Judgment and Decision-Making Processes of Avalanche Experts

1. As avalanche experts gain knowledge and experience, they develop more expansive mental models, and they use increasingly higher levels of decision complexity.

2. Using a systems thinking approach, the human, physical and environmental systems that influenced avalanche judgments and decision-making were understood as an integrated meta-system of related and interacting elements.

3. These avalanche experts used their experience to have greater confidence in their intuitive and analytic decisions, and to make better decisions when faced with uncertainty.

4. These avalanche experts had developed capacities to recognize subtle changes within the human, physical and environmental systems of influence, and respond by adjusting their decision actions accordingly.

5. Intuitive processes were the primary mode of decision-making used in high-stakes field decisions.

6. Analytic processes were the primary mode of decision-making used when making meso-scale decisions from non-field locations (e.g. forecasting and terrain use planning).

7. When avalanche experts encountered decision problems that rule-based or intuitive decision-making processes were unable to handle, they reverted to analytic processes.

8. The context of the situation, degree of time pressure, and level of uncertainty were key influencers in the type of cognitive function used by avalanche experts.

9. Pattern recognition and mental simulations were key cognitive strategies used in judgment and decision-making.

10. Critical thinking and metacognition were integral to objective and sound decision-making, and offered a powerful strategy to counter the influences of potentially dangerous heuristic traps and biases in the decision-making process.

C. Avalanche Expert's Approach to Dealing With Uncertainty

1. Uncertainty is a subjective factor, since different people will experience different levels of uncertainty in the human, physical (terrain) and environmental (weather) systems of influence when faced with the same situation.

2. Avalanche experts managed uncertainty by identifying the source and nature of the uncertainty (human, physical and / or environmental), attempting to reduce or resolve it, and then managing it accordingly.

3. In order to meet the boundary conditions of time and cognitive economics, the goal of these experts was to identify the most important factors concerned, not every possibility that may exist.

4. As uncertainty within the human, physical and / or environmental systems of influence increased, decision confidence decreased and resulted in more cautious decision actions.

5. The level of caution was a function of the perceived severity of the consequences of avalanche involvement.

6. Reducing exposure or choosing terrain avoidance were the primary methods these avalanche experts used to manage uncertainty.

7. Uncertainty was effectively managed through active and continual modification of the goals and objectives of the avalanche program, in relationship to the identified level(s) of uncertainty within the human, physical and environmental systems of influence.
8. When avalanche experts did not address and/or effectively manage the uncertainty they faced, they used several negative strategies to cope; denying the presence of uncertainty by explaining it away, or not dealing with its presence by continuing with their original goals and plans without modifying their decision actions.

D. Attitude and Approach to Practice

1. Participants possessed an attitude of deep respect for the complexities of avalanche phenomenon, and for the imperfect nature of human judgment and decision-making.

2. Avalanche experts held a commitment to safety that was the fundamental factor in their decision- making. As a result, they incorporated a buffer zone of safety within their decision actions.

3. An awareness of these limitations (metacognition), combined with an attitude of strong principles, enabled participants to modify their goals and objectives in order to achieve balance within the changing conditions in the human, physical and environmental systems of influence.

4. The task of avalanche decision-making is complex and difficult, and avalanche experts recurrently experienced internal conflicts and external pressures from clients and management as a result of their cautions decision actions.

5. Personal mastery involves making decisions based upon a strong set of core values and principles, and was a key foundation for these avalanche experts' capacities to make sound decisions.

E. Team Decision-Making

1. Team decision-making enhanced the learning and decision-making capacities of these avalanche experts, by adding collective knowledge, information, resources and diverse perspectives.

2. Team decision-making and collective metacognition reduced subjective biases that may have been present in an individual decision-maker.

3. The vicarious experiences of others influenced and aided participants' avalanche-related judgments and decisions.

4. Conclusions regarding decision actions were often based upon the most conservative perspective that existed amongst group members.

5. Teams used co-creative process of pattern recognition and mental simulations to arrive at sound decision conclusions.

6. Greater levels of communication within avalanche teams resulted in less uncertainty, richer mental and situational models, and higher levels of decision confidence.

7. An environment that encouraged effective and open communication within the team members is crucial for decision-making success.

F. Developing Avalanche Judgment and Decision Expertise

1. As avalanche domain-specific knowledge and experience increased, participants developed increasingly fine perceptual skills that enabled them to recognize subtle cues, and form meaningful patterns within and between the human, physical and environmental systems of influence.

2. Participants demonstrated high levels of motivation to evaluate and improve their judgment and decision capacities.

3. These avalanche experts used their experiences and those of others to aid their judgments and decisions, and subsequently learned from these experiences to generate new knowledge, insights and behavior for their future practice.

4. Decision feedback related to successful decisions, accidents, close-calls and case histories was a critical component of their experiential learning.

5. Mentoring, peer feedback and reflective practice transformed participants' experiences into strong mental models of the avalanche domain.

6. Exposure to new ideas and practices resulted in improved judgments and decisions, and a greater capacity to gather and communicate relevant information.

7. Avalanche experts actively engaged in deliberate practice activities such as reading, taking courses and participating in informal discussions to improve their expertise and decision capacities.

G. The Influence of Human Factors in Avalanche Expert's Decision-Making

1. Avalanche experts faced conflicting challenges as they strove to achieve a balance between the widely varying goals and objectives within the realms of human influence, and the constantly changing conditions in the physical and environmental systems.

2. Human factor influences included individual, team, client, organizational and socio-political realms.

3. The individual human factor influences included cognitive, physiological and psychological categories:

    a. Cognitive factors included deficiencies in the foundation of avalanche expert's decision-making: lack of relevant experience, lack of relevant knowledge and skills, and lack of information relevant to the human, physical and environmental systems of influence.

    b. Physiological factors included fatigue and environmental stress.

    c. Psychological factors included goals, ego, pride and overconfidence.

4. The fear of appearing incompetent and uncertainty regarding performance resulted in anxiety that influenced judgment and decision actions.

5. Repeated experiences of non-event feedback or false positive events can result in dysfunctional strategies for future decision-making.

6. Team human factors included inadequate communication, resistance to differing opinions, social pressures, and being negatively influenced by the perception, judgments and decisions of others.

7. The quality of communication within teams correlated directly with the quality of decision actions.

8. Client human factors included pressure to access terrain, inadequate verbal communication and loss of visual contact.

9. Organizational human factors included lack of risk comprehension, and financial, logistical and time pressure.

10. Social and political human factors included the current state of the industry and related associations.

11. These experts need a high level of personal mastery and strong leadership capacities to avoid being overly influenced by these factors.

12. Residual risk is always present in avalanche phenomena.

Study Conclusions

III.1. A Systems Perspective of Avalanche Decision-Making

Avalanche-related decision-making occurs at the centre of three systems of influence; human, physical and environmental (Figure 12).

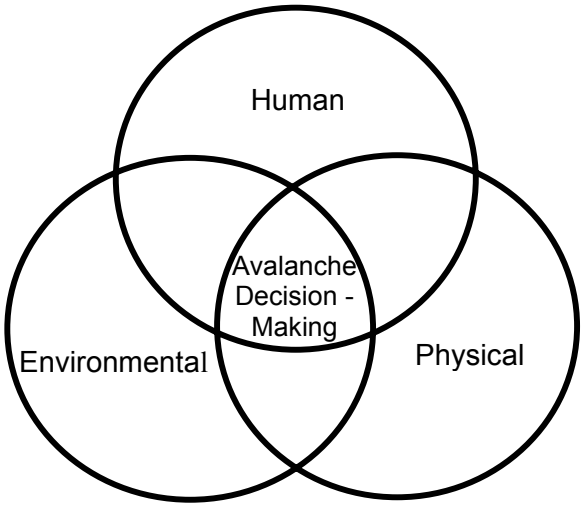

Figure 1. Systems of influence in avalanche decision-making.

For purposes of the analyses, the human system contains the individual, team, client, organizational, and socio-political realms. The physical system contains the terrain, including geographic location, slope aspect, angle, shape and ground cover. The environmental system contains the snowpack and the weather conditions that create it and influence its instability.

The avalanche judgement and decision process is influenced by individual, team, client, organizational and socio-political factors. The importance of understanding and considering the inter-relationships between these phenomena requires a systems thinking

perspective. This holistic perspective is considered integral to adequately studying and understanding complexity (Stefanovic, 2003; Wheatley, 1999). Since human behaviour is best understood in the social and natural frameworks within which it occurs, sound avalanche-related judgment and decisions cannot consider one of these systems in isolation.

The avalanche decision-making process involves making complex judgments regarding the current conditions and the level of uncertainty within the three systems of influence. It then requires making critical decisions regarding what decision actions will be taken. These judgments and decisions occur within a dynamic and complex decision process, and are embedded within a broad situational and human context. Thus, decisions are not made as discrete events or isolated moments of choice, and understanding the context that surrounds the decision process is essential (Orasanu and Connoly, 1993; Lipshitz, 1993).

III.2. Factors Influencing Avalanche Judgment and Decisions

Avalanche-related decisions were not executed as isolated events or individual moments of choice by the avalanche experts in my study. Decisions occurred within a dynamic context that was influenced by six categories of factors: one category encompassed the physical and environmental realm, whereas the following five encompassed the individual, team, client, organizational, and socio-political human realms. These realms represent a systemic perspective of the factors influencing avalanche decision-making. They are a fundamental source of uncertainty and a causal factor in the decision-makers cognitive, physiological, and psychological domains.

As I have demonstrated, human factors exert both positive and negative impacts

in avalanche judgment and decision-making. While human factors have received considerable interest in high-stakes decision-making domains, much of the focus has been on their negative influence in judgment and decision processes. It is curious how little research has been directed towards examining human factors in light of their positive influences.

III.3. A Conceptual Model of Avalanche Expert's Judgment and Decision-Making

I constructed a conceptual model that describes the decision modes and strategies used by the avalanche experts in my study. This model integrates the elements of judgment and decision-making within a holistic system (Figure 25).

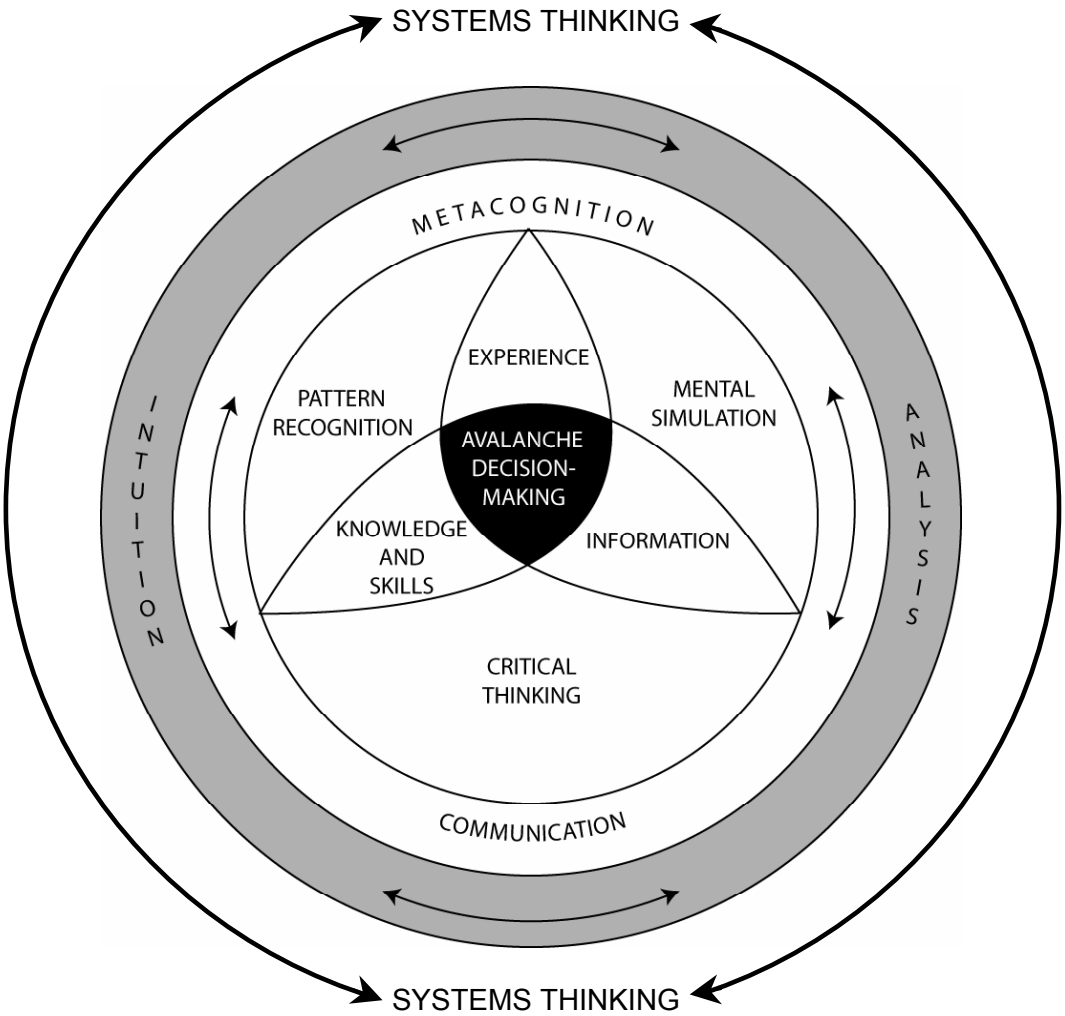

Figure 25: Conceptual model of avalanche expert's decision modes and strategies.

Avalanche experts' decisions are made within a systemic process that unfolds from the centre of the system. Experience, knowledge and skills, and information relevant to the human, physical and environmental systems of influence provide the foundation to sound avalanche decisions. The cognitive strategies of pattern recognition, mental simulation and critical thinking are driven and fed by this foundation. Through the use of metacognition, avalanche experts are internally and externally aware of the factors that influence their judgment and decisions. Effective communication fosters and enhances the quality of judgments and decisions. Intuitive and analytic decisions result within a dynamic systems thinking perspective.

III.4. The Role of Experience and Mental Models

Experience lies at the heart of sound avalanche-related decision-making and results in superior knowledge, skills and information processing capacities (see Ericsson and Charness, 1994; Shanteau, 1988). Experience is considered fundamental to objective avalanche decision-making, not only to accurately evaluate the snowpack, but also to aid complex decisions and avoid dangerous human biases (McClung, 2002a).

Experiences and knowledge events specific to the avalanche domain resulted in highly integrated knowledge structures and rich mental models depicting how the avalanche domain functions. These mental schemata guide avalanche experts to key aspects of the decision problem and filter out irrelevant information. The use of these mental models results in reduced information management, since the avalanche expert is able to notice subtle perceptual cues and does not need to process all of the available information in order to make an effective decision. Their knowledge of critical cues in the environment enables them to make very fine classifications (Endsley, 2001). As avalanche experts develop richer and more expansive mental models of the avalanche domain, they adapt their judgment and decision-making capacities into a holistic, systems thinking perspective.

III.5. Avalanche-Expert Judgment and Decision-Making Modes and Strategies

The avalanche experts involved in my study had evolved their judgment and decision-making processes beyond considering concrete systems (terrain and snowpack) to considering and synthesizing conceptual systems (higher-level information), which is a key component of the systems thinking perspective (see Kalaidjieva and Swanson, 2004; Wheatley, 1999). Thus, avalanche decision-makers evolve through a hierarchy of judgment and decision complexity that commences with rule-based processes and leads to integral systems thinking (Figure 14).

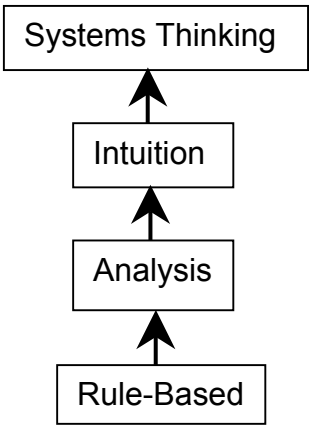

Figure 2: Hierarchy of avalanche judgment and decision-making complexity.

In addition to systems thinking, avalanche experts used three fundamentally different modes of cognitive function; rule-based, analysis and intuition. These modes occur within a cognitive continuum. Rule-based processes are consciously controlled by a stored rule or procedure (Rasmussen, 1993), analysis utilizes a conscious process of reasoning (Kahneman, 2003), and intuition pre-consciously utilizes the repertoire of patterns stored within our mental models (Klein, 2003).

The level of expertise of the decision-maker and familiarity with the current situation determines the application of these modes (see Lipshitz, 1993). Additional

factors include the systemic context of the situation, the degree of time pressure, and the level of uncertainty within the human, physical and environmental systems. My study findings concur with the work of Endsley (1997) who suggested that single decision problems are often solved using different modes, even though one mode may appear to be more dominant. For example, an avalanche expert may use systems thinking and intuitive processes for the parts of a problem for which adequate knowledge and mental models exist, while rule-based or analytic processes may be used to solve other parts of the problem.

These modes complement one another to produce effective decision actions. For example, when avalanche forecasting (e.g. office-based morning meetings), these avalanche experts used analysis as their primary mode of cognitive function, while in high-stakes field decisions, intuitive processes prevailed. In any situation, when avalanche experts encountered decision problems that rule-based or intuitive decision-making processes were unable to handle, they shifted to analytic processes (see Yates, 2001). Where possible, consultation with other team members was integrated into this process.

The avalanche experts in my study used pattern recognition to make effective judgements, and processes of mental simulation and critical thinking to analyse whether their judgments were accurate and if their planned decision actions would work. The systemic perspective of metacognition was used to monitor and regulate the thought processes of attention, situational awareness, comprehension, and biases, and resulted in better judgments and decision actions.

III.6. Situation Awareness and Metacognition

It is widely recognized by high-stakes decision researchers that situation awareness and metacognition are fundamental to sound decision-making (Endsley, 1997; Klein, 1998; 2004; Orasanu and Salas, 1993). Endsley (1997) argues that situation awareness involves much more that simply perceiving information in the environment, since it requires understanding the information in relation to the decision-makers goals, and then projecting the future actions of the environment. Metacognition enables decision–makers to be aware of their thought processes and control them appropriately. Thus, metacognitive skills are crucial for proficient problem solving and decision-making.

III.7. Dealing with Uncertainty

How to effectively manage uncertainty within the human, physical and environmental systems appeared to be the quintessential challenge faced by this group of avalanche experts. Lack of information relevant to the three systems of influence, time pressure, dynamically changing risks, and human factor influences resulted in uncertainty, and exerted significant limitations on the cognitive capacities of avalanche experts. Uncertainty is a subjective factor in the avalanche judgment and decision-making process, since different people will experience different levels of uncertainty within the three systems of influence when faced with the same situation.

Baumann et al., (2001) suggested that uncertainty is also experienced as a function of the decision-maker's assessment of their personal resources available to meet the task demands. Greater uncertainty regarding task performance increased anxiety and therefore impairs cognitive performance. In my study, uncertainty resulted in decreased decision confidence, which resulted in more cautious decision actions. The level of this

response occurred as a function of the perceived severity of the consequences of avalanche involvement. Resulting decision actions included increased mitigation, reducing terrain exposure, or choosing terrain closure or avoidance.

Avalanche experts draw upon their mental models that result from context-based domain experience in order to manage the uncertainty they face. Domain-specific expertise reduces uncertainty, and enables decision-makers to anticipate likely events, and avoid worrying about those that are unlikely (Baumann, et al., 2001). Rich and coherent mental models also compensate for incomplete, unreliable or ambiguous information (Klein, 1998; Rasmussen, 1997; Connoly, 1997). These mental models enable experts to have access to default information relevant to their domain, which yield more effective decisions than novices, who are challenged by missing information (Endsley, 1997).

A majority of the critical incident decision summaries (CIDS) in my research included time-pressured decisions. In order to effectively manage uncertainty, the avalanche experts in my study focused their attention on understanding the situation, and not comparing options. Developing an accurate perception of the situation enabled participants to arrive at a decision solution that would work in the least amount of time and energy when they were faced with time pressured, high-stakes decisions. However, upon retrospection, they explained to me that the decision action may not have been the best possible. Choosing the first option that works is an efficient decision strategy called 'satisficing' (Simon, 1957).

In his research on expertise, Shanteau (1988) reported that experts use this strategy to overcome the effects of cognitive limitations in high-stakes situations, and

suggested that while experts may make small errors when making decisions, they generally avoid making large mistakes. In his NDM research, Klein (1998, 2004) showed that experienced decision-makers recognize a reasonable course of action as the first one considered. He proposed that the experience these experts held enabled them to see even non-routine situations as a prototype, and skillfully know what to do without thinking of other options. This principle can be demonstrated in the following optimal decision threshold (ODT) model (Figure 26). As avalanche decision-makers gain experience, develop expansive mental models of the avalanche domain and evolve their cognitive capacities, they experience reduced cognitive effort while optimizing decision success.

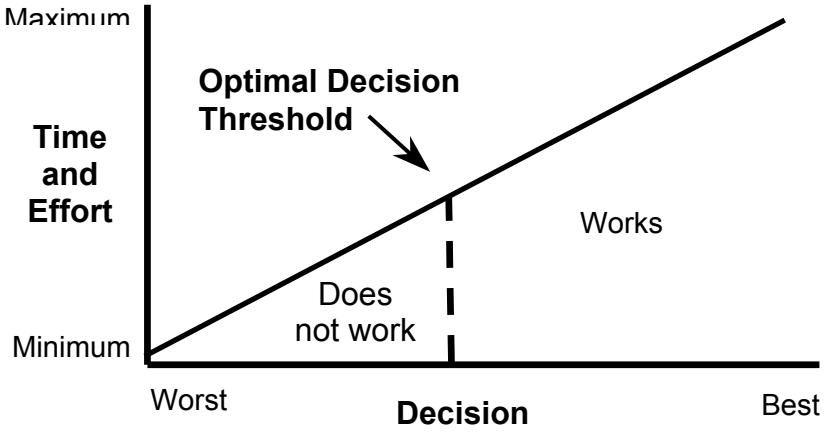

Figure 3: The Optimal Decision Threshold

Note: The ODT illustrates how workable decisions were made by these avalanche experts using the least amount of time and cognitive effort.

Developing an accurate perception of the human, physical and environmental factors in the situation was achieved through a continuous cycle of identifying, reducing and managing the uncertainty they faced (Figure 16).

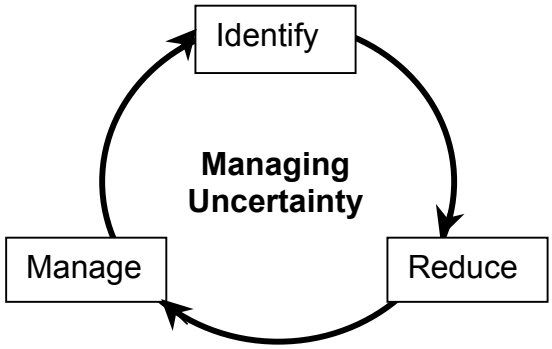

Figure 4: Avalanche expert's system for managing uncertainty.

In this continuous cycle, avalanche experts IDENTIFY the source and nature of the uncertainty, attempt to REDUCE or resolve the uncertainty, and then MANAGE the uncertainty by adjusting the goals and objectives of the avalanche program accordingly.

This finding is consistent with a review of nine Naturalistic Decision-Making (NDM) models that suggest decision-making in realistic settings occurs as a process of constructing and revising the situations representations, more often than evaluating the merits of potential courses of action (Lipshitz, 1993). Effective and successful decision-making is critically dependent upon attaining a good understanding of the situation (Lipshitz, 1993). Thus, building strong mental models and developing accurate situation awareness should be a key focus of avalanche decision skills training programs.

Avalanche experts managed the uncertainty by striving to achieve a constant balance between the goals and objectives of the avalanche program, and the identified level of uncertainty within the three systems of influence; human, physical and environmental. The successful reduction of uncertainty is cognitively taxing, and requires time, motivation and structured thinking processes (metacognition and critical thinking). High levels of motivation to achieve the goal of successful resolution of situational uncertainty leads towards success, while low levels may lead to negative consequences (Baumann et al., 2001).

As a result of complex situational and human factor influences, it is unrealistic to assume that uncertainty can always be reduced or managed effectively. In some situations, participants in my study failed to effectively manage the uncertainty they faced. Denying its presence by explaining it away, or not dealing with the uncertainty and continuing with original goals and plans are several examples. Research suggests that decision-makers often find it difficult to change their plans when faced with uncertainty, since the presence of expensive consequences, for example canceling a day of helicopter skiing, requires high confidence levels (Orasanu et al., 2001).

These conclusions illuminate the complexities inherent in avalanche decision-making. Actively identifying and managing uncertainty within the human, physical and environmental systems of influence is critical for sound decision-making. When faced with high uncertainty, a simple solution employed by these avalanche experts that requires limited cognitive economics is to reduce or eliminate exposure to avalanche terrain. This simple tactic can be executed by decision-makers of any level of expertise in the avalanche domain, resulting in higher levels of safety.

III.8. Team Decision-Making

While an individual avalanche expert may bear the final responsibility for the decision action, team members often contributed to the final product. Team environments add information, resources and diverse perspectives to the avalanche decision problem. In this way, teams operate as cognitive systems (Klien, 2003; Orasanu and Salas, 1993). The building of shared mental models and the collective consciousness of the team mind (Klein and Thordsen, 1989) creates a highly efficient context within which avalanche judgement and decisions can occur.

Performance is determined by the way teams use their resources, and how they communicate essential information (Orasanu and Salas, 1997; Sexton, 2004). Shared mental models provide a context within which information and tasks can be interpreted, as well as a basis for predicting the needs or behaviours of team members (Orasanu and Salas, 1993). Research indicates that team decision-making is preferred when tasks are extremely complex, as no single individual possesses all of the relevant knowledge with which to discover adequate solutions (Klein, 1998; Orasanu and Salas, 1993).

However, I found the capacity of teams to make effective decisions was a direct function of the quality of interactions amongst team members. Inadequate communication, failure to challenge assumptions about goals or values, inaccurate perceptions, and social pressures to conform significantly degraded the team decision-making process. Orasanu et al., (2001) suggested that implied expectations amongst team member may encourage risky behaviour, and may result in people behaving as if one is an expert, while in fact they may lack the knowledge to effectively execute an independent decision. An example provided by focus group participants described how assistant guides are often expected to assume complex tasks of significant responsibility such as snow safety for helicopter ski operations with limited supervision or discussion.

While these experiences offer tremendous learning experiences for less-experienced avalanche decision-makers, they may result in high levels of performance anxiety and acute stress (Baumann et al., 2001). Uncertainty regarding performance, and the fear of consequences of failure separately contributes to the level of anxiety experienced, and results in negative performance effects (Baumann et al., 2001).

The experience of negative team interactions was particularly strong in situations

involving supervisors, lead guides or individuals with higher status. Orasanu and Salas (1993) reported a similar finding in their aviation research, stating "high status can be used effectively to manage a team or it can lead a team to disaster" (p. 338). In addition to the social factors described above, they found that the pilot's point of view carried more weight, regardless of whether s/he was correct or not.

This discussion emphasizes the critical role that avalanche team supervisors have in leading their teams towards success. Verbalizing thoughts so the entire team can develop a shared situational model, encouraging diverse views, and providing positive feedback and direction during difficult tasks are examples of exemplary team leadership. Thus, individual skills and knowledge alone are not sufficient for successful team performance (Orasanu and Salas, 1993; Sexton, 2004). Communication, therefore, must be a key emphasis within the team decision-making process.

III.9. Communication

Communication is central to team performance, and is especially critical in non-routine tasks (Klein, 2003; Orasanu et al., 2001; Sexton, 2004). Environments that encouraged effective and open communication resulted in improved judgment and decision actions, and reduced subjective biases that may have been present in an individual decision-maker. Communication was fundamental to the creation of shared mental models in individuals, teams, organizations and professional associations in my study.

High quality communication is also associated with high-quality solutions and team performance. Research indicates that higher rates of verbalization result in better decision-making, such as task specific information exchange, suggestions of intent,

acknowledgements and disagreements (Orasanu and Salas, 1993; Sexton, 2004). When teams have strong, shared mental models they are able to create shared situational models, which are critical when situations and conditions demand non-habitual responses (Klein, 1998; Orasanu and Salas, 1997).

Greater levels of communication within the five human realms (individual, team, client, organization and socio-political) resulted in less uncertainty, higher levels of decision confidence and reduced human factor influences experienced by decision-makers. In addition, effective communication fostered shared mental models regarding goals and conditions between decision-makers and management, and resulted in collective understanding and higher levels of support for the decision-maker's judgments and decision actions. The importance of communication has been widely recognized in the literature, and along with enhancing predictability, has been identified as the primary method of reducing human error in high-stakes decision-making (Sexton, 2004).

Conversely, inadequate communication, resistance to differing options, and group-think (Janis, 1972) were key factors in the critical incident decision summaries (CIDS) of avalanche accidents and close calls in my study. This finding correlates directly with research in the aviation field showing that minimal communication, negative expressive styles, and low task motivation results in poor coordination and high performance errors (Orasanu and Salas, 1993; Orasanu, 1990). Thus, I suggest that an emphasis upon effective communication within all five human realms has significant potential in decreasing human error and increasing decision success.

III.10. Decision Success

As the results have demonstrated, experience, knowledge and skills, and information relevant to the human, physical and environmental systems are the foundation of avalanche judgment and decision success. Rich mental models developed from extensive avalanche domain-specific knowledge and experience, resulted in exceptional perceptual and cognitive expertise within the avalanche experts in my study.

These experiences resulted in participants having an attitude of deep respect for the uncertainties inherent in avalanche phenomenon, for the consequences of involvement, and for the imperfect nature of human decision-making. Knowledge of these limitations appears to be an invaluable tool that enhances the judgment and decision capacities of these avalanche experts. Maintaining an attitude of safety, being metacognitively aware, and incorporating a buffer zone in decision actions were primary strategies in achieving successful decisions.

The avalanche experts in my study possessed a deep motivation to learn and to improve their knowledge and decision-making capacities. They engaged in deliberate practice activities such as feedback, critical thinking, reflection and professional development, which have been found to be key learning tactics of experts for improving decision performance and developing expertise (Ericsson et al., 1993; Philips et al., 2004). These tactics result in the strengthening of intuitions and a deeper understanding of the intricacies and dynamics of the avalanche domain (Klein, 2004; Phillips et al., 2004).

The finding that participants were motivated, self-directed learners is an important finding in this study, since it suggests that avalanche decision-makers of all levels can significantly improve their judgment and decision-making capacities by engaging in

targeted activities and decision-skills training. Recommendations specific to building and supporting avalanche-related judgment and decision-making are discussed in detail in Chapter Five.

III.11. Time Pressure

The theme of time pressure resonated throughout this study and was a fundamental variable that determined the primary mode of cognitive function used to solve the decision problem, the degree that heuristic strategies were utilized, and the level of anxiety experienced by the decision-maker. While time pressure is a reality in avalanche decision-making, prior preparation and metacognition is fundamental to ensuring cognitive workload is not exceeded during time-pressured decision-making.

Building a strong mental model of the avalanche domain, a shared situational model of the current conditions, and choosing appropriate goals and objectives prior to the occurrence of decision events, prepared these avalanche experts and their teams for greater success. In addition, maintaining a high level of systems thinking and metacognitive awareness throughout judgment and decision actions, enabled the avalanche experts in my study to perceive the situation with greater accuracy resulting in sound decisions.

III.12. Decision Errors and Human Factor Influences

While a central proposition of traditional decision research is that decision errors result from the individual strategies or cognitive capacities of the decision-maker, recent research identifies the critical importance of understanding decision errors through an examination of the contextual factors that were present (Orasanu et al., 2001, Rasmussen, 1997; Reason, 1997; Stefanovic, 2003).

The biases and decision traps that I have reported may appear to be an irrational response when compared to normative frameworks. However, we must consider the strong influences of the individual, team, client, organization, and socio-political realms in these processes. Fear of appearing incompetent, social pressures within teams, pressure to open avalanche prone terrain by clients, logistical and financial pressure from organizations, and desires to maintain cultural cohesion within associations are examples that resulted from my study. Additionally, varying perceptions of risk, and varying levels of acceptable risk exist within these human realms.

Selecting appropriate avalanche program goals and objectives should include considerations for all of the human realms, including the level of acceptable risk. An additional consideration of key importance in reducing human error is the reality of the dynamically changing conditions that exist within the physical and environmental realms. These findings are significant since they clearly frame the boundary conditions within which avalanche decision-makers must consider the decision problem.

While in retrospection, a majority of the participants in my study recognized the human influences present in their CIDS's, they simply succumbed to the excessive pressure they faced. My research illuminates the conflicting challenges that avalanche decision-makers face as they strive to achieve a balance between the widely varying goals and objectives within the realms of human influence, and the dynamically changing conditions within the physical and environmental systems.

I suggest that a systems approach to identifying contributing factors in decision errors is to focus on the process and not the outcome, and to examine the interrelationships between individual human factors, situational and task influences, and

external human factor influences. This notion is consistent with recent literature emphasizing the need to understand the systemic causes underlying decision processes instead of casting blame upon decision-makers for the outcome (Orasanu et al, 2001; Rasmussen, 1997; Reason, 1997).

In the following sections, conclusions regarding the realm of the individual decision maker are offered within this systemic awareness.

Cognitive factors.

Lack of relevant knowledge, experience and information were the fundamental factors contributing to close calls and avalanche accidents in this study. "Lack of knowledge can lead to both misdiagnosis of a problem and to choice of a poor solution" (Orasanu et al., 2001, p. 217). For example, although the avalanche experts in this study had extensive experience in the avalanche domain, they may lack specific knowledge when faced with a novel situation. The deep persistent instability in the 2002 / 2003 snowpack was an example cited by numerous participants in my study.

A failure to simulate consequences when experiencing time pressure or increased cognitive workload was an additional related factor in my study. This was particularly prevalent when conditions in the physical, environmental or human systems were undergoing subtle changes. This notion is consistent with Klein (1993) who reported that failure to simulate outcomes frequently leads to errors in choosing decision actions.

Physiological influences.

Physiological influences such as fatigue and environmental stress degraded these avalanche experts' capacities to make sound judgments and decisions. Narrowing of attention, failure to seek alternatives, less discriminate use of information, and increased

use of heuristic strategies when inappropriate are examples of the resulting consequences. When suffering from the effects of physiological influences, avalanche decision-makers can improve their judgments using metacognition, however the stark reality is they are operating at a cognitive deficit when faced with situations that require increased cognitive workload.

In addition, modulating variables such as fatigue and stress, coupled with communication patterns, interact with individual variables such as knowledge and skills to result in unintended actions of the decision maker (Patel and Arocha, 2001).

Psychological influences.

Decision errors can often be attributed to the situation assessment as opposed to the selection of actions (Endsley, 1997; Klein, 1998). "Decision-makers make the correct decision for their perception of the situation, but that perception is in error" (Endsley, 1997, p. 270). While accurate perception is fundamental to good decision-making, goals and mental models are integrally linked and are critical to the formation of accurate situational models (Endsley, 1997; Orasanu et al., 2001).

Endsley (1997) argued that a decision-maker's goals and expectations influence how their attention is directed, and how information is perceived and interpreted within their mental models. He suggested that decision-makers select actions that line up their perception of the environment with their goals and objectives. Orasanu et al. (2001) reported similar findings, identifying the intended goals or outcome as key indicators, since decision-makers strive to achieve their goals through their decision actions. Thus, balancing the goals and objectives of the avalanche program with the conditions within the three systems of influence is of critical importance to ensure sound avalanche

decision-making.

The impact of goals and mental models on judgment and decision-making is particularly problematic in the high-stakes avalanche domain. Since avalanche accidents and close calls are infrequent, they are an insensitive indicator to decision quality feedback. As a result, false positive feedback experiences may become reinforcing experiences of poor decision actions, and may lead to overconfidence. Repeated experience develops mental models and expectations about future events that predisposes decision-makers to perceive information that is in agreement with their mental models (Endsley, 1997). For example, in a study of recreational avalanche accidents in the United States, the familiarity that resulted from past experiences and actions led avalanche accident victims to believing their behaviours were appropriate in the current situation (McCammon, 2002). Research indicates that the use of metacognition reduces the overconfidence bias by requiring decision makers to think about the reasons and assumptions that underlie their judgments and choices (Pilske, et al., 2001).

The fear of appearing incompetent and uncertainty regarding performance resulted in anxiety that can lead to a narrowing of attention resulting in impaired performance. Research indicates that social factors exert a significant influence on judgment and decision-making, and creates goal conflicts that can result in an unwillingness to admit lack of knowledge, and to continue even in the face of uncertainties (Orasanu et al., 2001). Applying metacognitive awareness is a fundamental approach to the correction of biases in intuitive judgments (Kahneman, 2003).

III.13. Concluding Remarks

Avalanche-related judgment and decision-making is very complex and occurs at the center of three systems of influence; human, physical and environmental. Even when the decision problem is well understood, the information upon which avalanche decision-makers depend may be more or less precise. Interpretation of this information involves the integration of complex data from a variety of sources, and occurs within a dynamic interaction of human systems that bring widely different perceptions and values to the decision process.

A major goal of my research was to decouple the judgment and decision processes of avalanche experts, and to illuminate the cognitive modes and strategies used in real-world settings. I suggest that a more complete understanding of these processes and the systemic factors that influenced successful judgments and decisions will enable avalanche decision-makers and training organizations to take a strength-based approach and focus upon the enhancement of these capacities at expert, and where appropriate, novice levels.

A second objective was to shed light upon the boundary conditions and human factors that posed significant challenges to avalanche-related judgment and decision-making in this group of avalanche experts. I suggest that a more complete understanding of the influence of potentially negative human factors will enable avalanche decision makers and stakeholders to recognize and manage their presence, therefore reducing the frequency of human factor decision errors in avalanche accidents.