

Situational awareness (data) bases in military command and control

SÁNDOR MUNK

Miklós Zrínyi National Defence University, Department of Informatics, Budapest, Hungary

Possibilities, techniques, and methods to collect and process situation information have radically changed due to the dramatic improvements reached in information technology. Basic components of IT applications, supporting collection and processing of situation information, are the data-, and knowledge bases representing situational awareness, and the application components used in creation, maintenance, and employment of situational awareness. In this paper we summarize the basics of situational awareness, analyze the concept, and characteristics of situational awareness (data) bases, and discuss the presentation of the situation supported by these (data) bases.

Introduction

Possibilities, techniques, and methods to collect and process situation information and to create and maintain situational awareness, have radically changed due to the dramatic improvements, and results, reached in information technology. The essential characteristic of military operations in the 21st century is the widespread and networked application of different information acquisition and processing means. Modern IT infrastructure provides an enormous amount of information, previously unimaginable for the command of 21st century forces: it ensures that commanders “see” almost anything in real, or near-real time on the battlefield – or in three, or more, dimensional battle space that is worth seeing. But this capability alone is not enough, it does not ensure automatically the understanding of the situation, and does not help directly with what to do. This requires a significant amount of professional expertise.

Basic components of IT applications, supporting collection and processing of situation information, are the data-, and knowledge bases representing situational awareness – in short, situational awareness (data) bases – and the application components containing procedural knowledge used in creation, maintenance, and employment of situational awareness. The purpose of this publication is to summarize the basics of situational awareness, analyze the concept, and characteristics of

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Address for correspondence:

SÁNDOR MUNK

Miklós Zrínyi National Defence University

Department of Informatics

P.O. Box 15, H-1581 Budapest, Hungary

E-mail: munk@zmne.hu

situational awareness (data)bases, and discuss the presentation of the situation supported by these (data)bases.

Basics of situational awareness

In psychology and cognitive sciences, *situational awareness* is considered as knowledge created through interaction between an agent and its environment. In this sense, awareness can be simply defined as “knowing what is going on”. Basic characteristics of awareness, setting it apart from other kinds of knowing, are the following:

- awareness is knowledge about the state of the same environment bounded in time and space;
- environments change over time, so awareness is knowledge that must be maintained and kept up-to-date: depending on the rate of changes, information has to be continually gathered and updated;
- maintenance of awareness is accomplished through interaction with the environment (gathering information through sensory perception, and actively exploring surroundings based on the information picked up);
- awareness is almost always part of some other activity that is maintaining awareness and is rarely the primary goal of the activity.

Awareness is an everyday phenomenon,* and its role becomes more noticeable as situations and environments become more dynamic, complex, information demanding, and with higher workload, or risks.

Creation and maintenance of situational awareness is a three-stage process, with the following components:**

- perception of relevant elements of the environment;
- comprehension of those elements;
- prediction of the states of those elements in the near future.

So an agent acting in an environment should first gather perceivable (observable) information; selectively attend to those elements that are most relevant for the task at hand; integrate the incoming perceptual information with existing knowledge and make sense of them in light of the current situation; and finally should be able to anticipate changes in the environment and predict how incoming information will change.

* Awareness allows us to walk around a room without bumping things, but in this context we usually don't give it a moment thought.

** See detailed in ENDSLEY, M.: Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37(1) (1995) 32–64 (Referenced by GUTWIN & GREENBERG, 1999)

Situational awareness knowledge about the relevant environment – essentially *is a set of particular information*, a system of facts and beliefs about the existence of, characteristics of, and relations between elements of the situation. Characteristics and relations of situation elements are subject, and activity-dependents: naturally different components are relevant in an emergency relief task, in an armed conflict, or in a peace operation. Systematization and analysis of the situational awareness' components can be done based on the situation elements, and the subjects of situational information.

In a given situation the subject of situational awareness does not usually act alone, so among the situation elements we should distinguish the *players* acting consciously (in between the subject too), and the *environmental objects and circumstances* as the background of the players' activities. Situational awareness generally includes information about existence in time, position in space, state, activity, and changes of, and relations between players and environmental objects.

The foundation of situational awareness constitutes environmental effects, and basic (usually raw) data collected, or acquired about the players, and the environment. From these should be selected, correlated and assessed, integrated and synthesized, information that can be used in reasoning to create situational awareness. Naturally not all effects, and data can, or should be used to generate awareness, so not all incoming data will be processed, and the active collection and acquisition of data is done, taking into consideration given requirements.

Situational awareness – as the previous statement had already suggested – contains not only acquired, selected, and synthesized data, but a complete picture can be generated with filling information gaps, and extended by reasoning, or assumptions. This is true in everyday life also, in the case of individual persons, or groups of persons.

In the case of military command and control the environment of a military organization is traditionally the battlefield, so in military literature, instead of situational awareness we find notions of *battlefield awareness*, or *battlespace awareness*.* Expression 'battlefield' belongs to the traditional land warfare, while 'battlespace'** is the term of the joint warfare of the XXI century. In addition to battlespace awareness, in many publications and professional documents we can find the *battlespace knowledge*

* *Battlespace awareness*: awareness of the battlespace yielding an interactive "picture" which provides timely, relevant and accurate assessment of friendly and enemy operations within battlespace. [Concept for Future Joint Operations, Part II – Terms and Definitions, p. 83]

** *Battlespace*: The environment, factors, and conditions which must be understood to successfully apply combat power, protect the force, or complete the mission. This includes the air, land, sea, space, and included enemy, and friendly forces, facilities, weather, terrain, the electromagnetic spectrum, and the information environment within the operational areas and areas of interest. [JP 1-02, p. 57]

expression too.* In these materials the meaning of this expression corresponds to the referenced meaning of battlespace awareness, and the latter used as a synonym, or with a narrower meaning, indicating a lower, intermediate level of the situational awareness.

In addition to the interpretation of situational awareness as particular knowledge about a situation, there is another interpretation that expresses a general capability to generate the situational awareness. This capability is based on modern information collecting (sensing, observing, etc.), and information processing means, connected in a unified system by different networks. This interpretation appears in the terms *dominant battlespace awareness*,** or dominant battlespace knowledge, that are considered essential capabilities of the XXI. Century warfare in American military visions, and plans.

Situational awareness can be interpreted not only in the case of individual agents (persons, etc.), but also in the case of systems of loosely, or tightly cooperating agents (e.g. organizations, groups). In these systems, agents with identical, or different capabilities work together in a coordinated way, to achieve common, or agreed goals (objectives). In consequence of their different capabilities, and activities, these individual agents, as appropriate, have their own unique situational awareness, more or less different from others'. The complex (set, or system) of this awareness constitutes the integrated, shared awareness of the organization or group.

Shared awareness is not only a summative set of its components, but a coordinated, continuously harmonized system, that in the case of complex organizations, can be even multilevel. Situational awareness of individual agents – according to the level and contents of cooperation between them – can overlap each other: to effectively, and successfully accomplish the related activities, they must have identical, or equivalent knowledge of the affected elements of the situation. In addition to these overlaps, naturally any agent's situational awareness can also contain other pieces of knowledge, typical for, and necessary to, the given agent.

In a cooperating group, or organization, the shared situational awareness, according to the division of labor, can be divided by spatial, or functional characteristics, and by levels. In case of spatial division (e.g. to adjacent operational areas) overlapping parts relate to the adjacent parts. That means the knowledge of the "neighbors' situation". In case of functional division (e.g. to arms, and services) the overlapping part contains objects with relevance for both agents. In both cases, the detail, and precision of the

* See for example WALTZ (1998) or JOHNSON & LIBICKI (1995).

** Dominant battlespace awareness: ... will permit visibility over the militarily significant events in the battlespace to such a degree that the commander is able to make informed decisions and employ weapons and systems precisely. Awareness includes knowledge and status of both enemy and friendly forces, facilities, weather, terrain, and the electromagnetic spectrum. [Concept for Future Joint Operations, Part II – Terms and Definitions, p. 84]

individual agents' situational awareness can, or usually will be, different. Similarly, different detail (precision) characterizes the situational awareness of different command levels in a complex organization.

Situational awareness (data) bases

Situational awareness (data) bases contain situational information available for a given (military) command. One command logically can have only one situational awareness (data)base that – functionally, physically, etc. – may be divided into different parts. From an application viewpoint this partitioning should be transparent. Up-to-date shared database technology ensures that the application of situation information, apart from some efficiency, and security issues, will be the same, whether the information is from one physically unique (data)base, or from a distinct part of a shared (data)base residing in the same, or at any other (being geographically near or far) place.

Present day situational awareness (data)bases can be divided into two main parts: the first one containing information visually represented in situation pictures (among them map information, track information, and other geographical information), and the second one with other, descriptive (textual, tabular, etc.) information. These are usually stored in different format parts of a situational awareness (data)base.

Map information is the most stable (invariable for years, decades, or even centuries) part of the situational information, and at the same time it constitutes a reference-base of geographical position, and background of visual representation of other objects of the situation. This information constitutes part of situational awareness (data)bases in the form of different *digital map products*, or tailored to a given situational requirement form of these products.

Format and information content of digital map products used in situational awareness applications can be very different, and their usefulness also depends on these characteristics. The role to serve as representation background or a means to determine geographical positions can be fulfilled simply with coordinate axes, and lines, with or without a raster map, or picture background. Much more information is included in object-oriented (vector products) digital maps that can be considered individual map databases. These vector product maps store geographical and descriptive information of objects belonging together in separate units, or so called layers.

Digital maps containing a mass of geographical information can usually be produced only with a lot of professional work, by national (government, military) imagery and mapping institutes, and agencies. These products are usually used in an unaltered format, possibly supplemented by different specific additional layers. Military

command and control primarily uses its own military “products”, but in some cases products from other sources (e.g. raster pictures with sufficient geographical precision) can be used in their original or somehow modified format. Supervision and appropriate transformation of these products requires professional skill of “knowledge-processing experts” in military geodesy.

Track information, on the other hand, constitutes the most variable part of situational information, changing every minute, or even every second. Spatial attributes recorded in this way are continuously changing, and these changes have to be observed in real or at least near-real time.* Timeliness requirements are first of all determined by the motion characteristics of mobile objects (e.g. their velocity), and by precision requirements of determining their spatial position.

Information about spatial position, and movement of mobile objects, and some identification attributes are stored and maintained in special *track databases*. These databases, and the first computer-oriented applications of situational representations historically have arisen from the equipments visualizing air, or maritime situations based mainly on radar information. Nowadays track databases are still relatively separated parts of situational awareness (data) bases.

Most track information – pertaining to elementary objects (aircrafts, ships, main ground equipments of combat, electronic devices, etc.) – has its source in different surveillance, or measuring devices (sensors), or global positioning systems, that make available their measurements, and observations in real time, usually in the form of standard format messages, for example on tactical data links (digital information links). Sources of other parts of track information – pertaining to friendly, enemy, and neutral forces (units, groupings) – are situation reports transmitted relatively rarely, by traditional, or electronic means, and formats.**

Objects of *other geographical information* are (can be) special, or temporary facilities (e.g. temporary runways, military bridges, field constructions); planned coordination points, lines, or areas (e.g. advance routes, areas of operation, no-fire/no-fly areas, mine fields, target objects); environmental (e.g. meteorological, or hydrological) phenomena influencing operations; and results of different spatial assessments, and estimations (e.g. cross-country movement/mobility, lines of site, zones of fire) not represented on ordinary maps.

* Timeliness of data or information is real time, when current active tracks show current location, updates occur immediately, and the only delay is that of electronic communication. In near-real time case data or information delayed by the time required of electronic communication and automatic data processing, but this does not impact the current planning cycle – no significant delays. [GCCS COP Handbook, Definitions, p. A-12]

** Military Text Format, or Message Text Format (MTF).

Objects with geographical (spatial) attributes are organized into, and stored in layers, initially to make their joint representation easier. These layers play a similar role as transparent overlays played, laid on maps, and used in traditional military staff work. Geographical information can be stored in separate *GIS databases*, or in the form of additional layers supplementing digital map products used as map background.

Most of these geographical information arise during planning and execution of military operations, in the process of military command and control, and their validity, usability is usually limited to the given situation, and operation. Other, smaller parts of this information – e.g. information pertaining to actual phenomena of natural environment, and their changes – are created, and provided by special professional organizations. These are usually national, or alliance military organizations, external to the forces executing the given operation, but other sources can also be used.

Other descriptive information includes information stored in traditional (relational, textual, multimedia, etc.) databases. Some of these databases contain information exclusively about elements of the current situation, but the majority of them store more general, broadly useful, but not situation-specific information.

The first group is composed from, for example, textual databases containing missions, plans, or orders for military operations in free, or semi-structured format; databases containing information about organization, formation of forces, establishment (TOEs*) of units, combat capabilities of forces, and individual equipments; and numeric databases containing information used in, or resulted by, tactical evaluations, and assessments. This information is usually generated in the course of military command and control, and valid for the given operation.

The second group includes databases containing fixed, or rarely changing attributes of different objects, such as political, administrative, demographical, ethnic, religious, economic, or cultural characteristics of a given area of operations (e.g. CIA Fact Book information on individual countries); summaries, descriptions, or estimates about characteristics, and activities of potential players (organizations, groups, or individuals, etc.); or basic military technical characteristics of different weapons, and equipments. Range, content, and format of these databases – as the previous examples already show – is extremely wide, and most of them are outside the authority of the military (or even the national) command and control. Their validity is usually not connected to a given military operation, and is much broader both in space and time.

Based on all of these it can be summarized, that knowledge of battlefield situations, required for military command and control, includes remarkable heterogeneous

* Table of organization and equipment

information in their format (graphical, pictorial, textual, numerical, or combination of these), in rate of change (seconds, hours, days, years, or even centuries), or in their sources.

Nowadays IT application systems handling situational awareness information are characterized mainly by distinct data management components, with very limited (or without any) data exchange capabilities between them. The two basic types are:

- (near-)real time track management systems, that handle basic identity and current locating data on numerous mobile, semi mobile, and selected fixed units, facilities, and equipment in the battle space;
- multiple large relational databases, that contain high volume of detailed data on less volatile entities in the battle space, including relatively current information on fixed facilities, and equipment.

This architecture has as a consequence a lot of redundancy, ambiguity, and conflicts between participating systems, and databases.

An additional characteristic of the present management of situational awareness is the use of centralized, mission-oriented systems, with little autonomy for cooperating actors (users), and with very limited (or without any) data exchange capabilities between them. Data exchange mainly based on standardized messages, or database-replication. These require preliminary agreements on semantic questions. Actual situational awareness systems usually lack for commonly accepted conceptual foundations. The consequences are: incompleteness, misunderstanding, and conflicts.

In the future actors (organizations, users) require fully integrated data management components, or a unified system with continuous synchronization, harmonization, and fusion, that is mainly a technical question. At the same time groups of cooperating actors require a system of autonomous, heterogeneous systems with continuous synchronization, and harmonization, that is mainly semantically and only secondly a technical problem. Every actor requires a system that supports the maintenance of its own situational awareness. The system:

- should meet the (possibly particular) requirements of its user;
- should function in “stand-alone” mode too;
- should function in different federations of cooperating systems;
- can be developed, modified, or improved independently of other systems;
- should support national interests.

These are the main reasons of the autonomy of situational awareness systems, or (data)bases.

Representation of the situation

Spatiality is a basic characteristic of military operations: objectives of military activities are usually specified in spatial form; spatial maneuver is an essential element of military activities. Spatial position and movement of military operations' players essentially influence their capabilities, and results of their activities. Therefore the basic form of presentation of military situational awareness is visual (mainly map-based graphical), that can be supplemented with textual, tabular, or other formats.

Visualization of the battlefield situation (or battlefield visualization) makes possible a clear representation of position, movement, actions, objectives, and important characteristics of players, and environmental objects. Visualizing the battle space for a long time has been a process of intuition of commanders, during which they coupled disparate – sometimes inaccurate, untimely, or incomplete – elements of information with a “feel” for the battlefield, and created a mental image from which they conducted the battle. This mental image was then translated with different means and methods into a commonly usable “picture”, to unify and focus the participants' actions. Lack of common understanding of commander's vision has often resulted in imprecise or diffused application of forces.

Formulation of the commander's battlefield vision, the *battle space visualization*, is an essential phase of military command and control. It is “the process whereby the commander develops a clear understanding of the current state with relation to the enemy and environment, envisions a desired end state which represents mission accomplishment, and then subsequently visualizes the sequence of activity that moves the commander's force from its current state to the end state”.* The commander's vision is based on the information provided by the staff, and on his own knowledge, experience, and intuition.

Synchronized knowledge of the battle space situation, and its visualization, are essential for every cooperating organization, and all of their autonomous, functional units. This knowledge forms the basis of the common, coordinated activities of these players. The pieces of common situational knowledge are visualized in the form of different “pictures”; in the English-language literature usually attributed with the terms ‘recognized’, and ‘common’.

Recognized pictures – The Recognized Air Picture, Recognized Maritime Picture, and Recognized Ground/Land Picture – contain assessed information about essential objects (and their descriptive and spatial characteristics) in a given area, belonging to a given dimension of the battle space (air, sea, land, etc.). These pictures are basically the

* TRADOC Pam 525-70, 1-3. Explanation of terms.

objects, and the results of the intelligence, situation evaluation and assessment organizations. They usually contain minimal map basics (e.g. land and water bodies, boundaries of countries, hydrograph, main populated places, and roads) to help determine the real geographical positions, and items to represent position, and movement of the relevant objects of the situation. In the military application, the representation of these situational (generally mobile) objects is usually accomplished in the form of so-called tracks.

Common pictures provide a uniform, clear representation of knowledge about all relevant elements (players, and their environment), for a given command level. In their map-based framework they usually contain:

- information about actual position and status of friendly, enemy (adversary), and neutral, ground, maritime, and air forces;
- information about known future (planned, or anticipated) movement of friendly, enemy, and neutral forces;
- information about environmental (e.g. weather) conditions influencing the positions and activities of friendly, enemy, and neutral forces;
- and different objects (lines, areas), that support planning and executing, and coordination of activities in space and time.

Common pictures describe the actual situation, and contain components, that help commanders to anticipate and influence future situations. The two basic types of these pictures – depending on the command level, and the area represented – are common operational picture, and common tactical picture.

Common Operational Picture (COP) is the complex of situational information available for a commander with an area of responsibility.* In the former NATO command structure such commanders were, for example, the five regional commanders,** or in the case of the U.S. armed forces, the combatant commanders. In those states, where there are no military commanders with a unique area of responsibility, the common operational picture is connected with the level of Joint Staff, and the Chief of Staff.

Naturally COPs of different areas of responsibility, or union of them should be made available to the higher (national military, national political, alliance, or coalition) command levels, since they are necessary for these levels to determine military

* *Area of responsibility*: A defined area of land in which responsibility assigned to the commander of the area for the development and maintenance of installations, control of movement and the conduct of tactical operations involving troops under his control along with parallel authority to exercise these functions. [AAP-6, p. 2-A-15]

** CINCSOUTH, CINCSOUTHLANT, CINCEASTLANT, CINCNORTH, and CINCSOUTH.

missions appropriate to reach given defense, or security objectives, and to control or supervise the execution of assigned military operations, and activities.

Common Tactical Picture is a concept connected with a given operation, the appropriate area of operations,* and with the (multinational, or national) Joint Task Force executing this operation. Common Operational Picture of a given area of responsibility is basically generated, and maintained using the recognized pictures of the component commands of the given area (command), and the common tactical pictures of the operations executed in the given area, completed with information from other sources if required. Similarly recognized, or common tactical pictures can be created from other, or lower levels (e.g. local air picture, subordinated unit's tactical picture, etc.) by integration, coordination, and completion. The COP building process is shown in the next picture.

The contents of a recognized, or common picture, and the shared situational awareness represented by them, are always the responsibility of the the given commander (chief, etc.) . It is his/her responsibility to interpret, or extend incomplete information, to harmonize conflicting information, and to determine information he/she "owns". So the situational picture of a higher command level determines the situational pictures (situational awareness) of subordinates, because the commander's assessment and concept forms the basis of the given operation and the basic condition of the coordinated execution.

Summary

At the end of this publication, it can be summarized that situational awareness is an inherent feature, an essential condition of existence and activity (operation) of every active, goal-oriented, autonomous object, being in interaction with its environment – knowledge about the relevant environment, including facts and beliefs about existence of, characteristics of, and relations between elements of the situation. Situational elements are the conscious players, and the environmental objects and circumstances.

In competitive and conflicting environments, the quality of situational awareness plays a decisive role: comparative advantage of economic players in situational awareness is an essential condition of making efficient economic decisions. In military operations situational awareness first of all means knowledge of the operation's environment (battlefield, battle space), so military literature prefers to use the terms 'battlefield awareness', or 'battle space' awareness.

* Area of operations: The portion of an area of war necessary for military operations and for the administration of such operations.. [AAP-6, p. 2-A-15]

Situational information available for a given (military) command is stored in a logically uniform situational awareness (data)base, perhaps physically built from different parts. Contents of these situational awareness (data)bases include two main categories: information visually represented on situational pictures, and other descriptive information with different formats. These categories are usually stored in different (data)base parts.

Based on the basically spatial feature of military operations, the basic form of presentation of military situational awareness is visual (mainly map based graphical) and can be supplemented with textual, tabular, or other formats. Battlefield visualization is an essential component of military command and control: a process of developing the commander's vision of the battlefield. The result of battlefield visualization is in some respect broader than situational awareness, because it contains elements related to future objectives, and actions of players.

In military practice, situational knowledge is visualized in the form of different "pictures". Recognized pictures (Recognized Air/Maritime/Land Picture) contain assessed information about essential objects (and their descriptive and spatial characteristics) in a given area, belonging to a given dimension of the battle space (air, sea, land, etc.). Representation of the relevant (generally mobile) objects is usually accomplished in form of so called tracks.

Common pictures provide a uniform, clear representation of knowledge about all relevant elements (players, and their environment), for a given command level. Two basic categories – depending on the command level, and area affected – are common operational picture, and common tactical picture. Common Operational Picture is the complex of situational information available for a commander with an area of responsibility, and Common Tactical Picture is a concept connected with a given operation, the appropriate area of operations, and with the Joint Task Force executing this operation.

Detailed contents, and characteristics of situational awareness are dependent on the organization, and the task, so there are no appropriate uniform solutions. Military organizations must have an appropriate level of autonomy, both from application, and security point of view. Military organizations must operate in different coalitions, must cooperate with different organizations, and situational awareness (data) bases, and applications can work in such a heterogeneous environment too. The big question is: how to handle semantic heterogeneity, how to harmonize different views, different concepts. The second question is: how to adapt to the dynamically changing environment, to the different situational awareness (data)bases, applications.

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