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Coastal Surveillance, Command and Control

I&S Monitor

CHALLENGES OF NAVAL TRANSFORMATION

New security challenges and advances in technology, communications and information technologies in particular, impact the way militaries around the world are organized and equipped to perform their roles. The expectation is that, rather than leading to one-step reorganization and restructuring of the military, these factors bring permanent adaptation of military organizations, designated recently as *transformation*.

To reflect the impact of these developments on navies and related organizations, the Editorial Board of *Information & Security: An International Journal* (I&S), jointly with the AFCEA-Varna Chapter and the Naval Staff of the Bulgarian Armed Forces initiated the preparation of this special I&S issue.

Naval transformation was the overarching theme of the Second International Conference "The Bulgarian Navy – New Missions, Roles and Capabilities," organized by the AFCEA-Varna Chapter [1] and held at the end of September 2003 on the Black Sea coast near Varna, Bulgaria. The articles in this volume are based on a selection of presentations discussed during this conference.

Reference point of transformation is the new roles, missions and tasks of the Navy. Naval forces are preparing to deal with ill-defined asymmetric threats, under uncertain scenarios in multi-agency and multinational setting. In addition, very often naval forces are expected to assist civilian authorities in border control, law enforcement, search and rescue, and environmental tasks.

To do that effectively, navies shall be able to act in a network-centric manner, where net-centricity is achieved through very high degree of connectivity, near real-time situational awareness, distributed decision-making authority, and a range of flexible capabilities. Such features are in the process of institutionalization through development of novel naval doctrine and tactics, adequate organization, and insertion of advanced naval technologies.

In addition, technological opportunities allow for smaller size of personnel, however with higher and more diverse skill levels. Therefore, transformation places a special emphasis on continuous education, e-learning, and qualitative improvements in individual, crew, and staff training.

In order to succeed, naval transformation needs a clear vision, supported by adequate concepts, doctrine, policies, and technology acquisition. The reader will not find answers to all related questions in this issue. We believe, though, that this I&S volume will provide novel ideas, analysis of experience, and description of advanced technological opportunities, that will be of service on the thorny path of naval transformation.

Information & Security

[1] More about the activities of the AFCEA-Varna Chapter the reader may find at www.afcea.bg.

BULGARIA IN NATO: NEW ROLES AND CAPABILITIES OF THE NAVY

Rear Admiral Emil LYUTZKANOV
Chief of Main Staff of the Bulgarian Navy

Abstract: In a comprehensive manner this article presents roles and missions of Bulgaria's Navy, and the capabilities it develops to deal with the 21st century security challenges in cooperation with other services, security organizations, and allied navies. In the process of transformation, the Navy has developed ambitious plans to insert advanced technologies, commensurate to its new missions and tasks. This article looks specifically at plans to introduce advanced communications and information technologies in order to achieve required naval capabilities and to facilitate individual, crew, and staff training.

New Roles, Missions, and Responsibilities of the Navies Facing 21st Century Security Challenges

Historically, the term "national security" had various specific definitions and dimensions; however, they all had one common meaning – the reliable protection of the territorial integrity and the independence of a sovereign state. The challenge in this respect was how to approach and in what manner to realize this "national security."

The turmoil of the political and societal changes in Europe in the 1990s and thereafter, the dissolution of a number of multinational states, e.g., the Soviet Union and the Socialist Federal Republic of Yugoslavia, the unification of Germany, the processes of globalization and unification of Europe, as well as the aggravation of demographic, ecological, economic and social problems and, most importantly, the expansion of the international terrorism and organized crime, brought forward a number of issues related to the notion of national security and the ways to realize it.

In the last few years, the notion of national security went beyond the boundaries of a separate state.

Of increasing importance are the notions of *Individual Security*, *Collective Security*,

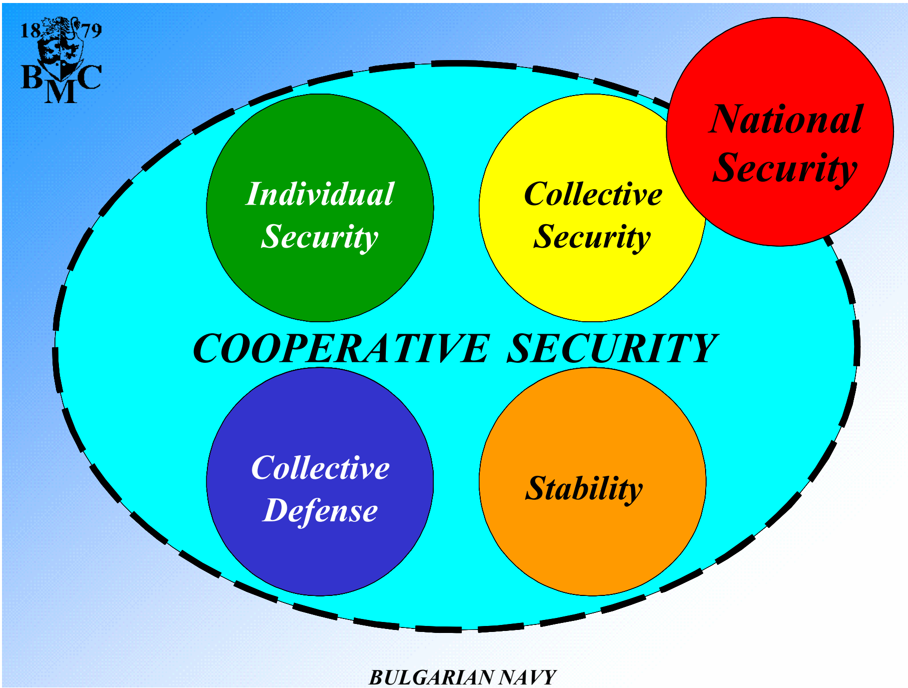

Figure 1: Constituents of the Cooperative Security System.

Collective Defense, and *Promotion of Stability*, constituting a system for common /cooperative/ security (This interaction of terms and notions is presented graphically in Figure 1).

Security is based not only on military force and government actions, activities of national institutions and non-governmental organizations within a state, but also on international (bilateral and multilateral) treaties and organizations.

In this respect I am proud to state that, since 1991, Bulgaria's naval forces stand firmly behind the Atlantic idea. The Navy incorporated in its plans variety of activities aimed to increase the confidence and to foster collective security in the Black Sea region and to promote stability. Even prior to the "Partnership for Peace" Initiative, in 1993 Varna hosted the international symposium "Black Sea Naval Review"—the first of its kind—on the topic "The Naval Forces in the New Geopolitical Environment." Under excellent organization, more than 100 participants form 13 countries actively discussed 26 reports. As a continuation of this effort, that same year Bulgaria hosted the first national naval exercise with international participation in the "Breeze" series.

Figure 2: International Exercises and Other Activities of the Bulgarian Navy.

Since the launch of the "Partnership for Peace" Initiative in 1994, the Bulgarian Navy actively participates in variety of exercises (Figure 2 provides a sample list). That allowed the Navy to gain international experience and recognition and to make a commensurate contribution to Bulgaria's efforts towards NATO membership.

The changes in the security environment, in the social, political and economic development of the country, the pending membership in NATO and the qualitatively differing approach to national security, and its military aspect in particular, prompted the conduct of the ongoing Strategic Defense Review. Based on our accomplishments and looking into the future, we reassess existing and define new links, parameters, and norms in the field of national security and defense, that constitute the fundament for our Vision how the Navy will evolve, what the new responsibilities are and how to develop the operational capabilities, required to accomplish the new missions and tasks.

The Strategic Defense Review is yet another step in harmonizing the national defense policy with the policy of the member countries of the North Atlantic Treaty, in defining and realizing Bulgaria's contribution to the Common European Security and Defense Policy.

In the review process, the Navy accounts for the following basic assumptions:

1. *Main purpose of defense* is to guarantee the sovereignty, the security and the independence of the country and to protect its territorial integrity. This goal will be accomplished in the context of the collective security and defense system with full mobilization of the national capabilities and resources.

2. The *collective security system provides the optimal approach to guaranteeing national security*. The membership in the North Atlantic Treaty is a factor with decisive importance for the security of the Republic of Bulgaria. At the same time, the membership in the Alliance requires that the Navy builds-up and maintains adequate military capabilities and contribution to the joint capabilities of the Alliance.

3. The *main risks and threats* to the country's security stem from the international terrorism, the proliferation and the use of weapons of mass destruction, the instability of democratization processes in conflict regions, organized crime, illegal traffic of strategic raw materials, technologies, arms, drugs, and people, as well as from destructive impacts on information systems, economic instability, ecological catastrophes, natural and man-made disasters. In the Black Sea region, Bulgaria's Navy has important responsibilities in respect to all these risks and threats.

4. The complex global and regional environment of dynamically changing opportunities and barely predictable challenges necessitates the *use of non-traditional, preventive and anticipatory approaches* and solutions, complementary and coordinated efforts involving political, economic, technological, and informational—both military and civil—resources.

5. The characteristics of the new risks and threats—*asymmetric, hard to predict, unconstraint by distance impact capability*—pose new and harsh tests to the Navy. These features demand a fundamental change in organizing, equipping and training the Navy and a completely different force planning approach – from one based on threats to one based on required capabilities.

6. The new defense policy commands a *new vision* on the role, the place and the tasks of the armed forces, on their structure, composition, and operational capabilities.

7. The development of the naval forces ought to guarantee the sustainment of *effective, combat capable, multifunctional, modular and mobile units*. These units shall be capable to participate in combined and joint operations, to be deployed abroad, to be relatively independent and fully logistically sustainable, to be able to react in real time to the challenges of the security environment and to be interoperable with allied

forces. The deployable forces—a subset of the force structure—are of highest priority in realizing defense objectives and planning force development.

Accounting for all these assumptions, the naval forces are developing operational capabilities for contribution to the following *missions*:

- Defensive;
- In support of the international peace and security;
- Contribution to the national security in peacetime.

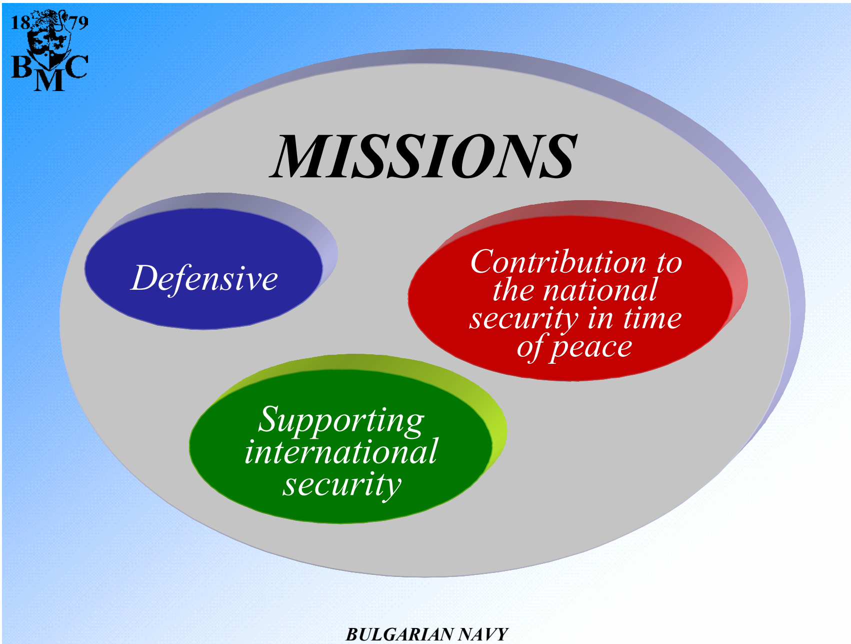

Figure 3: Missions of the Bulgarian Navy.

Figure 3 presents graphically the concept of new missions of the Bulgarian Navy.

The mission *Defense* comprises all activities related to guaranteeing the national sovereignty, security and independence, and the protection of the territorial integrity of the country, as well as those of the NATO member countries in the context of Article V of the North Atlantic Treaty.

The mission in *support of the international peace and security* is carried out in accordance with international and coalition obligations of the country in the fight against terrorism, for the prevention and management of crises and conflicts outside the country's territory, participation in multinational formations, activities in support to the evolving European Security and Defense Policy, arms control and non-proliferation regimes, in particular against proliferation of weapons of mass destruction and the means of their delivery, in support of humanitarian relief, international military cooperation and confidence building measures.

The *contribution to the national security in peacetime* covers the sustainment and utilization of capabilities in support of the control of the national air and sea space; collection and processing of information on potential risks and threats; operations to deter and neutralize terrorist, extremist and crime groups; protection of strategic sites; protection of and support to the population during natural disasters, industrial accidents and ecological catastrophes; humanitarian relief activities; search and rescue operations; support, when necessary, to other governmental organizations.

The analysis of this set of missions provides the following *conclusions* in regard to the Navy:

1. The role of the Navy increases and becomes decisive for the defense of the country in the collective security framework:

- Upon NATO membership, Eastern Bulgaria and the Black Sea coast becomes eastern border of the Alliance (and of the European Union in the near future. See the map in Figure 4);
- Surveillance, reconnaissance, early warning of threats /crisis/ and the timely warning are essential for the favorable operational regime in the sea spaces, this also being of immense importance for NATO and the European Union.

2. Functionally and structurally, the future naval forces shall be built to maximize the contribution to:

- the defense of the country in the framework of the collective defense;
- the international security;
- the national security and sovereignty in time of peace.

3. The asymmetry and the unpredictability of new risks and threats to the national security, as well as the destabilizing influence of regional hotspots demand the creation of a system for complete and comprehensive control of the sea spaces.

4. Priority for the Navy will be the development of operational capabilities for participation in the collective defense system, in support of the international peace and security, and for contribution to national security in peacetime.

5. The management of the human resources (selection, education, training, professionalization, promotion, motivation) is of increasing importance.

6. Financial constraints demand prioritization of spending in order to achieve the

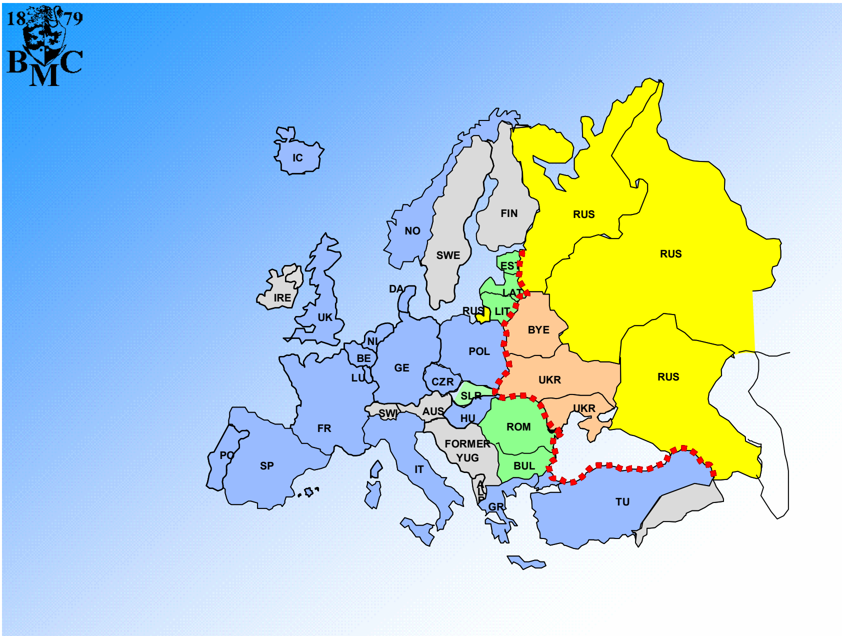

Figure 4: Bulgaria at the Eastern (Sea) Border of NATO.

required operational capabilities for participation in the system for collective defense, in support of the international peace and security, and for contribution to national security in time of peace.

7. It is necessary to review and update the naval doctrine and other conceptual and doctrinal documents, related to the evolution of the Navy and its activity.

New Missions and Tasks of the Bulgarian Navy – New Operational Capabilities

The Navy is one of the services of Bulgaria's Armed Forces (BAF). As a whole, the armed forces maintain readiness for participation in the full spectrum of missions in guaranteeing the sovereignty, security and independence of the Republic of Bulgaria and protection of its territorial integrity and interests in the sea spaces, participate in NATO's collective defense and support the international and national security in peacetime.

Mission I. Defensive

1.1. National defense in the framework of the collective defense system.

1.2. Participation in collective defense operations outside of the country's territory.

Mission II. Support to the international security

1.1. Participation in international crisis response operations outside of the country's territory

1.2. Participation in international operations to guarantee peace and security.

1.3. International military cooperation and participation in multinational or bilateral military formations.

1.4. Participation in arms control measures, activities against the proliferation of weapons of mass destruction, and confidence building measures.

Mission III. Contribution to the national security in peacetime

3.1. Surveillance, control and protection of the national territory, air and sea spaces.

3.2. Protection of and support to the population during natural disasters, industrial accidents and catastrophes.

3.3. Preparation of the population, the national economy, and the country's infrastructure for crisis response.

3.4. Participation in search and rescue operations.

3.5. Participation in the protection of strategic sites.

3.6. Contribution to the activity of other governmental ministries and agencies (information, hydrographic, meteorological support, mapping, ceremonial functions, VIP support, etc.).

3.7. Participation in the fight against terrorism, organized crime, and the illegal trafficking of drugs, people, and arms.

3.8. Participation in guaranteeing the information security and protection against cyber attacks on command and control and information systems.

3.9. Personnel development; preservation, development and further enrichment of BAF's traditions and values.

3.10. Protection of the environment and decontamination.

Requirements to the Navy

The accomplishment of the missions and the tasks requires that the future naval forces are highly effective, combat capable, multifunctional, mobile, deployable, relatively independent and fully logistically sustained, capable to react to security challenges and risks in real time and to be interoperable both with other security sector organizations and with allied navies.

In the development of the Navy, priority is placed on the capability of Bulgaria's naval forces to deploy in and outside Black Sea and the Mediterranean Sea for participation in the full spectrum of missions in the NATO's collective defense system, as well as in multinational peacekeeping operations and coalitions under the aegis of the United Nations, the European Union, the Organization for Security and Cooperation in Europe.

The list of development priorities includes:

- Deployable forces performing tasks:
    - in the system for collective defense;
    - in support of the international peace and security;
    - in support of the national security in peacetime.
- Forces that are not planned for deployment outside the country's territory.

To meet these demands, the Navy will develop the relevant required operational capabilities; will adapt its functional and organizational structure with priority on the deployable forces and the participation in the collective defense.

Required Operational Capabilities

In order to be able to accomplish the full spectrum of its missions and tasks, the Navy shall develop the following main operational capabilities:

- Maintain adequate force readiness to accomplish its defense missions and tasks.
- Maintain high level of training, including:
    - individual / personnel training;
    - training of the naval branches;
    - joint training of units from different naval branches;
    - training for joint and multinational operations.
- Comprehensive surveillance, early warning and control for the purposes of the timely and effective neutralization of potential risks and threats.
- Timely force deployment.
- Effective naval and joint operations.
- Timely and effective logistics.
- Effective actions in support to national security and sovereignty in peacetime.
- Effective command and control, communications, information systems, intelligence, surveillance and reconnaissance (C4ISR).
- Effective materiel and medical support to forces on the territory and in the aquatory of the country and to deployed forces;

- Force protection and survivability.

Vision for the Development of the Navy

On the basis of the differentiated missions, roles and tasks, the main criteria for the development of the Navy is defined as the achievement of full control of the sea spaces, early warning and timely neutralization of potential risks and asymmetric threats.

To this purpose the Navy, being one of the main operational components of the strategic defense system, will continue its development utilizing the *system approach* and enhancing the following *subsystems*:

- Operational surveillance, reconnaissance, early warning and control of the sea spaces;
- Command, control, and communications;
- Materiel and medical support (logistics);

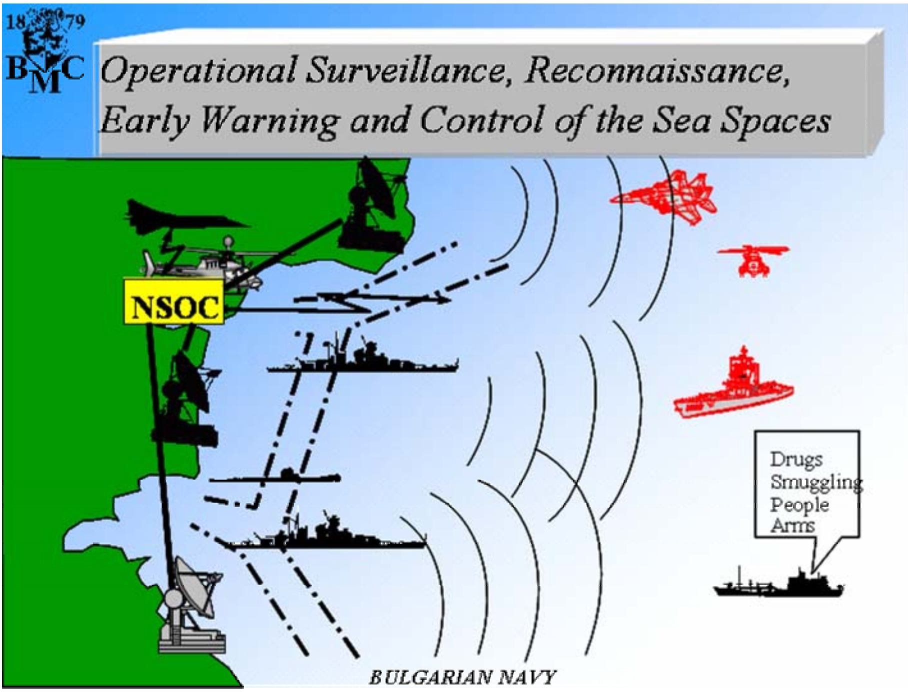

Figure 5: Subsystem for Operational Surveillance, Reconnaissance, Early Warning and Control of the Sea Spaces.

- Force training;
- Mobilization and mobilization training;
- Education and qualification;
- Social and personnel policies and personnel development.

A brief description of three of these subsystems follows.

Operational Surveillance, Reconnaissance, Early Warning and Control of the Sea Spaces

As part of the Navy's command and control system, the subsystem for operational surveillance, reconnaissance, early warning and control of the sea spaces provides (see Figure 5):

- Continuous collection, processing and discriminate dissemination of information in the interest of the Navy on potential risks and threats to the national security;
- Control of the sea traffic regime.

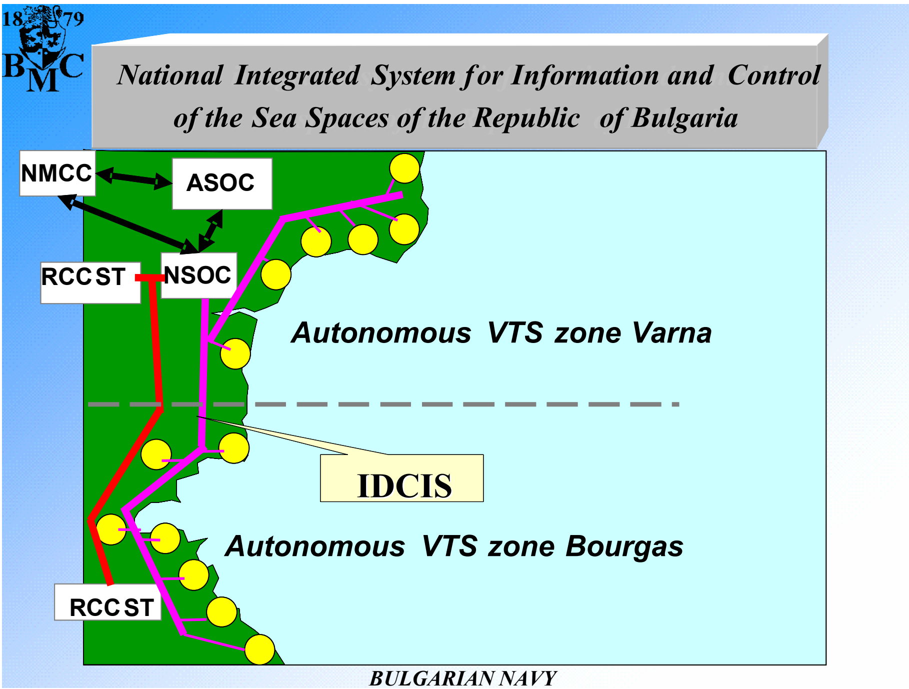

Figure 6: National Integrated System for Information and Control of the Sea Spaces of the Republic of Bulgaria.

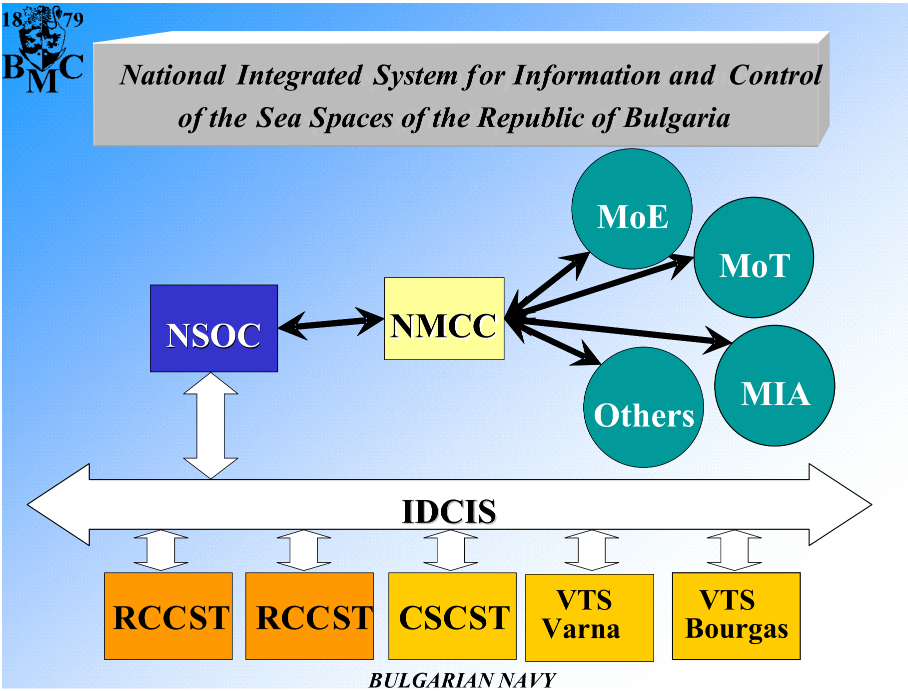

Figure 7: Structure of the National Integrated System for Information and Control of the Sea Spaces.

Abbreviations in Figures 6 and 7:

NSOC – Naval Sovereignty Operations Center
NMCC – National Military Command Center
ASOC – Air Sovereignty Operations Center
MoEW – Ministry of the Environment and Waters
MoTC – Ministry of Transportation and Communications
MoI – Ministry of the Interior
IDCIS – Integrated Digital Communications and Information System
RCCST – Regional Center for Control of the Sea Traffic
CSCST – Coastal System for Control of the Sea Traffic
VTS – Vessel Traffic System

The required operational capabilities of this subsystem may be attained through the establishment of a *National Integrated System for Information and Control of the Sea Spaces of the Republic of Bulgaria*. The concept and the structure are presented in Figures 6 and 7. Organizationally, this system includes:

- Naval Sovereignty Operations Center (NSOC):

- Regional Center for Control of the Sea Traffic (RCCST);
- Coastal System for Control of the Sea Traffic (CSCST);
- Two autonomous Vessel Traffic Systems (VTS) zones, respectively for the areas of Varna and Bourgas;
- Integrated Digital Communications and Information System (IDCIS).

In addition, through the Naval Sovereignty Operations Center, this system is integrated with the National Military Command Center (NMCC), as well as with other military C2 nodes and adequate organizations within the Ministry of the Interior (MoI), the Ministry of Transportation and Communications, the Ministry of the Environment and Waters (MoEW) and other governmental agencies and non-governmental organizations.

Command, Control, and Communications

The Navy's command and control will be part of the new integrated military structure of NATO. This shall allow using command mechanisms in conduct of operations with

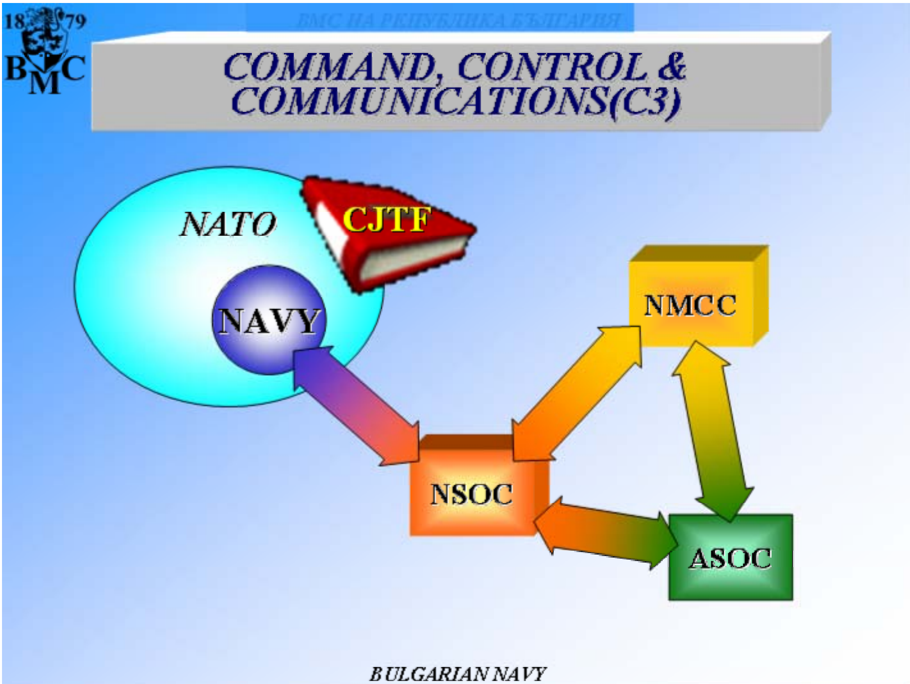

Figure 8: Command Hierarchy and Interaction of Command Centers.

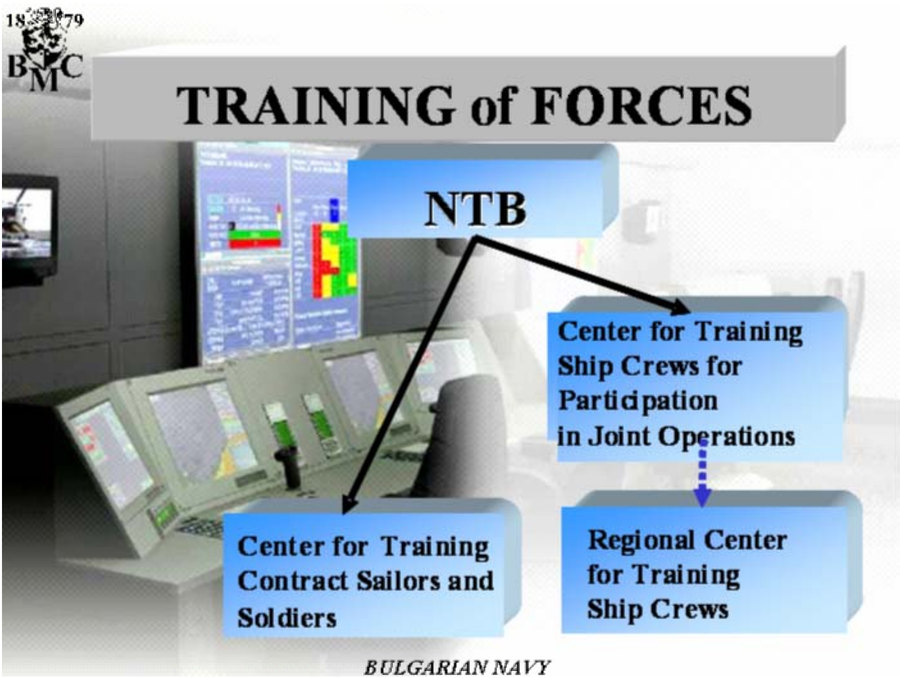

Figure 9: Force Training Concept.

participation of ready deployable forces on the basis of the Alliance concept for *Combined Joint Task Forces* (CJTF).

In addition, the accession to the Alliance command structure will require reorganization of naval headquarters structure in functional aspect without leading to decrease of the overall operational effectiveness. Part of this change is the establishment of the Naval Sovereignty Operations Center that will serve as both command and administrative management structure, closely linked and interacting with the National Military Command Center (NMCC) and the Air Sovereignty Operations Center (ASOC).

The establishment of this modernized system for command and control of all naval forces and maritime elements is an issue of considerable importance for the country. It shall be solved in a unified national maritime policy that integrates the efforts of all maritime organizations in the country. Responsible for the control in the national sea spaces, the Navy will play the leadership role and will coordinate all activities within these sea spaces.

Force Training

One of the most important requirements to the Navy is the successful integration in the Alliance collective defense system. To this purpose, the relevant standardization agreements of the Alliance will be fully implemented in the training of the naval forces and headquarters.

Preserving the best traditions and incorporating new training requirements of the Alliance, the Bulgarian Navy will also introduce extensive simulation-based training (The training concept is presented in Figure 9). To this purpose we established a new "Center for Qualification of Contract Sailors" at the Naval Academy in Varna. Furthermore, since October 2003 the Navy uses a new "Center for Training Ship Crews for Participation in Joint Operations." Our ambition is to turn this Center in the future in a NATO-dedicated *Regional Center for Training Ship Crews*. The goal is to guarantee interoperability with crews from other countries, participating in operations, as well as to support Bulgaria's policy towards increased understanding, good neighborly relations, and confidence in the region.

In the promotion of this concept, the crew of the "Smely" Frigate underwent the first training course in the Center. This training facilitated the successful participation of "Smely" in multinational exercises with NATO ships in the Mediterranean Sea.

Conclusion

The deployable forces from the Bulgarian Navy form the naval component of Bulgaria's contribution to Article V collective defense operations, as well as to multinational out-of-area operations. This type of participation, being of high priority in Bulgaria's security and defense policy, requires significant modernization of the fleet. The current article did not look at this particular aspect of naval transformation. However, both operational requirements and technological opportunities are discussed in detail in the remaining articles of this issue of "Information & Security."

The Bulgarian Navy certainly needs new ships, modernized coastal, sea- and airborne command and control, surveillance and weapon systems that fit the country' defense policy and allow for smooth integration of the Navy in the process of transformation of the North Atlantic Alliance. This journal issue provides a number of ideas that, we may be confident, will help us turn the Bulgarian navy into an important contributor to Bulgaria's national security and to the collective security of NATO.

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Rear Admiral (U/H) EMIL LYUTZKANOV is Chief of the Main Staff of the Bulgarian Navy. Since his commission in 1976, Admiral Lyutzkanov has served in variety of tactical command positions. From 1990 till 1995 he was Deputy Chief of the Operations Department of the Navy HQ. In 1996 - 1997 he was Chief of Staff, and from 1997 till 2001 - Commanding Officer of the Varna Naval Base. In 2001 - 2002 Admiral Lyutzkanov served as Chief of Operations (N3/5) in the Navy HQ, and in 2002 – March 2003 combined this position with the responsibilities of Deputy Chief of Bulgarian Navy. Admiral Lyutzkanov is nominated as Military Representative of the Bulgarian Armed Forces to NATO, Brussels, to assume this position at the end of 2004. Admiral Lyutzkanov is a graduate of the "N.Vapzarov" Naval Academy in Varna, Bulgaria (1976), the Naval War College in Saint Petersburg, Russia (1985), and the General Staff Academy in Moscow, Russia (1996). Recently, he took short courses at Beaconsfield, UK, and the Naval Postgraduate School in Monterey, California.

STRUCTURED DESCRIPTION OF NAVAL TASKS

Boyan K. MEDNIKAROV and Peter H. DERELIEV

Abstract: This article demonstrates the results of an effort to structure the missions and tasks of the Bulgarian Naval Forces with the objective to establish the operational architecture of the Naval Sovereignty Operational Center (NSOC) and the Shore-based System for Control of Shipping (SSCS). This development has been approached via the C4ISR Architecture framework. The missions and tasks of the Bulgarian Navy are systematized at three levels – strategic, operational and tactical.

The changes in the risks and threats to national security, the growing economic activity and the liberalization of the regime of navigation in the maritime spaces and the adjacent economic zone create a completely new environment for the control of forces and resources of the Bulgarian Navy. There are increasing risks of accidents at sea, including those of vessels transporting dangerous goods, risks of smuggling, illegal trafficking of drugs, people, arms and possible dual-use goods, and risks of terrorist threats and activities at sea. In this situation, there is a growing need not only for a more efficient management of the Navy, but also for ensuring an effective interoperability among all the organizations responsible for national security and safety of navigation, defense of the sea borders, environment protection, etc. These issues can be resolved with the implementation of modern communication and information technologies and sensors, ensuring a new quality of information collection, situation assessment, decision-making and control.

Taking into consideration these issues, in the fall of 2002, a team of scientists from the Central Laboratory for Parallel Processing of the Bulgarian Academy of Sciences, the "G.S. Rakovsky" Defense and Staff College, and the "N.Y. Vaptzarov" Naval Academy conducted a study entitled: "*Design and establishment of an operational center for marine sovereignty and shore-based system for control of shipping along the Bulgarian Black Sea coast*."

The main objective of the study was to develop the operational architecture and to define the operational requirements of the Naval Sovereignty Operational Center

(NSOC) and the Shore-based System for Control of Shipping (SSCS). The study was part of a larger project aiming to ensure efficient application of modern communication, information and sensor technologies in order to guarantee marine sovereignty and control of shipping by the Navy, in cooperation with other governmental bodies, local authorities, commercial companies, allies, partners and NGOs working in this and other related fields.

Within this study, the team has solved a number of separate tasks, one of which was a structured description of the *missions and tasks* of the Bulgarian Navy, a description of the types of *operations*, their main characteristics, and the operational formations of the forces controlling the national sea spaces.

To solve this problem meant to develop a system architecture of NSOC and SSCS, which was achieved on the basis of the operational architecture software; the specifically defined organizational structure, respectively the specific type of physical operational nodes; the specific number and characteristics of the sensors, sensor systems and the data transmitted by them; the available information about existing and anticipated bodies, command posts and information sources of interacting organizations; and the requirements for NATO membership preparation. The study was conducted in compliance with the requirements of the *DoD Architecture Framework*, *Version 2.0*. [1,2,3]

The essential results related to the structured description of the *missions and tasks* of the Bulgarian Navy, are presented in the current article.

The missions and tasks of the Navy as part of the Bulgarian Armed Forces are presented in various doctrinal documents such as the Military Doctrine, the Military Strategy, the White Paper on Defense, and the Naval Doctrine.[4] According to the White Paper, the Naval Forces have three missions:

- To contribute to the national security in peacetime;
- To contribute to peace and stability in the world;
- To participate in the defense of the country.

According to the doctrinal documents, in peacetime, the Naval Forces maintain a favorable operational regime in Bulgaria's maritime spaces and participate in contingents for operations other-than-war when required. In wartime, the Naval Forces, either independently or jointly with the other services and branches of the Armed Forces, block the enemy's aggression from the sea, secure the maritime communications and render assistance to the littoral flank of the Land Forces.[5] These tasks are developed in more detail in the Naval Doctrine.

In the development of the operational architecture of NSOC and SSCS, the team adopted an approach that builds a C4SIR system as part of the meta-system for strategic management, command and control of the armed forces, where part of the routine human intellectual functions of information gathering, dissemination and processing are transferred to the system and in which the mission and the doctrine of the armed forces, the organization, resources, technologies, knowledge, experience and traditions of personnel and leaders are integrated.

The *essence* of the C4SIR system can be revealed through selection and analysis of that part of the human information processing activities that is susceptible to formalization, standardization, unification, automation, and integration within a common process of: receiving, collecting, transferring, processing, storage, visualization, protection and preparation to use information. The analysis results in the formation of the underpinning functional (operational) concept of the system, in which it is interpreted as a tool for supporting the strategic management, command and control of large social organizations. In this interpretation, C4SIR is a big and complex human-machine system, which is generally created to serve as an "amplifier" of the human cognitive abilities.

The *mission* of the C4SIR system is to assist managers, commanders and staff in the processes of strategic management, command and control of organizations throughout all steps, stages and phases of the activities or operations that they conduct, by providing them with the information required for making or enacting decisions. The accomplishment of this mission results in a prompt decrease of the uncertainty in the assessment of situations and threats, prior to decision-making.

According to standard classification, command and control levels are divided into: strategic (national), operational (joint – as a rule), and tactical. Since command and control are realized as an uninterrupted dynamic cyclic-reversible process with conditional components, its maintenance (in the whole spectrum of situations and threats) requires a clear and accurate definition of the functions performed at all these levels. This is accomplished on the basis of methods and techniques from systems analysis, according to which these functions are divided (decomposed) and afterwards classified, arranged in groups, and defined as separate subsets of tasks performed in peacetime, in humanitarian non-military operations, at crisis situations of civil character, in peacekeeping operations, and during participation in armed conflicts with different degree of intensity.[6]

Each of these subsets is distributed and associated with the "nodes" of the hierarchical command and control structure; for each of the possible situations and threats accurate procedures for work and interaction that every node should perform and maintain are established. This allocation is the crucial point in the design of the so-called "operational architecture" of the system for strategic management, command and control. The operational architecture of the C4ISR system supplements it, providing an additional set of tools for the maintenance and exploitation of strategic management, command and control.[7]

In meeting the requirements for clear and accurate definition of the functions of NSOC and SSCS at the three command and control levels, it was found reasonable to specify the activities performed by the Bulgarian Navy in a hierarchically structured comprehensive system of tasks at strategic, operational, and tactical level, respectively. The application of such an approach makes possible not only the accomplishment of the objective of the present study, namely developing and improving the system of Naval Forces control, but also the objective of other research and studies related to optimization of personnel, organization, basis for operational and combat utilization of the Naval Forces, which also apply the system approach and the theory of meta-systems.

Analysis of the conducted research leads to the conclusion that in the proposed hierarchical structure of tasks not all of them are traditionally performed by the Navy. Part of these tasks is carried out (or will be carried out) only when naval formations participate in NATO or other allied operations.

In addition, consideration should be taken of the fact that the proposed system of tasks is a function of the available resources and the existing national and allied views on using the naval forces. In this sense, the proposed hierarchical structure of tasks should be considered open and amenable to further development and elaboration in case of a change of the determining factors. The restricted size of this publication does not allow presenting the entire list of activities and missions performed by the Bulgarian Navy at the three levels of command and control. Therefore, we present a structuring of the activities, showing only the details up to the second sub-level. It should be emphasized that the proposed structuring differs considerably from that in the adopted doctrinal documents of the Bulgarian Navy; however, it is in a full compliance with the Universal Naval Task List. [8,9,10]

Strategic Level Tasks

ST 1 Deploy, Concentrate, and Maneuver Theater Forces

Not to be conducted independently. When a Bulgarian Navy unit is deployed to another theatre with other NATO forces, task ST1 should be performed. It is assumed in the structuring of the naval tasks that the Bulgarian Navy carries out mainly tasks at the Black Sea Theater.

ST 2 Develop Theater Strategic Intelligence, Surveillance, and Reconnaissance

ST 2.3 Process and Exploit Collected Theater Strategic Information

ST 2.4 Produce Theater Strategic Intelligence and Prepare Intelligence Products

SN 3 Employ Forces

SN 3.1 Coordinate Forward Presence of Forces in Theaters

SN 3.4 Protect Strategic Forces and Means

ST 4 Sustain Theater Forces

Coincides with OP 4.

ST 5 Provide Theater Strategic Command and Control

ST 5.1 Operate and Manage Theater Communications and Information Systems

ST 5.2 Assess Theater Strategic Environment

ST 5.3 Determine Strategic Direction

ST 5.4 Provide Strategic Direction to Theater Forces

ST 5.5 Coordinate Theater-Wide Information Warfare (IW)

ST 5.6 Provide Public Affairs in Theater

SN 6 Conduct Mobilization

SN 6.1 Prepare for Mobilization

SN 6.4 Move to Mobilization Station

SN 6.5 Prepare Units and Individuals at Mobilization Station (MS) for Deployment

SN 6.7 Provide Command and Control over Mobilized Units and Individuals

ST 6 Provide Theater Protection

ST 6.1 Provide Theater Aerospace and Missile Defense

ST 6.2 Provide Protection for Theater Strategic Forces and Means

ST 6.3 Secure Theater Systems and Capabilities

ST 7 Establish Theater Force Requirements and Readiness

ST 7.1 Recommend Warfighting and Other Requirements and Test Concepts

ST 7.2 Maintain and Report Readiness of Theater Forces

ST 8 Develop and Maintain Alliance and Regional Relations

ST 8.1 Foster Alliance and Regional Relations and Security Arrangements

ST 8.2 Provide Support to Allies, Regional Governments, International Organizations or Groups

ST 8.4 Provide Theater Support to Other DOD and Government Agencies

ST 8.5 Coordinate and Integrate Regional Interagency Activities

Operational Level Tasks

OP 1 Conduct Operational Movement and Maneuver

OP 1.1 Conduct Operational Movement

Not to be conducted independently. It is applied when a naval unit of the Bulgarian Navy deploys in a different international theater within NATO forces. In such cases it includes:

OP 1.2 Conduct Operational Maneuver

OP 1.3 Provide Operational Mobility

OP 1.4 Provide Operational Countermobility

OP 1.5 Control or Dominate Operationally Significant Area

OP 2 Provide Operational Intelligence, Surveillance, and Reconnaissance

OP 2.1 Plan and Direct Operational Intelligence Activities

OP 2.2 Collect Operational Information

OP 2.3 Process and Exploit Collected Operational Information

OP 2.4 Produce Operational Intelligence and Prepare Intelligence Products

OP 2.5 Disseminate and Integrate Operational Intelligence

OP 2.6 Evaluate Intelligence Activities in Theater of Operations/JOA

OP 3 Employ Operational Firepower

OP 3.1 Conduct Joint Force Targeting

OP 3.2 Attack Operational Targets

OP 4 Provide Operational Support

OP 4.1 Coordinate Supply of Arms, Ammunition, and Equipment in Theater of Operations/JOA

OP 4.2 Synchronize Supply of Fuel in Theater of Operations/JOA

OP 4.3 Provide for Maintenance of Equipment in Theater of Operations/JOA

OP 4.4 Coordinate Support for Forces in Theater of Operations/JOA

OP 4.5 Manage Logistic Support in Theater of Operations/JOA

OP 4.6 Build and Maintain Sustainment Bases

OP 4.7 Provide Politico-Military Support to Other Nations, Groups, and Government Agencies

OP 5 Exercise Operational Command and Control

OP 5.1 Acquire and Communicate Operational Level Information and Maintain Status

OP 5.2 Assess Operational Situation

OP 5.3 Prepare Plans and Orders

OP 5.4 Command Subordinate Operational Forces

OP 5.5 Organize a Joint Force Headquarters

OP 5.6 Employ Operational Information Warfare (IW)

OP 5.7 Coordinate and Integrate Joint/Multinational and Interagency Support

OP 5.8 Provide Public Affairs in Theater of Operations/JOA

OP 6 Provide Operational Protection

OP 6.1 Provide Operational Aerospace and Missile Defense

OP 6.2 Provide Protection for Operational Forces, Means, and Noncombatants

OP 6.3 Secure Systems and Capabilities in Theater of Operations/JOA

OP 6.4 Conduct Deception in Support of Subordinate Campaigns and Major Operations

OP 6.5 Provide Security for Operational Forces and Means

Tactical Level Tasks

NTA 1 Deploy/Conduct Maneuver

NTA 1.1 Deploy Naval Tactical Forces

NTA 1.2 Navigate and Close Forces

NTA 1.3 Maintain Mobility

NTA 1.4 Conduct Countermobility

NTA 1.5 Dominate the Combat Area

NTA 2 Develop Intelligence

NTA 2.1 Plan and Direct Intelligence Operations

NTA 2.2 Collect Information

NTA 2.3 Process and Exploit Collected Information

NTA 2.4 Produce Intelligence

NTA 2.5 Disseminate and Integrate Intelligence

NTA 3 Employ Firepower

NTA 3.1 Process Targets

NTA 3.2 Attack Targets

NTA 3.3 Integrate Tactical Fires

NTA 3.4 Organize Fire Support Assets

NTA 3.5 Conduct Coordinated Special Weapons Attack

NTA 4 Perform Logistics and Combat Service Support

NTA 4.1 Arm

NTA 4.2 Fuel

NTA 4.3 Repair/Maintain Equipment

NTA 4.4 Provide Personnel and Personnel Support

NTA 4.5 Provide Transport Services

NTA 4.6 Supply the Force

NTA 4.7 Perform Civil Military Engineering Support

NTA 4.8 Conduct Civil Affairs in Area

NTA 4.9 Train Forces and Personnel

NTA 4.10 Perform Resource Management

NTA 4.11 Provide Operational Legal Advice

NTA 4.12 Provide Health Services

NTA 4.13 Conduct Recovery and Salvage

NTA 5 Exercise Command and Control

NTA 5.1 Acquire, Analyze, Communicate Information and Maintain Status

NTA 5.2 Assess Situation

NTA 5.3 Determine and Plan Actions and Operations

NTA 5.4 Direct, Lead, and Synchronize Forces

NTA 5.5 Plan and Employ C2W

NTA 5.6 Conduct Information Warfare

NTA 5.7 Conduct Acoustic Warfare

NTA 5.8 Establish a Task Force Headquarters

NTA 5.9 Provide Public Affairs Services

NTA 6 Protect the Force

NTA 6.1 Enhance Survivability

NTA 6.2 Rescue and Recover

NTA 6.3 Provide Security for Operational Forces and Means

NTA 6.4 Provide Disaster Relief

The need for applying new approaches when determining the missions and tasks of the Naval Forces of Bulgaria is determined by the evolution of the traditional and the appearance of new threats to national security in the sea spaces, as new negative tendencies are being projected on them. It evolves not only from the broadened interpretation of the category defense in the Defense and Armed Forces Act, but also from the increasing expectations for the armed forces to counteract the asymmetric threats. The conduct of the present research is in connection with the new type of defensive function of a maritime state, where its military and defense, and rights and environmental protection efforts are joined, combined with a variety of services in critical situations, ensuing from the environmental and the increasing technology-generated risks at sea and on the seaside areas and reflects the significantly increased requirements from the governmental institutions for a rapid reaction in critical situations, for integrating their efforts and for studying the crises of non-military character and the risks they entail.

Notes:

[1] *C4ISR Architecture Framework,* Version 2.0 (C4ISR Architecture Working Group, December 1997).

[2] *DoD Architecture Framework (DoDAF)*, *Volume I: Definitions and Guidelines*, Version 1, (Washington, DC: DoD Architecture Framework Working Group, February 2004).

[3] *DoD Architecture Framework (DoDAF)*, *Volume II: Product Descriptions*, Version 1, (Washington, DC: DoD Architecture Framework Working Group, February 2004).

[4] *White Paper on Defence of the Republic of Bulgaria*, adopted with a decision of the Council of Ministers of the Republic of Bulgaria on April 4, 2002 (Sofia: Ministry of Defence of the

Republic of Bulgaria, 2003), English translation is available on-line at http://www.mod.bg/white_book/ENWP.pdf (13 March 2004).

[5] Velizar Shalamanov, "C4ISR in Modernizing Security Sector in Bulgaria and South-Eastern Europe," *Information & Security: An International Journal* 6 (2001): 7-22; <www.isn.ethz.ch/onlinepubli/publihouse/infosecurity/volume_6/f2/f2_index.htm> (11 March 2004).

[6] Todor Tagarev, "Prerequisites and Approaches to Force Modernization in a Transition Period," *Information & Security: An International Journal* 6 (2001): 30-52; <www.isn.ethz.ch/onlinepubli/publihouse/infosecurity/volume_6/f4/f4_index.htm> (12 March 2004).

[7] *C4ISR Architecture Framework*; *DoD Architecture Framework*, *Volume I: Definitions and Guidelines*.

[8] CJCSI 3500.01, *Joint Training Policy of the Armed Forces* (21 November 94).

[9] CJCSM 3500.04A, *Universal Joint Task List* (13 September 96).

[10] OPNAVINST 3500.38/MCO 3500.26/USCG COMDTINST M3500.1, *Universal Naval Task List*, Version 1.0 (30 September 96) <neds.nebt.daps.mil/Directives/3500/3500_38.pdf>.

BOYAN MEDNIKAROV is Educational and Science Deputy Commandant of the "N.Y. Vaptsarov" Naval Academy, Varna. He has experience as a commanding officer of fast patrol boats and operational officer in the Operational Department of the Navy Staff Headquarters. Since 1995 he has worked in the area of military education, as a lecturer, head of department in the Naval Academy and the "Rakovsky" Defence and Staff College, Sofia. His current rang is Navy captain. He graduated from the Naval Academy, specialty "Navigation for the Navy" in 1984, "Kuznetsov" Naval Staff College, St. Petersburg, Russia in 1992 and received a PhD degree in systems and control in 1999. Since 2000 he has been an associate professor in the Naval Academy and the "Rakovsky" Defence and Staff College. His interests in research include studies of military systems, navy units' activities modelling and problems of Navy structure. *E-mail*: vicerector@naval-acad.bg.

PETER DERELIEV is a senior lecturer in the naval department of the "Rakovsky" Defence and Staff College, Sofia. He is retired Navy captain. He teaches also at the "N.Y. Vaptsarov" Naval Academy and the Varna Free University. He has experience as a commanding officer of the strike force unit. Since 1992 he has worked in the area of military education, as a lecturer and head of department in the Naval Academy and the "Rakovsky" Defense and Staff College in Sofia, Bulgaria. He graduated from the Naval Academy, specialty "Navigation for the Navy" in 1977 and "Kuznetsov" Naval Staff College, St. Petersburg, Russia in 1990, and attended courses on problems of national security in the country and abroad. His interests in research include studies in the field of security of the national sea spaces and naval operational art. *E-mail:* p_dereliev@abv.bg.

C4ISR IN NAVY TRANSFORMATION: ROLE, JOINT RESEARCH AND ADVANCED TECHNOLOGY DEMONSTRATIONS

Velizar SHALAMANOV

Abstract: This article elaborates on an important aspect of Navy transformation – the role of C4ISR concept. It provides a comprehensive treatment of enabling the transformation C4ISR issues, such as the role and importance of network centricity and the joint research in general, the necessity for and the benefits of concept development and experimentation and advanced technology demonstrations, etc. The author shares his opinion on a topic that deserves special attention – that of the successful development and insertion of the C4ISR systems in the navy establishments. The role of the academia represented by the Center for National Security and Defense Research (CNSDR) in the Bulgarian Academy of Sciences (BAS) as a key element in Navy transformation is particularly emphasized.

Within the Framework of Reform Plan 2004, the Bulgarian Navy is close to finalizing its structural changes and downsizing process. The Navy may turn to be the first all-volunteers service. Experience gained from cooperation with NATO and NATO countries provides excellent opportunity to the Navy to lead in the integration process. There have already been steps for visible presence of Navy officers in the General Staff – the first deputy and then chief of J5, as well as the deputy of J3 are Navy officers. The Naval Academy is separate from the National Military University; it includes a department at the Defense and Staff College.

In addition to the process of integration in NATO and to the improvement of regional cooperation in the BLACKSEAFOR format, the Navy faces the challenge to improve and maintain close cooperation with border police, sea administration and many other governmental services, as well as with all maritime organizations.

New security risks, stemming from terrorism, proliferation and threat of weapons for mass destruction (WMD), organized crime and corruption, illegal drug, people and arms trafficking in the Black Sea area, demand attention. They pose the question of transforming the Navy as a second phase of the reform. Transformation is considered

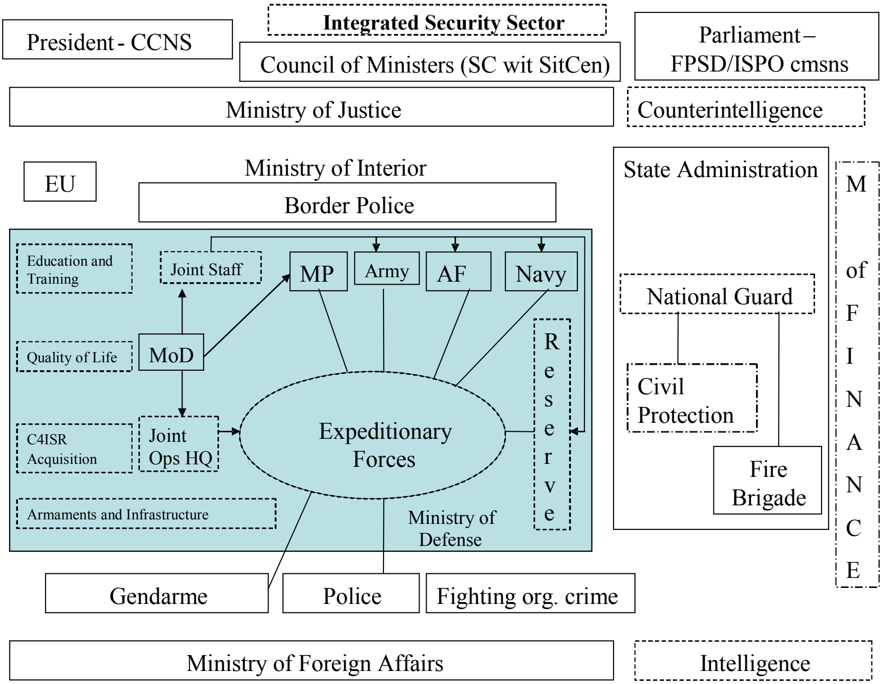

Figure 1: General Structure of an Integrated Security Sector in Bulgaria.

as a process of permanent and comprehensive (doctrines, organization, training, equipment, leadership, personnel, and infrastructure) changes, focused on building integrated capabilities for participation in an expanded spectrum of operations with particular stress on utilization of new technologies, which provide competitive advantages.

Transformation is primarily an institutional change that aims at building integrated processes, organizations and systems to address modern threats of integrated character.

Transformation is not a routine process.[1] For example, in order to implement it, the United States established JFCOM and the Office of Force Transformation in OSD. In Prague, NATO decided to establish Allied Command Transformation (ACT), which was opened in Norfolk in the summer of 2003.

At the same time Allied Command Operations (ACO), as well as various operations commands were established to strengthen the operations dimension of the Alliance – it is not more a static structure, but a dynamic organization coping with constant changes that performs operations all over the world with expeditionary type forces.[2]

Taking into consideration these developments in NATO, the fact that the Black Sea shore of Bulgaria will be an external border of the EU, as well as that the Black Sea itself is a key area of cooperation with the neighbors of the EU, will place great emphasis on Navy modernization as part of the integrated security sector of Bulgaria, of NATO, EU, and US in particular.[3]

Integrated Security Sector

Operations and the modernization of the Bulgarian Navy in particular can not be analyzed without assessing the role and place of the naval forces in the bigger picture of an integrated security sector (Figure 1), with well established coordination.[4]

Abbreviations used in Figure 1:

AF	Air Force
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CCNS	Consultative Council for National Security
EU	European Union
FPSD	Foreign Policy, Security and Defense (Committee)
ISPO	Internal Security and Public Order (Committee)
MoD	Ministry of Defense
MP	Military Police
SC	Security Council
SitCen	Situation Center

According to the tendencies of development of the force structure in the Ministry of Defense (MoD) with common elements for the whole security sector as shown in Figure 2, the Navy has close relations with practically all the players in the security area. Capabilities development has to be coordinated with other players and is deeply influenced by the NATO and EU integration processes.[5]

It has to be pointed out that the structure of the integrated security sector and the force structure in MoD are fundamentally vitalized through a C4ISR infrastructure, providing network-centric capabilities for network centric operations. It means that the key element in building such a security sector and Navy in particular trough processes of transformation is to build a network-centric C2 system as depicted in Figure 3.

Modernization Part of the Transformation Process

Activating such a force structure requires very serious modernization / acquisition of platforms and C4ISR systems in addition to other elements of the transformation process. The implementation of the modernization part requires profound analysis

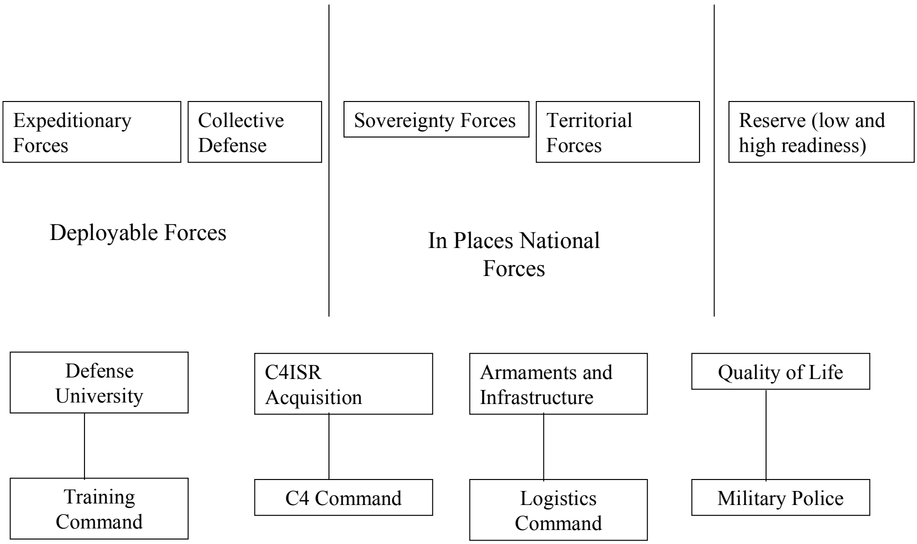

Figure 2: Force Structure in MoD with Common Elements for the Security Sector.

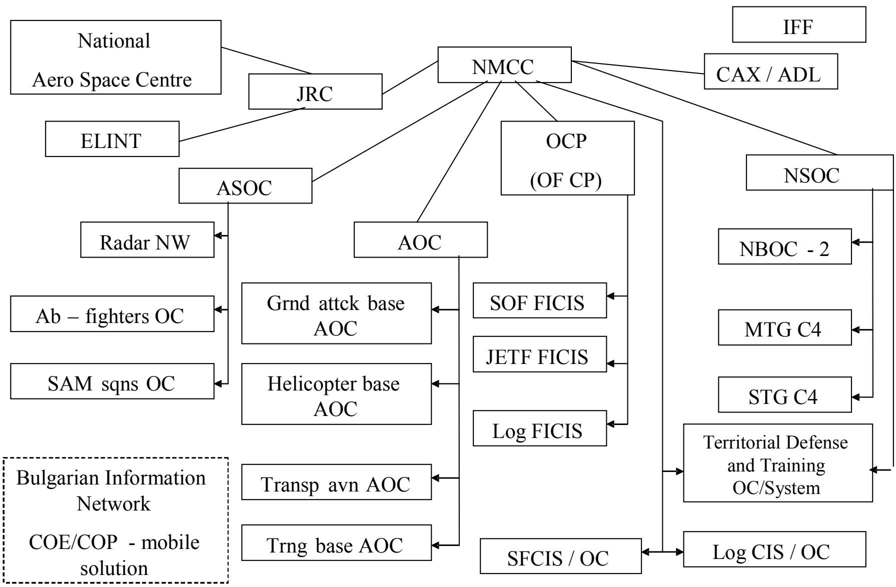

Figure 3: Target Network-Centric C2 System.

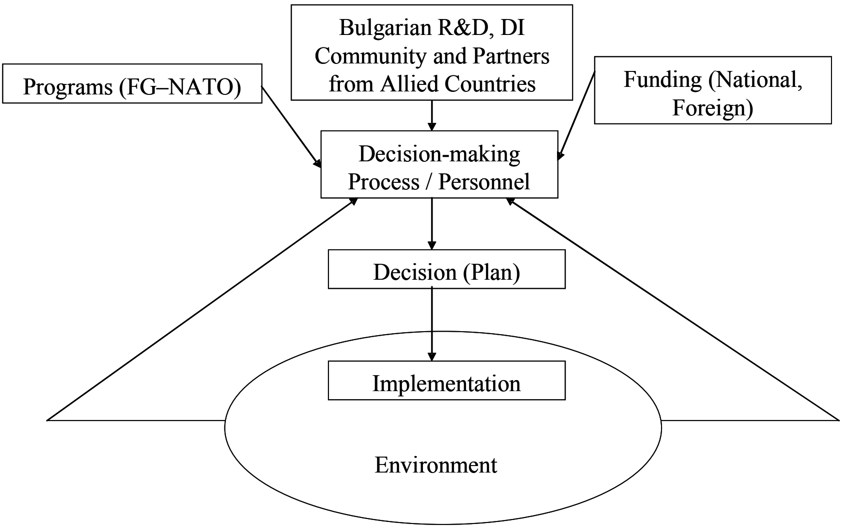

Figure 4: Analysis Scheme for Modernization Part of the Transformation Process.

and the establishment of comprehensive planning, programming, budgeting and acquisition processes.[6] An analysis scheme for the modernization part of the transformation process is proposed in Figure 4.

These efforts are supported by the Bulgarian R&D and defense industry (DI) community in cooperation with the relevant bodies from the allied countries.[7] In Bulgaria, practically, there is an established list of private DI companies such as: VMZ, Arsenal, Arcus, SAMEL-90, Armitech, Electron Progress, Cherno More, Bitova Electronika, Opticoelectron and others (related to the development of C4ISR systems).

State-owned arm of the community is represented by the Defense and Staff College and its Advanced Defense Research Institute and Interoperability Faculty, the *Bulgarian Academy of Sciences* with its *Center for National Security and Defense Research* (CNSDR), the *Space Research Institute* (SRI), the *Institute of Metal Sciences* (IMS), *TEREM SHC*, KINTEX and many others.

Funding is a critical factor and it could be divided into funding from national and foreign sources. National sources include: MoD's Investment Budget; MoD's R&D Budget; NATO Integration Program - MoD Share; Special "Mission Funds;" and Special "Mission Loans." Foreign funds come from FMF, IMET, EIPC, EDA and other related programs of the US, as well as similar programs from other countries.

Special “Mission related funds” for joint operations and training, NSIP and the other NATO programs as well as the EU–border control and Civil Protection funds could be added to the foreign funding opportunities.

The process of decision making and program management in MoD is a factor with very high importance for the overall success of the modernization process. Figure 5 represents the current structure of the decision making process, but there is a room for improvement.

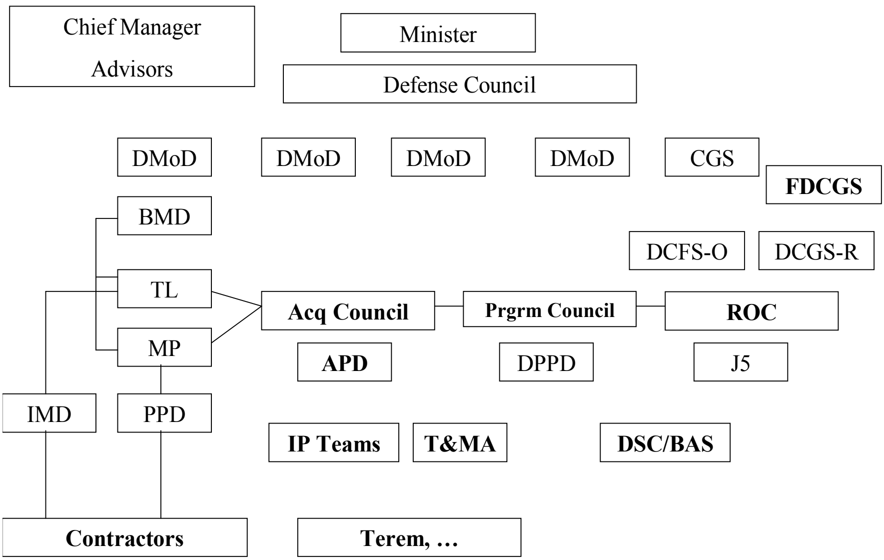

Figure 5: Decision-making at MoD.

The process of modernization has to generate a set of programs with the new focus of transformation – the network-centric warfare implications to integrate the existing elements into a new system through modern information networks. Analysis is required to provide interoperability and security in open coalition environment. In such a “coalition environment” the role of proxy servers is a key for providing integrated operational picture. Analysis of the target network C2 system compared to the current situation attempts to identify the missing elements and to start their acquisition (development, procurement).

Naturally, C4ISR projects are important, but only if there are platforms and weapons capable to engage precisely the targets. Currently there is a list of projects for Navy

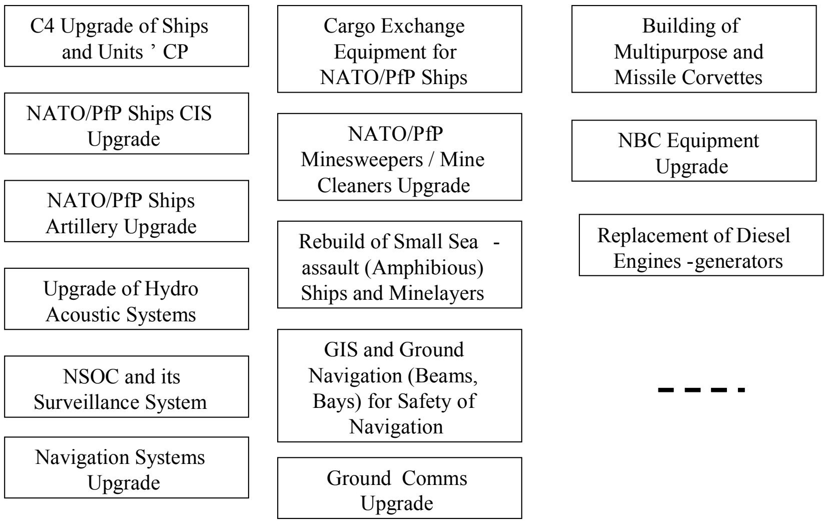

Figure 6: Navy Transformation through Modernization Programs.

modernization, represented in Figure 6, but the question is: are they really focused on the main stream of transformation.

For all important programs, and especially for the C4ISR ones, the spiral lifecycle approach using evolutionary prototyping is a key approach, particularly when the objective of transformation is to manage change and maintain deployability of forces for different operations.[8] Such a challenge requires intensive use of concept development and experimentation (CDE) approach with a set of advanced technology demonstrations (ATD). The main message to Bulgaria delivered from the experience of leading nations in transformation is: “Architecture approach, Standardization, Evolutionary prototyping.”

Central Transformation Instrument: Concept Development and Experimentation

Concept development is a critical creative process enabled by advanced research methods, typical for academic institutions. This process includes: assessment of the situation based on well developed framework of questions and development of the needed system architecture as a model. On the basis of this experimental parametric model (an empty model), a set of options has to be developed and carefully assessed with formal and often informal methods, with the intention to compare different options. Selection of the solution(s) for further assessment and improvement through experimentation is an expertise -based process with a need to integrate the assessment and choice of many different experts and to develop a selection matrix for the final solution.

The processes of transformation plan formulation and risk assessment are performed during all steps of concept development in order to check the achievability of the solution, how realistic and in what time frame it is. Such a process could lead to a really smart procurement.[9]

Experimentation with the concept is more oriented towards applied research as a whole, but recursively it could include CDE for some of the building blocks of the larger concept under experimentation. Selection (or development if not available) of the building blocks is, therefore, an important requirement for the experiment. Advanced technology demonstrations (ATD) could help in assessing and selecting the required elements for concept implementation. After the assessment of the elements, the challenge to face is the integration of the building blocks in the process of prototyping and testing of the whole system.

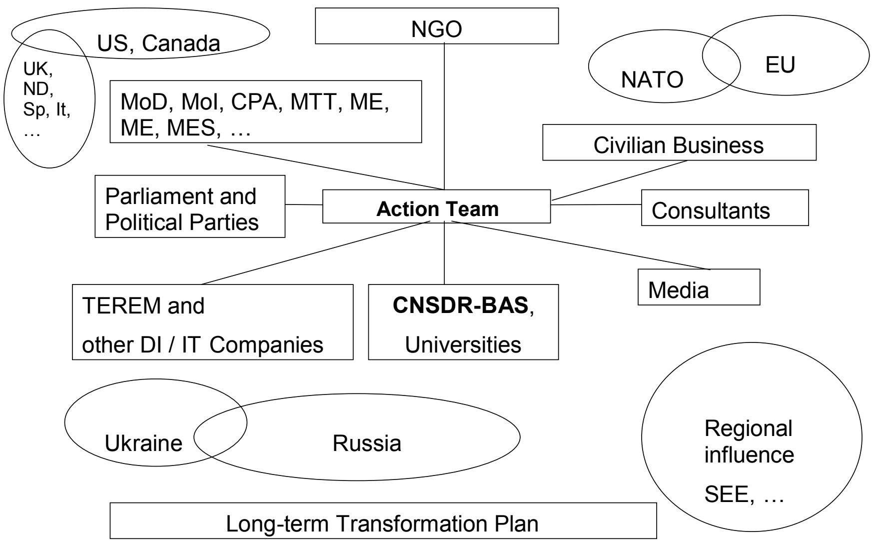

Figure 7: Environment for Implementation of Transformation: Network Centric Knowledge Based Approach / Strategy.

Advanced technology demonstrations are important area where the research community meets business people with real products; these products and solutions need to be improved and adapted to the operational and technical concept required by the transformation task.

ATD requires identification of the key building blocks and plan for basic or applied research in prototyping system elements. Testing, assessment, documentation and certification of the system elements are a long process before the final integration of the system.

The network-centric and the knowledge-based approaches, as well as a strategy for implementation of CDE/ATD in the process of Navy transformation are illustrated in Figure 7.

For every CDE project an action team is needed to integrate the capabilities and efforts of all other players. In the network, the other critical element (really connected with unique capabilities) is the academic world; in Figure 6 the role of the academia is played by the Center for National Security and Defense Research (CNSDR) in the Bulgarian Academy of Sciences (BAS).

Center for National Security and Defense Research as a Key Element in Navy Transformation

The Center for National Security and Defense Research was established in the Bulgarian Academy of Sciences with the principal objective to provide the necessary information, coordination and support to the BAS' units and individual scientists who take part in research activities in the area of national security and defense, in order to enable them to get deeply involved in the applied tasks faced by the Bulgarian Armed Forces, Ministry of Defense, the Ministry of Interior and other security and emergency management agencies in the processes of modernization and rearmament as part of transformation.

The organization and structure of the center and its environment prove the value of network and knowledge-based approaches. It is a typical enabler body as presented in Figure 8.

Functional areas, covered by CNSDR are:

- National security and defense strategies, security sector reform;
- Army, Air Force and Navy modernization;
- Civil Protection modernization;
- C4ISR infrastructure modernization;
- Logistics modernization;

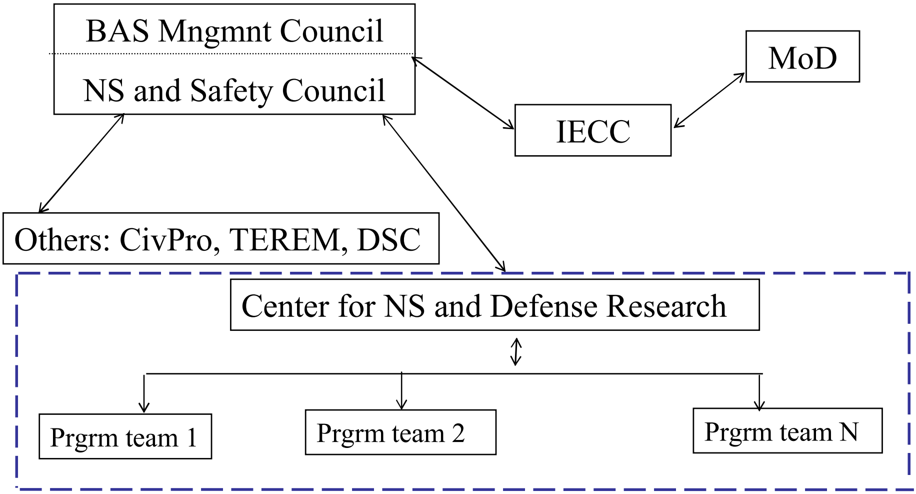

Figure 8: CNSDR Environment of Functioning as R&D Enabler in the Network of Bodies.

- Defense industry, R&D transformation;
- NATO and EU cooperation.

Forms of activity for the CNSDR are:

- Studies;
- Basic and applied research;
- Advanced technology demonstrations;
- Concept development and experimentation;
- Conferences, seminars, workshops and training courses;
- Consulting;
- Management services.

Principal projects of CNSDR currently are:

- White Paper on Defense;
- RAPIDS;
- Modernization Plan and PG/FG analysis;
- TEREM Transformation Plan;
- Civil Protection Early Warning System;
- HEMUS conference, CITMO conference.

Over 40 projects in specific areas ranging from information systems and C4 architecture development to specialized air reconnaissance modules have been developed since 2001.

International cooperation is one of the most important dimensions of CNSDR's activities. Main partners of the center are:

- NATO SC (Assistant Secretary General - Public Diplomacy);
- RTO;
- NC3A;
- TNO Defence Research;
- US ONR Global;
- USEUCOM Science Dimension;
- PfP Consortium … and in future ACT, Center for Technology and NS Policy in NDU.

CNSDR-BAS is established to solve the above-mentioned problems in cooperation with all involved institutions using a sound methodology and world class expert teams with deep national understanding of the problems. The upcoming HEMUS 2004 defense exhibition and conference in Plovdiv is an excellent opportunity to find good solutions for accepted force proposals from NATO and urgent requirements of deployed units through joint ATD, prepared by MoD-BAS-business teams.

Conclusions

For the Bulgarian Navy the year 2004 is crucial in transformation efforts. Currently AF has its MiG-29, ASOC, Pilatus and probably soon Mi-24/Mi-17 modernization projects; Army is moving forward with the different FICIS projects and upcoming Daimler Chrysler vehicles program; the Navy is waiting to receive its corvette and NSOC projects. There are many other smaller, but crucial for the force proposals and deployment objectives, which need serious R&D for CDE and ATD, performed by joint teams.

Progress in the field of modernization is very much dependent on the long-term vision, developed in cooperation with academic community and preparation of realistic, scalable and flexible to different contingencies programs as a tool for management of change.

Navy has additional difficulty, connected with the distance of the Navy HQ in Varna from MoD and GS in Sofia. On the other side, cooperation with CNSDR-BAS will give another Sofia-based pillar of Navy modernization process.

Initial steps could be supported through even larger team efforts, where in addition to Navy and their academic / business partners (as well as the NGO partner as is AFCEA – Varna chapter), other key players could be added – NATO, US and other allies.

Joint action plan for CDE and ATD financed through the R&D budget of Navy, as well as using FMF and other programs, could shape seriously the transformation process and on a very realistic basis.

Notes:

[1] Hans Binnendijk, ed., *Transforming America's Military* (Washington: NDU, Center for Technology and NS Policy, 2002).

[2] *NATO Response Force – NATO's Expeditionary Capability*, Briefing to the Ministerial Summit (Colorado Springs, CO, October 2003), available at <www.nato.int/docu/comm/2003/10-colorado/briefing02.pdf> (25 March 2004).

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VELIZAR SHALAMANOV is advisor to the President of the Bulgarian Academy of Sciences on security and defense issues and Chairman of "George C. Marshall"-Bulgaria. Being former Deputy Minister of Defense (defense policy and planning, November 1998 – July 2001), he serves as advisor to the Parliamentarian Committee on Foreign Policy, Defense and Security. Dr. Shalamanov holds the title of Associate Professor (Automated information processing systems) and has more than 150 publications in the areas of CIS architecture and development, information warfare, decision support, national and regional security policy, defense planning and reengineering. Dr. Shalamanov is member and co-founder of the AFCEA-Sofia Chapter and the Business Executives for National Security – Bulgaria. He serves on the International Advisory Board of DCAF. *E_mail:* Shalamanov@GCMarshall.bg.

NAVAL CRAFT, WEAPON AND SENSOR SYSTEMS

Fr. Lürssen Werft

Abstract: The article provides an inside view on trends in technology of current and future naval construction programmes as seen by Lürssen, the German shipyard for naval vessels located in Bremen, Germany. The changing operational requirements recognised in many western European and overseas navies focus on a surface combatant such as a corvette-sized ship with advanced capabilities to meet the specific demands for littoral warfare operations. Based on these new requirements the article outlines technologies in current and future designs for Corvette- and Frigate-sized ships. It includes different types of platforms together with their specific benefits and capabilities for the intended employment in littoral warfare. In addition, measures to reduce the ship's signatures for enhanced survivability are broadly discussed. With respect to adequate sea-keeping, manoeuvrability, speed and endurance (properties) in the littoral environment, the article also expands on the development and characteristics of new propulsion systems emphasising the overall need for a high degree of automation in all system components. The discussion on modern combat system technology once again underlines the need for a modular and flexible system design with open system architecture. The highest possible level of system automation reducing the number of personnel in the CIC and ensuring immediate reaction in a threat scenario is a further topic. Full integration of all sensors and weapons coupled with proven operational software is the essential technical requirement in this context. Finally, the article comments on some economical aspects of current building philosophies touching thereby on possibilities for crew reduction, costs reduction, potential capabilities for midlife refit, and growth potential.

The overall issue of "Transforming the Bulgarian Navy" is aimed at a permanent adaptation of Bulgarian Naval Forces to achieve high performance standards and combat effectiveness to meet the requirements of maritime warfare in the 21st century including those of interoperability and joint forces operations. This article on "Technologies for Advanced Naval Capabilities" has been developed from a leading modern shipyard's point of view, based on some essential convictions:

- A glance at trends of technologies in current and future naval construction programmes will show that evolution in modern shipbuilding has not come to an end and is continuing;

- Changing operational requirements for surface combatants due to the current global threat perception are demanding that these new technologies are integrated into combat ships of the future;
- The most important aspect driving future shipbuilding programmes worldwide will be the overall requirement for the vessels' littoral warfare capability and effectiveness to counter asymmetric attacks;
- Procurement programmes will increasingly be ruled by nations' restricted defence budgets.

Background of LÜRSSEN

Fr. Lürssen Werft (LÜRSSEN) in Bremen, Germany, has a remarkable record of success in building advanced and high quality innovative vessels for use in the German Navy and navies of the world. LÜRSSEN has gained a worldwide reputation particularly from construction programmes of fast attack craft (FAC), helicopter corvettes, fleet support ships and mine countermeasure (MCM) vessels.

LÜRSSEN's overall high-tech profile is marked by a number of "world's firsts" technical innovations, such as for example:

- The development of the semi-displacement hull, now forming the basis for all modern fast patrol boat (FPB) and FAC designs;
- Construction of the first helicopter corvette under 1000 tons with flight deck and hangar;
- Installation and integration of the first CIWS GOALKEEPER on a small corvette;
- Integration of the first Point Defence Missile System (PDMS), type RAM, on FPBs and other surface combatants;
- Development of the first fully operational remote controlled minesweeping system.

Over the last decades LÜRSSEN has increased the range of products even to tenders and fleet support vessels such as the German Navy ship BERLIN, of the class of more than 170 m length and 20,000 t displacement. LÜRSSEN is also fully involved in the production of the German frigate, type 124.

Currently, LÜRSSEN in partnership with two other German shipyards designs and builds the German Navy corvette, type 130 (see Figure 1).

New Operational Requirements for Future Naval Vessels

Today naval shipbuilding in Germany and in Europe is particularly challenged by new operational requirements of many regional nations bordering the sea. The need for rapid transformation of proven technologies and the development of more advanced technologies for new operational capabilities is driven by the magic term "Littoral Warfare Operations."

Historical Review

Until the end of the "Cold War" in the early nineties of the last century military planning, concept and operations were centred on national defence and on securing the area of NATO nations' interest and responsibility.

German Naval Forces were therefore at that time primarily tasked with homeland defence and safeguarding the coastal waters and transit routes in the Baltic and the North Sea. To achieve the overall objective of homeland defence and national security the German Fleet was mainly composed of smaller vessels such as Fast Patrol Boats (FPB), mine warfare vessels, tenders and submarines; all types being specifically designed for operations in the coastal waters. The destroyer/frigate components of the German Fleet, however, were assigned blue water tasks of escorting and protecting NATO convoys and Task Groups on their way from the Atlantic to national waters and ports.

Littoral Warfare – the New Area of Operation

In accordance with the development of the global political situation Germany is currently dealing with concepts and measures of a new defence strategy covering conflict prevention, crisis reaction and management as well as collective defence within a multi-national framework. Predominantly maritime forces will carry out these types of operations in the so called littoral sea areas, at long distances from own homeports and support bases.

Littoral areas comprise both the sea area from the open sea towards the coast and the strip of land ashore where own ground forces may have to operate, supported by naval assets. Operations in the littorals are by nature "Joint Operations," involving all three services (army, air, navy) under one common command. In most cases operations in the littorals will be carried out on a multi-national basis in multi-nation Task Groups or Task Force.

Advanced Capabilities for Future Naval Vessels

Future naval vessel designs intended to be employed in the littorals and in a multi-national formation require specific capabilities in order to cope with new specific tasks:

- Carry out tactical surveillance, reconnaissance and patrol in order to establish a picture of the tactical situation,
- Control of defined sea areas, transit routes and commercial shipping,
- Destroy, neutralise or deter hostile threats ashore in support of own ground forces,
- Destroy, neutralise or deter hostile surface forces afloat,
- Ensure self-protection and/or unit protection against air, subsurface and surface threats,
- Counter asymmetric (terrorist) attacks,
- Protect (cover) own forces' operations, for example own MCM operations or amphibious landing operations,
- Provide service support to and from own forces ashore.

With these naval capabilities, the operational requirements for operations in a high threat environment including conflict prevention, embargo control, crisis management and defence against terrorist attacks are ideally fulfilled by surface vessels of corvette-type ships.

Figure 1: German Corvette, Type 130, for Littoral Warfare.

Example of a Corvette for Littoral Operations

One example of a current corvette design specifically developed to meet the challenging requirements arising from littoral warfare is the German corvette, type 130.

Initially planned as replacement of German FPBs, the design was adapted to the new and wider scope of missions for littoral warfare. Due to its larger size, the corvette has a significantly longer endurance, an enhanced sea-keeping capability and increased sustainability. At an early stage of a crisis the corvette can relocate to the theatre of operation over long distance. With the K 130 the German Navy is able to operate—coming from the open sea—in coastal waters or close to the coastline either together with or in support to other navies. With its capability to engage targets ashore the corvette is particularly able to support own and allied ground forces operating ashore. This is possible by the land attack capability of the long range surface-to-surface missile installed on the vessel. Thus the K 130 corvette provides for sustained operations in littoral warfare with a high level of survivability. She is also capable of long range open and covert surveillance through the employment of naval drones and ensures sea-based engagements of surface targets at sea and ashore.

Technologies and Trends in Corvette Design

Platform, Design

Tasks and Size

Innovative corvette design is determined by the missions of the user navy and the required capabilities which have been drafted above as well as by the technical progress in naval engineering and related industries.

Technological progress of the naval industry may influence survivability, reliability, environmental protection and total cost. The total cost of a naval vessel comprises costs for production and lifecycle/maintenance cost.

The production costs of a vessel are directly influenced by the size and design of the vessel. The design, therefore, should be tailored to the specific needs and should not be larger than necessary. Varying tasks are accomplished by modular and exchangeable equipment. Thus a vessel for littoral warfare with a minimised crew of 60 to 80 people personnel may be as small as 70 to 100 metres.

With the 60 metres+ corvette class delivered to various navies, LÜRSSEN has proven that a powerful combat vessel does not need to be huge. An effective combination of missiles and guns together with a flight deck and a high performance combat management system can be integrated onto a ship of under 100 metres in length.

With respect to lifecycle cost, costs for personnel, maintenance, repair, and fuel accumulated over the life of the vessel, costs can easily exceed the procurement cost.

Figure 2: LÜRSSEN Corvette CM 65 – A Compact Vessel with High Combat Power.

Therefore the vessel's systems should be state-of-the-art equipment prepared for the future with low emissions, low maintenance requirements, a high level of automation and replaceability, and low consumption of consumables.

Future naval vessels can be operated with a crew reduced by 50% or more compared to the vessels of the late 20th century. This crew reduction is possible due to the high degree of automation, and the smart crew management that considers all the capabilities and skills of each individual crew member. As a result, the next generation of corvettes and frigate-sized vessels can be operated by a crew of 60 to 80 persons.

Hull Forms and Hull Lines

Nowadays the monohull is the standard hull form for naval vessels. Alternative hull forms which in recent times have been discussed and evaluated are:

- The SWATH (small waterplane area twin hull) concept,
- The trimaran,
- Types of catamarans,
- Types of air cushion vehicles (ACV), and
- The wave piercer mono-hull.

All these alternative hull forms provide certain advantages under specific operational conditions. In general, multi-hull vessels have the advantage of the very high initial stability resulting in small heel angles but high accelerations. However, they have a limit for seaworthiness which is determined by the distance of the individual hulls and the height of the transverse connections between these hulls.

A naval vessel designed for worldwide operation should not suffer such operational limits. Naval vessels have to survive under the most unfavourable sea conditions. Regarding modern Combat Direction Systems the ship motions as roll and pitch are less of a problem than high transverse accelerations. As a general approach the monohull, therefore, can be considered as the hull form of the past and of the future.

Figure 3: LÜRSSEN VSV 15 (design by Paragon Mann) – An Alternative Hull Form for Small Interceptor.

The hull lines are the source of resistance, engine power, fuel consumption and seakeeping. Nowadays optimisation of hull lines is done by means of computer fluid dynamics (CFD) in the computer long before the first tank test is performed. New developments for monohulls are:

- The parallel or even broadened aft body of the vessel compared to the slim yacht stern in the past,

- The slender bulbous bow for resistance and slamming reduction, and
- Flexible trim wedges or interceptors at the transom.

Wave piercing hull forms have proven to be successful for small interceptors, as for example in the LÜRSSEN built VSV 15 (Figure 3).

Wave piercer investigations for vessels of corvette and frigate size, however, revealed strong interference by green seas much more often washing over deck than with conventional bow shapes reducing the vessel's speed and causing big longitudinal accelerations.

Materials

Steel is the most often applied material for ocean going vessels including naval vessels. Steel is strong, elastic, homogenous, easy to work with and relatively cheap. However, some of the disadvantages are corrosion and heavy weight.

Corrosion can be controlled by either passive measures (zinc anodes) or active cathodic protection systems and, naturally, by careful coating. Non-corrosive materials used for shipbuilding comprise aluminium which is used for smaller patrol boats, reinforced plastics, either CRP (carbon fibre) or GRP (glass fibre) and austenitic steel. Austenitic steel, used for submarines and by LÜRSSEN for mine counter measure vessels, is a perfect material for any type of vessel. However, the price of the material dictates that it will be used only for special ships with requirements for non-magnetic characteristics.

The most common types of steel are shipbuilding steel grade GL-A (Germanischer Lloyd) and higher tensile steel GL-D 36. For the ships of corvette size such material allows for minimum scantlings and modular construction.

Steel is perfectly suited for the application of laser cutting and welding machines providing a high level of accuracy and quality. Steel sections and modules can be constructed at different locations based on the same CAD model and can be easily matched together. This is important since future naval projects more and more require the cooperation between different shipyards during design and production.

Modular Design

Future corvette components and equipment need to be modular and exchangeable. One example for modular mission is the container concept which is in use with the German Navy's support vessels type 404 (Elbe class) and type 702 (Berlin class, EGV), both constructed by LÜRSSEN. The containers house workshops, stores and even hospitals. In the future, dedicated standard containers may accommodate mine warfare equipment or unmanned aerial vehicles together with their launching catapult.

Also equipment installed on the vessel may need to be substituted by more modern equipment. Plug-and-play solutions as known from computer science are demanded in the future. They cover weapons, electronics, machinery and even accommodation in modular solutions.

Survivability of Future Naval Vessels

Survivability is based on protection and redundancy.

Protection includes stability, seaworthiness, armour protection and NBC (nuclear, biological, chemical) protection. Stability and seaworthiness are mainly influenced by the hull lines. Armour protection with modern composite structures using kevlar and ceramic tiles is a new technology, especially required in an asymmetric threat.

Splinter protection will protect all vital areas from small calibre ammunition and splintering. It can be planned for during design or can also be retrofitted on the vessel during service.

NBC protection today is a standard technology. Modern systems are based on a continuous overpressure maintained constantly. The ship is entered via double door air locks. NBC filters are integrated in the ventilation systems and provide air for each damage control (DC) zone individually. New technologies are applied to reduce the size and weight of equipment.

Redundancy is required as a backup solution since a failure of a system cannot be totally avoided and no system can be protected perfectly against all threats and all the time. This is of increased importance when accepting for naval vessels a reduced crew and hence damage control teams of a limited capacity. It is of a high importance then to identify vital equipment, which is to be provided at least twice on board at a maximum spacing in between. Vital and, consequently, redundant systems are:

- Propulsion trains,
- Rudders,
- Nuclear, biological, and chemical protection systems,
- Fire-fighting systems,
- Damage control systems, and
- Diesel generators and electrical switchboards.

Most of these systems are distributed over different DC zones. Depending on the ship's size there are two to four different zones independent of each other.

Until now only a few warship designs provide redundant propulsion and manoeuvring systems in different DC zones. In the future there will be a growing demand for the redundancy of the propulsion systems which can be satisfied by the fully electrical approach in combination with retractable thrusters or propulsors fitted at different locations to the hull.

Technologies for Future Propulsion Systems

Aim/Objectives

General

Modern surface combat craft with variable mission profile requires high capabilities and performance for the propulsion and power generating systems. Main topics are:

- Economic operation,
- Low emission,
- Low noise levels,
- High redundancy,
- Reduced signature,
- High degree of automation, and
- Design flexibility.

The prime movers of propulsion and power generating systems of today's combat craft are diesel engines or gas turbines driving either controllable or fixed pitch propellers or conventional water jets.

The potential for further improvement of the conventional propulsion and power generating systems is limited; however, components of the propulsion system give chances for improvement. For future systems specific equipment may be considered:

- Fuel cells (for power generation) and
- Pods (as propulsors).

All Electric Ship

The integration of these two components requires an All Electric Ship design which offers the advantage of a decentralised arrangement of both energy generating components as well as of propulsors.

The electric drive systems are more efficient than the conventional mechanical drive ones due to the eliminated need for reduction gears. In addition to supplying propulsion power to the vessel, the integrated power generating system manages and supplies power for all other systems, such as for example lighting, computer systems and combat systems.

Within the All Electric Ship the consideration of High Temperature Superconducting electric systems (HTS) technology for generators, motors and cabling may offer additional advantages in size, weight and efficiency of equipment.

Podded Drives

The All Electric Ship design permits a totally open ship in terms of arrangement, allowing even for podded propulsors.

The advantages of electrically driven pods, stated briefly, are:

- Excellent manoeuvrability,
- Low noise level,
- Excellent low speed capability, and
- Reduced installation time and costs.

In combination with fixed pitch propellers or water jets as main propulsors for high speed, podded drives are highly qualified as propulsors for cruising speeds.

Disadvantages of the podded drives are mainly the limited availability of propulsion power, the high weight and finally the high price up to now.

Fuel Cells

Now the fuel cell technology has not been developed to a degree that it can be integrated into a surface vessel as a continuous energy source for propulsion. However, for applications where cost, space, and weight are not decisive factors, fuel cells may be considered as energy source for restricted power generation offering a reduction of pollution emissions, noise, and vibrations. Also, a full independence from shore connections may be achieved.

Final Considerations for Future Propulsion Systems

The conventional propulsion and power generating systems are well proven and fulfil most of the requirements for a modern combat craft. The initial and through-life costs are reasonable. Therefore, these systems will also play an important role for future combat crafts.

The All Electric Ship with a distributed propulsion and power generating system may be an attractive solution for future combat craft from corvette to frigate size.

The main advantages of the All Electric Ship are:

- Operating flexibility, safety, reliability,
- Improved efficiency at low speeds and when manoeuvring,
- Increased manoeuvrability,
- Reduced maintenance, and

- Optimisation of ship's layout.

Signature Management

The first waves of "super stealth" ships named Sea Shadow (USA), YS 2000 (Sweden) and Sea Wraith (UK) ebbed away. These ships proved "how much stealth" was possible and the question what are these ships good for was raised.

Today and tomorrow stealth, which means signature management, will play a major part in all naval vessel designs but there should not be any restrictions in safety, manoeuvrability and of course in combat strength.

Figure 4: Turkish Navy Fast Attack Craft – Proven Stealth without Loss of Operational Performance.

Thus the designer is asked for new and innovative solutions. Such innovative solutions may be hidden and are visible only for radar, infrared seeker or sonar.

For surface vessels the most important signatures are the optical signature, radar signature, infra-red signature and acoustic signature. These signatures are detected by sensors of other vessels, aircraft, missiles and submarines. The reduction of these signatures shall

- Reduce the distance of possible detection with the aim to detect the other vessels/aircraft before they detect the own vessel,
- Confuse the enemy about the real size, shape, type and characteristic of the own vessel, and
- Support an effective engagement of decoy and chaff ammunition to divert missiles.

Modern seekers of guided missiles, however, have infrared sensors of such a high resolution that detection of the vessel may only be delayed. It is, however, not realistic that the reduction of signatures at any time will make the vessel “invisible.”

Radar Cross Section (RCS)

The radar signature is measured as radar cross section (RCS) in dB (m^2). Stealth shaping by flat inclined surfaces, tumblehome and avoidance of corner reflectors led to a remarkable reduction of RCS of present ship’s structure. Nowadays the RCS of the deck equipment is more intense than that of the ship herself. The reduction of the RCS contributed by equipment can be reduced by:

- Selection of stealth equipment: e.g., guns equipped with stealth shaped cupolas, railing stanchions made from rectangular sections, yards and other equipment made from radar transparent materials,
- Covering of deck equipment by bulwarks, radar reflecting metallic meshes, and radar reflecting covers,
- Installation of equipment below deck: e. g. use of vertical missile launchers,
- Coating/covering of equipment with radar absorbing materials (RAM) and paints,
- Removable equipment, removed under battle conditions, and
- Wires in window panes (radar reflecting).

Infrared Signature

The infrared signature is created by the heat sources of the vessel, in particular the engine exhausts, and by the effects of sun radiation. Reflection of the sun and solar heating are both significant signatures but each in a different frequency range. The sun effects may be suppressed by:

- Water sprinklers distributed all over the metallic surfaces to cool down the surfaces, and

- Special paints and coatings which diffuse the bright sunlight but which also do not heat up.

A good trade-off may be the use of the NBC sprinkler system for cooling down the metallic surfaces. More sophisticated IR reduction sprinkler systems are presently being developed.

A typical hot spot of any vessel is the funnel with the heat exhausts. Since decades it is for LÜRSSEN state-of-the-art technology to provide vessels with underwater exhausts, where the diesel exhaust/gas is merged with the water and becomes difficult to detect.

Figure 5: New 76 mm Gun with Stealth Cupola integrated by LÜRSSEN.

Acoustic Signature
A low acoustic signature protects the vessel from detection by submarines, torpedoes and mines. The key technologies used for years now are:

- Cavitation free propellers, highly skewed with controllable pitch and working with low revolutions,

- Double elastic main engine foundations, e.g. for MCMVs,
- Elastic mounting of all rotating machinery, and
- Noise capsules for diesel generator sets and other machinery.

New technologies are closely connected to advanced propulsion systems and new energy concepts as listed above. The All Electric Ship will allow for an installation of diesel generator sets where useful, the main engines are not connected to the propellers any longer. These diesel generator sets can be closed-in and elastically mounted.

Podded propeller systems work in an undisturbed wake since there are no shaft brackets. Therefore they run much quieter than propellers arranged conventionally on a horizontal shaft.

Fully submersed water jet units are expected to have a very low acoustic signature. It has to be proven in the future.

Combat Systems Technologies

CS Design Technology

Operational missions in littoral sea areas call for an optimised state-of-the-art combat

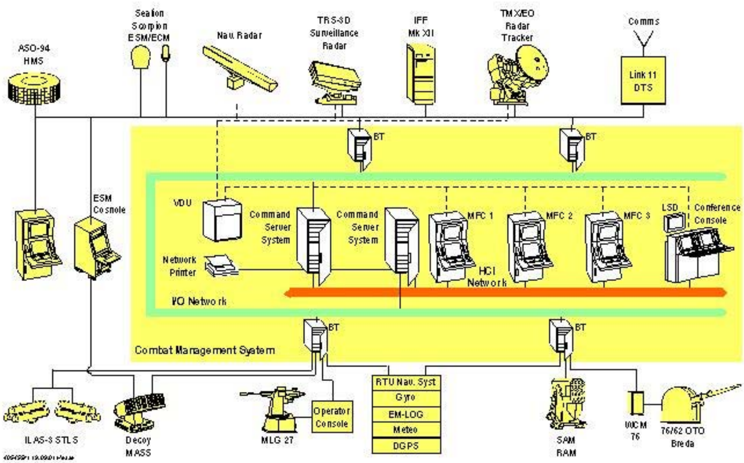

Figure 6: Advanced Combat System (CS) – Example.

system (CS) to be installed on the littoral warfare ships. This is an urgent requirement in order to ensure superior reaction times, to cope with the increased number of threats in the littoral environment, and to provide the required support to ground forces ashore.

A modern combat system consists of the CS infrastructure (consoles, displays, interface computers and system software) and the operational software derived from the navy's operational tactics and procedures. Advanced CS technology is characterised by a very high degree of automation.

State-of-the-art technology applied to modern combat systems comprises a modular and flexible design in a distributed multi-node open architecture configuration.

The weapons and sensors are controlled by the CS through a number of multi-function consoles (MFC). The CS automatically processes the data from external sources, i.e. tactical data link, and from own sensors; prepares and displays a situation map. The main threat, i.e. air and surface threat, is automatically calculated and indicated to the operator. In modern CS, sensors and weapons are linked to functional chains for automatic target engagements.

Figure 7: Example of Modern OPS Room Design

Operational tasks of OPS room personnel are executed via the MFCs which are serviced by a distributed multi-node processing over redundant computers, data bus including a video system. The MFCs allow for simultaneous display of tactical data as layover to sea and chart information of the respective (littoral) area of operations.

The modular open architecture of modern CS is composed of logically structured software clusters or modules such as the planning, the threat evaluation and weapon assignment (TEWA), control, training and simulation clusters (Figure 8).

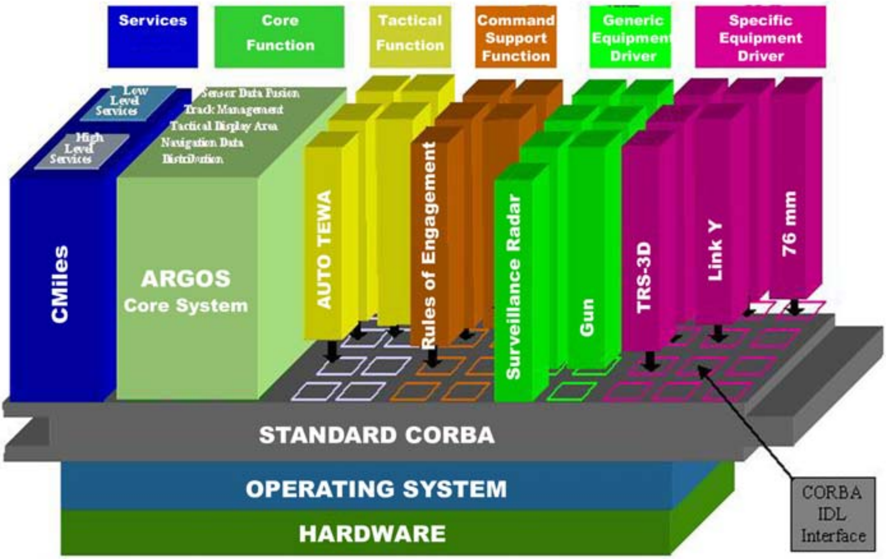

Figure 8: Advanced Combat System Architecture.

Sensors for Littoral Warfare

The complexity of the littoral environment results in challenging requirements for the performance of the sensor suite (Figure 9). The shoreline configuration with land masses and islands may well restrict the overall radar performance and generate inaccuracy of sensor measurements. Land clutter, numerous false targets, as well as masking of small targets in inshore waters will occur and have an impact on radar performance and the quality of the recognised maritime situation picture.

Underwater Surveillance and Defence

Naval operations in the demanding conditions of coastal and littoral sea areas may be

Onboard Sensor	Detection Range	Type of Information	Remarks
Surveillance Radar	15 – 25 km	Bearing, Elevation, Range	Multimode 3D Radar
IRST	9 – 16 km (subsonic) 14 – 27 km (supersonic)	Bearing, Elevation	In 3 – 5 µm and 8 – 12 µm band
ESM System	6 – 10 km	Bearing and seeker parameter	During seeker operation

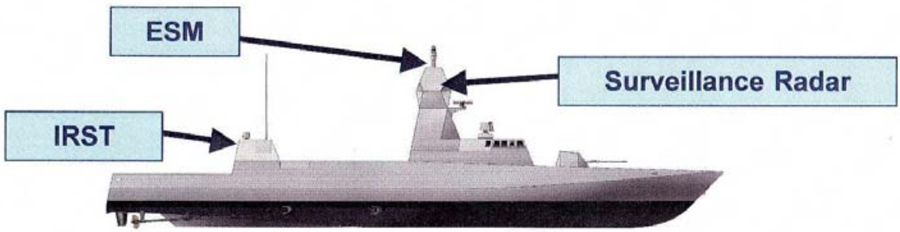

Figure 9: Primary Sensors for Littoral Warfare.

severely threatened or limited by different types of underwater threats which may come from either submarines or defensive sea mines.

In order to ensure survivability and sustainability of vessels employed in littoral warfare, due consideration needs to be given to an adequate underwater defence capability. Depending on the underwater threat of the respective sea area the vessel's underwater defence posture will be based on a multi-sensor sonar system providing the required underwater broad-spectrum surveillance capability, particularly for short detection ranges as typically required in the littoral region. The underwater defence system needs to include and preferably to integrate an effective mine countermeasures (MCM) capability with an anti-submarine/anti-torpedo capability to create a flexible defence system for underwater defence.

Demands for Information Superiority

Information superiority in the littorals is an important demand for command and control of forces in the littoral environment. Therefore advanced multi-function radars are an urgent requirement to cope with the specific drawbacks in the littoral operational environment. Active phased array radar systems may form the basis for an advanced surveillance sensor in the littoral environment. It provides important features such as rapid automatic detection, classification, tracking of small and fast moving targets including stealthy sea-skimming air and surface targets. Very low false alarm rates and accurate 3D detection with multi-path elimination at low elevation are further features. The radar's maximum detection range matches the vessel's maximum missile engagement range.

Information superiority requires an effective network of sensors and communications prepared for an adverse electromagnetic environment. In combination, an integrated and fully automated Electronic Warfare (EW) system with ESM for passive electronic surveillance and threat warning remains indispensable for enhanced survivability in littoral operations.

Unmanned Aerial Vehicles

Unmanned aerial vehicles (UAV) carried on board littoral warfare ships can be employed from corvette-type ships for long range surveillance, reconnaissance, and target identification in a dense environment. Sending targeting information for a long range surface-to-surface missile (SSM) system (third party targeting) can be carried out by UAV without endangering a flight crew of naval helicopters. There are several types of maritime UAV currently under development, which may become operational within a short time period. Due to the relatively small dimensions and weight of UAVs, these airborne drones are a serious and cost-effective solution for an advanced surveillance and intelligence gathering capability needed in littoral warfare vessels in the future.

Figure 10: Unmanned Aerial Vehicle (UAV) for Littoral Warfare.

Weapons for Littoral Warfare

The main wartime missions of littoral warfare ships are Anti-Surface Warfare (ASuW) and the support of operations ashore by Naval Fire Support (NFS). The weapon suite on board these vessels is therefore primarily focussed on achieving highest striking power against surface and shore targets at long range. In addition, the weapons on board must clearly ensure optimum self-defence in a multi-threat scenario.

Primary Long Range SSM System

The primary weapon on board littoral vessels is the long range SSM system which is capable of engaging targets at sea and ashore with a high precision effect. The adequate precision capability of these missiles is required to avoid collateral damage in the target area ashore. For this purpose the missile system is a multi-function system designed for surface target engagements and fitted with a shore target engagement capability ensuring optimum mission effect.

Due to the generally limited size and space on board littoral warfare vessels, the most preferred installation technology for the primary missile system is considered to be the containerised intra-deck (over two to three decks) installation. This method allows for the vertical launch (VL) missile firing mode and provides ample opportunity for enhanced stealth measures at the topside of the vessel.

Moreover, the containerised intra-deck installation method provides a good basis for future upgrades of the missile system for enhanced war-fighting capabilities. The missile containers may well be adapted and utilised for vertical launch of surface-to-air missiles (SAM) for medium range engagements of air targets in an air threat scenario.

Large Calibre Gun System

For a long range, high precision engagement capability against shore targets a large calibre gun mount capable of firing intelligent, target finding munitions with high mission effect may be an alternative fit.

Since littoral and shallow waters, however, prefer smaller platforms in the range around 100 m in length, the impact of a large calibre gun mount on weight, space, mobility and also stealth properties of the littoral warfare vessel needs careful consideration and comparison with the advantages of a vertical launch missile system. For larger ships, i.e. frigates, however, this could be a viable solution.

Weapons for ASuW Role

Seen from a generic point of view, a standard weapon configuration for the ASuW role will comprise the following components (see Figure 11):

- One long range SSM system as primary weapon with the following features:
    - Fitted with shore target engagement capability,
    - High precision mission effect ashore,

Role & Employment	Weapon System
ASuW	- 1 primary long range SSM with land attack capability - 1 medium calibre gun system - 2 light calibre guns - growth potential
AAW / ASMD	- 1 close-in weapon system (PDMS) alternatively - Combined PDMS and short range Surface-to-Air Missile system - 1 ECM System (Jammer) - Decoy Launchers for chaff / IR

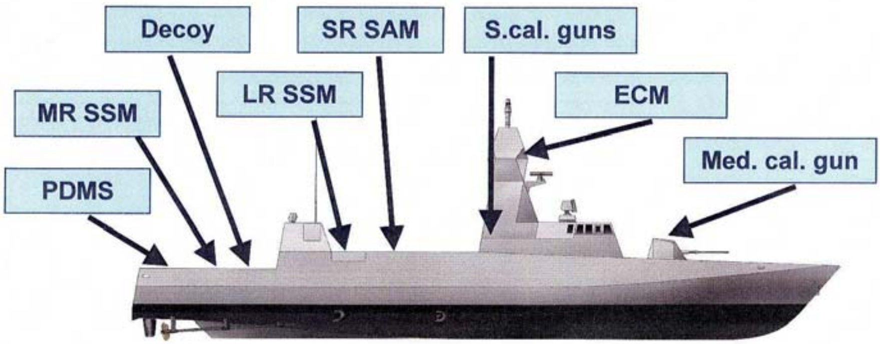

Figure 11: Weapon Suite for Littoral Operations.

- Vertical launch system (VLS),
- Containerised multi-function munition.

- One medium calibre gun system, especially for surface and shore target engagements at medium ranges. The gun is required for low-key missions such as crisis prevention, embargo control and policing operations. In an air threat scenario the gun will be used for air target engagement and for self-defence of the vessel. For future ship designs a stealth version of the gun mount is indispensable in order to contribute to the overall requirement for reduced radar signatures and low observability.
- Two or more small calibre guns, with automatic and manual control capability, exercised from the bridge, for immediate reactions and surface target en-

gagements in case of a sudden attack by high speed boats and/or other forms of asymmetric surface threats.

This weapon configuration covers the full range of possible littoral warfare missions within the ASuW spectrum.

Weapons for Anti-Air Warfare Role

In littoral warfare operations vessels are exposed to multiple threats from hostile land-, air- and sea-based weaponry. Survivability and mission sustainability are therefore of major importance. With respect to the Anti-Air Warfare (AAW) role of littoral ships the main objective is self-defence or more specific anti-ship missile defence (ASMD).

To ensure an adequate self-defence posture, hard and soft kill weapons are needed on board the littoral warfare vessel:

1. One point defence missile system (PDMS) to engage missiles and other air targets within the vessel's vital close-in zone of about 4 miles around the vessel. Mandatory is a launcher arrangement to ensure missile engagement coverage of a full 360° azimuth around the vessel.

   The PDMS must be fully integrated with the ship's combat management system (CMS) for rapid and automatic reaction. The target designation data is being provided by the ship's passive and active sensors. The missile of fire-and-forget type is guided by passive RF and IR features with the ability for day and night/all-weather operation.

2. Alternatively the PDMS as well as the medium range (MR) surface-to-air missile (SAM) system can be launched from a vertical launching system (VLS).

   Mandatory again is an installation arrangement with full 360° azimuth missile engagement coverage. The MR SAM system which is currently being developed and will be soon operational within the NATO naval weapon inventory enables the littoral warfare vessel to engage missiles and other air targets at an extended range of about twelve miles. The option "Combined PDMS/MR SAM" is logically dependent on the specific operational requirements for the respective vessel. The installation will have an impact on the length of the vessel.

3. The dual-role medium calibre gun mount, which is an essential weapon for the ASuW role as described above, is of course seen also as a valuable means to support the ship's AAW role, in particular for engagement of air

targets such as rotary aircraft and helicopters at a maximum effective range of about three miles.

Future trends and studies on the gun system concentrate on the development of new ammunition for the anti-ship missile role through the development of a sub-calibre guided projectile with canard control which is fully compatible with the existing loading and firing mechanisms of present gun mounts. The new guided ammunition is designed and intended to defeat sub- and sub-sonic missiles, sea-skimming and high diving air as well as any other fast manoeuvring target.

Integrated Communications

Prompt and efficient communication is essential for the sophisticated operational scenarios on modern warships. Today’s communications systems for ship-borne applications are designed in accordance with the roles they undertake in times of emergency and in the environment in which they operate. One of the major design objectives is to centralise the activities of integrated communications control and also provide easy access to the communication facilities from various locations.

An Integrated Communications System fulfils the technical requirements for tactical, administrative and safety communication link for a modern naval vessel. The system provides ship-ship, ship-shore, as well as ship-air communication facilities, i.e. military as well as civil communications in all applicable modes of operation. The modes of operation include voice communication (encrypted as well as decrypted), all required RATT modes and data communication, e.g. on LINK 11, LINK 14 and other LINK, according to the special tasks. The frequency range covered is from LF to UHF. The communication can also be laid out to supply voice and data line interfaces for dedicated military SHF-SATCOM equipment. For communication with submarines an underwater telephone may be advisable.

The external communication needs to comply with the international IMO/SOLAS (GMDSS) requirements.

The backbone of a modern integrated communications system is to include:

- Digital communications network,
- Communications management system,
- Secure automatic military messaging system,
- Multifunction integrated antennas, and
- Internal communications system.

Digital Communications Network

The digital communications network provides features such as digital audio processing, distributed topology, fibre-optical cables, redundancy and survivability.

Communications Management System

The overall communications management system includes a number of management terminals which are prepared for control of system and communication network equipment. By a gateway to the combat management system, all functions are partly or fully allocated to multifunction consoles of the CMS.

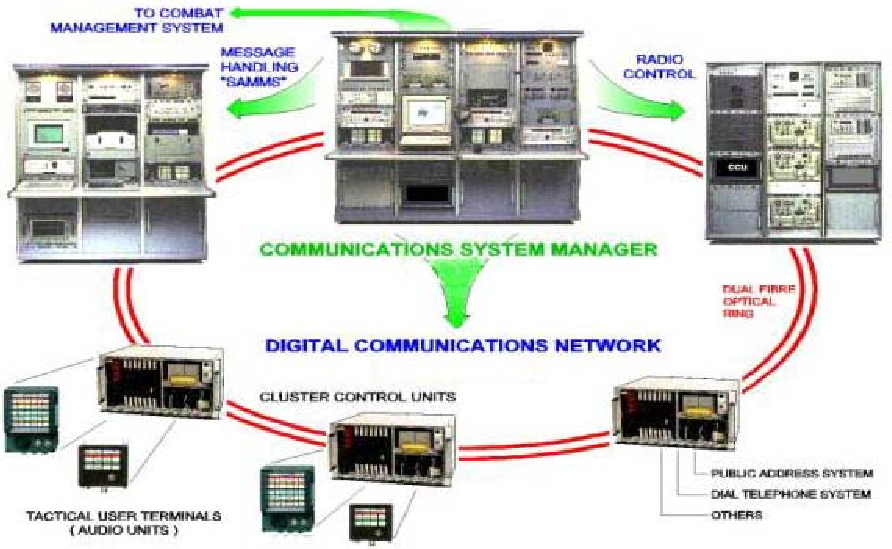

Figure 12: Communications System.

Secure Automatic Military Messaging System

The secure automatic military messaging system provides convenient, menu guided, ACP 127 message handling including automatic routing and distribution of messages.

Integrated Multifunction Antennas

Integrated multifunction antennas are vital components installed on modern warships of stealth technology. The antennas are integrated in the ship's structure or integrated in a multifunction mast module.

Internal Communications System
The internal communication consists of different subsystems according to the needs, which are installed at all relevant and redundant positions throughout the vessel. They cover:

- Tactical intercom,
- Public address and alarm system,
- Automatic telephone system,
- Sound-powered telephone system,
- Entertainment system, and
- CCTV.

Conclusion for Future Communications Systems
Advanced military Communications Systems have to be adaptive to the various mission/roles of the vessel. The increase of information exchange and the lowering of reaction time have to be supported by the Communications System. Ergonomic man-machine interfaces are self-evident requirements. Interoperability with other ship's subsystems is mandatory design objective for modern ship-borne Communications Systems.

Navigation System
The traditional skills of celestial observations, dead reckoning and harbour piloting, handed down through the centuries, are giving way to integrated computerised navigation systems and electronic charts, referred to as Integrated Bridge Systems (IBS). IBS will automatically collect, process and display ship's navigation and other sensor data in order to maximise bridge watch efficiency and navigational safety. In a modern IBS, data is gathered automatically from the vessel's navigation sensors, navigation radar and other devices. The data is fed directly into a computer, where it is instantly converted into a single integrated picture that shows the ship's position and movement in real time on a colour electronic chart display (ECDIS). IBS and ECDIS provide important tools to enhance the safety of the ship and improve situation awareness. Integrated Bridge Systems comprise the following major modules:

- Planning station,
- Navigation station with ECDIS,
- Conning display,
- Autopilot system and steering control,
- Navigation radar, and
- Navigational sensors,

which all are tied together by a Local Area Network (LAN), under control of a management software.

The navigation systems are grouped as a compact system in the integrated bridge according to modern, ergonomic design. Workstations in the bridge or in other locations anywhere in the vessel are networked to provide full functionality at any location. In the event of failure of any station, all other stations remain available for operation. In addition to navigational data, supplementary data from the ship's service and from the combat system are available to the watch-keeping officer on the IBS workstations.

Summary

Current warship design and construction worldwide are undergoing a period of considerable change calling for a wider spectrum of capabilities. Currently, littoral warfare operation is the dominating topic for future naval vessel designs.

Future littoral vessels need to operate across a scope of defence missions ranging from conflict (hot war) through collective, multi-national peacekeeping to defence diplomacy (crisis prevention and management) and to policing tasks, such as countering drugs and piracy. These modern vessels with advanced capabilities are considered to be an amalgam of innovative, highly integrated technologies which partly are and still have to be developed.

LÜRSSEN, the German shipyard for high quality surface vessels since 1875, has analysed and outlined essential features of current and future designs for corvettes and frigate-sized ships which are intended for employment in littoral warfare. Notwithstanding the constantly growing amount of budgetary constraints of most national procurement programmes, LÜRSSEN has in the past and continues for the future to provide viable approaches for advanced technologies to meet the challenging requirements of future littoral combat ships.

For further information please contact: defence@luerssen.de or www.luerssen.de.

ADVANCED NATO-COMPATIBLE SOLUTIONS FOR SURFACE VESSELS

Olivier BUSSIÈRE

Abstract: This article presents the expertise and know-how of ARMARIS in the field of combat systems for surface ships. It begins with an account of the excellence of the combat systems of the French naval forces—developed by the two leading French manufacturers, DCN and Thales, who have combined their activities within ARMARIS—and their total interoperability demonstrated in various operations. The author then provides a comprehensive definition of a combat system for surface ships, which meets all Navy requirements for future naval units. The article then states the principles on which the naval combat systems of ARMARIS are based. Based on these principles and on various other developments of DCN and Thales, ARMARIS proposes a design of a modern combat system that meets all challenging requirements.

Over the last ten years, NATO Joint Forces have been obliged to participate on a large scale in operations in the Balkans and in Afghanistan. The resources deployed for these operations included ground troops, air facilities and various other naval aviation units, which could only be put in operational use due to their interoperability. This capacity to interoperate has been revealed at various levels:

- At strategic level, (not a subject of this article), under the aegis of Inter-Allied Command, and in relation with the national authorities concerned;
- At the level of Operational Command, through the use of proven procedures, compatible and adapted communications systems, and above all, intensive preparation based on the training of all the echelons deployed;
- At tactical level, owing to adapted procedures supported by Tactical Data Links 11 and 16.

The French Naval Forces have participated actively in these operations whose success demonstrated the excellence of their combat systems, and in particular, their total interoperability with the other naval and joint forces of the NATO nations.

The surface ships of the French Naval Forces are equipped with combat systems de-

Figure 1: Operation in Afghanistan (CDG-US-UK-IT).

veloped by the two leading French manufacturers, DCN and Thales, who have combined their activities within ARMARIS, covering prime contractorship of surface ships and submarines, integration and development of combat systems and maritime surveillance systems. The extremely high-level performance and the reliability of the combat system of the *Charles de Gaulle* aircraft carrier, its full integration and interoperability with NATO's defence systems have proven DCN's comprehensive expertise in this field (Figure 1). The results obtained by the frigates in controlling maritime activities in the Straits of Hormuz and the Gulf of Oman also show the total interoperability of these systems and the superb competence of Thales in production of such systems.

Thus, it becomes obvious that combining these two poles of excellence in the field of naval combat systems will guarantee the efficient development of joint systems.

And that explains how ARMARIS has taken the leadership in the development of the Combat System for the Franco-Italian Horizon programme air-defence frigates, within the Eurosysnav Franco-Italian consortium.

A large number of the surface ships of other Navies are also equipped with combat

Figure 2: Saudi Arabian Frigate Equipped with Combat System Developed by ARMARIS.

systems developed by one of these two leading manufacturers: the Naval Forces of Saudi Arabia, Brazil, South Africa, to mention just a few.

DCN and Thales have also acquired vast experience in the field of Automatic Tactical Data Links (ATDL), more specifically Thales with its participation in the Command and Information Systems developed for the Army, Navy, Air Force, Joint Forces, Combined Forces, the corresponding communication networks, etc.

With such references, it is possible to achieve a joint definition of a combat system for surface ships, which meets all Navy requirements for future naval units to be commissioned before the end of this decade.

The Combat System Requirements of Naval Force Units

To fulfil their missions, naval units have at their disposal data compilation and processing systems and action facilities integrated in the Combat System. These missions include, among others, anti-air warfare, anti-submarine warfare, anti-surface warfare, special operations (smuggling, drug trafficking, piracy, illegal immigration, etc.), public service operations (on behalf of civil administrations), and Search and Rescue (SAR) operations.

Naval units operate alone or jointly with other units or forces. This leads to a strong requirement for exchange of all types of information:

- Between naval units operating jointly, mainly via Link 11;
- Between groups of naval units, via Command links;
- With a naval Command, at sea or ashore;
- With other surveillance or control facilities, for instance, maritime surveillance;
- With a High, National or Inter-Allied Command;
- With any other concerned administration, depending on the type of operations, etc.

The characteristics of the communications systems chosen to perform these exchanges will greatly depend on the type of exchange.

- Link 11 for exchange of tactical data enabling the establishment of a joint local tactical situation;
- Command link for transmission of operational orders, reports, sitreps, message handling, videoconferencing, etc.;
- Specialised links for exchange of the surface situation with the maritime surveillance systems, intelligence, SAR, etc.;
- All other dedicated links depending on the type of mission.

Principles Developed by ARMARIS

Based on the experience of its two members, DCN and Thales, the Naval Combat Systems of ARMARIS follow certain principles.

A surface ship Combat System (CS) is composed of several elements: *sensors*; *weapons* (or *effectors*); *communications*, *navigation* and *data processing* systems. Together they enable the accomplishment of its missions (*alone or within a naval force or a multi-task organisation*). All these resources are integrated in order to provide optimum operation.

(It has to be pointed out that not all sensors and effectors may be embarked; some of them may be remote, such as helicopters and drones).

Operators who *perform the functions of command, operation control and processing of tactical and command data* operate the Combat System at different levels. These operations could be *automated* to a different degree.

Combat System (CS) = Combat Management System (CMS) + Effectors (hard & soft kill weapons) + Sensors + Internal & External Communications Systems + Navigation System

The Combat Management System (CMS) or the information-processing kernel of the naval CS—in turn the centre of the warship—is the keystone of prime contractorship of combat vessels. It provides the optimal operator interface in all fields of warfare and at each operational level. It provides also facilities for management and processing, for distribution and display of data and operational orders. The Combat Management System can be subdivided into:

- A *Combat Direction System (CDS)* – dedicated to the control of tactical, real-time actions, including weapon deployment (Force Control); the CDS manages the current tactical situation;
- A *Combat Support System (CSS)* – dedicated to the control of pre-arranged non real-time actions (short, medium and long-term) and to the analysis, planning, preparation and programming of these actions (Force Coordination); the CSS manages the informed area situation.

CMS = Combat Direction System (CDS) + Combat Support System (CSS)

The CMS is the data processing system which compiles, formats and displays the information provided by own ship sensors or by tactical data transmission and ship or shore-based command networks, analyzes these data to set up a *single and common tactical situation* (identification, classification, threat evaluation), determines the appropriate effectors to deploy (planning), transmits orders to these effectors (weapon assignment) or, as required, to their own Command & Control systems (co-ordination at naval force level).

Generally speaking, the CMS is composed of networks, computation, recording and training facilities, equipment interface units, man-machine interfaces (display consoles, large screen displays, etc.) enabling the operators to configure the system, to control the evolution of the tactical situation and to authorise, if required, the deployment of the ship's weapon systems. Other subsystems are interfaced with the CMS, for example the Integrated Platform Management System (IPMS).

The interoperability of a naval force is therefore achieved at several levels:

- At the tactical level through Automatic Tactical Data Links which enable real-time data exchange between several CMS. Link 11 allows to set up a tactical situation common to all the connected ships;
- At Command level through Command links enabling exchange of non real-time data between several CSS.[1] It must be pointed out that there is no need the Commander of a naval force to have available all the real-time tactical data used for the immediate execution of an action; CSS is sufficient for him to ensure the Command functions for the naval units. The Commander of the force also maintains the relations with the Authorities, as he is integrated to the national and Inter-Allied C4ISR.

ARMARIS' Combat System Proposals

Based on the above-mentioned principles and on the developments implemented by DCN for SENIT and by Thales for the Tavitac systems—all combat proven—the *Basic Combat System* proposed by ARMARIS performs the basic functions of a multi-role ship, corvette or frigate:

- Data compilation and processing for the establishment and diffusion of the updated local air and surface situation;
- Deployment of the air-defence resources, with hard and soft weapon coordination;
- Control of anti-surface warfare operations;
- Participation in anti-submarine warfare.

This development also considers the latest principles imposed by Navies: crew reduction, consideration of cost-effectiveness studies, life cycle cost reduction, and environment control.

There are also some specific functions developed and added to the basic Combat System for more specialised ships, such as:

- Area air-defence by air-defence frigates;
- Above-water warfare by anti-submarine frigates;
- In-depth anti-shore fire support for strike frigates, etc.

As already defined, the ARMARIS' *Basic Combat System* is composed of a *Combat Direction System* (CDS) and a *Combat Support System* (CSS), the latter subject to specific development, which takes into consideration the specificities of the Command of the Navy concerned.

The *CDS* is organised around a high-rate local area network, COTS Ethernet or FDDI, to which are interfaced the sensors, the weapon systems, Automatic Tactical Data Links (ATDL), the processing resources, the display systems, the multifunction consoles, large-screen displays, etc.; they are based also on COTS equipment which considerably reduces integration risks, minimises development costs and guarantees the possibility and the quality of future upgrades. The CDS operates through real-time operational software that is with a data renewal rate of less than 500 milliseconds for all data. This software reuses a large number of modules already developed for other applications. These different standard active modules are developed using COTS equipment and are compatible with LINUX-type Operating Systems. The middleware providing the interface between the COTS processor and the applications is also standard equipment using CORBA type procedures. Existing applications, already developed and operational, are reused through the principle of encapsulation in a container and through the use of a standard interface with the basic services. This original method of operational software development was invented within the framework of tasks performed by DCN and Thales.

The *CSS* features an original organisation allowing the cohabitation of two worlds through adapted portals: the CDS real-time world and the world of the IP exchanges selected to ensure the operation of all Command resources, transmission of orders and reports, message handling, video conferencing, data base consultation, hot line, file transfer, and more. The data exchange is performed on the Combat System LAN to which the Web servers providing the required services are connected. The CDS tactical data and the data from the IP world (Intranet/Internet) are displayed for the operators on their multifunction operational consoles. This CSS organisation was jointly developed and validated. It is the basis for the development of SIC 21 Information and Command System and RIFAN "Réseau d'Information des Forces Aéro Navales" for the French Navy which will be integrated into all units in service and future units.[2]

The *sensors* and the *effectors* (or weapon systems) of the Combat System are chosen and proposed according to the needs expressed by the Navy:

- MRR NG type 3D surveillance radars or Herakles type multifunction radars depending on the main anti-air system, short- or very short-range air-defence (Shorad or Vshorad) missile system, PDMS, anti-air gun;
- Infrared Surveillance & Tracking Systems (IRST);
- Radar detectors (ELINT) and communications detectors (COMINT), and associated weapons, jammers, chaff launchers, etc.;

- Automatic Tactical Data Link (Link 11), Helo Data Link, (NB: Link 16 concerns more specifically the units involved in joint & combined air operations);
- Hull-mounted and/or towed sonar, and associated anti-submarine weapons;
- Surface-to-surface missile system (SSM) and/or anti-surface gun;
- Gun / missile Fire Support Systems for firing against a land-based target;
- Helicopter configured for its mission: anti-surface warfare with a surveillance radar (and anti-surface missiles, if required) or anti-submarine warfare with a dipping sonar (and anti-submarine torpedoes, if required);
- Navigation radar and a helicopter recovery radar, if required (considered as a remote sensor transmitting its track data via Helo Data Link);
- Interface with the Integrated Platform Management System (IPMS), etc.

Developed from COTS equipment, this basic Combat System is naturally fully open to evolution with regard to both hardware and software. It can integrate complementary applications. Therefore, it has a very high potential for growth.

Another component which influences the reliability and availability of units has to be mentioned: the Logistics Information System. Although it is not part of the CSS, it uses the same Intranet network as the ship and the Naval Forces. Thales has developed the OASIS system (On-board Ashore Support Information System) which performs the following functions:

- Support to preventive and corrective maintenance of all onboard equipment;
- Preparation of programmed actions;
- Hot line;
- Dynamic management of spare parts.

These principles were applied by the French Navy for the development of the SIGLE Logistics Information System currently deployed by Thales and DCN on all their units.

The Future

In addition to these developments—most of which are in progress for the French Navy and in co-operation with other Navies—ARMARIS, DCN and Thales prepare for the future.

The generalisation of COTS hardware and software has already been mentioned. These are to become the standards of tomorrow.

The integration of technologies derived from the Web is also a reality, as well as the

Figure 3: Horizon Destroyer.

control of their cohabitation with the real-time technology of Combat Direction Systems. Another future development is the realisation of co-operative engagement for which several programmes and initiatives are now in progress. To start with, a multi-platform situation establishment has been considered aiming at optimal use of all the engaged units' information sources, which are combined to create a multi-sensor virtual unit. This programme and those to follow will be developed in co-operation with other European Navies.

This cooperation guarantees that future equipment intended to perform these functions will be interoperable.

Conclusions

Combining the expertise of DCN and Thales, ARMARIS has acquired unrivalled know-how in the field of Combat Systems for surface ships. The systems in service are all combat-proven; they have met the challenging requirements of interoperability in all recent Joint/Combined operations in which European Navies have participated, in particular in Afghanistan, in the Balkans, and others. Interoperability requirements will increase and will have to be taken into consideration for all future programmes. ARMARIS has already done this for the programmes in which it is engaged – Horizon programme air-defence frigates, for example.

New information technologies also offer enormous possibilities and they are taken into account extensively in all new developments.

Finally, within the framework of prime contractorship for complete programmes, ARMARIS is supported by the vast experience of DCN in design, manufacture, setting-to-work and support of platforms of all types and dimensions. Consequently, joint integration and installation of the Combat System on board a ship is a guarantee of the quality and the optimal performance of the whole unit.

Notes

[1] These links support an information and communications system dedicated to the level of responsibility concerned, Navy, Air Force, Army, Combined, National, Joint, etc. For example, SIC 21, SIC F, SCOOA, SICA in France; ACCS, JMCIS for NATO. All information and communications systems ensure interoperability between the various Forces, Command and Operations Centres, Authorities and Administrations concerned, etc. Thales is developing the Internet Network for the French Navy (Réseau d'Information des Forces Aéro Navales – RIFAN).

[2] SIC 21, the French Navy's Information and Command System, is composed of two parts: (1) a Command Support System and (2) a tactical action support system. Each is composed of a generic part installed on all units and a specific part depending on the type of ship—multi-role frigate, air-defence frigate, aircraft carrier, submarine, mine counter measures vessel, etc.—and on the mission ordered. This information system is supported by an IP RIFAN network (Réseau d'informations des Forces aéronavales), also under development at Thales.

OLIVIER BUSSIÈRE is a senior consultant for Naval Systems & Programs. He spent 21 years in the French Navy performing various functions – two commands of naval units, gunnery & missile officer, Training officer in various French Naval Schools from 1962 to 1983. Then he joined Thomson-CSF as naval Project manager, marketing manager, and he has been in charge with several programmes in France and the Netherlands. He was appointed as Head of Marketing department of Thales Naval France from 1993 until May 2003. *E_mail:* o.bussiere@wanadoo.fr.

THE MULTI-ROLE NATO-INTEROPERABLE LIGHT WEIGHT TORPEDO FOR THE 21ST CENTURY

Claudio CECCARINI

Abstract: The growth of the hostile submarine ability to escape detection and destruction by anti-submarine forces is an increasing concern. The proliferating conventionally-powered (SSK) submarines are pushing the shift of the operational theatres toward naval operations in littoral and coastal areas, where the complex acoustic environment represents a highly opaque operating environment and it is acting as a natural discrimination factor for the serviceability of the existing and future Light Weight Torpedos (LWT) inventory. The operational emphasis toward littoral areas and the need of NATO-interoperable torpedoes capable to be deployed at any corner of the globe resulted in the need to optimise the existing inventory of ASW weapons nowadays for both the engagement of diesel/electric boats in coastal areas and the nuclear-powered ones in the blue waters. This has resulted in several recent torpedo development efforts that often run contrary to the originally adopted torpedo design. On the other hand, the MU90/IMPACT Advanced Multi-role Light Weight Torpedo has been envisaged from the beginning to cope with any-task and any-environment; it is the only NATO-interoperable ASW weapon designed to respond to the multi-threat operational needs of the future.

The Submarine Threat

The increase of the hostile submarine ability to escape detection and destruction by anti-submarine forces is an increasing concern. The proliferating conventionally-powered (SSK) submarines are pushing the shift of the operational theatres toward naval operations in littoral and coastal areas (green and brown waters). The latest technologies are offering to the vessels unprecedented stealth, endurance and command, control, communication and intelligence capability. The propulsion improvements that reduce the traditional drawback result in the ability to remain undetected for extended periods of time. Quieting and coating technologies render the submarines acoustically stealthy and high-strength steels are used to improve survivability. New computerised combat systems offer the greatest improvement in diesel submarine capabilities due to the integration of fire control, sonar and weapon systems functions. The effectiveness of the SSK is maximised in shallow water, littoral areas and especially in choke points in strategic waterways where diesel submarines can exploit the restricted waters at their great tactical advantage. All listed features combined with the proliferation of expendable anti-torpedo countermeasures result in an extremely hard life to its primary threat: *the Light Weight Torpedo (LWT)*.

Figure 1: MU90 Torpedo Mass Production.

The Torpedo Inventory

The complex acoustic environment of the shallow and coastal waters presents a highly opaque operating environment for infiltrating submarines and it is acting as a natural discrimination factor for the serviceability of the existing and future LWTs' inventory. Nowadays, the operational emphasis toward littoral areas resulted in the need to optimise the existing inventory of ASW weapons for both the engagement of diesel/electric boats in coastal areas and the nuclear-powered ones in the blue waters. This has triggered several torpedo development efforts that often run contrary to the originally adopted design. On the other hand, the *MU90/IMPACT* Advanced Multi-role Light Weight Torpedo has been conceived from the very beginning of the project to cope with *any-task* and *any-environment* capability requirement; and it is the only ASW weapon designed to respond to the multi-threat operational needs of the next decades.

MU90 Torpedo: Generalities

The NATO-interoperable MU90 torpedo—a joint development between WHITEHEAD ALENIA Sistemi Subacquei (Italy), DCN International (France) and THALES (France)—is the only “new torpedo” on the market today. As such, it features unique system characteristics which allow real operational capability in waters as shallow as 25 m and against any threat, including bottomed midget submarines. Presently, it is in a full-steam mass production phase (over 1000 units) for major NATO countries such as *France*, *Italy*, *Germany*, *Denmark*, *Poland* and *Australia* (see Figure 1). The first deliveries were already made in 2002. Designed and built with the most advanced technology, the MU90 permits undersea battle-space domination well into the 21st century.

Multi-role MU90 Torpedo: General Description

The MU90 ALW torpedo is a *multi-role* NATO-standard-calibre fire-and-forget weapon with weight of 304 Kg and length of 2850 mm, designed to counter *any type of nuclear or conventional submarine*, acoustically coated, deep and fast-evasive, deploying active or passive anti-torpedo effectors. The torpedo can be deployed by *any type of platform* such as surface vessels, fixed or rotary wing aircraft or missile (MILAS). *Hard-Kill* (anti-torpedo torpedo), *continental shelf mine* and *submarine launching capabilities* have been included during the torpedo design process. Pre-arrangements to cope with Submarine-launched Anti-air-missile (SLAAM) have been already incorporated in the system as the torpedo features unique deployment altitude (up to 900 m) and speed (up to 400 Kts from MPA), which combined with the stand-off long deployment range capability (well above 10 Km), grant the air-platform a realistic safety against such threat.

Main Anti-Torpedo Counter-Counter Measures
Stationary target detection capability
Spatial correlation and data fusion
Target classification through scoring
Frequency/time code emission pulses
Simultaneous Multi-frequency
Target size, speed, aspect computation
Target history and mapping
Simultaneous multi-type processing
Adapted sub-pulses endurance
Decoy classification
Anti-Jammer tactics

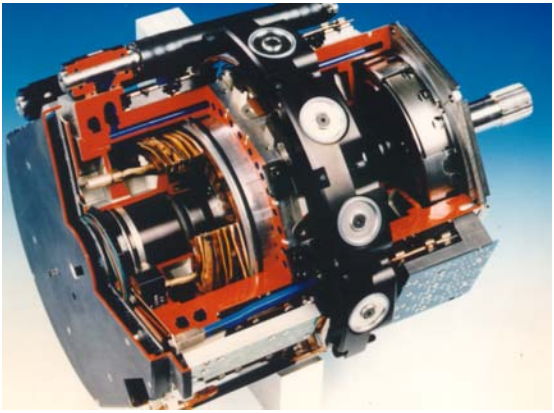

Figure 2: MU90 Motor.

MU90 Propulsion System

The weapon is powered through an Aluminium-Silver Oxide (AgO-Al) sea water battery using dissolved sodium-dioxide powder as electrolyte and incorporating an advanced closed-loop electrolyte re-circulation system. The hazard-free, pollution-free electrical power-plant of 120 KW (*) [1] does not only grant high speed and endurance but also high torpedo safety during transportation and carriage, reduced ILS infrastructure needs and no disposal costs. The replacement of the one-shot sea-water propulsion battery with a multi-firings rechargeable battery for exercise live trials further minimises the LCC of the weapon.

Figure 3: MU90 Pump-jet.

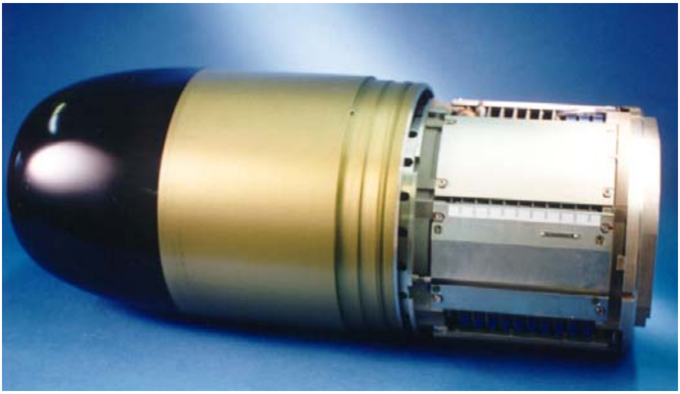

Figure 4: MU90 Acoustic Seeker.

Propelled by an innovative electronically controlled high-RPM brushless motor (see Figure 2) driving a skewed multi-blades pump-jet propulsor (see Figure 3), the torpedo features a linearly variable torpedo speed between 29 Kts and >50 Kts, automatically selected, in step of 1 Kts, by the tactics of the weapon according to the scenario, the environment and the operational phase. Speeds changes Min-to-Max and to opposite are achieved in less than 3 seconds.

Of extremely long endurance and range {>12,000 m (*) at max. speed and >25,000 m (*) at min. speed} the weapon operates without any speed degradation, without any limitation of salinity and temperature at depths >1000 m (*) and as shallow as 25 m, and retaining navigation capability up to 3 m.

The cavitation-free and very low-radiated noise achieved through the use of the most modern pump-jet technologies combined with an extended selection of torpedo preset parameters and proper tactics allow the weapon a silent approach to the target minimising the alert range of even sophisticated submarine detection systems and thereby increasing the overall killing probability of the weapon.

MU90 Homing System

The high-power, advanced acoustic seeker (shown in Figure 4) features 47 transmission and 33 reception pre-formed beams for a total acoustic coverage of 120°Hx70°V. It operates on six different frequency bands with an operational bandwidth well above 10 KHz (*). Its parallel processing and simultaneous acoustic mode operations allow the mapping of up to 10 simultaneous targets, active detection distance >2500 m (*), echo sounding navigation and high performance in very shallow waters providing the weapon with high immunity to the most advanced anti-torpedo countermeasures.

The torpedo homing system, matched with the high energy propulsion system, grants target engagement ranges >15,000 m (*) with an average killing probability >75 % (*).

The control and guidance electronics, of incomparable computation power and digital memories, accommodates the operational and tactical software including the signal processing, the data processing and the torpedo guidance laws allowing the weapon to continuously self-adapt its configuration and tactics according to the evolution of the operational situation and the threat.

The inertial system exploited for the torpedo control and guidance is based on 'strap-down' technology providing the weapon with an excellent manoeuvrability, all-altitudes capability including bottom following capability, low drift during approach phase to the target and high accuracy for the final impact on the target.

The fully-insensitive directed energy shaped charge warhead (see Figure 5) composed of V350 explosive, proven to penetrate double hulled large submarines, grants killing capability at any operational depth, including close-to-the-sea surface operational situations where the effectiveness of any blast-charge torpedo warhead is heavily jeopardised. The impact-type µ-processor-controlled exploder is of advanced design and exploits front-located sensors to trigger the explosive chain well before any premature mechanical deformation caused by the torpedo hit may compromise its functioning. It incorporates mechanical and electrical independent safety devices. The warhead fully meets any STANAG safety requirement.

Figure 5: MU90 Warhead Cut-way.

MU90 Exercise Version

The exercise section, interchangeable with the warhead section, allows live exercise evaluation, war stock surveillance and training firings. Composed of a pneumatic recovery system based on inflatable collar technology, it features high recovery reliability and easy localisation. The exercise head also incorporates redundant safety and localisation devices, underwater tracking capability, as well as a solid state memories data acquisition system, providing computer-based post-firing evaluation analysis capability. The length, weight and CoG of the Exercise round are strictly the same as those of the war-shot weapon, thus granting fully realistic live firings. The cost of live exercise firings is significantly reduced by the use of a Li-ion rechargeable battery and of a Practice Delivery Torpedo which allows a full training at a very low operating cost.

MU90 ILS

The all-in-one automatic torpedo test equipment TTU 102 allows an easy computer-driven preventive and corrective maintenance throughout the system shelf life. The modern approach to the MU90 ILS renders the 30-years Life Cycle Cost of the weapon significantly low with respect to all the existing torpedo systems and furthermore it minimises the need for significant infrastructures and human resources.

Figure 6: Shipborne Presetter.

MU90 Torpedo: Shipborne and Airborne Launching Systems

To exploit in full the MU90 Torpedo capabilities, ‘turn-Key’ *shipborne* and *airborne* torpedo presetting and launching systems (see Figure 6) have been developed and are presently or will be in short time in service onboard the following platforms:

- Shipborne: MAESTRALE FRIGATE, ARDIMENTOSO FRIGATE, GARIBALDI CARRIER, F124 FRIGATE, STANFLEX 300, F70 FRIGATES, ANZAC, FFG-7, F123 FRIGATE, HORIZON FRIGATES, FFG-7;
- Airborne: AUGUSTA, AUGUSTA/WESTLAND, EUROCOPTER, DASSAULT, MIL, NHI, EUROCOPTER, LOCKHEED, SIKORSKY, KAMAN.

Figure 7: Example of B515/2/F Torpedo Launching Tubes.

Based on advanced *Man Machine Interface* techniques meeting the modern requirements of automation and permitting consolidation of fire control and weapon systems functions, these computerized systems are built to fulfil turn-key *stand-alone*, *par-*

tially-integrated or *fully integrated* system requirements either for the MU90 or for combined weapons capability.

Last but not least, the innovative long-term production lines in France and in Italy, together with modern concepts of COTS components for electronics, double-sourcing of critical items and partnership with major subcontractors, have enabled to significantly reduce torpedo procurement cost, rendering the MU90 highly competitive in the worldwide market.

Notes:

[1] (*) denotes a classified figure.

CLAUDIO CECCARINI is born in Italy in 1953. He graduated as a Doctor in Electronic Engineering from the University of Pisa (Italy) in March 1979 and joined WHITEHEAD ALENIA (a FINMECCANICA Company) in the same year where he has been given tasks of increasing responsibility in the technical, commercial and management fields. In 1997, he entered the EUROTORP Consortium where he is presently Senior Marketing & Business Development Manager. *Address for correspondence:* 399, route des Cretes-“Les Boullides” B.P.113, 06902 SOPHIA ANTIPOLIS CEDEX, France; *Phone:* ++33 4 92 96 39 61; *Fax:* ++33 4 92 96 38 55; *E_mail:* c.ceccarini@eurotorp.com.

MINE HUNTING WITH DRONES

Philippe WAQUET

Abstract: This article deals with an important subject – mine hunting with drones. The author begins with a comprehensive overview, emphasizing the need for remotely controlled operations in mine warfare: mine reconnaissance, minesweeping, and mine neutralization. The advantages of semi-submersible vehicles and multibeam side-scan sonar technology are presented with a focus on the deployment flexibility with containerized units allowing an instant adaptation to any non-specialized vessel or shore facility. The article then presents in details the drone system architecture. Description and results of full scale operational evaluations conducted in 2001-2003 in Canada and in France demonstrate the excellent performance of a mine hunting drone system at sea.

Overview

The Need for Remotely Controlled Operations in Mine Warfare

Sea mines have proven to be a very deep concern for navies in the 20th Century, as stated by Admiral Forrest Sherman, U.S. Chief of Naval Operations (CNO) in 1950: "When you can't go where you want to, when you want to, you haven't got command of the sea." [1] The most recent war, Operation Iraqi Freedom in 2003, gives the last example of the strength and efficiency of this threat: "Although Iraq had little or no other means of striking out at the coalition shipping, these desultory attempts [2]—even the simple threat of the presence of mines—proved once again that the weapons are a powerful *deterrent*, managing to slow coalition progress and deny access to the coast, if only for a relatively short time." [3] To face this threat, the most promising approach allowed by today's technology is the use of remotely controlled platforms, which *reduce the risk to human lives*, as it is strongly recommended by Admiral Vernon Clark, U.S. Chief of Naval Operations (CNO): "We need to do everything we can to *de-couple* the hull of a ship from as many operational systems as we can." [4]

Remotely controlled unmanned vehicles, that we may call "drones" even if they are not flying but just sailing at the sea surface, bring a great deal of operational advantages to mine warfare, starting with the possibility to keep it "*organic*" into the blue water force. Rear Admiral Paul Ryan, former Commander of the US mine warfare force (COMINEWARCOM), explains the first goal of this approach: “Organic MCM modules will provide an initial capability to enable naval forces to determine the extent of a mine threat and ‘punch through’ if required.” [5] Furthermore, the inherent “*modularity*” of such systems opens a wide area of possibilities for a flexible operational organization: “The creation of a modular equipment which could be fitted on a wide number of *craft of opportunity* (COOP), (….and) can be pre-positioned or/and airlifted in-theatre for installation on locally available boats and crafts” [6] matches the demanding requirements of *fast deployment* in amphibious operations, as well as it introduces cost-effective answers to the growing needs of *homeland security*.

Mine countermeasure missions can be split between various drones performing specific tasks: detection, localization, neutralization, sweeping … This principle follows the rules of modern warfare: “The hallmark of a *network-centric* approach to warfare is that the act of sensing is separated from the act of attacking what the sensor revealed.” [7]

Advantages of Semi-Submersible Vehicles and Multi-Beam Side-Scan Sonar Technology

The considerable progress of technologies applied in unmanned underwater vehicles (UUV) during the past decade makes possible the achievement of all the mine hunting tasks: “It does not require much imagination to picture how an MCM UUV without a tether, with good endurance, range and autonomy, equipped with a proficient sensor suite and some form of mine disposal capability, could make an effective mine-detection, -localization, and, ultimately, a –neutralization platform – all with the human out of the minefield.” [8]

Among other alternatives for UUV, semi-submersible vehicles present the great advantage of a *proven technology*, thoroughly tested at sea in real conditions on mine fields, and superior to other concepts on several decisive points:

- An autonomous processing of sensor data and vehicle parameters under positive control through a radio link, allowing a *permanent check* of the mission progress, which is not possible with totally submerged vehicles,
- A *mobility* unmatched by AUV (autonomous underwater vehicle) with the high speed and endurance of diesel propulsion,
- A *seaworthiness* compatible with sonar stability requirements even in oceanic conditions, contrary to surface drones.

Side scan sonar has proven the highest performance in mine detection and classification since many years, with a sensor located near the sea bottom and unaffected by adverse environmental conditions.

Deployment Flexibility

A drone system can provide a mine hunting capability fully integrated into stand-alone containers. It combines equipment for remotely controlled operations including a vehicle towing multi-beam side-scan sonar, and a containerized command and control system allowing an instant adaptation to any non-specialized vessel or shore facility.

A drone system can perform mine reconnaissance: assessing and monitoring the extent of the sea mine threat in an area where naval operations or maritime activities are considered. The missions are controlled from a command and control container carried by a vessel or installed ashore and located at a safe distance from the operation area, up to 15 km. The vehicle is launched from a harbour and transits to the operation area by its own propulsion system, thanks to its high mobility and autonomy. A specific vessel is not necessary for handling the vehicle.

The system is designed to be operated and maintained by a small crew who is never exposed directly to the danger of mines. The command and control container can be installed in any location where a radio data link can be established with the vehicle. This location can be anywhere ashore or on board a ship having the required payload capacity. The large logistic autonomy of a drone unit allows a deployment far from the home base and without external technical support for long duration.

A typical mine hunting mission includes the following tasks:

- Preparing the vehicle on its cradle before the mission, and launching it by use of a standard crane from a quay or from a transport vessel. The vehicle can be launched and recovered in any harbour facility having the required water depth and crane capacity. This allows choosing a location as close as necessary to the operation area. The vehicle can alternatively be launched from any ship, military or civilian, having the required payload and crane capacity.
- Controlling the vehicle during its transit between the harbour or the transport vessel and the operation area. This control is performed remotely from a command and control container installed either ashore, or on the transport vessel, or on another vessel. The vehicle has its own capability of transiting by sea, with a speed, autonomy, and seaworthiness compatible with most encountered conditions for coastal navigation. The radio control for the safety of navigation during a transit requires only a small vessel.
- Controlling the mine hunting mission performed by the vehicle. This task includes the deployment, command and control of the tow fish carrying the side scan sonar. Sonar operations can be conducted at a speed up to 10 to

12 kts, which allows for a high area coverage rate, two to three times faster than with traditional means.

- After completion of the mine hunting mission, controlling the vehicle during its transit back to the harbour or to the transport vessel and recovery of the vehicle on its cradle.

During transit and operations, a surveillance of the traffic may be performed, if necessary, by a dedicated unit (e.g. police boat) to ensure the safety of navigation.

Except for the handling manoeuvres of launch and recovery of the vehicle, the crew is operating in the command and control container, which contains all the necessary equipment:

- One or two consoles for the management of the mine hunting task, operated at the level of the officer in charge of conducting the mission, and the command and control of the vehicle,
- One or two consoles for the operation of the side scan sonar: detection of "mine-like" echoes and classification.

An organization in two watches in order to perform a continuous operation on a full time basis (which is allowed by the large autonomy of the vehicle) requires a total crew of less than eight persons.

The hardware, including the vehicle with its sonar payload and the containers, is easily transportable by sea, air and road. ISO containers can be loaded with no delay on any transport system available.

During the delivery of each mine hunting drone system, the crew can be trained for operations and maintenance of the system, and with an appropriate Integrated Logistic Support (ILS) program the system can be operated and maintained by its crew without any further assistance from the Navy.

Other Missions

In addition to mine hunting missions, drones have a capability to perform mine-sweeping missions, when operational and environmental conditions require it.

The capabilities of a drone system apply to secondary missions that may be given by a Navy to make optimum use of the investment: hydrographical survey, search and rescue, and area and harbour surveillance.

Description of a Drone System

Open system architecture applies easily to "multi body" systems. It allows flexibility and future upgrade. A drone system is divided into three parts:

- The “wet” segment,
- The “dry” segment,
- The “communications” segment.

Wet Segment

The wet segment consists of the following equipment, which are all deployed under the water during normal operations:

- An autonomous vehicle (also called drone);
- A sonar tow fish, towed body which carries the sonar antenna, and is equipped with a large horizontal motorized wing and at the stern four motorized aft planes performing dynamic attitude correction;
- The side-scan sonar antenna which comprises acoustic arrays, power amplifiers, reception electronics, and command and control electronics;
- The cable which links the sonar tow fish to the vehicle for mechanical towing, power supply transmission, and data communication;
- An underwater positioning system composed of a deployable range of acoustic buoys allowing a very high precision tracking of the sonar tow fish.

Dry Segment

The dry segment consists of the following equipment, which are all integrated into a container installed on-board the support vessel:

- data link interface electronics,
- vehicle man machine interface,
- vehicle computer,
- sonar man-machine interface,
- sonar computer,
- Command & Control (C&C) man-machine interface,
- C&C computer.

The dry segment has a distributed hardware architecture which can interconnect, through a C&C network, consoles and computers with other Combat System equipment when the container is embarked on a combat vessel.

This architecture may be updated by adding new computing power consoles to take into account future upgrades, such as mine disposal or mine sweeping.

If necessary, gateways are used to exchange data with other systems.

Communications Segment

The communications segment provides radio data links between wet and dry segments.

- A low-rate bi-directional data link allows exchange of command and control orders and data (including, if applicable, Mine Avoidance Sonar) between the drone and the command and control container.
- Two high-rate mono-directional channels are necessary to allow video and sonar data to be transmitted from the vehicle to the command and control container.

Actual Performance of Mine Hunting Drones at Sea

As a typical example the recent achievement of a full scale evaluation at sea of the mine hunting drone "SeaKeeper" is described here.[9]

Context

Based on its experience in the design and production of several generations of MCM vessels, including the most successful "Tripartite" mine hunters, the French company DCN has developed SeaKeeper as an answer to face the challenging threat of modern mines. The considerable recent progress of communications and computer technologies were introduced by DCN engineers, skilled on the most advanced combat management systems such as the SENIT 8, into a remote mine hunting system.

The SeaKeeper vehicle is the well known "Dolphin" designed by International Submarine Engineering Research (ISER), Canada, with 12 units produced since 1982 for hydrography, and extensively tested by the US and Canadian navies for remote mine hunting. A full scale operational evaluation was conducted in 2001-2002 by the Canadian Department of National Defense / Defense Research and Development Canada (DND/DRDC), including tow-fish tracking and deep sonar trials (down to 200 m) giving a complete satisfaction to Canadian authorities.

SeaKeeper (previously named "FDS3") was presented for the first time in Brest in June 2003 in the complete configuration including the DCN "dry segment". It was transported to Brest naval base in two ISO containers, and embarked on board the 500-t Support Vessel "Armorique" of the French administration (Phares & Balises). The evaluation program conducted in June 2003 includes:

- Testing of a new sonar variant for DGA/DCE/GESMA and DND/DRDC,
- Evaluation by the French Navy,
- Presentations to foreign navies.

A field of dummy mines laid in an exercise area near Camaret-sur-mer allowed for a full scale demonstration of the system capability to detect and classify the most dangerous modern mines from a safe distance of several kilometres. Each demonstration included the deployment from the naval base, with the SeaKeeper sailing by its own means under the control of the support vessel.

This evaluation gave a good example of the easiness of deployment of mine hunting drones for an urgent operation in a remote area.

Demonstrations Objective

SeaKeeper is the latest solution available for sonar reconnaissance against the most modern mines. With a vehicle remotely controlled by radio, it offers the highest level of safety for the crew, together with an unmatched performance in terms of area coverage rate. The system, integrated by DCN, is raising interest in several navies over the world, and it became necessary to give a full scale demonstration in an actual theatre of MCM operations. Demonstrations were organized in June 2003 for this purpose, seizing the opportunity of an evaluation of the system in Brest for the French Navy.

The demonstration program included testing of a new sonar variant for DGA/DCE/GESMA and DND/DRDC, evaluation by the French Navy, and presentations to foreign navies. All the navies interested by this demonstration could not come to Brest, because of other activities, but more than 100 persons did attend.

In addition to the technical staff in charge of the evaluation, the French Navy sent several delegations from the Headquarters and from the forces, including a delegation led by Admiral Alain Dumontet, Flag Officer Naval Action Force (ALFAN).

Operation Area

The demonstrations took place in a mine hunter training area located near Camaret-sur-Mer, at a distance of 5 nautical miles from Brest naval base. With a bottom of sand and gravels and a profile of small ripples, at depths between 25 and 40 metres, this area offers mine hunting conditions quite typical of the continental shelf off Brittany.

The French Navy evaluation was made in the “Goulet”, a narrow channel leading to Brest road, with a harsh profile very demanding for MCM equipment.

In addition, some sonar scientific trials were performed in a specific pattern.

Environmental Conditions

Wind and sea conditions were fair, with less than SS3, which made things easier but was not representative of the possibilities of the equipment, already demonstrated by previous trials performed up to SS6.

Current conditions are relatively difficult for MCM in this area, with tidal current up to 5 knots in the “Goulet”, the maximum encountered during the demonstrations.

Organization and Schedule

Demonstration Team Organization

Sponsored by DCN, the demonstration was performed through a cooperation of several partners:

- The operations at sea were under the responsibility of GESMA, a research and trials centre of DGA (French MOD), specialized in mine countermeasures and having a level of expertise in mine-hunting techniques unique in the world. Operations were conducted under the supervision and control authority of the French Navy mine warfare specialists (ALFAN/MINES).
- The technical support was performed by DCN and its subcontractors, with the assistance of a Canadian team led by a delegation from the Defense Research & Development Canada (DRDC).

Shore Support

Due to the self-contained design of the system, the shore support was very limited:

- The 40’ container used for the transportation of the vehicle was also carrying the spares and tools necessary for the day-to-day maintenance of the system. This container was installed on the quay near the support vessel.
- Setting up the system, which came with the necessary cradles, required only basic handling facility (8-ton crane), as well as electric power and water.

Support Vessel

A support vessel was not necessary in itself for the inshore operation conducted, with the vehicle sailing within the range of control from the coast. However, it was worth demonstrating how the system can be deployed and operated from a ship.

The support vessel chosen for this role was the buoy tender “Armorique”, belonging to the French administration. With a light displacement of 500 tons, a length of 47.50 m and a wide deck equipped with a crane, it featured the perfect example of a craft of opportunity (COOP) capable of hosting a SeaKeeper system.

It took half a day to install the system on board, with the C&C shelter on starboard and the vehicle cradle beside it. Removable arrays were installed on the ship's mast for radio links.

Time Schedule

May 26, 2003:	Installation of SeaKeeper on board "Armorique"
May 27-28:	Mine laying in the exercise area and work-up trials
June 2 to 6:	Scientific trials and demonstration for the French Navy
June 11, 16 and 19:	Evaluation for the French Navy
June 12:	Demonstration for DGA (French MOD)
June 13:	Press demonstration
June 17-18:	Demonstration for foreign delegations
June 20:	Equipment pack-up.

Operation Scenario and Targets

As the home port of the French Strategic Submarines, Brest is one of the most important theatres of operations for MCM vessels. Therefore, the operational scenario chosen for the demonstration was a full scale operation of mine reconnaissance in an area of the Brest approaches where a hypothetical mining was suspected.

The SeaKeeper C&C shelter, stored permanently ashore, was embarked on board "Armorique" for a deployment. After the vehicle handling in the water in the harbour, both units, "Armorique" and the vehicle, left the quay and sailed out to sea.

During the transit, the SeaKeeper vehicle was maintained in line in front of the ship so that the officer of the watch could ensure its safety against incoming traffic. The transit speed, which could go up to 16 knots, was kept below 10 knots to satisfy the traffic regulations in the channel of Brest.

When arriving in the operation area, "Armorique" was kept apart from the dangerous area and the vehicle sonar tow-fish was deployed down to an altitude of 10 m above the seabed.

During the search, sonar operators were making a systematic recording of the position of any echo on the bottom. An analysis was made for each one on the basis of its dimensions and shape, so that all the bottom objects were recognised either as a non-mine bottom object-NOMBO (rocks, debris, etc.) or as a mine-like object (MLO).

Classification as MLO requires generally several observations from various orientations, in order to make sure of the shape in three dimensions. For this purpose the SeaKeeper tactical software generates automatically a "flower pattern" which is followed by the vehicle. It takes less than ten minutes to have, with this capability, a positive classification, which is faster than with traditional mine hunting techniques.

After completion of the sonar search of the area, the sonar tow fish was recovered and the SeaKeeper vehicle was guided back to the naval base.

Four mine shapes of the French Navy exercise inventory were laid in the exercise area:

- A cylindrical mine with a diameter of 0.53 m and a length of 2.5 m;
- A spherical mine with a diameter of 1 m;
- A Manta mine ;
- A Rockan mine.

In order to have a reference for the positioning performance of the SeaKeeper system, mine positions were measured precisely after mooring with the help of a diver carrying a GIB acoustic Beacon.

SeaKeeper Configuration

Vehicle

The SeaKeeper vehicle is a semi-submersible of the "Dolphin" family built by ISER. This prototype, belonging to DRDC under the name "Dorado," was thoroughly tested

Figure 1: SeaKeeper Semi Submersible Drone at Sea (Photo DCN).

during the Remote Minehunting System Technology Demonstrator (RMSTD) trials in 2001 and 2002. Tests were performed successfully including sonar and manoeuvrability trials with a towing depth down to 200 m, sea-keeping trials up to SS6 and endurance trials.

For the evaluation in Brest, the vehicle was equipped for the first time with a bathymetric multi-beam echo sounder RESON SEABAT 8125.

The bathymetric multi-beam echo sounder was used for measuring the bottom profile, which is quite difficult to follow in canyons such as the "Goulet", with slopes up to 20%. The bottom profile and 3-D bathymetry was displayed on two flat screens installed on the bridge of "Armorique" and used for programming the automatic towfish control. In the future, the multi-beam echo sounder software and display will be integrated into the C&C shelter.

C&C Shelter

The SeaKeeper C&C shelter (Figure 2), designed and integrated by DCN, was shown for the first time during these demonstrations. All the equipment necessary for controlling the system and conducting a mission is integrated in the shelter. In the configuration of the demonstrations, four consoles were used:

- Tactical console,
- Vehicle console (SCC),
- Two sonar consoles (SAC1 and SAC2).

The functions performed by the C&C shelter include:

- Management and display of the tactical situation, including sonar contact positions and an automatic computation of the search and analysis patterns to be followed by the vehicle;
- Control of the vehicle and tow fish, including a display of the vehicle mast head and keel cameras, and a display of the "Armorique" orientable camera following the vehicle;
- Sonar detection on a waterfall display in real time and on a page-by-page fix image display;
- Sonar classification on magnified images with a computer-aided device for measurement of echo and shadow dimensions, and a database of recorded images;
- Automatic calculation of positions using the GIB Aquatic software;
- CD-recording and printing of any data, including tactical maps, sonar images and reports.

Figure 2: Mine Hunting Drone Command and Control Shelter (Photo DCN).

GIB Precise Positioning System

The SeaKeeper positioning precision was measured during the demonstrations with a GIB (GPS Intelligent Buoys) system made by ACSA.

Results

Operational Availability

During 13 days of trials and demonstrations, the SeaKeeper achieved more than 100 hours of sonar operation, showing a remarkable reliability for a prototype. A few failures occurred, which did not impact on the overall trial program, thanks to the logistic support brought with the system.

Mine Search Performance

All the mines laid in the area were detected by the system with a classification as a mine-like object.

The automatic track following on search patterns and classification “flower” patterns demonstrated the manoeuvrability and flexibility of use of the system, with a short turning radius and a capability of fast reconfiguration of the vehicle tracks.

Positioning Precision

Measurement of the positioning error of each sonar contact on the targets gave a detailed knowledge of the performance of each of the subsystems used in SeaKeeper for MLO localization. The average positioning error on sonar contacts during the demonstrations was 2.5 meters.

System Efficiency

The system proved itself very fast and easy to deploy and operate:

- The average time for handling the vehicle in the water was 5 minutes.
- The average speed of transit was 9.5 knots, with a maximum of 16 knots and a speed limit of 5 knots in the naval base and 10 knots in the "Goulet."
- The average speed through water during sonar search was 10 knots, which allowed progressing even when facing a 5 knots current:
- This means a permanent availability of the system whatever the tidal conditions.
- It gave an area coverage rate three times faster than with traditional means.
- The use of a multi beam echo sounder on the SeaKeeper vehicle for piloting the tow-fish altitude on a harsh bottom profile proved very successful. 100% sonar coverage was achieved even in areas with slopes of 20%. Based on these results, it appears useful to adapt the SeaKeeper mission preparation software with the multi beam echo sounder information.

Conclusion

Mine hunting with drones is not anymore a future concept; it is a reality of today. A breakthrough in the endless fight of MCM against sea mines, it provides a cost-effective capability, available for any navy caring about safety for the crews during operations.

Notes:

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[1] Admiral Forrest Sherman, citation in "Warfare concepts," *Naval Forces* 3 (March 2003): 28.

[2] of mooring mines

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PHILIPPE WAQUET is MCM Systems Project Department Manager at DCN (Paris) since 1993. He has worked on several projects on unmanned naval systems since 1996. He served in the French Navy from 1972 to 1992. After serving as a clearance diver and a mine warfare officer on board several mine hunters and mine sweepers of the French Navy MCM force (1977-84), he was involved in new mine hunter projects as Deputy Vice-president of the French Navy Mine Warfare Studies centre (1984-86). He was Commanding officer of the tripartite mine hunter "Cassiopée" (1989-90), and Vice-president of the French Navy Diving and Underwater Studies centre (1990-92). He retired from the French Navy in 1992 with the rank of Commander. Mr. Waquet graduated with an Engineering Degree from the French Naval Academy (1972-75), and from the Naval War College, Paris (1987-89). He also holds an MBA from the San Francisco State University (1992-93).

THE C4I SYSTEM CONCEPT AND THE CONTROL OF NATIONAL SEA SPACES

Peter H. DERELIEV and Boyan K. MEDNIKAROV

Abstract: The paper analyzes an aspect of the modern control of national sea spaces and tries to characterize the ways and means it is achieved. The C4I system concept is examined as the only viable alternative for bringing efficiency into the system for control of the national sea spaces. The authors examine the major challenges faced during the development of naval C4I-systems and the experience gained by the Bulgarian maritime institutions.

The C4I system concept has found wide acceptance and application in many fields; however, its potential has not yet been fully realized in the control of national sea spaces (CNSS). This article aims at provoking interest in the problem of CNSS and the reason for its implementation in view of the fact that the concept of C4I system control is the only viable alternative for building a suitable system by means of which to protect national interests and to overcome the disagreement between maritime institutions.

The actuality of the topic is determined, on one hand, by the broadened contents of defense as a category in military art,[1,2,3] which includes the safety of maritime transport system, safety of navigation, safeguarding of human life, protection of marine environment, etc., and, on the other hand, by the necessity to conduct new type of operations in CNSS and navigational defense.[4,5,6] The analysis considers the trend for conversion of civil technologies to the military sphere, as well as for conversion of military art into a universal methodology for crisis management.

Characteristics of Modern Control at Sea

The development of the situation at sea globally and in the region is characterized by uncertainty and unpredictability. It is influenced by the factors shaping national security, which are deeply related to the dynamics of global processes. The economic factors have received priority due to the fact that these factors in conditions of severe competition, unregulated use of sea spaces and asymmetric threats stimulate the increase of risks, violations of legal norms and constant necessity of critical services at sea. They determine the modern CNSS, its subject and the forms and methods used.

The physical and geographical characteristics of the sea spaces of Bulgaria, the high likelihood they to become a zone of intense ship traffic and their geo-strategic location determine their vital importance for the realization of national interests and the counteraction to global threats. They have a complex structure, formed at the boundaries of three macro-spheres (physical, informational and moral) and from three elements (water, land and air). They have different dimensions: geo-strategic, military-strategic, geographical, economic, legal, informational, and ecological. The information dimensions deserve a particular interest since the defense of the national interests at sea, its utilization and especially the counteraction to asymmetric threats require permanent information support, and, in crisis situations – guaranteed information superiority. All this is related to the growing importance not only of the processes of collecting information, but also of those related to its dissemination, sharing and storage. Nowadays, the control of these processes should be organized and carried out above the water, under the water, in the air and in the so-called "information space". In this conditional space all types of control are integrated into a complex functional system and they take on a new dimension.[7]

CNSS is a combination of adequate to the situation initiatives and activities, coordinated and interrelated according to aims, time, tasks, and place, carried out according to a cohesive plan of the state leadership through a specially designed system for defense of maritime interests of the country and counteraction to the threats at sea. The control is based on the operations of the authorized institutions and the provision of information related to them (providing, collecting, analyzing, and disseminating information about the situation and all the appropriate activities). The emphasis is placed on control at sea in times of crises, which is technologically and organizationally regulated in the underlying maritime conventions. The strength of CNSS is not in registering events and phenomena, but in reacting fast with the most suitable measures, e.g. in carrying out effective operations.

CNSS is a new kind of defensive function of the state, which requires a high level of integration of the maritime institutions, as well as their good preparation and faultless support. Generally, it can be realized through: active defense of the maritime transport system, assistance to navigation, protection of maritime environment and sea resources, prohibition to use the sea against the international agreements, and opposition to violation of national interests.

It ensures the defense of state's sovereignty and, if necessary, the defense of its coast. All these large-scale tasks can be accomplished only within the framework of a special operational concept, provided by a modern information system. Such a system enables us to have a complete control of CNSS without the constant presence of specialized personnel and means in them.

CNSS provides the linkage between the tasks in time of war and those in peacetime of the Navy; it manifests the preparedness of the state to fight global threats and to defend its interest in time of peace, and in time of crisis – to counteract expansion.

The characteristic features of CNSS are: universality, aerospace support, integrity between institutions, information-electronic character, military organization, defensive purpose, and wide openness for international cooperation. Nowadays, emphasis is put on its information-electronic character, e.g. its main activities aim at providing, analyzing, distributing, disseminating, and storing information, which is done primarily electronically. Control—considered as a part of the management process or as a system of operations—is based on radio-electronic and optic-electronic surveillance, exchange of information and constant coordination of the multilateral activities in CNSS. Therefore, it is very important that the information is reliable and presented in real time. Generally, CNSS can be defined as universal, with vast spectrum of applications in time, space, extent, and methods.

The implementation of the new defense concept requires very good coordination among the different CNSS institutions. Despite their specific characteristics these institutions have much in common – techniques, strategies and procedures; command and control; cooperation; provision and training of the interrelation-aiding forces. In fact, exactly here is the focus of all the difficulties in maritime reform, which includes not only alteration of the property ownership or establishment of new economic relations, but mainly efficient coordination in the sea industry and a new type of civil-naval relations.

At present, CNSS encompasses parallel and duplicated structures with different institutional subordination. Their uncoordinated actions result in an increase of potential efficiency lost. Therefore, the control must be the responsibility of one body. The adopted model in Bulgaria is dominated by the Navy, and is identical to that adopted in Europe.

Worldwide, similar control bodies are established in accordance with the principles of military art and are analogues to combat systems. Nowadays, there are two interrelated tendencies in the development of CNSS, national and international; the latter dominating the former. Priority is given to the joint efforts of the Black sea countries; efforts based on adopted norms and principles of international law and the necessity for a scientific, technological and technical cooperation. Different projects for regional cooperation specify as a priority the development of information network based on C4I systems. This approach is also applied to security, which features unusual trends in the functions of national Navies. These ideas have been realized in the establishment of the Black Sea Pollution Prevention Board and the Black Sea Military Cooperation Task Group – BLACKSEAFOR.[8] Both structures include C4I-infrastructure features and apply the model of military operational planning.

Application of the C4I System Concept to Sea Control

For the requirements of CNSS, autonomous C4I systems are established in the maritime institutions at all control levels. They provide system integration of the different components and reduce the conflicts between them arising from different organizational structures and subordination. The C4I systems provide the integration of the existing communication means, the databases, etc., of the institutions. Applied in the maritime field, these systems increase the efficiency of supervision, monitoring, and inspections and provide a record of the violations needed to impose sanctions.

The development of the C4I systems began with the first Vessel Traffic Services (VTS) prototypes in late forties. For only half a century they advanced from simple shore radar systems to sophisticated communication systems ensuring safety of navigation. The number of these systems has doubled in the last 15 years accounting to more than 500 VTS nowadays, differing in range and application. This development has resulted from the increase of cargo turnover in ports and shipping, as well as from the risk of collision and ecological disasters at sea.

During the 60s and 80s, the then-existing navigational aids did not provide efficient and accurate navigation. That forced the specialists to focus on VTS capable of aiding ship navigation. The advanced technical aids to navigation highlight the VTS' importance for the shipping and for the navigation rules and control. Nowadays, the VTS cover the whole European coast, except the Black sea coast. The development of the C4I systems, as one of the most important elements of shipping, is based on national and European projects.

The development of the Bulgarian C4I systems started in the mid-eighties. The MoD developed the "Obhvat" system, while the Navy and the Inspectorate of Shipping developed jointly the shore-based automated "Ekran" system. NMB shipping company had their own project "Emona." Due to various factors these projects were not completed, which influenced negatively the sea control and coordination.

After the changes, the C4I system concepts have been oriented mainly towards a specific object of CNSS, sea transport, without taking into account some of their important military-defensive aspects. Despite the limited funding, the Naval Forces continued their work and in 1995 the "Obhvat-4" was experimented. At that time special attention was paid to the sensors and to the organization of information flows. There is still no uniform concept for operational use of such a system but the ideas of applying high technologies go beyond information provision and the prototype has already become a combat means. This is the first step of the Naval Forces into the information era where weapons automation and the transfer of their control to such systems is a significant move in the functional-technical integration, marking the intellectualization of military activities.[9]

A Bulgarian-Dutch program for developing the organizational and technical structure of a vessel control service started in the second half of 1999. To start with, IAMA developed a fragment of a VTS system providing the safety of coastal navigation in the Bay of Varna. At the moment IAMA is building a uniform automated information and communications system for situation assessment, sea traffic control, SAR, operations planning, cooperation in rescuing ships, etc., capable of reacting in real time. It has a huge potential for information support of the Naval Forces, the Border Police National Service, the Customs Agency, the pilot services, and other users of national sea spaces. Priority has been given to providing the safety of navigation, improving the organization of work and enhancing the ports' competitiveness and the passage capability of the approach waterways at the expense of reduced risk. The development of the concepts of VTS systems can be seen in Table 1.

It is worth mentioning of the experience of the sea section of the Border Police National Service in the end of 2002 when a cutter was included in the sea C4I-system using "Transas" equipment.

In the recent years, with the development of the doctrinal concepts for use of the Naval Forces [10] and especially with the development of the theory "operations of providing the sea sovereignty" (a variation of the seamen's term "naval control and protection of navigation"), the views [11,12,13] on the application of the C4I system concept in the Naval Forces have been broadened and aimed mainly towards their organization and conduct. Their operational architecture contains in its kernel a provisional "primary" CNSS operation,[14] which is a functional system of concrete techniques, tactics and procedures based on various international documents. Until now, in the realization of the concept, this very elementary operation has been underestimated, which is a retreat in principle from the system approach. The system analysis technology requires one to start with a description of missions at tactical, operational and strategic level of all elements of such a system, investigation of their functional relations, the volume and character of the information flows and after that to look for their technical solution.

The implementation of the C4I System Concept is connected with overcoming some disparities, which come along the reform in maritime business and the national institutions. The main disagreement is related to: the differences in regimes depending on whether the country functions in time of peace, crisis or war; different maritime institutional and national organizations, "aviation" and "maritime" approaches to sea traffic control; the theory to be ascertained and the practice which precedes it in the field of sea control; the difference in the sea control authorities' methods, resulting from the lack of common tactical doctrines; the legislative nature and the military way of conducting most operations connected with CNSS.

The disagreements become especially clear in the forces' control and command system, in their information support and the applied methods of control. They are reflected in the training of Bulgarian seafarers, which is apparent from the recent state of maritime education, forcefully framed by the educational reform without considering the fact that it is subjected to different logic and generally accepted international criteria.

The practical application of the C4I System Concept provides solution of the above-mentioned challenges and settles the complicated relationships within CNSS. In this context, the efforts should be aimed at: unifying both the control theory and the methods, operations and procedures applied in different institutions, ascertaining normatively the C4I systems by a state standard; creating integrated information environment for all subjected to control and uniting functionally the data-gathering units with the maneuvering forces; redefining of the main elements in the theory of coast component in the system for surveillance and development of adequate tactics for its application.

The C4I System Concept initiates the application of the situational approach in CNSS. Priority is given not to make final decisions but to develop a methodology and to create an environment for immediate decision-making in complex situations. This type of control is not related to some new theories; it is a new methodology initiated by the revolution in communication and information technologies. It actually provides substantial increase in leadership culture and the application of teamwork principle is mandatory. The CNSS' situational control presupposes prediction of situation development and determination of main tendencies. To this end it is necessary to organize the collection, storage and analysis of all the data and information about it, irrespective of time of receiving, but considering the fact that the recent information has a priority.

Application of the C4I System Concept in CNSS

In the developed countries, the pragmatic approach to build the subject of their sea control around the navigational safety systems gains wide popularity and acceptance. Their development is coupled with sea traffic control as part of the control of risk at sea, as well as the protection of sea environment. They are compatible with the automatic control systems of the Navy, and supply them with up-to-date information which is necessary in time of peace, crisis control and combat operations. They fol-

Table 1: Legal Requirements of VTS

№	Phase	Main IMO Documents	Application
1.	VTS	SOLAS Convention	Rule 5/8-2 Vessel Traffic Services
			Rule 12 in the new amendment of Chapter 5
2.		IMO Resolution A.857(20) Guidelines for Vessel Traffic Services	
3.		IALA Manuals and Recommendations	
4.		IALA VTS Manual	
5.		IALA Recommendation V-103	
6.	SRS	SOLAS Convention	Rule 5/8-1 Ship Reporting System
7.		International Convention for Search and Rescue at Sea SAR	Chapter 5 Ship Reporting System
8.		IMO MSC.43(64) Resolution	
9.		IMO A.851(20) Resolution	
10	AIS	IMO MSC.74(69) Resolution	
11		SOLAS Convention	Rule 19 in the new amendment of Chapter 5

low the military systems logic and have military systems' hierarchical structure at strategic, operational and tactical level. Systems development has several different aspects – to establish the necessary legislative basis, to provide appropriate technical equipment, to create organization, and to train personnel. All these problems are solved within the frame of a unified operational concept.

The international maritime conventions and the respective national laws based on them regulate the implementation of CNSS, as well as the technical-organizational basis of the C4I systems that support CNSS. Nowadays, most maritime countries work persistently on the improvement of the legislative basis, in which the contemporary requirements for safety at sea and sea environment protection are reflected. Special attention is paid to the development and functioning of VTS as one of the most important facilities providing safety of shipping in ports and coastal areas (see Table 1).

The technical ground for practical application of C4I system concept in CNSS includes technologies and equipment for: collection of data (sensors based on various physical principles and remote control devices including satellites); data processing for communication and navigation; data systems integration, data protection and data systems security; automatic identification systems. The importance of these means and technologies should not be underestimated; however, it should be noted that they only provide support to the concept and should not be brought forward to a leading position.

The major subject of sea control is the state. The state delegates the organization and implementation of control to the relevant institutions. Their efforts are functionally combined in a system for control of national sea spaces (SCNSS) in traditional maritime states. It is organized by the Navy and functions as a naval structure, which adequately meets modern threats.[15] Such systems are structured in advance in accordance with the declared interests, recognized needs and real capabilities. There exists always such a system in the general structure of state government and military control, which is further developed and maintained in a relevant to the situation condition. Even in cases when such a system is not especially organized and developed, when there is a need, the system self-organizes, i.e. its main components come to existence. Table 2 illustrates the main functions of such a system, which uses some existing structures developed on the basis of the C4I-system concept.

To be able to realize its functions with utmost precision, CNSS should operate a well deployed structure. Generally speaking, it includes the following subsystems: command; control and communications/information support; maneuverable execution forces; post-reconnaissance cover-up and imposition of sanctions and/or for rendering services in crises situations; for support, training and preparation of personnel and forces; readiness and duty staff; and reserve.

Nowadays, this subdivision is provisional, since computer networks form ‘a unified system for information and control’ integrating all subsystems and even system components from different organizations. In this way, new functional relationships are created capable of enhancing the quality of control and considerably reducing its cost. In this case, the application of system approach guarantees increase in efficiency by at least 30 percent, compared to the traditional methods of control applied by independent control systems.

Conclusion

The system approach is widely applied in developed countries in all spheres of state building and especially in the development of protective structures with civil and military designation. The maritime control promoted by them is subordinated to the strategic concept for protection of national interests, and the implementation of the C4I system concept provides an instrument suitable for the purpose. It offers active counteraction against all threats to national and regional security. Their asymmetric nature and the redefined national interests require this control to be considered not

Table 2: Basic CNSS functions.

<table>
<tr><td colspan="5">Functions in support of the Armed forces</td><td rowspan="17">Applications of the system concept C41</td></tr>
<tr><td rowspan="4"></td><td colspan="4">Creation of a complete tactical picture</td></tr>
<tr><td colspan="4">Ensuring of connections for a fast and reliable information exchange</td></tr>
<tr><td colspan="4">Direct sensor consumer information emissions</td></tr>
<tr><td colspan="4">Information warfare</td></tr>
<tr><td rowspan="10">Functions in favor of navigation</td><td colspan="3" rowspan="2">AIS
Automatic Identification System</td><td>‘ship-to-ship’ mode - prevention of collision</td></tr>
<tr><td>‘ship-to-shore’ mode:
- receiving information about ships and their cargo;
- a technical VTS method.</td></tr>
<tr><td colspan="3">SRS II
Ship Reporting System</td><td>- insuring safe and efficient shipping;
- Protection of the seas (when transporting dangerous cargoes)</td></tr>
<tr><td colspan="3">SRS I
Ship Reporting System</td><td>- crew safety crew at sea;
- increased efficiency in SAR operations.</td></tr>
<tr><td rowspan="6">VTMIS
Vessel Traffic Management and Information System</td><td rowspan="5">VTMS
Vessel Traffic Management System</td><td rowspan="3">VTS</td><td>Organization and control of harbors and approaches to them, as well as in narrow seas, control on following the sailing rules and regulations.</td></tr>
<tr><td>Ensuring safe shipping in complex navigational meteorological and hydrological situation;</td></tr>
<tr><td>Conduct of search and rescue operations and oil pollution follow up operations</td></tr>
<tr><td rowspan="2"></td><td>Assistance with port authorities (pilot, tug, operators, etc.)</td></tr>
<tr><td>Navigational control of coastal waters as state security measures, informational backup of border and customs authorities.</td></tr>
<tr><td colspan="2"></td><td>National and international VTS data exchange on ships</td></tr>
<tr><td rowspan="5">Additional</td><td colspan="4">Creation of a common information media</td></tr>
<tr><td colspan="4">Record on trespassing and penalties</td></tr>
<tr><td colspan="5">Planning of operations</td></tr>
<tr><td colspan="5">‘Situation’ workout and training</td></tr>
<tr><td colspan="5">Networking with similar systems</td></tr>
</table>

only as an element of the mechanism for preventing conflicts but also as a fundamental part of the management of country’s maritime policy, of the exploitation of marine resources, their protection, etc. Regardless of the expenses and the difficulties, the implementation of the C4I system concept in CNSS is absolutely necessary for the performance of the Navy missions and for the improvement of state governance. The research conducted during the last few years and the analysis of our and international experience allows us to make the following conclusions:

- There is a common trend of increasing the integration of the various institutions by the functioning C4I infrastructure and unification of their control functions, which results in higher efficiency and reduced maintenance costs.
- The operational and economic expedience gives priority to military forces due to the fact that the C4I system concept is best developed there, and because they have the necessary means, aids and qualified personnel for the good performance of the tasks pertaining to control.
- The state-of-the-art maritime control is based on the development of an integrated information environment for the situation at sea, getting information from all information-collecting structures and providing authorized access for the interested parties.
- The control systems of national sea spaces are developed with the help of the Navy and are maintained as military defense structures. The C4I-infrastructure is a universal instrument for modern situational management.

The practical implementation of these conclusions could be realized by fulfilling the following recommendations:

- For successful introduction of the C4I system concept in CNSS, a state standard that regulates the development and use of such systems has to be established;
- For utilization of the limited resources, parallel and concurrent structures have to be integrated and the duplicated elements eliminated;
- For efficient functioning of the CNSS system it is necessary to have: a new management culture, recognition of the situational approach in management and education; wide use of the basic principles of the system approach and the new information technologies.

The C4I concept is the only viable alternative to overcome the disparities within the CNSS system, which is being developed now. Relevant insight into the C4I concept and its proper implementation has a great methodological importance for the development of a working national maritime policy.

Notes:

[1] Peter Petrov, VADM, BU N, "Towards Creation of a Unified Information System of the Navies of the Black Sea Countries," *Information & Security: An International Journal* 6 (2001): 94-101, <http://www.isn.ethz.ch/onlinepubli/publihouse/infosecurity/volume_6/a4/a4_index.htm> (14 March 2004).

[2] *United States Coast Guard – Model Maritime Service Code* (Washington, D.C.: US Department of Transportation, 1995).

[3] *White Paper on Defence of the Republic of Bulgaria*, adopted with a decision of the Council of Ministers of the Republic of Bulgaria on April 4, 2002 (Sofia: Ministry of Defence of the Republic of Bulgaria, 2003), English translation is available on-line at http://www.mod.bg/white_book/ENWP.pdf (13 March 2004).

[4] EXTAC 1012 – *Maritime Interdiction Force Procedures*.

[5] EXTAC 1013 – *Regional Naval Control of Shipping*.

[6] Petrov, "Towards Creation of a Unified Information System of the Navies of the Black Sea Countries."

[7] EXTAC 1012 – *Maritime Interdiction Force Procedures*; EXTAC 1013 – *Regional Naval Control of Shipping*.

[8] *Agreement on the Establishment of the Blacksea Naval Cooperation Task Group*, <www.blackseafor.org> (20 March 2004).

[9] Petrov, "Towards Creation of a Unified Information System of the Navies of the Black Sea Countries."

[10] Petrov, "Towards Creation of a Unified Information System of the Navies of the Black Sea Countries;" *White Paper on Defence of the Republic of Bulgaria*.

[11] Stoyan Balabanov and Karmen Alexandrova, "C4I System Reengineering: Essential Component of Bulgarian Armed Forces Reform," *Information & Security: An International Journal* 5 (2000): 41-59, <http://www.isn.ethz.ch/onlinepubli/publihouse/infosecurity/volume_5/a2/a2_index.htm> (14 March 2004).

[12] *C4ISR Architecture Framework, Version 2.0* (C4ISR Architecture Working Group, December 1997).

[13] *DoD Architecture Framework (DoDAF), Volume I: Definitions and Guidelines*, Version 1, (Washington, DC: DoD Architecture Framework Working Group, February 2004).

[14] *United States Coast Guard – Model Maritime Service Code*.

[15] Balabanov and Alexandrova, "C4I System Reengineering: Essential Component of Bulgarian Armed Forces Reform;" *United States Coast Guard – Model Maritime Service Code*.

PETER DERELIEV, see page 34.

BOYAN MEDNIKAROV, see page 34.

CURRENT TRENDS IN TACTICAL NAVAL COMMUNICATIONS

Stephan METZGER

Abstract: Nowadays secure and protected radio-communications – especially at sea – are more important than ever. Mobile naval forces require reliable, jam-resistant and secure voice and data connections. Standardised communication media has long been part of today's naval communications and are now indispensable. Manufacturers specialising in tactical radio-communications offer state-of-the-art solutions that will soon be standard on naval vessels with up-to-date equipment. Today, many of these methods can be implemented in software-defined radios. In radio-communications, interoperability is a particularly important aspect with multinational forces. It is also a must in the co-operation with allied nations in joint combined operations and partnership for peace (PfP) missions. Prerequisites are standardised waveforms, protocols and methods. The use of digital software radios ensures this right from the beginning. Modern systems for radio monitoring and radiolocation are frequently integrated into the communications system. In addition to well-known transmission media, satellite broadcast systems (SBS) and global broadcast systems (GBS) will soon open up completely new prospects. The trend in naval communication systems is toward a comprehensive integrated information monitoring, command and weapons system.

In times of increased necessity for international crisis management, secure and protected Radio-communications—especially at sea—are more important than ever. Mobile Naval forces require reliable, jam-resistant and secure voice and data connections. Standardised communication media, such as e-mail, Intranet, but also Internet connection via radio, has long been part of today's naval communications and is now indispensable. Manufacturers specialising in tactical Radio-communications offer state-of-the-art solutions that will soon be standard on naval vessels with up-to-date equipment.

Even today, the entire frequency spectrum of VLF, LF, HF, VHF and UHF, as well as UHF, SHF and soon also EHF SATCOM is used to set up communication with units and forces at sea. Which of these transmission media is selected depends mainly on the availability of the information channel in terms of coverage range, transmission

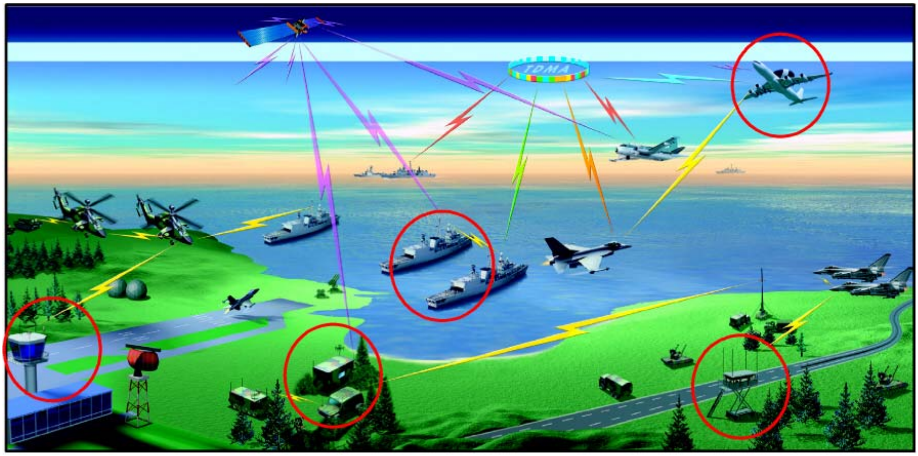

Figure 1: Communications Scenario.

speed and, last but not least, required data rate.

However, the decisive factor is, and will continue to be, the geographical distance to the receiving station. We can distinguish between three such distances: line of sight (LOS), a quasi-optical connection; extended line of sight (ELOS), up to approx. 300 NM; and beyond line of sight (BLOS) for coverage beyond 300 NM. New modulation methods and transmission protocols have contributed to increasing the previously rather low data transmission rates of approximately 2.4 kbps to 9.6 kbps or more in short wave and 16 kpbs to 64 kpbs in the UHF band. Data link methods, such as Link-11, Link-16 and Link-22, play an important role in the exchange of radar data, position data and EW information. These modes permit information exchange about identified contacts, course and speed, as well as target instructions for the assigned weapon control systems and operational commands between the involved units, the maritime headquarters (MHQ) and a commander ashore or afloat. In addition, Link 4/Y is available for the exchange of situation data.

Protection against intentional jamming in the HF range, as well as in the LOS/ELOS range, is a crucial factor in radio system design and influences significantly the transmission waveforms. Standardised methods, such as STANAG 4444, HQ I/II and SATURN, are by now established in naval communications. In the same context, non-NATO COMSEC/TRANSEC methods are used for international operations. Several orthogonal networks can be set up without interfering with each other. With the exception of integrated COMSEC/TRANSEC methods, transmissions must be encrypted additionally to protect them against interception and deception.

Today, many of these methods can be implemented in software-defined radios, which enables also the subsequent addition of new waveforms or functions via software download. Conventional operating modes are complemented by e-mail, as well as intranet and Internet access.

Important in this context are methods that allow e-mail over the air, such as the R&S Postman II system, which is used to transmit mail, faxes, or TCP/IP service on the Internet or in military intranets via radio. Practical radio demonstrations at the NATO manoeuvre JWID 2001 illustrated that remote stations at sea, on land and in the air were able to participate via short-wave in a coalition-wide area network (CWAN) communication using the STANAG 5066 protocol.

In Radio-communications, interoperability is a particularly important aspect with multinational forces. It is a must among the three forces, but even more so in cooperation with allied nations in joint combined operations and partnership for peace (PfP) missions. Standardised waveforms, protocols and methods are necessary prerequisites. The use of digital software radios ensures this right from the beginning.

The new generation of digital software radios with their multi-band, multi-mode and multi-role capability also complies with the demand for improved performance at lower weight and less space. Unlike the previously fixed allocation of the frequencies

Figure 1: The New Generation of Digital Software Radios.

of radios to sub bands from the HF/VHF/UHF ranges—for example, combat net radio in the range from 30 MHz to 88 MHz or NATO navies from 225 MHz to 400 MHz—these modern multi-band radios cover an ample scope of frequency ranges. Owing to VLSI components with a more complex design, a multi-band radio can thus replace several conventional Transceivers. Long operational life is another demand placed on this type of unit: a useful life of 20 years or more calls for future-oriented concepts that allow inexpensive and flexible fitting and retrofitting at any time. The R&S M3xR product series from Rohde & Schwarz is a proof that high modularisation and a joint platform concept meet the above requirements. Thus, even future or planned methods can be retrofitted as software extensions owing to the pre-planned product improvement (P^3I) concept.

New waveforms (e.g. SATURN, STANAG 4444), protocols (e.g. STANAG 066) or possibly even methods such as TETRA may be loaded onto the unit from a laptop using a fill-gun (loadable buffer) or even directly via the air interface (over the air management, OTAM), without any hardware modifications being necessary.

Figure 2: A Modern Console.

The signals management and control system SiMCoS, which can be set up by means of flexible network topology, is an example of a contemporary hardware and software solution for processing and distributing information. Systems of this kind typically include subsystems such as the automatic message handling system (AMHS), frequency and antenna management (FAM) and computer-aided workstations for the operators. They are based on an open processor structure that includes the use of asynchronous transfer mode (ATM) processors, synchronous digital handling (SDH)/Giga Ethernet or similar high-speed data bus systems. The systems are designed as modern local area networks (LANs) with server clusters and computer workstations operating in a client/server configuration.

AMHS includes text processing in ACP 127/123/mil.X.400 format (STANAG 4406) for transmitting and receiving messages (teletype, fax, and data) and is connected to the external communication system. For the transmission or reception of encrypted data, separate lines with high cross-talk attenuation have to be switched, taking into account RED/BLACK separation. High-priority data—for situation display, for example—can be connected with any communication line, provided that the line is equipped with high-speed data modems. SiMCoS automatically handles all routine work and, as expected, also includes automatic routing functions.

Even in the event of a power supply failure, AMHS is protected against data loss and ensures 100% redundancy, as well as secure and error-free storage of all information. All vital communication subsystems of a ship are interconnected. There are no restrictions for InterCom system and digital information distribution system (IDS) switching, onboard loudspeakers, alarm systems or the FAM system.

Especially the latter is indispensable in a modern naval communications system, since it supports the radio operators by suggesting the optimum available radio link on the basis of a selection of operational data. For this purpose, information about the desired distance, date and time of day (HF links), as well as the direction of the receiving station and, last but not least, the S/N ratio of transmitter/transmitter and transmitter/receiver is evaluated. These FAM suggestions about the frequency band to be used, the frequency, the optimum output power and the most suitable antenna available all form an integral part of the automatic message handling system.

Modern systems for Radio-monitoring and radiolocation are frequently integrated into the communication system, e.g. the R&S COMINT (communication intelligence) suite. These systems are used to search for, detect and process communication signals in the 10 kHz to 3 GHz frequency range. They include special antennas, state-of-the-art receivers, digital direction finders, as well as recording and analysis equipment.

In addition to the well-known transmission media, such as HF/VHF/UHF radio and SATCOM, satellite broadcast systems (SBS) and global broadcast systems (GBS) with their data rates of several Mbps will soon open up completely new prospects. In particular, with regard to communication via Internet, which is increasingly gaining importance (e.g. database access, voice over IP), these media ideally complement the previous mainly narrowband media. The US projects Joint Maritime Command Information System (JMCIS) and Maritime Command, Control and Information System (MCCIS) of the German Navy are the first projects in this field. In most cases, however, the Internet applications involve asymmetrical communication: a relatively short request results in a far larger data stream in response. This can be remedied by combining narrowband media, such as HF for request purposes, and broadband media, such as GBS for data download from the Internet. Future transmission paths are expected to be a mix of well-known transmission media, where not only military but also economic criteria are of importance. A crucial aspect will be the increased integration of COTS (commercial off-the-shelf) products.

The trend in naval communication systems is toward a comprehensive integrated information monitoring, command and weapons system. This system will cover all external radio and telephone frequencies, as well as onboard command functions, thus providing considerable support for the operator and making the conventional radio operator on board the information manager.

The large extent to which EDP has become part of naval command systems, especially on ships and vessels, is striking. The era in which EDP was viewed rather critically and with only limited acceptance finally seems to have been relinquished to the past.

STEPHAN METZGER is Director of Sales Naval Communications at Rohde & Schwarz. Former Air Force Officer (Captain), he has been with Rohde & Schwarz since 1991. He is Engineer in Electronics/Tele-Communications (Dipl. Ing.).

NAVAL INTERNET SOURCES

United States Navy
http://www.navy.mil/

United States Marine Corps
http://www.marines.com/

Space and Naval Warfare Center
http://enterprise.spawar.navy.mil/

U.S. Office of Naval Research
http://www.onr.navy.mil/

Office of Naval Research Global (ONR Global)
http://www.onrglobal.navy.mil/

U.S. Naval Research Laboratory
http://www.nrl.navy.mil/

U.S. Department of the Navy Chief Information Officer
http://www.doncio.navy.mil

Navy Marine Corps Intranet (NMCI)
http://www.nmci.navy.mil/

Naval Sea Systems Command
http://www.navsea.navy.mil/

Naval Surface Warfare Center
http://www.nswcdc.navy.mil/

Naval Surface Warfare Center, Dahlgren Division
http://www.nswc.navy.mil/

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Navy Modeling & Simulation Management Office (NAVMSMO)
http://navmsmo.hq.navy.mil/

Modeling, Virtual Environments and Simulation (MOVES) Institute, Naval Postgraduate School
http://www.movesinstitute.org/

DMSO Modeling and Simulation Resource Repository (MSRR)
http://www.msrr.dmso.mil/

Navy Test and Evaluation Repository for Models and Simulations (NTERMS)
http://nterms.mugu.navy.mil/

Army Modeling & Simulation Resource Repository
http://www.msrr.army.mil/

War Gaming Department, U.S. Naval War College
http://www.nwc.navy.mil/wgd/

Team Orlando
http://www.stricom.army.mil/TEAM_ORLANDO/

U.S Department of the Navy: IM/IT Strategic Plan, Naval Transformation Roadmap, Naval Power 21
http://www.doncio.navy.mil/fy04stratplan/
http://www.oft.osd.mil/library/library_files/document_202_naval_transformation.pdf
http://www.chinfo.navy.mil/navpalib/people/secnav/england/navpow21.pdf

Marine Corps Strategy 21
http://www.usmc.mil/templateml.nsf/25241abbb036b230852569c4004eff0e/$FILE/strategy.pdf

MARINES: The Official Magazine of the Marine Corps
http://www.usmc.mil/magazine/

Marine Corps Publications
http://www.usmc.mil/marinelink/ind.nsf/publications/

AFCEA BULGARIAN CHAPTER VARNA

On May 12th, 2000, in Varna on the Bulgarian Black Sea coast a new Chapter of the Armed Forces Communications and Electronics Association (AFCEA) was founded. This second Bulgarian Chapter of AFCEA pursues the objectives and abides to the principles of AFCEA International. It thus, contributes to the success of the Bulgarian military reform, as well as to the strengthening of maritime power and national security, by paying special attention to the Navy and marine technologies. The chapter is, however, planning to extend its membership and activities into the other branches of the Bulgarian Armed Forces in the very near future.

Chapter Varna has been spreading its activities throughout the Bulgarian Black Sea coastal areas. In so doing, it is mutually supporting and complementing the Bulgarian Chapter Sofia, in contributing to a wider dissemination of the ideas and activities of AFCEA throughout Bulgaria, South-East Europe and the whole of the Black Sea region. This is very much seen as a positive contribution towards peace and stability in the region.

The Chapter's Board consists of active and retired naval officers from the Bulgarian Navy HQ, from the Naval Academy, as well as representatives of the high-tech business community in Bulgaria.

Chapter Varna now has about 50 individual members, including the Commander of the Bulgarian Navy, the US Naval Attaché in Sofia, the British Deputy Defence Attaché in Sofia, as well as the former Deputy Defence Minister of Bulgaria Velizar Shalamanov. Additionally there are four corporate sponsors, namely Thales Nederland B.V., Unimasters Logistics Group Ltd, Varna, the Institute of Air Transport, Sofia, and WESTEL Ltd., Sofia.

Since its inception more than three years ago, AFCEA Varna Chapter has proven its value as a centre for defence and security matters, for business contacts and for personal development. It regularly holds meetings, lectures and conferences on these and other related issues, attended by many government, military, NGO and industry leaders.

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In 2003, the Chapter received important recognition for its consistent efforts for promoting the ideas and principles of AFCEA in Bulgaria:

- In March 2003, AFCEA Chapter Varna was awarded the Albert J. Myer "Special Recognition" Award of AFCEA International.
- In May 2003, Nikolai Bozhilov, founding member and 1st Vice President of the Chapter, was elected Director of AFCEA International. With this appointment, Nikolai Bozhilov becomes also member of the AFCEA Board of Directors, the governing body of the Association, and member of the European Advisory Council.

The major event organised by AFCEA Varna is its annual International Conference on the Bulgarian Navy. The Chapter has so far organised two conferences – the first one took place on 2-3 July 2002 at Euxinograd Government Residence under the title "The Bulgarian Navy – Global Trends and Local Aspects", and the second one – on 29-30 September 2003 at the Imperial Hotel under the topic "The Bulgarian Navy – New Missions, Roles and Capabilities". Both conferences were held under the auspices of the Minister of Defence of Republic of Bulgaria. Each event was attended by 90 delegates, including representatives from the Ministry of Defence of Bulgaria, the Ministries of Defence of Germany and Turkey, the Bulgarian General Staff and Main Naval Staff, and the NGO community. During the Second International Conference in September 2003, more than 30 of the delegates were foreign representatives of leading Western defence companies, defence diplomats from Sofia and AFCEA Europe officials.

Contact information:

40 Graf Ignatiev Street
P.O. Box 229
BG-9000, Varna
Bulgaria

Phone: +359 52 6655 777
Fax: +359 52 6655 755
Web site: www.afcea.bg
E-mail: secretary@afcea.bg

AFCEA VARNA HOSTS SECOND INTERNATIONAL CONFERENCE ON THE BULGARIAN NAVY

The Bulgarian navy's new priorities and missions, its modernisation, and other issues related to Bulgaria's NATO accession were discussed in detail at the AFCEA Varna Chapter's second international conference, "The Bulgarian Navy – New Missions, Roles and Capabilities," held on 29-30 September at the Imperial Hotel near Varna, Bulgaria. The conference was organised under the auspices of the Minister of Defence of the Republic of Bulgaria Nikolai Svinarov. The event featured speeches by representatives of government, nongovernmental organisations and industry leaders; panel discussions by seasoned professionals; and exhibits by defence companies offering naval equipment. Industry sponsors of the conference were Thales Nederland (The Netherlands), Fr. Luerssen Werft (Germany), Atlas Electronik (Germany), Aeromaritime Systembau (Germany), Armaris (France), Eurotorp (France / Italy), Mauser Oerlikon (Switzerland).

The conference opened with a briefing by Robert Howell, General Manager of AFCEA Europe, who spoke about AFCEA International's role in modernising the European defence establishment.

Rear Admiral Emil Lyutzkanov, Chief of Bulgarian Main Naval Staff, presented the Bulgarian Navy's vision on its new missions, roles and required operational capabilities. Svetoslav Shumanov, government expert from the Armaments Policy and Equipment Directorate at the Bulgarian Ministry of Defence, discussed the current status and prospects for the modernisation of the Bulgarian Armed Forces. Dr. Velizar Shalamanov, Chairman of the George C. Marshall Association and former deputy minister of defence of Bulgaria, spoke about C4ISR in Navy Transformation, the role of joint research and advanced technology demonstrations. Dr. Todor Tagarev, Director Programs, Centre for National Security and Defence Research at the Bulgarian Academy of Sciences, discussed the Naval Sovereignty Operations Centre (NSOC) architecture development effort.

The afternoon session on Day 1 started with a presentation by Heinz Dockhorn, product manager, Atlas Elektronik, who described the company's Multi Role Combat Management System for NATO interoperability. Jaap Jonker, regional marketing

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manager, and Hartmut Günther, senior project manager at Thales Nederland BV discussed a Common Combat System concept for modernisation and new building. Horst Witschel, senior sales director at Fr. Luerssen Werft, presented the company's naval platforms for littoral warfare. Didier Jorioz, regional sales manager at the French Armaris spoke about the company's advanced NATO-compatible solutions for surface vessels.

Capt. Dimiter Ispirski, BU N, chief of the Planning and Development Directorate at the Bulgarian Main Naval Staff, opened the second day of the conference. He described the prospects for modernisation of the Bulgarian navy, which included construction of new ships and acquisition of modern weapons and equipment; rearmament with major weapon systems and equipment, as well as acquiring second-hand ships from the navies of NATO nations; modernisation and integration of C4ISR and major weapon systems and equipment on board of ships with operational life until 2015–2020. Helmut Damke, international business development manager at Atlas Elektronik spoke about future mine warfare scenarios and systems. Jaap Jonker, regional marketing manager, and Hartmut Günther, senior project manager at Thales Nederland BV, discussed ways for delivering capabilities in naval combat systems and communication systems. Horst Witschel, senior sales director at Fr. Luerssen Werft, discussed future trends and developments in naval warfare.

The afternoon session on Day 2 started with a briefing by Plamen Petkov, director of TEREM – Varna Branch, who presented the company's capabilities for implementation of off-set programmes in the modernisation of the Bulgarian Navy. Andreas Schneider, regional sales manager at Mauser Oerlikon, presented the company's light naval gun system MLG27 and 27mm FAPDS ammunition. Dr. Ing. Claudio Ceccarini, senior marketing & BD manager at the French-Italian company Eurotorp presented their multi-role NATO-interoperable light-weight torpedo. The working part of the conference concluded with a presentation on maritime security by Greg Cumming of Raytheon Systems Limited.

Conference organisers noted that as several countries in the eastern part of Central Europe are preparing themselves to become NATO members, AFCEA is an often sought after partner to support this process. It was also noted that this was the first event at which so many big players of the West's defence industry gathered to demonstrate their strong interest in the modernisation of the Bulgarian Navy. Maybe the interest is not so surprising. Bulgaria's coming NATO accession is associated with a good many projects which could prove beneficial for the Western defence companies.

FULLY INTEGRATED COMMUNICATIONS SYSTEM FOR FRIGATES

Prompt and efficient communications are essential for the high technology operational scenarios. Today's communications systems for ship-borne applications have to be designed according to the roles they undertake in times of emergency and in the environment in which they have to operate. Therefore, one of the major design objectives is to centralise the activities of external communications control and to provide also easy access to the subsystems from various locations.

The Fully Integrated Communications System for shipboard applications provides *all* necessary and vital internal and external communication links for a modern naval vessel like a frigate. It fulfils the general requirements for tactical, administrative and safety communications.

External *administrative* and safety communications are covered by the GMDSS system. Internal administrative and safety communications are achieved by various subsystems like dial telephone system (PABX), public address system, sound powered telephone system, administrative data network, etc.

Reliable and secure *tactical* communications in the military frequency ranges and latest modes of operation are achieved by dedicated LF/HF/VHF/UHF radio equipment and the optional satellite communication equipment. Simultaneous operation performance of all radio circuits will be optimized by dedicated design of the antenna arrangement and by use of filters, multi couplers and pre-selectors.

Military external communications modes include plain or encrypted voice, data and formatted messages. Switching and distributing these signals to the actual user and management of entire ICS is done by the following AEROMARITIME manufactured subsystems, which represent the back-bone of the tactical internal/external communications system:

- Digital Communications Network *ASYM 3000 (A)*,
- Communications System Manager *COSYMA*.

The *ASYM 3000 (A)* subsystem provides external voice and data communications in plain or encrypted modes, as well as tactical internal communications at all relevant

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positions throughout the vessel. These communication functions are available at tactical voice terminals, Audio Units, fitted at locations according to the tactical communication requirements of the vessel.

Through interfaces provided to the external radio system, the *ASYM 3000 (A)* network allows distribution of radio signals to voice or data users including insertion of voice or data encryption equipment.

The *COSYMA* subsystem includes a redundant server and a number of workstations (Communications Management Terminals) which provide overall system and network management, as well as ACP 127 military message handling at dedicated positions. The COSYMA includes radio remote control of all major tactical radio equipment. Some of the offered ASYM 3000 (A) tactical voice terminals (audio units of type "F") include the capability to access the radio remote control facilities of COSYMA, thus combing tactical voice communications with radio remote control functions.

The overall *management and control* of the integrated external/internal communications system is handled by a computer based Communications Management and Control System (COSYMA) including a Secure Automatic Military Messaging System (SAMMS).

Contact information:

AEROMARITIME Systembau GmbH
Ludwig-Erhard-Str. 16
85375 Neufahrn
Germany

Phone: +49.8165.6171.216
Fax: +49.8165.908.389
E-mail: w.franke@aeromaritime.de