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Identifying the team skills required by nuclear power plant operations personnel.

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Identifying the team skills required by nuclear power plant operations personnel.

Abstract

The purpose of this study was to identify the team skills required by nuclear power plant operations team members. An initial domain familiarization consisted of a review of company documentation; observations in the control room, on-plant and in the simulator; and role interviews. In the second phase, Critical Incident Technique (CIT) interviews were carried out with 38 operations team members on three British nuclear power plants. A total of 314 statements concerned with teamworking skills were identified from the interview data and used to develop the nuclear team skills taxonomy. The taxonomy had five categories: shared situation awareness, team focused decision making, communication, co-ordination, and influence, with 16 component elements.

Relevance to industry

Effective teamworking in high-risk industries is crucial for both safety and productivity. The methods described in this paper could be applied to identifying team skills required by personnel in other domains. The taxonomy of team skills can then be used to develop a behavioral rating system to evaluate or assess team skills, identify team training requirements and to aid in mishap investigation.

Keywords

Nuclear, team skills, critical incident technique.

1. Introduction

The majority of operational work in high risk industries is performed by teams rather than by people working in isolation. Given the importance of effective team working for the maintenance of workplace safety, teams in high risk work settings have become a key topic for researchers (Turner and Parker, 2004; Glendon, et al., 2006). This has been driven by the findings from a number of high profile accidents in which a lack of effective teamwork was identified as causal, e.g. the collision at Tenerife between the *Pan-Am* and *KLM* planes, 1977 (Weick, 1990) or the shooting down of the Iran Air passenger aircraft in 1988 by the *USS Vincennes* (Cannon-Bowers and Salas, 1999).

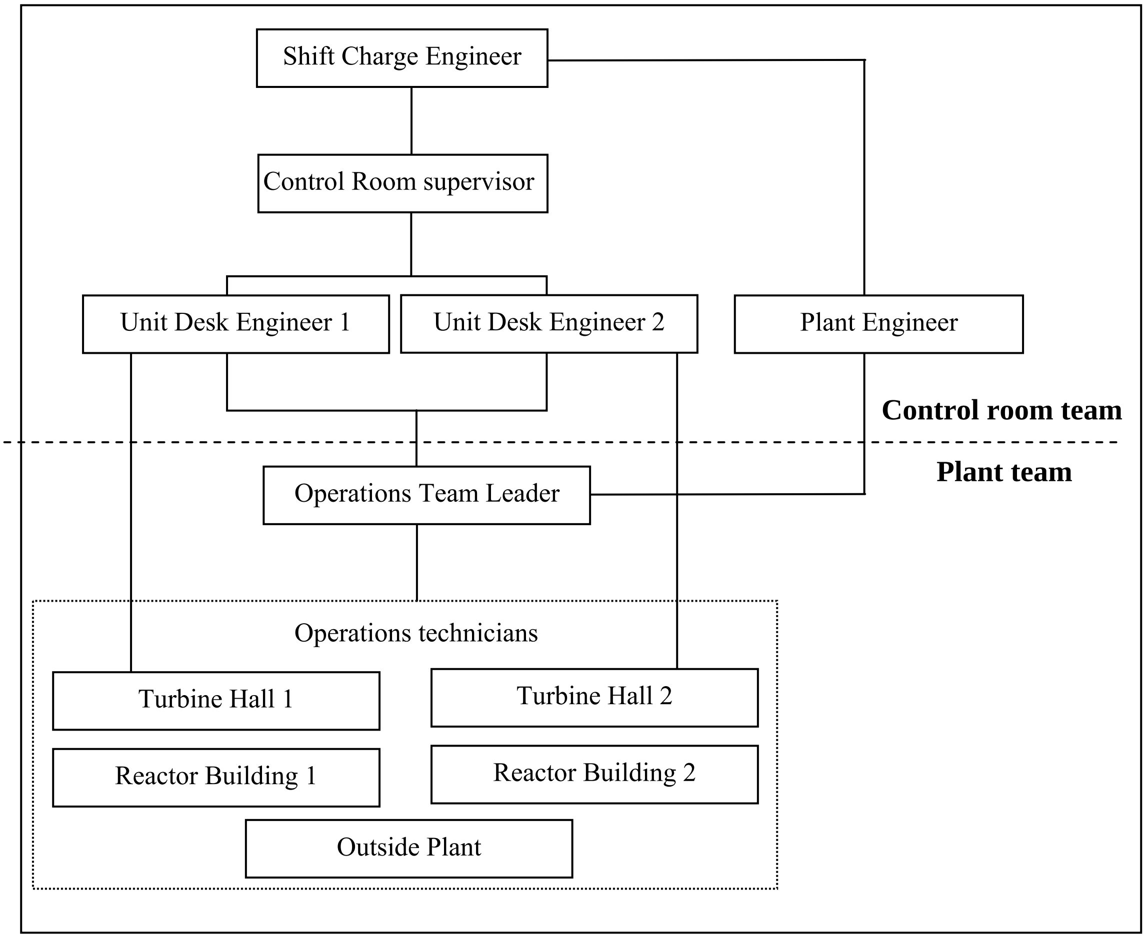
Problems in team working have also been implicated in accidents on nuclear power plants. Wilpert and Klumb (1993) discussed the social dynamics within and between teams in the radioactive release from the German *Biblis-A* nuclear power plant in 1987. Similarly, problems in communication and co-ordination were identified in the *Votgle-1* nuclear plant incident (Patrick and Belton, 2003). The focus of the research described in this paper is on those skills that support effective teamworking: "*the repertoire of required skills and behaviors necessary to perform the team task effectively*" (Cannon-Bowers, et al., 1995: 336). The purpose of this study was to develop a preliminary taxonomy of the team skills required by individual members of the operations team on a nuclear power plant.

1.1 The Operations Team

The nuclear operations team is an example of an action team. Action teams consist of personnel who are experts with specialist training, the team has an extended life span, and is synchronized with other personnel (Salas, et al., 2004). Moreover, action teams work in environments characterized by conditions of time pressure, ambiguity, stress, incomplete information, and severe consequences of error (Paris, et al., 2000). Other examples of action teams include: medical teams, civil aviation teams, and military teams.

The nuclear operations team is responsible for running the plant (see Figure 1) and consists of personnel in six different roles, in two different locations – the control room and out on the plant. The Shift Charge Engineer (SCE) is the most senior team member and has overall responsibility for the safe production of electricity. In the Central Control Room (CCR) are the CCR Supervisor (CCRS) and two Unit Desk Engineers (UDEs) who monitor the plant from their desk indications and from their communications with the Operations Technicians. The Plant Engineer (PE) carries out trouble-shooting tasks out on the plant. The Operations Team Leader (TL) supervises five to seven Operations Technicians (OT) who generally work independently out on the plant. They carry out routine checks, and are also under the direction of the CCR team.

Figure 1. Operations team of a typical UK nuclear power station.



1.2 Research on the team skills of action team members

A literature review was carried out to identify whether there were any specific frameworks of teamwork skills that could be applied to these nuclear power plant personnel. There were no such frameworks in the literature from the nuclear power or similar energy production industries. The vast majority of the research on identifying team skills has been carried out with military teams (e.g. Cannon-Bowers, et al., 1995). However, there is a growing literature on the team skills required for safe and productive teamworking from civil aviation, and, more recently, the health care industry. In the aviation industry these skills are generally described as Crew Resource

Management (CRM) skills. While, there is no standard set of CRM skills, the literature tells us that CRM skills include: teamwork, leadership, situation awareness, decision making, communication, and personal limitations (Flin and Martin, 2001; Salas, et al., 2006a).

In the nuclear industry, research on teamworking is limited. Most of the studies address the team skills, cognitive skills, or the ergonomic considerations of Control Room personnel only. Studies that have examined the cognitive aspects of performance of Control Room personnel include: Hogg, et al. (1995) developed a situation awareness measure for control room staff; Carvalho, et al. (2005) examined how control room supervisors make decisions; Patrick and Belton (2003) measured differences in situation awareness between six control room teams; Bobko, et al. (1998) examined the effects of circadian change on the performance of control room teams; Meister (1995) developed a method for describing the cognitive behaviors of desk engineers; and Yun et al. (2000) assessed a checklist for evaluating the ergonomics of a system designed to aid control room personnel the human factors evaluation of the operator aiding system. Studies that have examined teamworking include: Gaddy and Wachtel (1992) report on a training program which was designed to foster team skills in the control room; Montgomery and Hauth (1992) describe the development of a rating scale for assessing the human factors skills of control room staff; Sebok (2000) compared the effectiveness of interface design and staffing levels on various aspects of team performance in the control room; and Harrington and Kello (1993) assessed the attitudes of control room staff to human factors and teamworking issue.

However, plant teams who work in conjunction with the control room team, to form the operations team, rarely feature in published reports of nuclear team performance research. The plant team are the ‘eyes and ears’ of the control room team. Therefore, the performance of the plant team and their interface with the control room team are crucial for safe and productive operations. While the teamworking skills on the plant may be similar to those of the control room, there has been no taxonomy systematically developed for either group. Furthermore, the interface aspect of skills required for effective functioning between the two groups has not been previously examined. For these reasons, the more general literature on teams in workplace settings was used to source a possible framework.

Salas and Cannon-Bowers (2000) summarized over 30 years of research from multiple domains, into the skills required for effective teamwork. They formulated an initial list of over 130 skill labels, that they summarized into 10 teamworking behaviors: adaptability, shared situational awareness, mutual performance monitoring, motivating team members/team leadership, mission analysis, communication, decision making, assertiveness, interpersonal relations, and conflict resolution.

While the Salas and Cannon-Bowers (2000) list of team skills represented a good starting point for the development of a nuclear team skills taxonomy, it was not appropriate to simply apply this framework to UK nuclear operations teams. The reasons are:

1. The Salas and Cannon-Bowers (2000) framework is largely based on research carried out with US military teams. The culture and organizational norms of military personnel do not equate to those of civilian industrial workers. For example, there is likely to be a different outcome of challenging a manager's instruction to do a task in a nuclear power plant, compared to questioning an order from a superior officer in the military. There may also be cultural differences between social norms and behaviors in UK versus US settings.

2. It is based upon research papers often only investigating a single team competency, e.g. decision making by aviators (Orasanu, 1993).
3. There is overlap between the concepts, thus it may be difficult to use the list to categorize team competencies with an acceptable level of reliability. For example, the definition of shared situational awareness is the "process by which team members develop compatible models (shared understanding) of the teams' internal and external task environment" and the definition of decision making is the "process by which team members gather and integrate information, use sound judgment, identify alternatives, select the best solution, and evaluate the consequences" (Salas and Cannon-Bowers, 2000, p.317).
4. The definitions of some of the 10 team skills are imprecise, and thus open to interpretation. To illustrate, the definition of interpersonal skills is the "process by which team members optimize the quality of team members' interactions through resolution of dissent, utilization of co-operative behaviors, or use of motivational reinforcing statements" (Salas and Cannon-Bowers, 2000, p.317).

Therefore, the list of team skills identified by Salas and Cannon-Bowers (2000) can only guide the identification of team skills required by nuclear operations team members.

1.2 Study aims

The aim of this effort was to develop a taxonomy of team skills for a nuclear power company that was parsimonious, consisted of discrete subcategories, and written in language that would be readily understood by nuclear operations team members. This was to be designed as a tool for practitioners rather than for researchers. The purpose of the taxonomy is to provide a framework for trainers to identify the team skills required to be developed, allow for more effective debriefing of team performance, and aid in investigating mishaps.

2. Method

There are a number of methods that can be used to identify team skills, such as accident analysis, observation, questionnaires, and interviews (see Flin, et al., 2008). In deciding on the most appropriate methodology to identify the team skills required by operations personnel, there were two main issues for consideration: accidents are extremely rare in the nuclear industry so they are not a rich avenue for study; and there is limited industry-specific research to guide the identification of team skills for operations team members. Therefore, there was a need to use a methodology that allowed for the identification of a rich data set for study.

The process of developing the nuclear plant operations team skills taxonomy consisted of three phases: a) domain familiarization and b) critical incident interviews and c) taxonomy development.

2.1 Domain familiarization

The researchers familiarized themselves with the roles, culture, and technical language of the nuclear power company by examining role profiles, job task analysis documentation and process documentation for each operations team member. They also carried out extensive observations, on site, at three nuclear power plants (27 hours in the CCR, 13 hours on the plant and 27 hours in the control room simulator). Finally a total of 22 role familiarization interviews, of 30 minutes to an hour in length, were conducted with a cross section of operations team members. This data gathering phase was an essential first stage in understanding the roles, processes, technical details associated with each team role and paved the way for the critical interview phase.

2.2 Critical Incident Interviews

Interview sample. The research was conducted at three nuclear power stations from a single company within the UK. A total of 38 operations team personnel were interviewed, Operations Technicians (12), Unit Desk Engineers (11), Shift Charge Engineers (5); Operation Team Leaders (4), Control Room Supervisors (3); and Plant Engineers (3). All respondents were male, and all volunteered to take part in the study. Permission to tape record the interview was granted by all respondents. Interviews took place on the power plants during normal working hours and each interview was conducted by the psychologists on the team (working in pairs). The mean time of the interviews was 55 minutes, ranging from a minimum of 35 minutes, to a maximum of 90 minutes.

Interview Procedure. The Critical Incident Technique (CIT) interview was employed to aid respondents' recall of a challenging case or incident for analysis. Challenging situations provide a rich source of data for researchers investigating expertise in highly skilled workers (Crandall, et al., 2006; O'Connor, et al., 2007; Seamster, et al., 1997). The CIT interview is a task analysis method used for evaluating systems and behavior in work environments. The technique was originally developed to examine flight crew selection, readiness, and performance (Flanagan, 1954) but has subsequently been adapted for other domains (Crandall et al., 2006) including nuclear power plants (Carvalho et al., 2005). The CIT enables the researcher to identify the (often tacit) knowledge of skills and expertise possessed by respondents. It goes beyond procedural knowledge by probing the behavioral aspects of experience. It should be noted that the term 'critical' implies a crucial role in the system and not whether or not the event was an emergency.

The CIT interview uses recollection of a specific incident at its starting point and employs a semi-structured interview format which involves a number of 'sweeps' through the incident. The four sweeps in the CIT interview include:

Sweep 1 - Prompting the interviewee to identify a relevant incident:
Each participant was asked to select and describe an event from their own perspective and to describe it in detail, stage by stage as it developed.

Sweep 2 - Filling in gaps in the incident:
The interviewer repeated the reported incident back to the respondent, in order to check understanding. The respondent was told they should correct any mistakes in the account or add any information that was omitted during the recounting. This sweep helps to pinpoint gaps, both in time and events, and typically aids in recall of the missing portions. In addition, this enabled the researchers to trace the development (or deterioration) of teamwork throughout the incident.

Sweep 3 - Expanding on the incident to look for cues and factors affecting teamwork:
The interviewer went through the event again, this time probing at various points and asking for more detailed description of the teamwork aspects of the situation. This sweep involved questioning the reasoning process and looking for cues and rationale for the actions taken by team members.

Sweep 4 - "What if" queries:

A typical question might be, "Would you have acted the same way at an earlier point?" or "would someone with less experience than you have acted in a similar way?" The researcher listens for other possible courses of action and interpretations.

Interview transcription. Rather than transcribe the whole interview, the recording was used to develop a single full report of the incident. The events were put into chronological order and repetitions omitted. The interviews were 'edited' into a standard format that was concise, clear and comparable across the 38 interviews. The written account was then sent back to each respondent via e-mail or by post. This allowed the report to be checked for accuracy and to allow the respondent the opportunity to include any additional information. Of the total 38 reports, seven were returned including extra comments. For the other 31 reports, no changes were specified.

2.3 Taxonomy development.

The first stage of the process was to identify the statements concerned with the team skills necessary to perform team tasks effectively in the challenging situation. Two researchers, who had participated in the domain familiarization and carried out the critical incident interviews, conducted the data analysis. A total of 432 statements were extracted from the interviews. The researchers independently separated those statements that were concerned with skills relating to teamwork from those that were not. Statements concerned with attitudes (e.g. "*everyone respected the other team members*"), knowledge about the team (e.g. "*it can be difficult to work with a different shift, all shifts do not work the same way*"), or technical knowledge or information (e.g. "*the pressure indication was 3000 psi*") were not selected. Cohen's kappa was used as a measure the inter-rater agreement on whether the statements judged to be a teamwork skill or not. A Cohen's $\kappa = 0.88$ of resulted. Landis and Koch (1977) propose that values over 0.81 indicate near perfect agreement. The raters discussed those 36 statements to which they did not agree, until they reached a consensus about whether they represented skills related to teamwork or not.

A total of 314 statements concerned with teamwork skills were identified for categorization from the 38 interviews. Each rater read through the 38 interviews again, and developed an initial coding structure guided by both the interview data and the Salas and Cannon-Bowers (2000) teamworking behaviors (see Table 1).

Table 1. Initial nuclear team skills coding framework.

Category	Elements
Building situation awareness	Information gathering
	Develop understanding
	Anticipation
	Maintain overview
	Performance monitoring
	Cue strategy association
Team focused decision making	Analytical decision making
	Procedure following
	Resource allocation
Communication	Assertiveness
	Information exchange
	Listening
Co-ordination	Co-operation
	Adaptability
	Supporting behavior
	Team workload management
Leadership	Leadership
	Motivation
Team characteristics	Followership
	Initiative

Cross analysis. The 314 statements concerned with team skills were categorized independently by the two raters using this coding framework. On the first occasion this was completed, the reliability between the two raters was $\kappa = 0.65$. The raters discussed the areas of disagreement, and revised the initial framework. Revision involved combining categories, splitting categories and making categories more distinct. The changes made to the initial coding taxonomy are summarized in Table 2.

Table 2. Changes to the initial coding taxonomy.

Category	**Element**
Building situation awareness	• Information gathering and developing understanding elements integrated. • Cue strategy association moved to team focused decision making category and renamed as Intuitive decision making.
Team focused decision making	• Intuitive decision making added to category. • Initiative moved from Team characteristics category to team focused decision making. • Resource allocation element removed and integrated with team workload management element in co-ordination category.
Communication	• Listening element integrated into information exchange.
Co-ordination	• Co-operation element moved to new influence category.
Collaboration (previously leadership)	• Motivation element integrated into leadership element. • Followership element from team characteristics category added. • Co-operation element added (from co-ordination category).
Team characteristics (This category was removed)	• Followership transferred to Influence. • Initiative moved to Team focused decision making category.

The revised classification system consisted of five categories and 16 underlying elements (see Table 3). The data were again independently recoded by the two raters, and the reliability between the two raters was $\kappa = 0.90$. The 29 statements for which there was no initial agreement were discussed by the raters, and they reached a consensus upon how they should be categorized.

Table 3. Nuclear team skills taxonomy with the percentages of classifications attributed to each role.

Category	Elements	Definition	*Example*	SCE*	CCRS	UDE	PE	TL	OT
Building situation awareness	Develop understanding	Analyzing and sharing the information in order to develop an accurate model of the problem or task.	*The CCR team had to think back to what was being done just prior to the power loss in order to identify what might have caused the power loss.*	8	8	11	14	5	6
	Anticipation	Forward planning to identify and discuss contingency strategies and/or possible future problems.	*A consideration that they kept in mind at this time was: if they had come off, then the whole side of the country might have lost electrical supply.*	3	5	3	3	2	3
	Maintain overview	Retaining a broad picture of a task or situation without becoming involved in the details.	*The SCE took the bigger picture while the other CCR personnel dealt with the problem.*	12	9	2	0	4	2
	Performance monitoring	Observing the activities and performance of other team members.	*CCR Supervisor took account of the inexperience of the desk engineer and kept a watchful eye on what he was doing.*	2	12	1	0	7	9
	Building situation awareness category total			**26**	**35**	**16**	**16**	**18**	**19**
Team focused decision making	Analytical decision making	Gathering and integrating information from team members, selecting the best solution, and evaluating the consequences.	*The CCR team had to decide whether to trip the reactor or stay on load.*	11	9	6	3	4	2
	Procedure following	Following written procedures.	*Operations Technicians work to the job instructions.*	2	0	5	11	4	7
	Intuitive decision making	Associating cues in the environment to appropriate corrective actions and making a decision.	*The CCR team was responding to alarms, and reacting to the system.*	0	4	8	0	0	0
	Initiative	Using judgment to make decisions and carry out tasks without needing to be told what to do.	*The Team Leader heard about this on the radio and thought it sounded strange, and went over to investigate the problem.*	1	0	1	11	5	5
	Team focused decision making category total			**15**	**13**	**19**	**24**	**12**	**13**

*SCE= Shift Charge Engineer; CCRS= Central Control Room Supervisor; UDE= Unit Desk Engineer; PE= Plant Engineer; TL= Team Leader; OT= Operation Technician

Table 3 continued. Nuclear team skills taxonomy with the percentages of classifications attributed to each role.

Category	Elements	Definition	*Example*	SCE	CCRS	UDE	PE	TL	OT
Communication	Assertiveness	Communicating ideas and observations in a manner which is persuasive to other team members.	*The Operation Technicians had to tell the control room personnel to wait.*	1	1	3	3	2	5
	Information exchange	Exchanging information clearly and accurately between team members.	*The Plant Engineer was kept informed of how things were progressing.*	11	13	19	27	20	13
	Communication category total			**12**	**15**	**22**	**30**	**22**	**18**
Co-ordination	Adaptability	Reacting flexibly to changing requirements of a task or situation.	*UDEs from another shift were in the control room at this time working as a single team.*	3	3	4	3	1	4
	Supporting behaviour	Giving help to other team members in situations in which it was thought they need assistance.	*If someone is struggling, and the operation technician is not busy, he will come and help.*	2	3	6	0	4	12
	Team workload management	Prioritizing and coordinating tasks and resources.	*There was a need to prioritize activities.*	9	4	9	5	18	8
	Co-ordination category total			**15**	**9**	**19**	**8**	**22**	**24**
Collaboration	Leadership	Directing and coordinating the activities of, and motivating other team members, assessing team performance, and establishing a positive atmosphere.	*The CCR Supervisor directed the activities on the desk.*	15	19	8	14	19	1
	Co-operation	Two or more team members working together on a task which requires meaningful task interdependence without any leadership.	*At times like that the generation team 'muck-in' together to get jobs done.*	17	9	15	8	6	17
	Followership	Co-operating in the accomplishment of a task as directed by a more senior team member.	*The operation technicians needed to work to the directions of the control room personnel as required.*	1	0	1	0	1	8
	Collaboration category total			**33**	**28**	**23**	**22**	**26**	**26**

3. Results

The final nuclear team skills framework is shown in Table 3. It has five categories and 16 elements: building situation awareness (four elements), team focused decision making (four elements); communication (two elements); co-ordination (three elements); and teamworking (three elements). Table 3 gives a definition of each element and examples from the CIT interviews – the categories are defined below. Table 3 also shows the percentage of statements (of the total for that role) which relate to a specific skill element for that role. The table highlights how often team members referred to that particular skill element for that role. To illustrate with an example, of the 40 statements made regarding the role of SCE 12% of these statements were categorized as 'communication'. Of that 12%, one percent were concerned with 'assertiveness', and 11% were concerned with 'information exchange'. These percentages could be viewed as a preliminary indication of the importance of each skill relative to the other skills for each role in the operations team. Each of the categories and elements are discussed in more detail below.

3.1 Building situation awareness.

Building situation awareness refers to the process by which individual team members build and share their mental models of what is going on with the plant and how the team is managing the situation. It is the process by which situation awareness is achieved and as such, it is a critically important facet of skilled performance to understand and develop (Klein et al., 2006). Definitions of the specific four elements that make-up building situation awareness, and examples of each, are shown in Table 3.

As can be seen from Table 3, shared situation awareness was of particular importance for the SCE and CCR Supervisor. In particular, the SCE was required to maintain an overview (e.g. "*the*

SCE was free to have the bigger picture across the two units, and this prevented him being sucked into the individual tasks"), and the CCR Supervisor had to monitor the performance of other team members (e.g. "*CCR Supervisor took account of the inexperience of the UDE and kept a watchful eye on what he was doing*").

3.2 Team focused decision making.

This category relates to the collaborative decision making skills of operations personnel. Team decision making differs from individual decision making in the sense that it is managed decision making (Orasanu, 1993). That is, in general, it is a more senior member of the team that makes the decision (for example, the SCE or CCR Supervisor in non-routine situations), but they are supported by input from the other team members. Team members can support the SCE by assisting in the monitoring of the situation, suggesting alternative options, reducing the workload, providing different areas of expertise etc. (Orasanu, 1990). When all team members share the same problem definition, they can provide or suggest relevant information or strategies, and understand requests or commands unambiguously (Orasanu and Salas, 1993).

The CIT data suggests that if the SCE was involved in the incident, then he was a key part of the analytical decision making process (see Table 3). However, decision making was usually not done in isolation, but rather in conjunction with the CCR Supervisor (e.g. "*the SCE and CCR Supervisor discussed the situation, and between them they decided that they would not trip the reactor*"). The greatest proportion of statements about team focused decision making were related to the Plant Engineer; this is not surprising given his role as an intermediary between the CCR and plant team.

3.3 Communication.

This skill category is concerned with the exchange of any information between different team members. It encompasses asking for, or providing information to other members of the team and assertiveness. The failure to exchange information and co-ordinate actions is one factor that differentiates between good and bad team performance (Driskell and Salas, 1992). Leaders who articulate their views of a task, and encourage this in other team members should be more successful in creating a shared mental model (Cannon-Bowers, et al., 1993). Exchanging information was found to be particularly important skill for the individuals out on the plant (i.e. the Plant Engineer, Operations Team Leader, and Operations Technicians). In many of the incidents, the people out on the plant were required to report back to the CCR on what they saw (e.g. "*the communication between the CCR and plant were between the UDE and Plant Engineer*").

3.4 Co-ordination.

The co-ordination category of skills applies to the skills of team members in organizing their joint activities to achieve a goal. In particular, the interviews indicated that operations team members must support the other members of the team as required and monitor their own and others' workload (see Table 3). For example, "*it can be difficult performing set checks and respond to calls from the CCR*."

3.5 Collaboration.

Collaboration is used here to refer to the manner in which members of a team are working together. The team or individual may be working under the direction of a leader (followership; "*the UDE told the Operations Technicians what to do*"), they may be working together without any one individual leading the task (co-operation; *"the UDE was aided by the SCE"*), or they may be the person responsible for the team carrying out the task (leadership; "*CCR Supervisor maintained charge of the CCR"*). As can be seen from Table 3, the extent to which the personnel in the operations team require these skill elements is dependent on their role within the team. As would be expected, statements about leadership were most often related to the leadership roles such as SCE, CCR Supervisor and Team Leader positions. However, co-operation was required by members in all positions in the team. For example, *"generally you don't have to ask for help, someone will just realize you need help."*

4. Discussion

The nuclear team skills taxonomy details the teamworking skills required by every member of the operations team. Efforts were made to make the taxonomy parsimonious, consist of discrete subcategories of team skills, and written in language that would be readily understood by nuclear operations personnel. It is our contention that the critical incident interview method could be usefully applied to other high risk industries for the identification of team skills and team training needs. Moreover, the resultant team skills taxonomy can be applied in a number of different ways to improve the safety and performance of operational teams. These are discussed below.

4.1 Evaluation or assessment of team skills.

The nuclear team skills taxonomy could provide the precursor of a behavioral marker system of team performance for nuclear operations team members. A behavioral marker system is a taxonomy or listing of key non-technical skills associated with effective and safe task performance in a given operational job position (Civil Aviation Authority, 2006). Behavioral markers are used by airlines (Flin, et al., 2003) and the acute medical specialties (Yule, et al.,

2006) to evaluate the performance of operators. However, if the nuclear team skills taxonomy was to be adapted for this purpose its validity, reliability, and sensitivity would have to be evaluated (see Flin, et al, 2008, for more details).

4.2. Identification of team training requirements.

The nuclear team skills taxonomy identifies the team specific skills that are required by each member of the nuclear operations team. The identification of training requirements is a crucial first step to guide the design, development, delivery, and evaluation of team training. (Goldstein and Ford, 2002; McGehee and Thayer, 1961; Salas, et al., 2006b). There is no point in developing a training course that does not address the needs of a given job and ultimately the needs of the organization, because it was based upon a poor training needs assessment. The nuclear team skills taxonomy could also be used to aid in selection, promotion, and to develop more detailed documentation on the roles in the operations team.

4. 3. Mishap investigation.

The nuclear team skills taxonomy provides a framework to allow mishap investigators to identify whether failures in teamworking may have contributed to the mishap; and provides a vocabulary to identify those teamworking failures. The proportion of causes of mishaps in high-reliability industries due to human error is generally estimated as about 80% (Reason, 1990). The collection of accurate accident data is important for improving, and maintaining, industrial safety. However, research suggests that many accident reporting systems are vulnerable to inaccuracies such as underreporting, incomplete recordings, and incomplete information about conditions and contexts, and do not provide a complete picture of the conditions under which accidents result (Stoop, 1997). For example, Gordon, et al. (2005) stated that most oil companies who operate on the U.K. continental shelf produce accident forms with extensive information, but the quantity and quality of the data concerning the human factors causes of such accidents is generally poor.

If accident investigators are to use the nuclear team skills taxonomy to investigate mishaps, they should be trained to ensure that they are able to use the taxonomy accurately and consistently, by reducing the likelihood of judgment biases and improving inter-rater reliability. To achieve acceptable levels of agreement will require extensive training to use the framework. Further, there may also be the need to provide CRM type training to investigators so that they are knowledgeable about human factors in team operations.

4.4 Limitations of the study

The main limitation of this study was that it was not possible to obtain outcome measures that revealed the behaviour patterns of high and low performing teams. This would allow for the identification of skills that differentiate between high and low performing teams. In studies carried out with military teams, it is very easy to find team-level outcome measures which provides very useful objective metrics for distinguishing between high and lower performing teams (e.g. number of targets identified, targets destroyed; Johnston, 1997; Bowers, et al., 1998). However, the problem of studying nuclear operations teams are that there are fewer unambiguous outcome measures available. Potential measures such as unplanned shut downs, accidents, or near misses happen so rarely, that these cannot be used as a useful method for distinguishing between higher and lower performing teams. Though, if the research described in this study is used to develop a behavioral marker checklist, this tool could be used by trained raters to evaluate the performance of members of the operations team during real or simulated events.

5. Conclusion

The complexity of a nuclear power plant requires multiple people with different knowledge, skills, and attitudes to work together as a team. Moreover, teams in high reliability organisations are responsible for tasks that, if performed incorrectly, can have implications for safety and for the commercial success of the company. Therefore, it is imperative that the science of team training and performance is used to help organisations understand the complexity of teamworking, and to identify techniques which can improve performance.

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