

# Safety in Marine Operations

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## ABSTRACT

Safety in marine operations primarily depends on forward-planning and people being aware of their surroundings and managing the presence of others in the same arena at the same time. Marine operations must contend with challenging environments and hazards that require greater domain awareness; especially when many operators from different organisations are working in the same area. Being aware of what is going on around you in a marine domain, is termed Marine Domain Awareness (MDA), which involves the perception and understanding of environmental factors, their meaning and effects, and foreseeing their likely status and impact in the near future. This paper applies Situational Awareness (SA) concepts to the safety of marine operations and proposes a model for developing an information exchange system to enhance marine operational safety. The proposed model enhances MDA and can help in developing procedures and training programs to promote domain awareness. A framework for the safe marine operation is outlined in this paper.

## 1. Introduction

Marine operations take place in an arena where members of several different organizations are required to work together within the same space and time. In such situations, several activities will take place in parallel. Participants may have incomplete or inaccurate knowledge of the whole operation, as well as the activity of others, which could affect their safety. Safety in a marine domain primarily depends on people working together and being aware of their surroundings and activities of other people.

This paper refers to the arena where activities are taking place as the “marine domain”, and people being aware of what is going on in the domain as Marine Domain Awareness (MDA). MDA is defined as the effective understanding of anything associated with the marine operational arena (with its spatial and temporal boundaries), which could adversely impact personnel safety or the environment. For this, information/data must be collected, analysed, understood and reported to those who need to know. Collected information should be shared with all people and organisations that are legitimately present in the arena. The collected data should identify likely hazards that need be avoided, controlled and mitigated. For the purpose of this paper, the goal of MDA is to establish an adequate level of operational and situational awareness for working in a shared domain, while considering the safety of others and operational requirements. MDA is the application of

Situational Awareness (SA) to the marine domain. MDA is a critical, yet not a fully developed component, for all marine operations. The Navy uses the term MDA to mean intelligence gathering and surveillance, which is only one element of MDA as described here.

*Effective understanding* occurs when a decision-maker has all the relevant data, as well as a good comprehension of it, enabling him/her to take appropriate actions. MDA consists of what is observable and known (Situation Awareness), as well as what is anticipated or suspected (Hazard Awareness). It is important that these two components are brought together to provide the decision maker with reliable and actionable information. The term “effective understanding” is meant to acknowledge that information requirements may vary depending upon the task at hand. Therefore, MDA equates to the correct understanding of the content, activity patterns, changes, and potential hazards in the operational arena.

Figure 1 summarises the basic principles of marine domain awareness as described in this paper. The concept of MDA is the cornerstone of the safety of marine operation

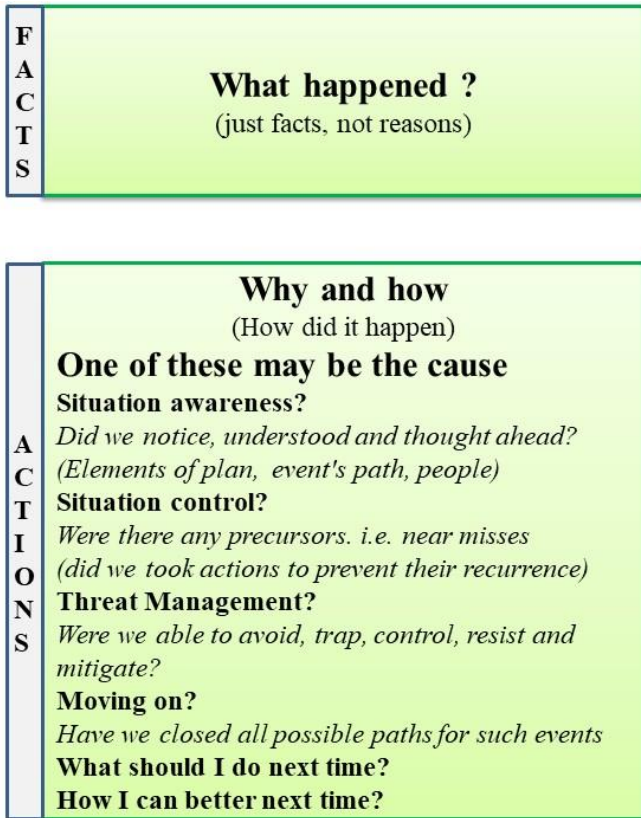


Figure 1: The basic ideas of using SA in marine operations.

Every individual has a different level of SA depending upon his/her own perception of reality, experience and knowledge. The situational awareness level of the person in charge determines the situational awareness level of a team. This is contrary to the belief that the team's level of awareness is the sum of the individual members' awareness (Garland and Endsley [12]). *Failures of situation awareness and situational assessment overwhelmingly predominate, being a causal factor in the majority of those accidents attributed to human error.* (Baker and Seah [2])

Codes of practice such as ISO 19901-6:2009 [22], DNV H101 and H102 [4 and 5] provide guidance for the planning and engineering of marine operations, encompassing the design and analysis of the components, systems, equipment and procedures required to perform marine operations, as well as the methods or procedures developed to carry them out safely. These codes, however, do not give much guidance on the influence of human elements. G-OMO [15], mentions SA, but the emphasis is the first element of the SA model, which is 'knowing what is happening around you'.

The claim is that good situation awareness results in good decision making, which in turn leads to a good

outcome. Awareness is a variable state, and that state can only be successfully maintained by continued reassessment the situation.

The aim of this paper is to detail a framework for the safe marine operation.

## 2. Situational Awareness

Awareness of what is happening in a marine arena, whether it is happening below, on, or above the water is a major step towards preventing accidents (Boraz [3]). Understanding the environment, judging the consequence of one's actions and the potential risks, are necessary components for safe operations. The method of understanding a situation is known as Situation Awareness (SA), and the application of the SA principle to marine operations is termed as Marine Domain Awareness (MDA), where the generic SA rules (Endsley [2012]) are adapted to the marine domain. The goal of MDA is to establish a level of situational awareness, for working in the shared marine domain (Harrald and Jefferson [18]), while not adversely affecting the safety of self, others and the operations. Figure 2 shows the steps of assuring safe marine operations. In order to make a decision, the decision maker must start with a situation assessment by first identifying any potential hazards. These include existing hazards, as well as things that could become hazardous if their intensity or location changes. The movement, in time and space, of these potential hazards must be predicted to the location relevant to the decision maker.

This study starts by knowing what is going on by asking questions like "What could go wrong?" "Who is doing what?" "What has happened before?" or "What could happen next?" ... and so on, and then trying to eliminate or avoid any identified potential hazards. Any hazard identification is naturally incomplete, errors will inevitably occur and systems must be in place to prevent and control them. If by any chance, a hazard is not detected, and hence no control is in place, then undesirable events could follow. Hence, there is a need for a last line of defence to mitigate their consequences.

Figure 3 shows the abstraction of two major elements for safe operations, namely Understanding (sense-making) and Resolution (decision making). Sensemaking is an attempt to understand what has happened and what is happening. The decision maker then asks "What should we do?"

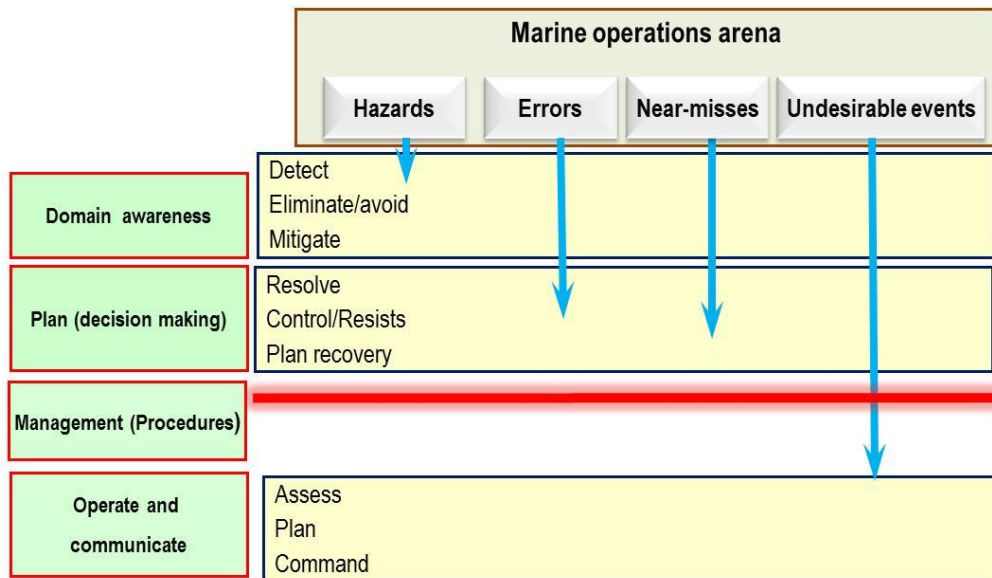


Figure 2: Steps of assuring safe marine operation

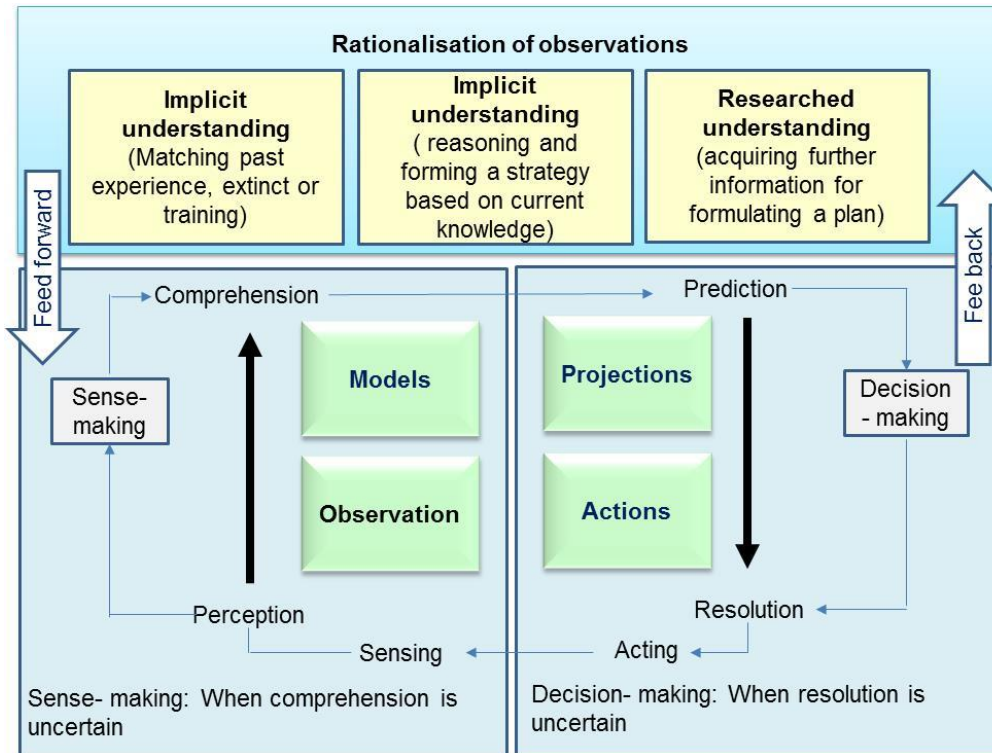


Figure 3: Sensemaking and decision making

The left-hand side shows information, which must be gleaned from the real world, and is fuzzy. If the implication of the obtained data is not immediately clear, then a mental model is used for sense-making; (the upper part of Figure 3). Such mental models may be based on past encounters, training or calculations and use of analytical methods (i.e. reasoned), new by research or assistance from experts. A decision is then made based on the forecasted outcome. In light of the likely consequences of the decision, the forecast may be revised.

Pilots developed the SA concept during World War I (Stanton et al, 2001). After World War 2, analysis of air combats showed that cognitive ability played a

large role in combat ability; 80% of all planes were shot down by 15% of pilots. A large majority of 'combat aces' survived the war. Flying skill or gunnery were not predictors of combat success (Jones and Endsley [23]). At this time, German and Allied Air Force officers noted that a large proportion of fighter pilots that were hit did not realise that they were under attack before their plane was destroyed (Nardon [24]). The term, "Space Situational Awareness" was coined by the US Air Force around this time.

In the late 1980s, interest spread to other domains such as the military (e.g. Endsley [7]), driving (Kaber and Ma [17]), and medicine (Parush et al [25], and

Wright et al [29]). However, with the exception of one article (Hudson & van der Graaf [21]), the concept has remained relatively unknown in civil marine operations. Lately, Finch [11] proposed a model for Undersea Domain Awareness. Endsley [6] defines situation awareness informally and intuitively as “knowing what’s going on” and, more formally, as: *“Situation awareness is the perception of the elements of the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.”* This definition appears to have stood the test of time, and it is also expressed in similar terms by other authors. SA is also defined as “up-to-the-minute cognizance required operating or maintaining a system” (Adams et al 1995). In other words, SA is the ability to successfully pay attention to, and monitor, the environment and essentially ‘think ahead’, in order to evaluate the risk of an accident occurring.

Endsley [8 and 9] differentiates between situation awareness, *“a state of knowledge”*, and situation assessment, *“process of achieving, acquiring, or maintaining SA.”* This distinction becomes important when trying to apply SA to marine operations. Since situation awareness is “a state of knowledge”, it resides primarily in the minds of humans (cognitive), while situation assessment is a process, which requires “sense-making”. Endsley also noted that:

*“SA, decision making, and performance are different stages with different factors influencing them and with wholly different approaches for dealing with each of them; thus it is important to treat these constructs separately.”*

In the context of Marine operations, Situational Awareness may be defined as (Garland and Endsley, [12]):

*“Knowledge and understanding of the unfolding events which promotes timely, relevant and accurate assessment of actions of self, team-members, and other participants and operations, within the working arena in order to facilitate accurate decision making.”* This requires an informational perspective and skill that fosters an ability to determine quickly the context, relevance and consequence of events as they unfold.

The term *situational awareness* describes the awareness of a situation that exists at a particular point in time (Endsley [8]). In some instances, information on the unfolding of events that preceded the current situation may also be relevant, as well as insight into how the situation is likely to unfold. The components of a situation include the mission and constraints on the mission, the capabilities and intentions of other operators, and key attributes of the operation. *Understanding* involves having adequate knowledge to be able to draw inferences about the possible consequences of events, as well as sufficient ability to predict future patterns (Endsley [9]).

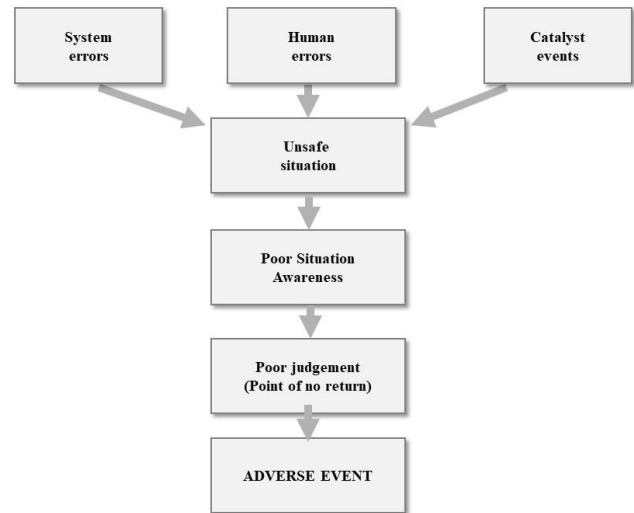


Figure4: Chain of events leading to a disaster

In general, a disaster follows a chain of events with some contribution from the human elements (Figure 4). Modern systems are designed to be in a safe state if any part fails to operate properly. The phrase “safe state generally mean s safe shut down without incident. Despite every effort system errs could happen either triggered by human or by a combination of poor design and degradation augmented by human error.

Endsley [7] defined three *levels* of situation awareness (SA) that are: Perception (including “noticing”), Comprehension, and Projection (Figure 5). Clearly, success at higher levels depends on the success at lower levels, and on the decision maker’s ability to predict the path of evolving events.

According to this model, SA begins with perception (Figure 5). *Perception* provides information about the status, attributes, and dynamics of relevant elements within the environment. Obviously, without a basic perception of important environmental factors, the likelihood of forming a correct picture of the situation is low. *Comprehension* of the situation encompasses how people combine, interpret, store, and retain information, as well as making sense of it. Thus, comprehension includes more than perceiving or attending to the information; it includes the integration of multiple pieces of information and a determination of their relevance to the underlying goals and the ability to infer or derive conclusions about the goals. Comprehension leads to an organised picture of the current situation with regards to the significance of objects and events. Furthermore, as a dynamic process, comprehension must combine new information with that which already exists to produce a meaningful picture of the evolving situation. The last level is knowledge of the status, the dynamics of the events, and the ability to make predictions based on that knowledge. These predictions represent a *Projection* of the elements of the environment (situation) into the near future (Endsley [6]).

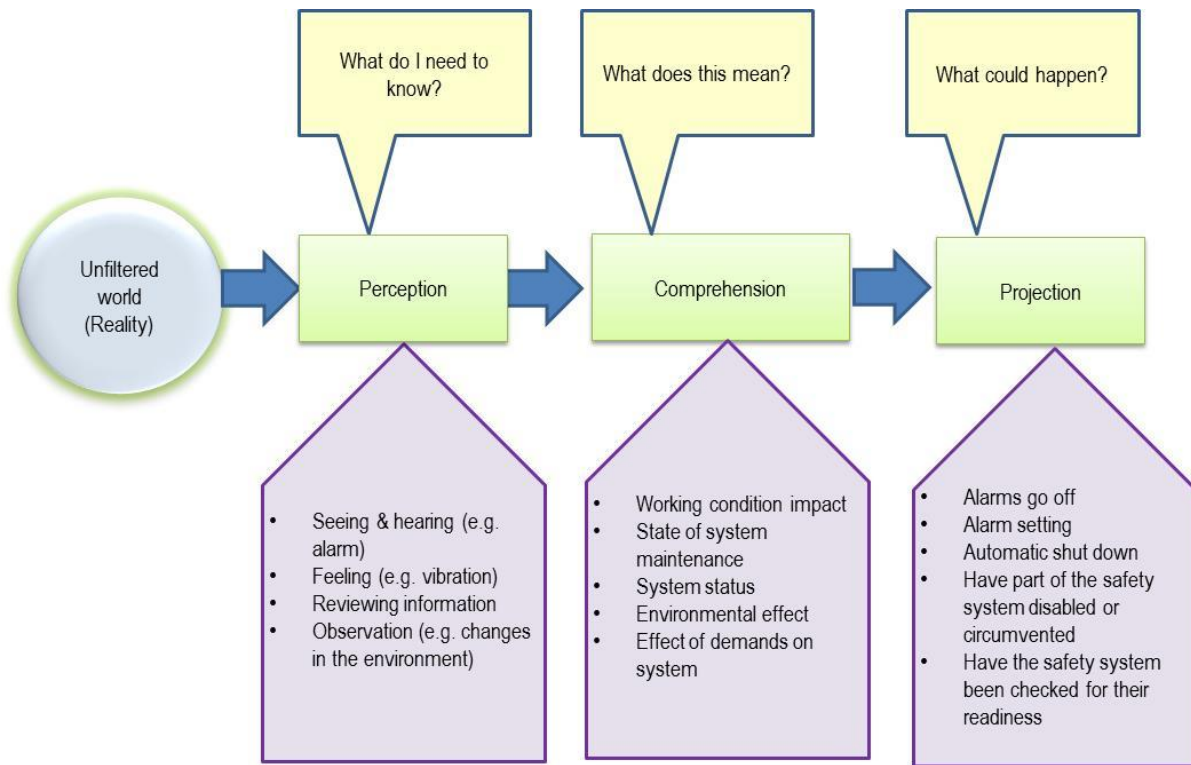


Figure 5 Three elements in Endsley's model

In Figure 5, Perception is the attempt to answer the question “What are the current facts?” Comprehension asks, “What is actually going on?” Projection asks, “What is most likely to happen if...?” All elements of Endsley's model run concurrently with continuous feedback and feedforward between them. As time marches on, any analysis will provide a higher level of understanding and transparency to the decision maker. SA is not action or performance. An operator with excellent SA of a failing system may not possess the knowledge of procedures to remedy the failures, or may not have the execution skills to implement the required remedy. In contrast, where automation can support effective performance, it is quite possible to have a good appreciation of the system performance in the absence of good SA. Within a few years of the appearance of the Endsley's article [7], the issue of team situation awareness emerged as an important part in understanding team dynamics: What does each worker know about the understanding and workload of his co-workers? and How is this supported by inter-worker communications and technology? -(Endsley & Robertson [10]). An issue of critical concern is how the concept of the “Team SA” extends beyond the collective average, or the sum of the individual SAs who make up the team (Kaber and Endsley [16])

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### 3. Endsley's Model

Situation awareness is recognised as a critical enabler for operational effectiveness and is a central element in contemporary system design approaches (Smith and Hancock [27]). Endsley [6] presents a model of situation awareness that highlights a number of issues relevant to the understanding and measurement of situation awareness. The model includes a consideration of the role of limited attention and working memory, mental models, pattern matching and critical cues, ties between situation awareness and automatic action selection, categorization, data-driven and goal-driven processes, expectations and dynamic goal selection (see Figure 6). Endsley's model defines situation awareness in terms of three levels:

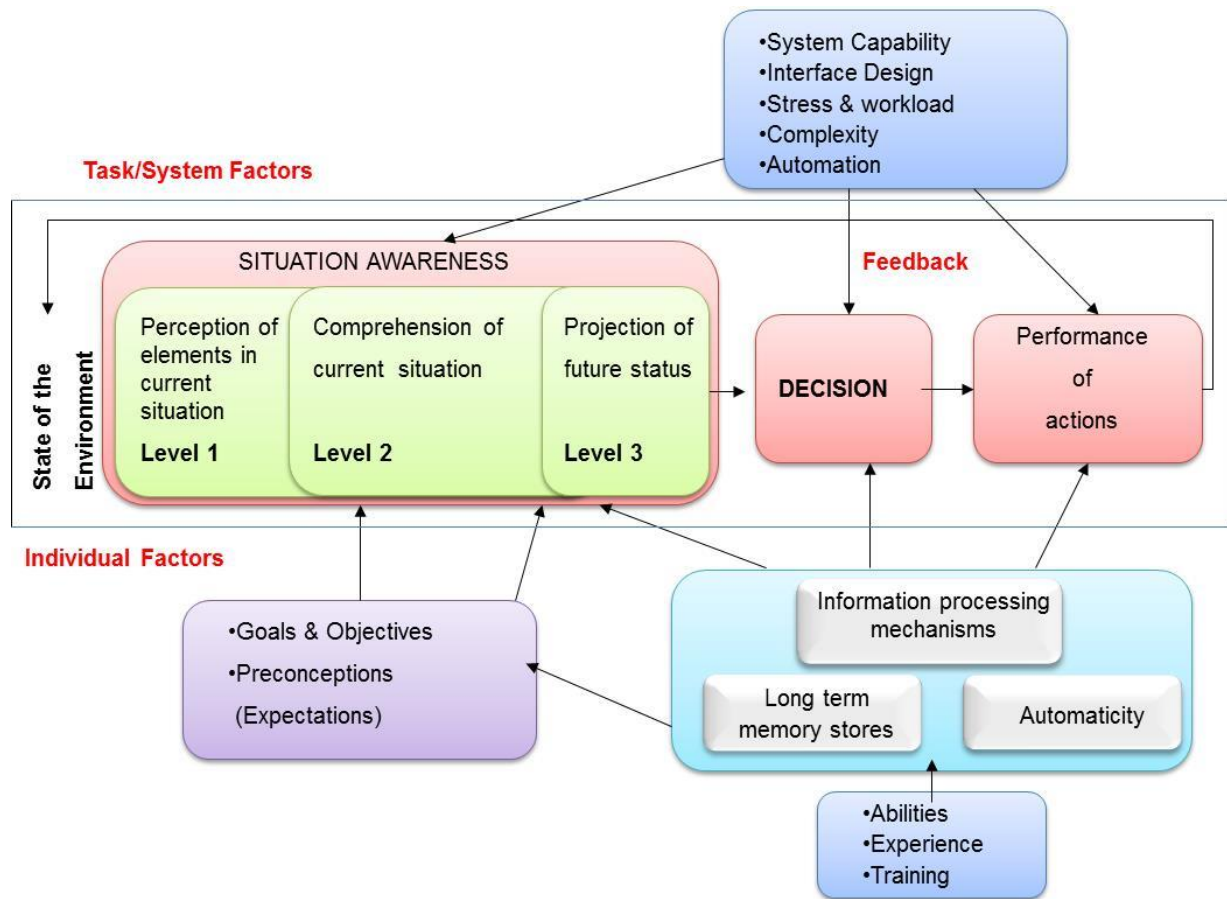


Figure 6: Endsley's Model of Situation Awareness

- **Level 1 – Perception:** Perception of environmental cues is fundamental to situation awareness. Without the basic perception of important information, the odds of forming an incorrect picture of the situation increase dramatically.
- **Level 2 – Comprehension:** The notion of situation awareness also encompasses how people combine, interpret, store and retain information. Thus, it includes more than just perceiving or attending to information; it also involves the integration (fusion) of multiple pieces of information and a determination of their relevance to the person's goals and objectives.
- **Level 3 – Projection:** At the highest level of situation awareness, the ability to forecast future events and dynamics is required. This ability to project from current events and dynamics to anticipate future events (and their implications) constitutes the basis for operationally-useful decision making, e.g. knowing that a threat to an aircraft is current and from a certain location, allows fighter pilots or military commanders to project that the aircraft is likely to be attacked in a given manner.

According to Endsley's model, situation awareness involves far more than simply perceiving information within the context of the environment. It also includes the importance of comprehending the *meaning* of the

information in an integrated form, especially in terms of being able to understand the implications of the current situation in terms of future projected states. Such an understanding is of critical significance in making operationally and strategically effective decisions in the marine domain.

As marine operations become more knowledge-based, the notion of domain awareness, along with domain assessment, becomes increasingly important for describing and discussing operational procedures; with a lexical definition of "knowing what's going on." Thus, MDA is about "everything" related to acquiring situation knowledge in a complex dynamic environment such as marine operation (Figure 7).

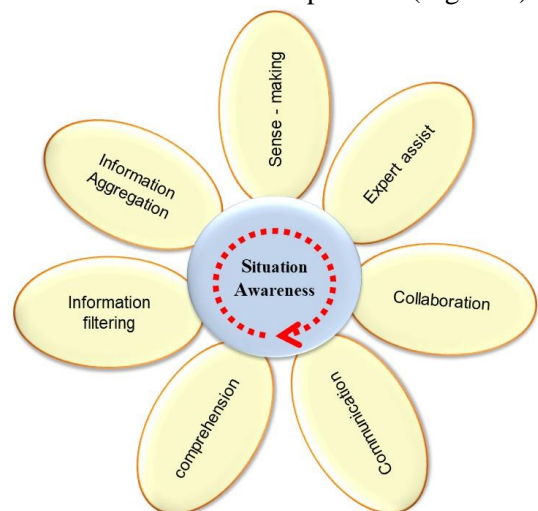


Figure 7: Capability requirements of SA

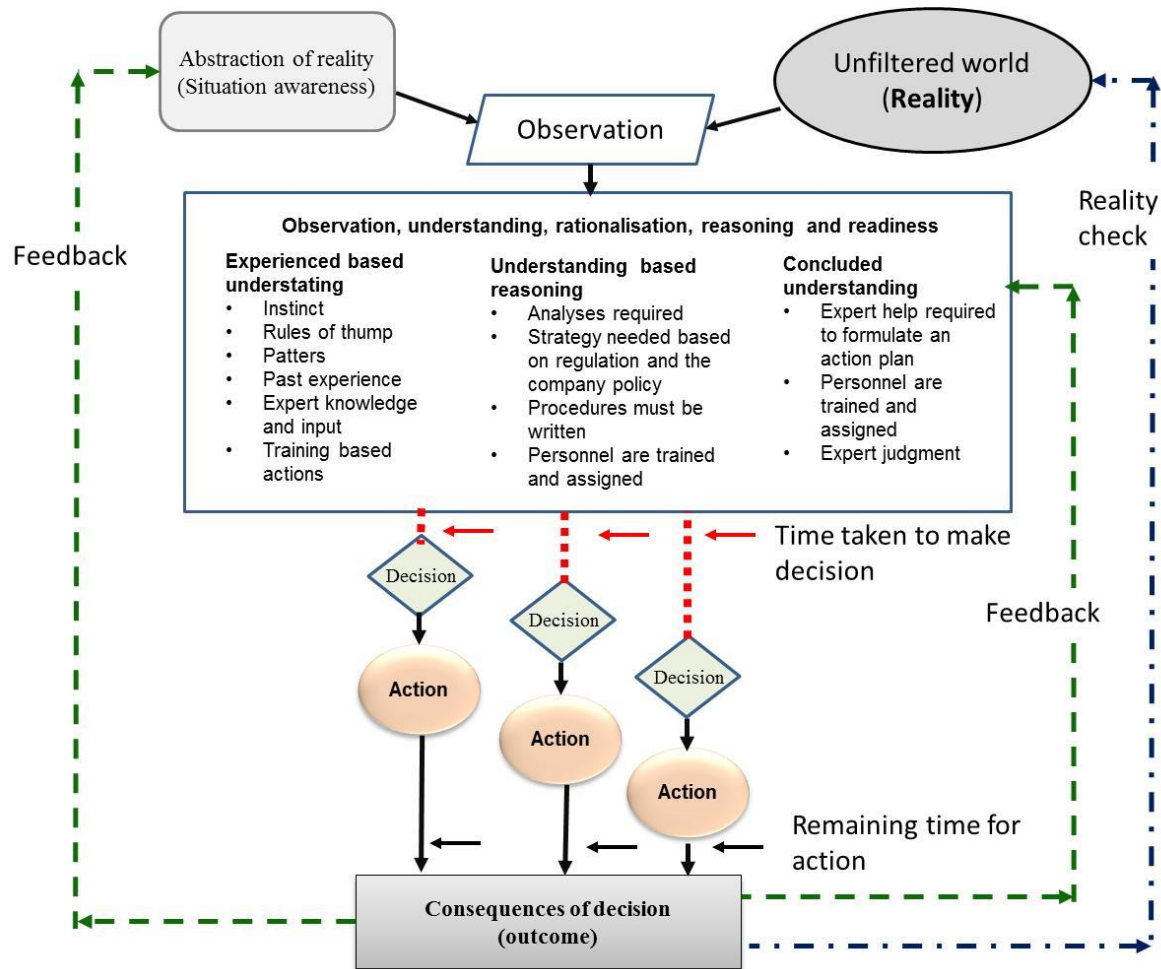


Figure 8: The decision making process and penalty of taking too long to decide.

A domain-specific account of SA for marine operations should depict the unique characteristics of activities, challenges and knowledge that are meaningful and relevant to the operators. Such an account should give practitioners insights to SA – what and how SA measurements should be collected in representative environments. Operators must deal with the inherent diversity of various company procedures; all of them valid in their own right, but may cause conflict when combined. MDA ultimately depends on the ability to deal with this heterogeneity - to aggregate, integrate and process task-relevant information in ways that support decision making in an operationally effective manner.

An evolving event takes a certain time to unfold and reach the target via unguarded paths. This governs the available time for observation, comprehension, decision-making and action. Figure 8 shows how resolution for action is achieved. The primary aim of SA is to shorten the time needed to decide. A faster decision by a prepared personal leaves more time to act, with a better chance of arresting the event.

#### 4. Elements of MDA

In general, the notions of situation awareness used throughout the literature emphasises the perception and processing of subsets of environmental information. In particular, those informational subsets that are relevant to on-going needs and concerns, and which promote a selection of responses strategically aligned with operational goals and objectives. Inherent to such definitions is the notion of what is important (Figure 9).

Operators are often confronted with a dazzling array of data that must be perceived, comprehended and interpreted. Often such information is highly dynamic and complicated by uncertainty. What is important must be gleaned from masses of data, which is usually masked by irrelevant information (noise). The task confronting the operator is to filter information in a manner that avoids information overload and promotes the selective focus of available cognitive resources to those aspects of the incoming information stream that are of the greatest relevance to their monitoring and decision-making responsibilities

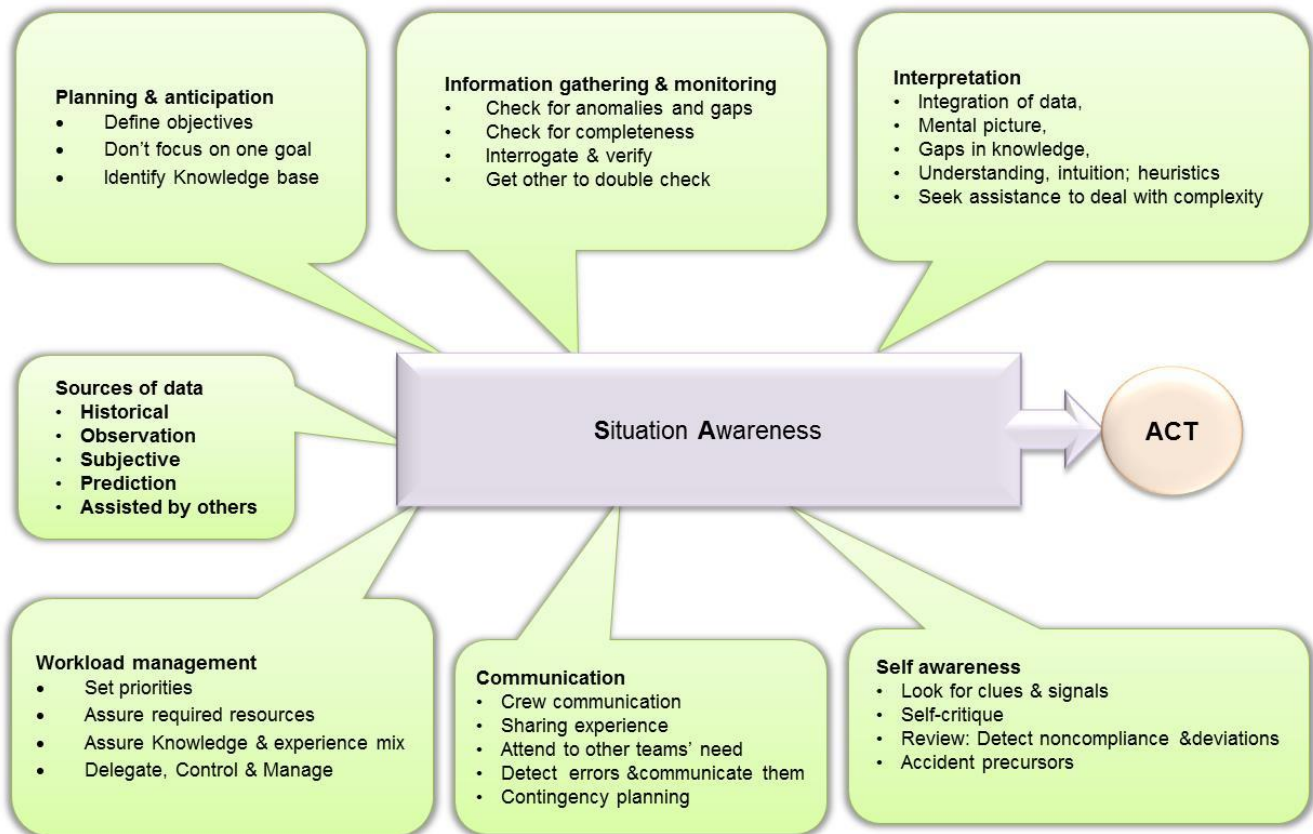


Figure 9: Perceiving the environment and sense-making

Information sources may be divided into three general categories based on chronology; information from the past, present and future (Figure 9). There is also a fourth category, which is subjective information, i.e. the observer's state of belief. Historical information is used for background and understanding of the general structure of what has gone wrong in the past. Current observations represent the state of the world. Predictive information attempts to explicitly present the future to the decision maker using a model. Moreover, the decision maker must decide if old information is still relevant and of value. As information ages, its value to a decision maker generally decreases. Finally, the subjective information category is coloured by factors such as training, confidence and the decision-makers bias. The basis for any prediction of a future state is a determination of the current state, combined with a model for how the world can change from that state. Predictive information sometimes may be available to a decision maker. This is information that some source, external to the decision maker, produces. This is most useful when it can predict the location, time, or intensity of a hazard. However, this is rarely the case. Generally, current information is combined with other information gathered by observations, past cases, and this assembly is used to make sense of the state of the world. Predictive information is generally produced by putting data into a computer or human model. Therefore predictive information is only as

reliable as the observations and the model itself. A decision maker must check the reliability of predictive information by comparing old observations with current observations and trends.

Endsley's (2012) definition of situation awareness encompasses the notion of spatial-temporal aspects of the perceived information. A critical part of situation awareness is the understanding of how much time is available until some event occurs or some action must be taken. The 'within a volume of space and time' phrase in Endsley's definition is intended to reflect the fact that operators should concentrate only the parts of the situation that are of interest to them, based not only on space (how far away an element is) but also how soon that element will have an impact on their goals and tasks - i.e., now and here (Sarter, and Woods, 1991). Such abilities depend on understanding the meaning and implications of events as they relate to operational objectives, and in this sense, knowledge becomes an inherent feature of the situation assessment and analysis process. To make informed decisions, the operator must be cognizant of all the relevant elements of the environment, what these elements mean, and how those elements will affect the operational environment over time (Smith and Hancock [27]).

## 5. Measuring MDA for Marine Operation

Measuring awareness of an individual or a team requires metrics and methods. Endsley [6] outlines a

number of issues of relevance to the derivation of SA metrics. She argues that such metrics need to:

- Measure the parameter they actually intend to measure and not be influenced by other processes.
- Provide the required sensitive and diagnostic insight into situation awareness, i.e. measures should indicate why aspects of a system design fail to improve or degrade situation awareness.
- Avoid substantially altering the design by providing biased data and altered behaviour.

Ideally, measurement of SA should not distract the operator from essential tasks, thereby compromising safety and adversely influencing on-going levels of situation awareness and task performance. However, it is possible to identify a number of problems confronting the adequate measurement of situation awareness using some metrics (Hudson and Graaf [21]). Firstly, the fact that decision making and performance are considered as distinct from situation awareness means that operational metrics cannot be based on the quality of decision outcomes or task performance criteria. With high levels of expertise, in well-understood environments, there may be a direct link between the quality of a decision and the situation awareness, whereby a good understanding of the situation leads directly to the selection of appropriate action from memory (Endsley [6]). However, individuals can still make poor decisions with good situational awareness. In some cases, the context may also dictate when the implementation, or non-implementation, of actions adversely, affect outcomes. Secondly, a focus on the processes by which individuals acquire information is largely insignificant from the perspective of measuring situation awareness (Endsley [6]). Different individuals may use different processes to arrive at the same state of knowledge, or they may arrive at different states of knowledge based on the same processes. Thirdly, measurement techniques that affect the allocation of attention resources should be avoided, as these are likely to compromise existing levels of situation awareness, especially in high workload and stressful situations (Endsley [6]). Finally, because measures of situation awareness often depend on the ability to recall situations and associated information states, it is important to consider human memory limitations when aiming to measure situation awareness.

## 6. Competencies

The phrase Marine Domain Awareness (MDA) is used to mean an effective comprehension and response to all information associated with a specific marine operation in a domain that could impact on safety, operations, or the environment. This requires managing information regarding vessels, tools, activities, people, and infrastructure. This is further complicated by the additional activity of sharing information among the stakeholders. MDA relies on

the ability to build a comprehensive awareness of activities within the time and space of the marine operation. MDA's purpose is to generate actionable knowledge for the stakeholders. The quantity and depth of information collected from various sources need to be joined to create a common relevant picture that can be shared among the involved parties.

Endsley's theory of SA levels was tested in the marine domain by Grech and Horberry [14]. They conducted a study that focused on the lack of situational awareness among mariners by analysing 177 accident reports between the years 1987 and 2001. Their analyses revealed that 71% of human errors were associated with lack of situational awareness. Of the situational errors, 58% were associated with level 1 (failure to correctly perceive information, detect information or failure to monitor data), 32.7% were associated with level 2 (failure to comprehend information), and 8.8% were associated with level 3 (failure to project future actions or over-projection of current trends).

The analysis of information (i.e. analysing the domain) identifies threats. Courses of action are generated to mitigate deviations from approved procedures. The preferred alternative is selected from an evaluation of various alternatives using established criteria. The preferred alternative is planned in sufficient detail to direct the operation with a coordinated set of tasks. Both domain analysis and threat management functions are needed to achieve safety goals.

Table 1 show a listing of the required skills and their description, which is based upon the principle of Sensing, Assessing, Generating options, Selecting, and directing efforts. The analysis of the domain consists of data gathering, processing & dissemination – (termed analysing the domain) and command and control - (termed threat management) (Hoermann et al [19]). Knowing the nature of an event, a threat management plan can be developed, to intercept, mitigate or cope with the consequences of the residual threats. The success is postulated on the basis of contingency operational procedures, developed from data analysis, to counteract them.

An experienced decision maker is generally sceptical about 'normal' functioning conditions and is constantly making contingency plans for those circumstances when things might go wrong. The slightest change in an observed situation should trigger alarms and bring alternative plans of action to the foreground.

**Table 1: MDA Competencies**

SA Skill	Description
Attention Management	Ability to determine priorities and allocate resources accordingly.
Attention Span and Allocation	Ability of allocate attention to all tasks and focus adequately on each. Stay focused.
Information Gathering	Ability to determine what data is needed and organise its gathering.
Analyses, Comprehension and Interpretation	Ability to judge integrity of information, compare and integrate data from different sources, analyse them and make appropriate decision
Anticipation and contingency planning	Foresight. Ability to see where the actions would lead, projecting their consequences, and devise contingency plans to remedy the situation if things go wrong.
Common Sense balanced judgment	Ability to exercise a balanced judgment and have a sense of proportion
Recognition of SA impairment	Ability to recognize loss of SA
Recovery from loss of SA	Ability to rectify break down in SA

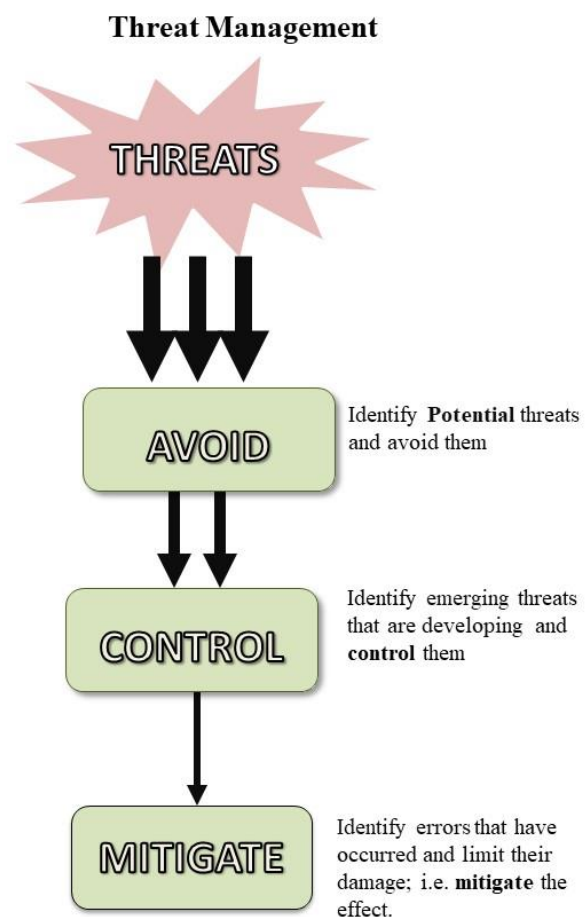
Procedures are often used to help make the decision process easier or faster. They have the effect of relieving the decision maker from the responsibility for certain aspects of decision making. The decision maker simply has to assess the situation, find the pattern that best fits the situation, and then follow the prescribed procedure. A whole class of situations may be categorised by one procedure, along with the appropriate characteristics to classify the situation, and the corresponding choice or rule sets that should be followed. Such decision processes are established well in advance of any actual operation. The decision maker then needs only to gather enough data to determine the pattern and significance of variation on the theme, and then to apply the prescribed procedure. This will reduce the number of incorrect decisions that are made by decision makers in high-risk situations. Decision makers in the presence of high risk, tend to be aware of patterns for resolving situations, and are heavily influenced by them. The Army's "rules of engagement" is an example, which is designed to make the appropriate decisions depending on the situation encountered. Companies' procedures, as well as codes of practice, are also designed to help in decision making by identifying appropriate (and corrective) actions for every situation

## 7. Discussion

Elements of SA differ depending on the situation, but its nature and mechanisms could be described generically. Without the perception of the important information, our image of the reality would be incomplete or false. The SA concept exceeds mere perception and takes into account how humans combine, interpret, store and retain information

(Endsley [6]). It is necessary to integrate multiple pieces of information and determine their relevance for a person's goals. But these are not all that is needed. At the highest level of SA, the ability to forecast future events and their dynamics is also required.

A large part of SA training is related to learning how to detect available patterns or options. A training programme should aim to teach these elements until they are performed without hesitation. Ability to be aware of what is going on can be taught, similar to driving. The majority of training relates to learning hazard identification, how to avoid them and what the options are if mitigations are needed; i.e., patterns of approved actions for every situation. However, the attention span and innate ability of individuals will differentiate between them.

**Figure 10: Steps in threat management**

Domain Analysis is needs driven and includes, proving periodic and non-periodic information and support to each member of the other teams engaged in the arena for achieving the shared goals; hence each operator in the arena is both an information provider and consumer. By posting data to the designated interface member, the complete information becomes available for everyone who needs it. Factors which influence the results are; 1) Uncertainty and error in

what decision makers know; 2) How they act on the information they have; 3) The ability to collect the information needed. Such skills can be greatly enhanced by training.

The threat management (Figure 10) function is a command and control function. The commander on scene generates actions to avoid and mitigate residual threats. A preferred course of action is selected, with an evaluation of alternatives, to assure effectiveness and conformance with established criteria. The preferred alternative is planned in sufficient detail to be communicated to all stakeholders with a coordinated set of tasks.

Hone [20] reduced Endsley's model into three questions:

- Who is where? (Simplified from "...a person's perception of elements in the environment within a volume of time and space ...")
- What are they doing? (Simplified from "...the comprehension of their meaning ...")
- What they will do? (Simplified from "...the projection of their status in the near future")

As in the original Endsley's model, the three questions relate to a single individual viewpoint. In this simplification, it is assumed (Hone et al, 2005) that the "Who" in "Who is where?" also includes inanimate objects and environment features. Another simplification uses these three questions: What has gone before? What is going on? What is going to happen? Such simplification can help to operationalise SA in an emergency response or in a game of football where the situation changes very fast.

Marine operations typically involve the extensive use of information technologies for information gathering, communication, etc. and because these technologies are the fundamental tools for developing situation awareness, the content of such technologies have dominated the current research (Endsley [6]). However, some situations rely on raw sensory experience as input, with less use of technology and information systems. It is characterised by shorter response times, more immediate feedback, and more rapid fluctuations in relevant conditions (Grech et al [14]).

## 8. Concluding Remark

Understanding and responding correctly to complex situations, and anticipating consequences, are essential skills for the safety of marine operations. These skills require situation awareness (SA): i.e. the ability of the operator to take correct, timely actions. The claim is that superior SA will increase the probability (although not the certainty) of success through improved assessment of, and response to, unfolding events in the domain of marine operation. Good SA cannot guarantee good decision making, but without it everything depends on chance. Errors can still occur even following well-defined rules - such as

approved work methods, permit to work and procedures. Inadequacies, improper tools, operational constraints, poor judgment or bad execution of an appropriate response could lead to an unsafe situation. Furthermore, SA is influenced by the available time and mental ability to process information, and the fact that most situations are dynamic, which aggravates the problem, as it requires continuous adjustment.

Although poor SA does not preclude good outcomes (the chance element), it is reasonable to believe that good SA improves the likelihood of a good outcome. SA revolves around "knowing what is going on around you." Such knowing for untrained personnel originates from past experience, intuition and innate ability to be observant. It is argued that training, which is devised to teach competencies, can instil these abilities in people.

In conclusion, SA may be gained by answering four simple questions:

1. What has happened?
2. Where is everybody?
3. What is happening?
4. What could happen?

The rule-based framework outlined in this paper goes a long way towards safe marine operation, however, in a dynamic environment heuristics (gut feeling, the rule of thumb etc.) are still needed to shorten the decision making process to allow more time for reaction.

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