CONFIGURATION OF COMBAT SYSTEMS IN THE PROCUREMENT AND MODERNIZATION PROCESS OF SURFACE SHIPS

Antonio da Silva Castro Sobrinho, Captain (Naval Engineer)

Captain (NE)Antonio da Silva Castro Sobrinho has a Master's Degree in mechanical engineering from the Massachusetts Institute of Technology (MIT) and worked as Project Manager in the modernization project of the "NITERÓI" Class Frigates and in the weapons system integration of Corvette "BARROSO" at the Diretoria de Sistema de Armas da Marinha (Navy Weapons Syatems Department). He was also posted as Officer in the first crew of the Centro de Projetos de Navios (Ship Design Center).

ABSTRACT

The present paper proposes a methodology for the selection of surface-ship combat system components. Its objective is to evaluate the performance of the system while it is still in the design phase. Initially, proceedings for the selection of weapons and sensors are presented, with the proposal of mathematical models for the adequate simulation of each equipment's operation in stand-alone mode. Then, one addresses the definition of the architecture for the Tactic Control and Weapons System (SICONTA[1]), as well as the required stages for its systemic evaluation integrated with the weapons and sensors. Finally, one analyzes system performance in a simulated combat against an air threat, describing each event, from detection to assessment of kill probability of threat at the end of the engagement sequence.

Key words: Combat System; and Kill Probability

INTRODUCTION

The procurement or modernization of a ship is a project that involves activities related to the ship's platform and combat systems. This division refers to the historical separation there is of the various systems on board, i.e.

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[1] The acronym SICONTA was used for the first time in the modernization project of the Light Carrier "MINAS GERAIS" to refer to the Tactical Control System. During the frigate modernization (Modfrag) project, the acronym SICONTA started to designate the Tactical and Weapons Control System.

propulsion, steering, power generation and distribution, air-conditioning, damage control, etc., traditionally united in the "platform" group, and those related to the configuration of the ship's combat system. The latter involves higher complexity of command functions required for the implementation of the ship's combat capability itself.

The practical result of this separation has been pointed out by some authors as a simplification of the weapons and sensors selection processes during the combat system configuration activity. That is the opposite of what happens with the other surface ship platform component systems (ARTHOU, 1997, p. 39). This simplification has limited the selection of equipment for the combat system to qualitative information.

On the other hand, combat in current naval warfare scenarios take place at high speed and demand the automation and integration of detection, target designation, and threat engagement actions. The large amount of information made available by the combat system is still cause for debates about the need to increase the Artificial Intelligence of Digital Operative Systems, in such a way that, according to Zimm (1999, p. 31), are "*attuned to the human decision making process*". The case of American frigate STARK, hit by an *Exocet* missile in 1986, and the incident with the USS VINCENNES that, on July 3, 1988, shot down, in the Persian Gulf, an Iranian commercial airplane (flight IR655) with a *Standard SM-2* missile, are cases that continue to motivate the development of adequate functionalities for the SICONTA – an integral part of the current combat systems.

In such context, the present paper presents a project methodology divided in three distinct parts, but which are connected by means of a logical sequence. To start with, are discussed procedures regarding the selection of weapons and sensors whose performance needs to be technically analyzed with the help of mathematical models that simulate the operation vis-à-vis the threats and scenarios that appear on the ship's Systems High Level Requirements (RANS). Then, the SICONTA architecture is addressed. It integrates weapons functionalities and sensors to the tactical scenario of the ship's operation. The last part addresses a proposal for the simulation of the engagement against an air threat, with the purpose of checking the performance of the combat system while it is in the design stage.

THE EVOLUTION OF THE NAVY COMBAT SYSTEMS PROJECT

The idea of combat system is relatively new. This system has been traditionally associated to a simple set of weapons and sensors that are part of the ship's configuration. However, the combat system is the primary reason for the existence of warships, whose objective is to use all their integrated capabilities in a combat mission. According to Baker (1990), a warship has two major divisions: the platform and the combat system, i.e., *Warship = Combat System + Platform*. Other authors, such as Gates (1987, p.1), argue that a warship is the combat system itself and prefer to define the system as *Warship = Combat System* .

In the Brazilian Navy (MB) the first concept has been used more often, maybe due to the equipment jurisdiction division between Diretoria de Sistemas de Armas da Marinha (Navy Weapons Systems Department), that deals with weapons, sensors, and SICONTA – the combat system – and the Diretoria de Engenharia Naval (Naval Engineering Department), responsible for all the other systems in a ship, such as hull and structure, propulsion, steering, air-conditioning, electric power generation and distribution, etc. – the platform.

Ship building and design technologies, that produce the platform of surface ships, have been a Navy domain since the time when Brazil was still a Portuguese colony (BARBOZA, 2005). The development of the techniques employed in the platform design and building by Brazilian shipyards has more or less followed the technological advances occurred in countries that have traditionally invested in the intense development of new techniques, such as the European Community countries and the United States. However, the same can not be said regarding the technological domain required for the design and development of combat systems for our Navy ships, especially surface ships.

The first steps towards qualifying our national industry to produce such equipment were taken with the modernization project for the Light Carrier "MINAS GERAIS". But its peak was reached with the modernization project of the "NITERÓI" Class frigates (Modfrag).

Before these two projects, the configuration of the combat systems was limited to comparative studies of arrangements in which the weapons and sensors were selected without the use of simulation tools. Rear Admiral Alan (Naval Engineer) (ARTHOU, 1997, p. 39) had already identified this fact as a drawback in the acquisition process:

> Feasibility Studies, in the Brazilian Navy, are limited to comparing the different arrangements of weapons systems for a given ship; only a few studies are able to demonstrate the effect of alterations in certain systems of the ship, as it is done in the USA and the UK. These studies allow the operations sector to balance the requirements for the systems with the support of a factual basis.

WEAPONS AND SENSORS SELECTION CRITERIA

The Modfrag project marked the beginning of the use of mathematical modeling tools to simulate surface ship weapons and sensors. While the project was underway, emphasis was given to the analysis of the performance of combat system engaged in air targets, since the times involved in the attack kinematics are extremely short. Thus, in the case of surface ship anti-air defense, the Modfrag paradigm indicates selection criteria that are applied from tactical sensors, such as vigilance radars and sonar, to weapons and sensors employment in the engagement, including equipment for electronic warfare systems.

In the process for procurement and modernization of the means employed by the MB, it is in the conduction of Feasibility Studies (FS) that weapons, sensors and SICONTA are selected. The studies vary in complexity and according to the tasks and specified scenarios. These studies check which of the weapons and sensors available in the market are capable of engaging and destroying the threats expected to take place during a naval operation.

Before the Modfrag project, such selection was either contracted with foreign companies that supplied a "complete package" with all the components for the combat system, or simply carried out based on the data provided by the manufacturers. In both cases, the result was not very reliable.

Another aspect in favor of this selection methodology is the possibility of designing weapons and sensors to an adequate level, thus preventing discontinuities and blind sectors in their employment coverage. On the other hand, precise knowledge on the capabilities and performance of the equipment enables systems composing the combat system to be economically dimensioned, i.e., without the use of extremely sophisticated weapons and sensors to face threats that could be effectively fought with simpler configurations.

A key remark should be made here: the difference between the MB combat system project and that of the other countries with the capacity to design and manufacture the weapons and sensors that equip their fleets. Brazil could be placed among the countries that master the systemic project and the integration of combat system components, but have limited capability to manufacture their own weapons and sensors. Consequently, the equipment selected for the Feasibility Studies is commonly used by the MB and is available in the international market. The countries that master the production technology for those combat system components are less liable to the limitations imposed by the weapons market, even if they are partially conditioned to the traditional supply lines of the companies in their defense-oriented industrial park. These countries are able to design weapons and sensors to meet specific requirements of combat systems for new ships.

The next items of this paper will address the modeling of weapons and sensors that are typical to this system, and are of widespread use in the MB, aiming at providing an example to the methodology proposed for their selection. The modeling of the other combat system equipment, such as the Gun, the Surface-to-Surface Missile, the Sonar, the Close-in Weapons System, the Tracking Radar, the Optronics Sight, the Optical Sight, and the Electronic Warfare

System, are described in the CASTRO SOBRINHO paper (2007), whose selection process is addressed with equal extent and depth.

SEARCH RADAR

The modeling of this sensor is a key element for the assessment of a combat system since all the command sequence and required actions for both attack and defense take place, in most cases, after the detection of a contact by the search radar. The time elapsed from detecting till engaging the target must be enough to allow a response of the combat system as a whole; otherwise, the threat might hit the ship with its weapons before the defense systems are able to neutralize it. In short, the radar must be able to detect the contact the further away from the ship as possible.

In order to evaluate how critical the capacity of a radar to detect a threat is, one has to estimate the time a ship will have to defend itself from an anti-ship *sea-skimmer* missile, for example. In general, this threat has an attack speed of 300 meters per second. If one considers its detection at a distance of 30 kilometers (16.2 nautical miles), a very optimistic performance, the ship will have 100 seconds to identify it, designate it to the tracking system and engage it.

Radar operation is also a stochastic phenomenon whose detection probability is inversely proportional to the target distance, as well as being affected by the atmospheric propagation conditions. For the purpose of comparative performance analysis in a selection process, one assumes that the propagation conditions are the same for all the analyzed equipment. However, one must simulate equipment performance in some adverse propagation conditions to check the performance of the radars in situations related to the ship employment.

One of the analytical tools normally used to model radar performance is the coverage curve. Figure 1 shows the coverage curve of a typical radar used for the detection of a hovering helicopter with a two square meter radar cross-section – RCS. Two different antennas are considered here: one mainly for the detection of surface targets ($sen(x)/x$) and another for combined search ($cosec^2(x)$). The detection probability adopted was 80% for sea state 4 on the Beaufort scale. This curve was obtained with the use of a "*Radar Evaluation Software*", as mentioned by Macfadzaen (1992, p. 300). This diagram represents, on the left side of the curve for each antenna, the region with over 80% probability of radar detection.

The analysis of the radar coverage curve presented on Figure 1 confirms that the range estimate made previously for the detection example of a *sea-skimmer* missile is very optimistic, because apart from the fact that the radar cross-section for this type of missile being much smaller than that of a helicopter (of around 0.1 m^2), its high approach speed makes it difficult to confirm it as a target and start tracking. Another aspect indicates that the detection of an anti-ship missile is only possible at even smaller distances is the 80% probability adopted for the building of the Figure 1 diagrams. If for detection sake a larger probability is used, the diagram contours will come closer to the graph's origin, meaning an even shorter detection distance. It is important to emphasize that this preliminary analysis presented here does not consider other restrictions to radar performance, such as atmospheric propagation conditions or "fading zones" formed near the sea surface, causing intermittent detection for low-altitude air targets, as is the case of the *sea-skimmer* missile.

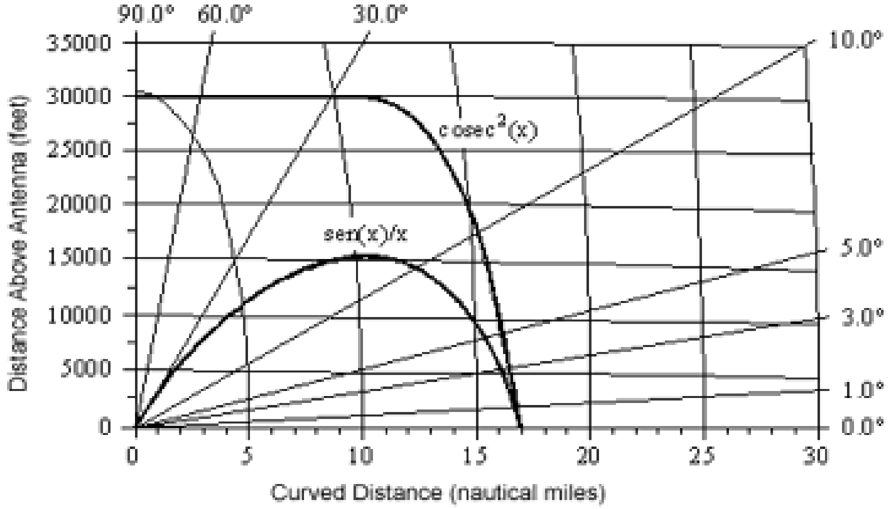

Figure 1 - Typical radar coverage diagram for an 80% probability of detecting a hovering helicopter (RCS = 2 m^2) over a Beaufort scale sea state 4. Comparison between *cosec^2(x)* and *sen(x)/x* antennas (obtained through "*Radar WorkStation* version 2,2" program).

Another critical aspect in the selection of a search radar is the radar antenna rotation speed. Using the same above-mentioned example on the detection of a *sea-skimmer* missile, for each scan of a radar operating at a maximum angular speed of 15 r.p.m., search, detection, acquisition, start tracking, identification and target destruction evaluation will take at least 24 seconds, 24% of the total response time (100 seconds). This estimate considered that at least one scan (4 seconds each) is needed for each stage. CIWS radars operate at 60 r.p.m., which reduces this time to 6 seconds.

SURFACE-TO-AIR MISSILE (SAM)

A surface-to-air missile, or anti-aircraft missile, is similar to a gun-shot projectile with an autopilot. The analogy with gun ammunition is possible since the missile accelerates to reach projectile supersonic speed. This similarity has given rise to research on the production of course-corrected gun ammunition and increase kill probability of guns.

The autopilot that guides the missile to the target is the feature of this weapon that provides it with more or less kill probability during target engagement. One can use different ways to implement this characteristic depending on the missile type, classified according to autopilot location, tracking sensor radiation, and algorithm used in the autopilot.

As to the location of the guidance control, the SAM are divided in two groups: those guided from the launching base – surface ships, in this case – and those whose guidance control is located in the missile itself. The missiles from this second group are guided by the radiation coming from the target. Such radiation allows for yet another variation within this group, i.e., semi-active missiles and active and passive missiles. The semi-active ones are provided with another energy source located in the ship and which "focuses" the target so the missile sensor can be guided by the energy reflected by the target. The other missiles are guided by means of active or passive emissions, i.e., they either pick up the energy reflected by the target, coming from a source located in the very missile, or follow the energy generated by the target.

According to the type of energy the sensor picks up, missiles can be classified as electro-optical or electro-magnetic, depending on the band of the given spectrum. From the standpoint of the algorithm used in the guidance control, the SAM can be of *Command to Line Of Sight* (CLOS) that maneuvers the missile to keep it in the line of sight, uniting the target to the sensor installed in the ship. The other type of guidance is proportional navigation, whose corrections during flight are proportional to the missile deviation angle in relation to the target, i.e., the missile seeker angle[2], so that its trajectory intercepts the target trajectory at a future point (GARNELL, 1977, p. 181-189).

The type of algorithm used in the guidance control is of key importance for the modeling of a SAM. This algorithm will influence the form of the kill probability diagram for the missile designed to be used against a given target.

The mathematical model of a SAM describes its guidance by means of a transfer function whose input is the relative position of the missile in relation to the target, and whose outputs are the commands for correction of the trajectory of the aerodynamic surface controls of the missile, according to the

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[2] It is the angle the radar or missile infrared sensor describes with its symmetry axis.

type of navigation implemented, i.e., CLOS or proportional (MACFADZEAN, 1992, p. 136 e 213). The first results obtained from the simulation with the missile model are the constant lateral acceleration kinematic curves, shown in Figure 2. The curves represent the maximum lateral acceleration (normal) a missile is able to develop, i.e., its maneuverability.

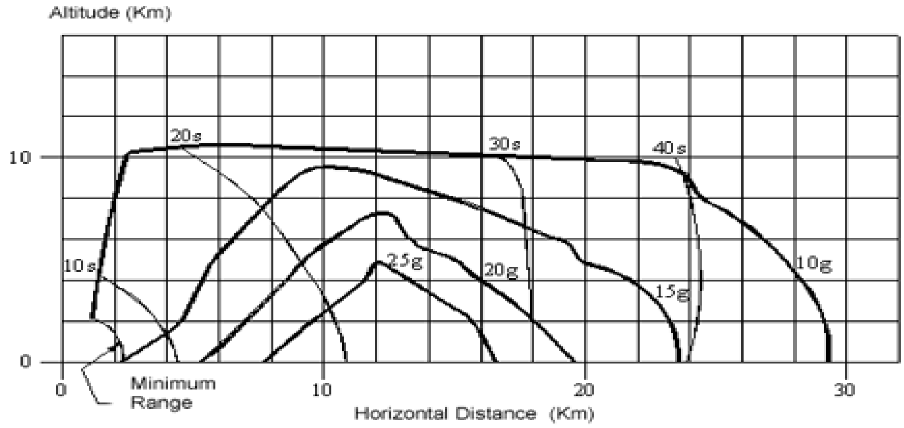

Figure 2 - Constant lateral acceleration kinematic curves (g = gravity acceleration) and flight time (s = seconds) of an anti-aircraft missile achieving supersonic speed Mach 3.0 in 22.7 seconds (MACFADZEAN, 1992, p. 200-208).

The kill probability diagram for a missile is designed from the kinematic curve shown on Figure 2, where the constant kill probability curves are similar to those of constant *g*.

Besides maneuverability, which keeps a direct relation with the miss-distance missile-target, the proximity fuse model is also considered, increasing the action radius of the missile warhead within a stochastic analysis. Macfedzen (1992, p. 262) comments that "*[...] warhead characterization data is used in conjunction with the miss-distance distribution that results from the guidance and control functions to estimate kill probability.*"

THE PROCUREMENT CONTRACT AS A PERFORMANCE GUARANTEE

All the models and analyses proposed in this paper depend on the reliability ofthe information provided by the manufacturers of the weapons and sensors considered during the selection process. In some cases it is possible to evaluate the consistency of the data through the output obtained in the simulations. Actually, this is one of the aims of using an analysis methodology.

However, since it is impossible to confirm through simulations much of the information supplied, the data declared by the manufacturers should appear in the agreement for future verification purposes during factory tests or in the operational assessment of the equipment (BAKER, 1990, p. 513).

SICONTA SELECTION

Feasibility Studies (FS) are the starting point for the selection of weapons and sensors for the configuration of a surface ship combat system. SICONTA selection is done during the FS phase and it defines a weapons and sensors integrated architecture which will allow the ship proper task performance within the scenarios specified in the RANS.

Nevertheless, the methodology used for the SICONTA performance analysis differs from the one proposed for the selection of weapons and sensors. As a Digital Operational System, developed to process information and perform commands and controls in "real time" [3], its design phase simulation consists of three basic activities: design of the functional combat system model; analysis of the flow of information at SICONTA (data net traffic); and interface simulation.

The functional combat system model is designed considering the requirements established in the ship RANS and it is a diagram that originates in the system high level functions. The functions to be performed at lower levels are detailed using this graphic representation, until achieving the lowest levels, which represent the resources needed for the performance of the system tasks, i.e., equipment, software, personnel, information, and logistical items, among others (BLANCHARD, 1998, p. 62-64). Nowadays there is software that helps in the design of the system functional diagram, such as *System Architecture*.

The exercise of representing a combat system by means of a functional levels detailed diagram (*breakdown*), following a sequence that goes from the highest to the lowest level (*top-down*), is the approach that helps in the selection of the architecture during the FS phase. Combat systems that need to perform a large number of high-level functions all at the same time, for a large number of threats, will probably be better designed with a distributed architecture. Other systems that have been created to face scenarios of just a few threats, might be configured with a centralized architecture.

Another activity needed for combat system performance analysis is the simulation of the flow of information passing through the SICONTA for the execution of its functions. Even after the type of architecture to be used in the

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[3] In most definitions, "real time" is described as a fast response feature, compatible with the functions a system should perform (ALLWORTH, 1981, p. 12).

system is defined, it is necessary to test its performance in order to check its ability to process in "real time" the essential combat functions, such as target engaging, both in attack operations and ship-defense operations. Besides, the system should be able to perform auxiliary functions, such as gyro, anemometer and hodometer signal distribution, at a priority level compatible with the required speed for the essential processes of the system.

The simulation of the flow of information during the Feasibility Studies phase may be done either by means of merely theoretical studies of the system load or by comparison with other combat systems already in operation. More complex modeling might even use computers and data networks with the same capacity designed for the SICONTA architecture.

Feasibility Studies, within the same evaluation of the combat system while performing its essential and auxiliary functions, should also analyze the interfaces that enable the interconnection between SICONTA and the weapons and sensors. Depending on how important the equipment is, interface analysis might vary from a simple theoretical checking of signals to a test involving simulators that monitor data traffic through the interface during the operation.

SICONTA ARCHITECTURE

The purpose of SICONTA is to automatically perform functions that used to be performed by operators, before the advent of digital computers. Tactical picture compilation, navigation problem solving, tracking initiation, etc. started to be implemented by the various systems composing SICONTA (PAKENHAM, 1989, p. 96-103).

In this case, two basic architecture types for SICONTA can be identified and will be addressed in this chapter in order to illustrate aspects that need to be considered in the design and development of this system: centralized and distributed.

Due to the historical development of computer systems, the centralized architecture was the first one to be used in combat system design. This architecture is basically composed of a central processing unit, denominated *mainframe*, through which passes all the information and where are processed all the calculations needed for the conduction of system functions; and of peripheral units that are the users of such information.

As illustrated by Figure 3, the centralized architecture demands the entire system load to go through the central computer (Central Data Processor). This requires high performance processing in order to keep up the high speed needed to simultaneously perform combat tasks even in intense system load, i.e., during intense information flow in the central computer. Pakeham (1989, p.101) comments that "*the demand for such rapid response taxes even a computer's* *ability, and the need to react within few seconds can pose an impossible task in a busy situation with several threats occurring simultaneously."*

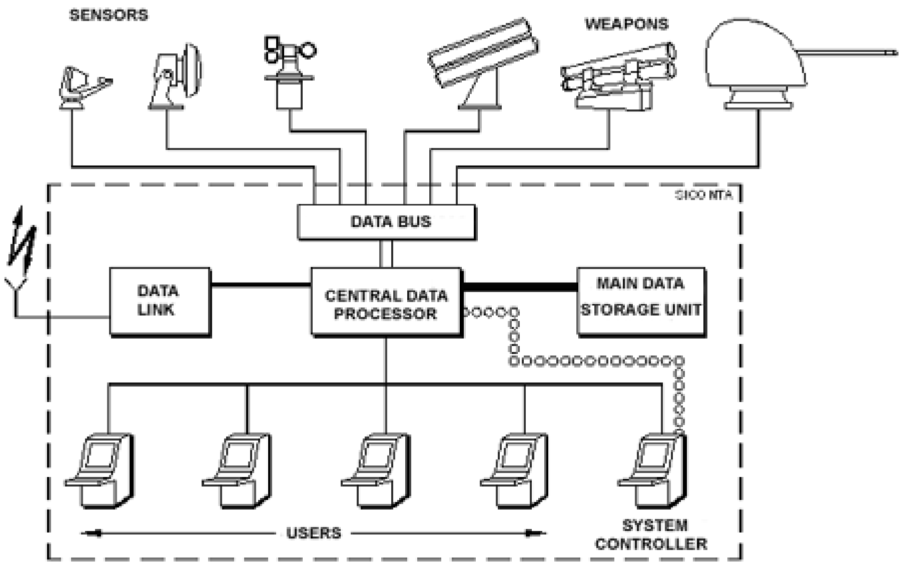

Figure 3 - Diagram of a centralized architecture combat system for SICONTA (source PAKENHAM, 1989, p. 97).

re 4 is composed of several o share system function Data Network that enables and sensors, with various ce of more than one task,

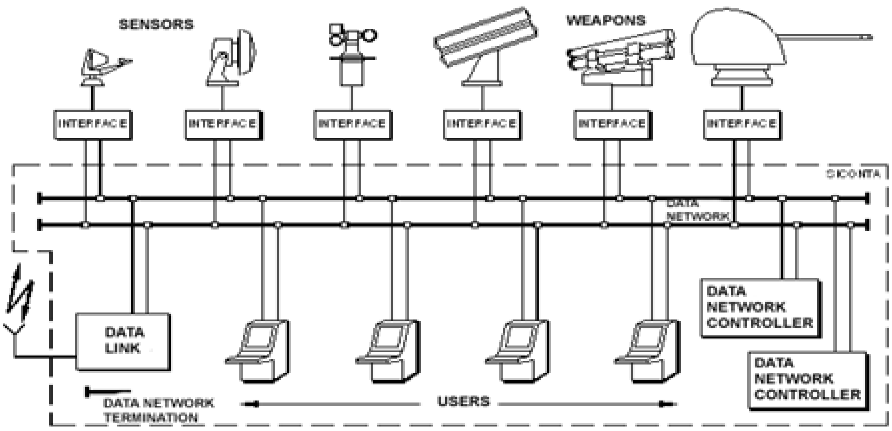

Figure 4 - Diagram of a distributed architecture combat system for SICONTA (source PAKENHAM, 1989, p. 102 and BAKER, 1990, p. 493).

A distributed architecture provides more reliability to SICONTA because it allows system re-configuration in case of damage of one of the computers (Users on Figure 4), which means that the system can continue to operate in degraded mode, something not normally possible with a centralized architecture. (PAKENHAM, 1989, p. 103).

However, the operation on degraded mode cannot be applied to all system functions. The ship must be able to keep certain combat capabilities even in the presence of damages. In general, this redundancy principle should be applied to the critical system functions, in conformity with the requirements established by RANS.

COMBAT SYSTEM PERFORMANCE ANALYSIS

Macfadzean (1992, p. 289-290) suggests that engagement simulation is the proper level to analyze combat system performance. The engagement process, when the ship meets a threat, involves the basic functions of the system which should be performed within a time frame compatible with the attack kinematics.

Similar to what was discussed previously, an engagement simulation is conducted with the help of a mathematical model that enables the evaluation of combat system performance within a pre-established scenario. Nevertheless, it will require more than a model to describe all the engagement phases, some of which have a deterministic nature, as the guidance model of a flying missile, and others are stochastic, as the gunfire model.

COMBAT SIMULATION

The combat system macro-functions, performed when a threat is confronted, are detection, target designation for one of the weapon systems (*Target Indication* – TI), and threat engagement. During the last phase of this sequence, the system selects the weapon and the sensor, fires at the target and assesses the destruction of the threat.

Figure 5 illustrates a surface ship's point defense against an aircraft armed with bomb. The combat sequence is represented by numbered steps, from (1) to (12), in which the weapon used during the engagement is an anti-aircraft missile.

The sequence simulation starts with the search (1). The moment the threat reaches maximum detection distance is used as the count-down mark for aircraft approach and will determine its position in each combat stage.

Then there is the threat detection (2) by the search radar. Besides the radar coverage diagram shown on Figure 1, it is necessary to establish a minimum acquisition probability value from which the establishment of a valid contact will be considered, i.e., target acquisition (3). This event involves a minimum number of radar scans (detections) before the acquisition takes place since the radar coverage diagram is usually calculated for a single scan. Since each detection is an independent stochastic event, the acquisition probability after 3 scans is, for instance, obtained by the expression: $P_{(N\ scans)} = 1 - (1 - P_{(1\ scan)})^{N}$, for $N=3$. For example, for an 80% detection probability in 1 scan, the acquisition probability after 3 scans will be 99.2%.

The initiation stages of target tracking (4), identification (5), and designation (6) are modeled regarding the time spent for the performance of each of the stages, whether they are done manually or automatically by the system. These times will affect the distance in which the target will be destroyed, and, consequently, the system combat performance evaluation. The same happens with the weapon/sensor designation (7) stage which will start the engagement sequence.

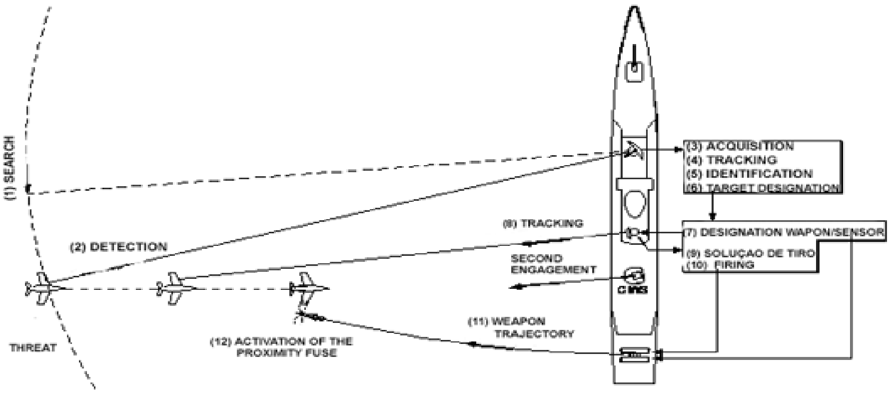

Figure 5 - Combat process against an air threat. Detection phase: search, acquisition, tracking, and identification. Target designation phase. Engagement phase: weapon and sensor designation, tracking, solução de tiro, firing, ammunition trajectory, and activation of the proximity fuse (source GATES, 1987, p. 24-28 and MACFADZEAN, 1992, p.298).

During tracking (8), one must take into account the times intervals needed for the performance of manual and/or automatic sensor operation events. This stage introduces a new variable in combat simulation: tracking precision used for the miss-distance calculation, in case the missile used is the CLOS.

After that, the system calculates the firing solution (9) according to the data continually received from the tracking sensor. In the mathematical model adopted for the combat simulation, the algorithm used in predicting the aiming point for the target must be implemented according to the characteristics of the weapon employed in the engagement.

The firing (10) ends the simulation of the events involving the systems installed on board. The time spent for the firing solution, up to the moment when the weapon is effectively fired, should be considered for the target position calculation in the beginning of the following combat stage, i.e., weapon trajectory.

During the weapon trajectory (11) simulation specific models should be used for each type of ammunition. It is worth pointing out that the mathematical treatment for the gun projectile is considerably different from, for instance, the one used for a missile whose trajectory is corrected by its guidance system.

Once the missile position relative to the target is obtained in the miss-distance, one must check the activation of the proximity fuse (12) that will blow the missile warhead in case the miss-distance is shorter than the maximum sensibility distance of the proximity fuse. One must apply the missile warhead fragment spreading model and calculate the target destruction probability.

After evaluating target destruction, the model might also include a second engagement to be performed with the same weapon or with another weapon more appropriate for the engagement at closer distances from the ship, with the CIWS shown on Figure 5, or any other small caliber gun.

PERFORMANCE MEASURING

When establishing the requirements for a ship one must bear in mind the performance of tasks in real operation scenarios. Because there are no opportunities, during the phases before commissioning, to carry out system operation tests, in order to do intermediate verifications, it is essential to employ some performance measure to allow for requirement alterations before the detailing phase of the ship design. A type of measure that can be used for this purpose is threat destruction probability. This type of measuring can be calculated by means combat simulations.

CONCLUSION

The first phase of the procurement and modernization process of MB ships is the conduction of Feasibility Studies whose purpose is to propose configurations that will meet the functionalities established for the ship's RANS. The results of the FS are used to validate the requirements or subsidize changes meant to make them feasible. For this reason, it is essential to use mathematical models to simulate the operation of the systems while performing their various functions, especially in combat operations against anticipated threats in the scenarios where the ship is likely to operate.

Naval construction technologies are the domain of the Navy since the Brazilian colonial period (BARBOZA 2005), whereas the use of anti-aircraft missiles was only introduced in the MB in the 1970's with the procurement of the "NITERÓI" class Frigates. The same can be said about the use of combat systems based on Operative Digital Systems.

The first project to use mathematical modeling procedures and simulations to evaluate combat system performance was the Modfrag project. Similar procedures were used during the Ocean Patrol Vessel project, but in a smaller scale, since the weapons and sensors configuration was simpler than the Modfrag project combat system.

This was the main motivation for the present paper. A combat system configuration methodology is proposed for the surface ship procurement and modernization process, more specifically in the conduction of the FS.

The proposed methodology is divided in three connected phases. It starts with the selection of weapons and sensors by means of the performance simulation of each equipment individually, i.e., in stand-alone operation. This procedure is built over mathematical models of weapons and sensors related to qualitative analyses of their technical features.

The second phase concerns the study of the features of the architectures adopted for SICONTA which will be, once integrated to the weapons and sensors, the configuration of the ship's combat system.

After the conclusion of the first two phases, the possible configurations for the combat system are attained – the ones that are theoretically capable of meeting the RANS-established requirements. However, it is essential to check weapons and sensors integrated to SICONTA as to their performance during combat against anticipated threats, for the scenarios in which the ship is likely to operate. This is done on the last phase of the proposed methodology with the simulation of the various engagement stages against an air target and within a given timeframe. Thus, it is possible to achieve a performance measurement for the system, expressed in terms of kill probability of a representative threat. The main purpose of the methodology proposed in the present paper is to anticipate problems and deficiencies while the combat system is still in the design stage; these are usually identified only in ship's operational evaluation stage.

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