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# *Preliminary Design of a New Bridge System for a Modern Mine Hunter Vessel*

*D. Boddi* [(a)], *M. Vezzani* [(b)]

[(a)] Naval Academy, Dipartimento di Informatica, Italy
[(b)] Naval Academy, Dipartimento del Genio Navale, Italy

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Corresponding author:
*Marco Vezzani*
*Tel.: ++39586238296*
*marco_vezzani@marina.difesa.it*
*Address: Accademia Navale, Viale Italia 72 - 57127 LIVORNO (ITALY)*

## *Abstract*

*The present work summarises some of the most relevant aspects of an activity for a preliminary design of a new bridge system for a modern Italian Navy mine hunter vessel. The authors have contributed to such activity as a naval consultant and a CAD consultant respectively. The solution proposed by the authors is an integrated bridge system, which is an original solution for Italian Navy.*
*The first part of the work defines the optimum instrumentation for the implementation of operational tasks and analyses the correct positioning for each and every console within the integrated bridge.*
*The second part of the work describes the design activity through the use of 2D and 3D CAD software, taking into consideration the functional, operative, dimensional and ergonomical aspects of the instrumentation. As a result of the activity, an operative methodology is proposed, aimed to reduce the design time.*
*It is not possible to provide a complete design description as far as part of the information is confidential.*

## *1 Introduction*

The current mine hunter vessels employed by the Italian Navy were commissioned during the 80's and have gradually been refitted and upgraded over the last few years. Even though they are still fully capable of carrying out all their assigned missions, the current bridge system installed is made up of separate and independent modules, as shown in Fig. 1, which are not as effective as an integrated bridge would be. The integrated bridge, as suggested by the authors, is designed to reduce the time spent on navigation by eliminating manual data processing and providing watch officers with several displays, which aid him in quickly evaluating the operational scenario. The term "integrated bridge" encompasses several possible combinations of equipment and software designed specifically for the individual needs of each vessel. Therefore, each integrated bridge system can be tailored to the specific need.

***Fig. 1 Current mine hunter bridge.***

Recently, in light of the changing world scenario and the threat posed by new improved mines, the Italian Navy has decided to design a new ship, called the New Generation Mine Hunter vessel (NGMHv) equipped with superior instruments and enhanced capabilities.

The NGMHv [1] are designed to counter the mine threat in both littoral and deep waters. The former requirement is necessary in order to ensure that ships can navigate in shallow waters and can enter ports, while the latter is required so as to achieve the sea lane control in international waters in order to project naval forces at farther distances. Mines evolve constantly and very rapidly, with the main concern of most countries being the creation of very deep water mines, which are more difficult to detect and neutralize. Consequently, more effective search, detection, classification, identification and neutralization capabilities against Under Water IED, mooring and ground mines, are considered the target to pursue and therefore the new NGMHv requirements are:

- Protect national naval shipping;
- Give support to amphibious and maritime operations;
- Survey access routes to the harbors, sea lines of communication (SLOCs) and all national maritime areas;
- Counter terroristic activities inside ports;
- Clear territorial waters from WW II mines;
- Protect worldwide archaeological sites;
- Search for sunken plane or vessel wrecks;
- Acquire oceanographic data related to routes/areas of interest.

Mine hunting operations are usually divided into several phases [2]: they generally involve an initial search to confirm the presence or absence of mines and if necessary, assess the limits of a minefield, allowing the establishment of diversion routes to avoid it. Clearance operations involve the NGMHv searching along parallel tracks in the channel or area to be cleared. On detecting a mine-like contact on the seabed or in the water column, the NGMHv 'hovers' near the contact using its precise ship control system. Any mine identified can then be neutralized by remotely detonating a mine disposal charge laid in close proximity.

Consequently, NGMHv require accurate maneuvering and position keeping to follow a predetermined track or maintain position relative to an object on, or tethered to the seabed. This is achieved through precise navigation and a ship control system.

## 2 The operational concept

During Mine Counter Measure (MCM) operations, most of the time the vessel is controlled by the operations officer located in the Combat Information Center, whose main concern is to keep the vessel on the planned tracks using the auxiliary propulsion. The watch officers, on the other hand, merely carry out collision avoidance duties and in case of emergency, if they need to maneuver, have to be ready to take control of the auxiliary propulsion. Therefore, within an MCM operation, even though different and many additional tasks are carried out by the watch officers, the main duties which they are involved in are generally similar to those on all other ships and can be summarized as follows [3]:

**Navigation:**

- They process navigation information from several different sources, take fix positions from satellite receivers, measure bearing lines and radar ranges to suitable navigational references points and plot all this information on a paper chart.
- Once all the information has been plotted, they evaluate the operational scenario to determine if the ship's current position is a safe one. By means of dead reckoning, they project the ship's future position and plan for future contingencies. The evaluation step is very important in the navigation process. Properly executing this step is a measure of the watch officer's skill and how well the ship's actual navigation situation is represented on the chart. That representation, in turn, is an estimate of both plotter and sensor accuracy.

**Collision Avoidance:**

- They evaluate, both through the use of the radar and by visual contact, the target situation and calculate the closest points of approach (CPA's) for various targets.
- They maneuver in accordance with the Rules of the Road to avoid close CPA's and collisions.

**Ship Management:**

- They conduct ship maneuvers, both as an individual ship routine and when integrated inside a naval formation.
- They are trained to promptly face any emergency that can occur when at sea/ashore.

**Further MCM activities:**

- They can direct, using a joystick, a Remote Operated Vehicle (ROV) from its launch position, normally at stern, towards the position of the mine;
- They lead the RHIB (rigid hull inflatable boat), using an arrow indicator positioned outside the roof of the bridge, towards the mine's position in order to lay a sonar reflector on the sea bottom in the vicinity of the mine.

Preliminary tests indicate that time spent on navigation as a percentage of total watch officer duties drops significantly when using the integrated bridge. This does not necessarily lower the overall watch officer workload, but it does increase the percentage of time he can devote to other different tasks.

The following section introduces the main equipment likely to be found in any integrated bridge system.

**Computer Processor and Network:** This subsystem controls the processing of information from the ship's navigation sensors and the flow of information between various system components. Electronic positioning information, contact information from radar, and gyro compass outputs, for example, can be integrated with the electronic chart to present the complete navigation and tactical picture to the watch officer. The system's computer network processes the positioning information and controls the integrated bridge system's display and control functions.

**ECDIS:** At the heart of any integrated bridge system lies an electronic chart display. An electronic chart system meeting the International Maritime Organization (IMO) specifications for complying with chart carrying requirements is called an Electronic Chart Display and Information System (ECDIS).

Electronic charts can display different types of data far better than conventional charts and they can display only the data the user needs. The database for a typical civilian electronic chart contains layers consisting of hydrographic aids to navigation, obstructions, port facilities, shoreline, regulatory boundaries and certain topographic features. Other layers, called Additional Military Layers (AML), contain additional data such as detailed bathymetry, small bottom objects, large bottom objects and meteorological data. This allows the user to customize his chart according to his particular needs, something a paper chart cannot do.

**Conning Display:** This unit provides information on sensor status and ship's control systems. It displays heading data and ship's speed and provides a station where the operator can input warning parameters such as minimum depth under the keel or maximum cross track error.

**Radar/ARPA(Automatic Radar Plotting Aid) :** Radar for navigation and collision avoidance is also included in the integrated bridge. The radar is mainly designed to detect surface targets and, when feasible, low flying air targets. Moreover it can provide, through a navigation network, all detected targets to be visualized on a different display.

The "picture" from either one can be overlapped on top of the picture of the other as a further layer. This allows the navigator to see an integrated navigation and tactical display and to avoid both navigation hazards and interfering targets.

The ARPA system can also provide targets representation with courses and speeds.

## 3 Integrated bridge proposal

The Integrated bridge proposed by the authors includes all equipment supporting the navigation functionality needed to undertake mine counter measure operations.

A dedicated piece of equipment, named the Ship Data Distribution Unit (SDDU), is in charge of collecting, weighting, filtering and redistributing data from all sensors in order to provide the other systems with a unique and reliable source of navigational and meteorological data.

The Navigation System includes all navigation and meteorological sensors, which are the raw sources of all cinematic and environmental data. Each navigation sensor is able to work on its own, displaying the measured data even when the other equipment is off.

In particular, the Navigation System includes the following main equipment, as shown in Fig. 2:

- Electronic Chart Display and Information System (ECDIS);
- Radar/ARPA Displays;
- GPS;
- Fibre Optic Gyrocompass (FOG) with Gyrocompass Repeaters;
- Doppler Velocity Log (DVL);
- Echo Sounder;
- Meteo Station;
- Ship Data Distribution Unit (SDDU);
- VHF/DSC Radio;
- Automatic Identification System (AIS).

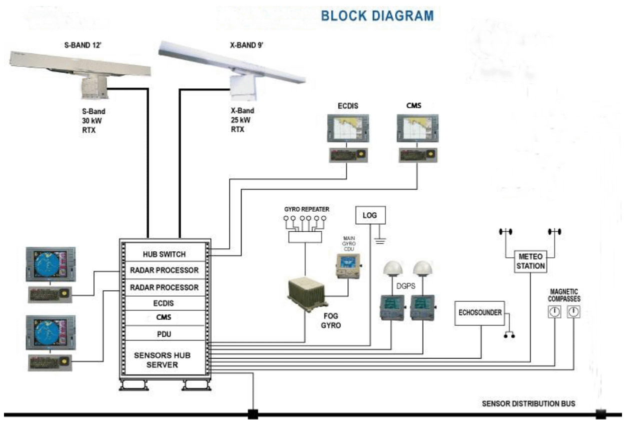


***Fig. 2 Block diagram.***

Most Navigation System equipment is accessible from the Bridge, a unique location that allows for a centralized, safe and efficient management of Ship navigation.

The **integrated bridge**, which is part of the Navigation system, is made up of 8 main modules hosting the following instrument:

- two **radar/ARPA systems**;
- **ECDIS** system;
- **control and monitoring** system;
- **auxiliary** control system;
- **main propulsion** control system
- **CMS** (Console Multi Screen);
- **CCTV** system.

As the **radar** equipment is considered crucial for the ship, a second radar has been suggested; one X-band radar sensors plus one S-band sensor. Both are fitted with digital output of the raw video through ethernet link. The two LCD radar displays are fully equivalent and interchangeable with each other.

Should one radar sensor fail, the relevant display is able to work in slave mode for the other radar unit; in this case however, it only receives signals without the possibility to issue any command to the radar sensor.

On the contrary, in case of failure of one of the two radar monitors, the video from the relevant transceiver can be displayed by re-routing it through the SDDU unit to another processor and another monitor.

A different approach has been adopted for the **ECDIS** as it's not considered crucial for navigation and in case of failure the watch officer can still accomplish his mission through the use of traditional nautical charts without hampering the mission itself. For this reason only one ECDIS system, complying with IHO s-52 standards, is needed. Suitable application software allows the display of electronic charts, including the ship own position, speed and bearing, route planning, the determination of the kinematics parameters for navigation and the transmission of the data to an autopilot.

This module also receives, through the sensors bus, the tracked target data coming from the radar modules to show them on the console displays, according to the operator's preference, and represented through graphic symbols and a window containing kinematics data and label of the selected track.

The **control and monitoring system** is an integrated, distributed, microprocessor based system which manages the following major equipment:

- Diesel generators;
- main propulsion;
- auxiliary systems (air conditioning, fuel, lubricating oil);
- damage control.

The system enables remote monitoring and control of machinery from the machinery control room with a secondary remote control position on the bridge. Data for maintenance purposes is recorded and performance analysis can be undertaken.

During mine hunting operations, the **auxiliary propulsion systems** are used for automatic control of ship maneuvering. This provides the ship with the auto-hover and auto-track keeping capabilities required for effective mine countermeasures operations. During this operation the ship is mainly maneuvered by the duty officer located in the Combat Information Center and as a result, the console on the bridge is in stand-by mode, ready to be used by the watch officer in case of emergency.

On the contrary, the **main propulsion control system** is used when mine hunting operations are not undertaken, for example when the ship needs to be transferred from one area to another.

In addition, in order to have full integration with command and control system and to allow personnel on the bridge to have a clear idea of the current operational scenario, one **CMS** has been installed. In this display they can show all the pictures concerning the consoles located in the CIC.

Finally, the last console is connected to the **CCTV** system. This console can provide the Watch Officer with different images coming from several important ship locations. For example, he can control the stern of the ship when Remote Operating Vehicle (R.O.V.) operations are ongoing.

The final integrated bridge should contain the aforementioned instrument placed as shown in Fig. 3.

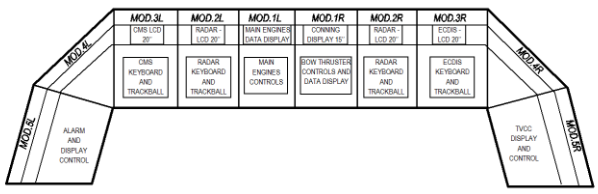


***Fig. 3 Integrated bridge.***

**ECDIS**: This is constantly monitored by the watch officer when standard navigation is ongoing, while is supervised by the navigator when different main navigational roles are undertaken, for example when the ship enters or leaves the port or when maneuvering in dangerous waters. During the above mentioned roles, the Commanding Officer (CO) is always on the bridge and to be constantly updated by the navigator he needs to be as close as possible to him. For this reason, considering that by tradition the seat on the right is reserved for him, and in order not to hinder the his outside view, the authors suggest placing the ECDIS console on the 3R panel.

**RADAR/ARPA**: during any navigational roles they are constantly monitored by the personnel on duty and for this reason it should positioned on the front part of the integrated bridge (panel 2L and 2R).

**Auxiliary control system**: this is employed when the ship needs to maneuver to moor or to leave the quay. To allow the operator a clear view, its position should be as close as possible to the center line (panel 1R).

**Main Propulsion system:** This is normally monitored by an operator and its position could be anywhere. However, given that in rare cases it might be used in combined mode with the Auxiliary control system, it would be more practical to place it close to that (panel 1L).

**Control and monitoring system:** This is controlled by and, in case of any alarm (true or false), silenced by the personnel on duty in the bridge. In order not to interfere with CO's activities it's advisable to put it as far from him as possible (mod. 5S).

**CCTV** system: This is mainly used when vehicles are launched at sea from the ship's stern. The CO should be able to follow these operations from his seat and for this reason the right position for this system is the module 5R.

## 4 Preliminary design of an integrated bridge system

In the designing of a new generation bridge system for a mine hunter vessel, the shipbuilder has to satisfy the customer's demands, to choose the components builders and to suggest an up to date and efficient design. As far as design is concerned, the shipbuilder can ask the help of a naval consultant who is competent and acquainted with mine hunter military activities.

First (see par. 3) the naval consultant defines the bridge system functions, he chooses the instrumentation needed to carry out the assigned tasks and he defines the component list for each instrument.

As a second stage, the naval consultant works in collaboration with a CAD designer to define the optimal position of the instrumentation lodging modules and the correct position of each component in the modules.

The scheme in Fig. 4 reports the whole design methodology.

Such a methodology aims to indicate the most efficacious way to obtain a valid preliminary bridge system design.

In this paragraph the second phase of the design methodology is described. Such a phase begins when the naval consultant has completed the components list.

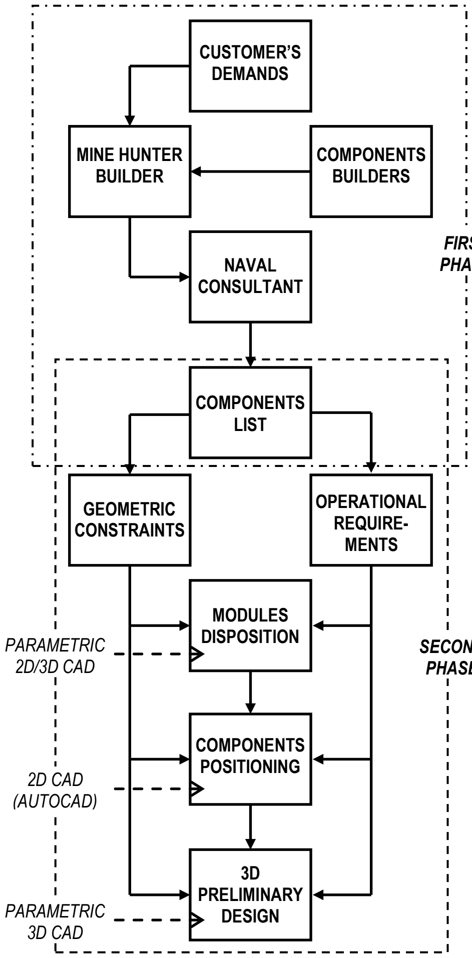


**Fig. 4 Design methodology.**

### 4.1 Geometric constraints and functional requirements

In order to define a correct bridge system design, the instrumentation must be placed considering both the geometric constraints and the functional and operative requirements of each single component.

The geometric constraints are essentially concerned with:

- bridge shape and dimensions,
- modules shapes and dimensions,
- overall dimensions of instrumentation components,
- ergonomical aspects.

The functional/operational requirements are those indicated by the naval consultant for each component and are related to the bridge system working activities.

### 4.2 Modules disposition

The instrumentation lodging modules can be disposed in various ways in the bridge. The modules number can vary too, according to the instrumentation to be included into the bridge system. The integrated bridge system concept developed in the present work provides a disposition of the modules one next to the other, in order to create a single console as a continuum.

Therefore it is necessary to define number, dimension and geometric disposition of the bridge system modules. Such a problem has not an immediate solution, because it involves many variants: geometric, functional, ergonomical and aesthetic variants. In order to reduce the time for such a designing activity and to optimise the result, it is convenient that a parametric SW CAD is used

[4][5]. In fact, a parametric SW allows modifying the modules disposition geometry more easily, so that it can be modified for operative/functional/aesthetic needs.

Moreover, it is to be observed that the typical instrumentation lodging module allows inserting components either on a horizontal working plane or on an oblique plane. Therefore a 2D drawing with a top view allows identifying both planes. As a conclusion, in order to define the modules disposition, a parametric 2D CAD SW is sufficient, without wasting time with a 3D CAD SW.

Fig. 5 shows two possible configurations, which can be obtained from the same parametric 2D drawing. In the two configurations the wideness of five central modules is different.

A 3D drawing is required just when the customers requires a preliminary 3D rendering already in this phase. Fig. 6 shows a preliminary 3D model. The bridge console geometry, in this case, is that of an arc of a circle.

Drawings and model in Fig. 5 and 6 have been realised by parametric CAD SW Pro/ENGINEER.

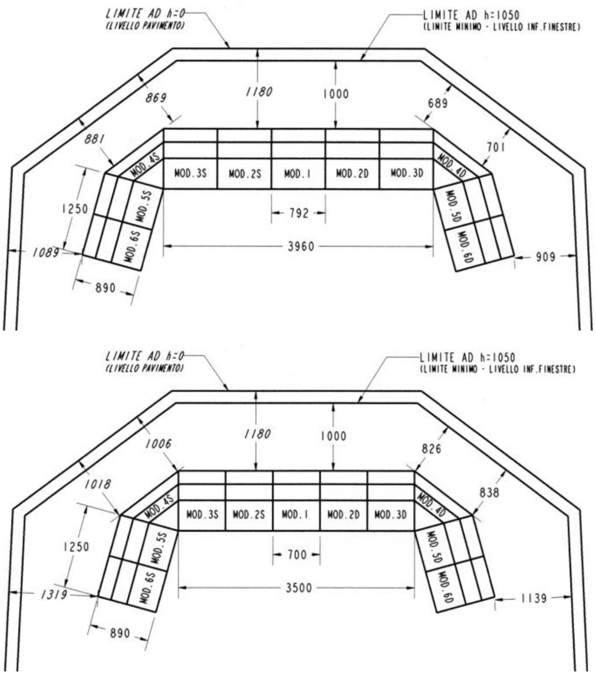


***Fig. 5 Parametric 2D drawings for modules disposition.***

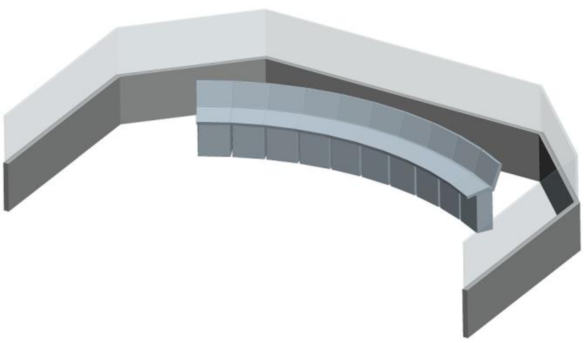

***Fig. 6 3D model for modules disposition.***

It is to be pointed out that the modules disposition choice is a phase of most relevance. It is convenient to define the choice of modules disposition and type as soon as possible. In fact, later substantial modifications would be much onerous.

## 4.3 Components positioning

Once the modules disposition in the bridge is defined, the components disposition in the modules is considered.

In this phase, and for the first time, technical information about the room geometry, the modules disposition and the components disposition in the modules is gathered in a single document. It is convenient to carry out a careful examination of the components positioning, with respect for the positions indicated by the naval consultant.

This phase is long and complex and it requires many modifications both to correct possible mistakes or defects and to optimise the components positions.

In order to simplify and promptly modify the components positions it is suggested to firstly start from a 2D drawing of the modules disposition in which the components are indicated simply by their names. Fig. 7 shows two examples of drawings with the components positions indicated.

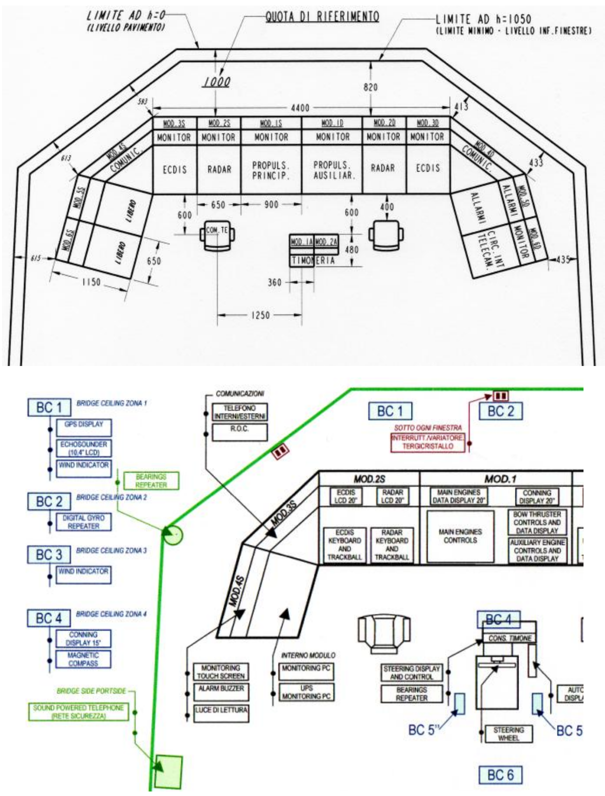


***Fig. 7 2D drawings for the components positions.***

Once each component ideal position is defined, it is necessary to verify the components actual overall dimensions in each module.

For this purpose it could appear that a 3D CAD modelling is optimal just at this moment. As a matter of fact, 3D modelling does solve the problem, but probably it does not reduce to a minimum the time for a preliminary design. In this phase direct experience demonstrates that type, model, and also builder of each component can change more than once. Therefore it would waste time creating the 3D model component without using it.

At this point it is useful to underline that the components builders do not generally supply components 3D models, but just technical drawings in dwg format (Autocad). Therefore it is convenient to take the parametric drawings of the modules disposition and to change them in dwg format, so that it is possible to integrate them with the numerous components drawings supplied by the components builders. Fig. 8 shows an example of integration of components dwg drawings with the modules disposition drawings. Most of the difficulties connected with overcrowding and interferences can already be faced off and solved with these drawings.

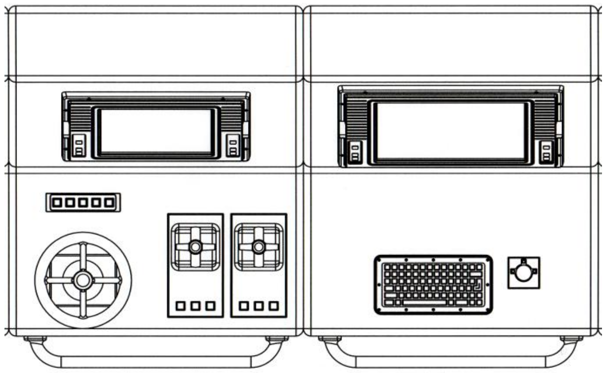

***Fig. 8 Integration of components dwg drawings with the modules disposition drawing.***

## 4.4 Preliminary 3D design

The CAD 3D modelling phase helps to complete the preliminary design. The 3D model allows a prompt check of the components overall dimension constraints, an evaluation of staff transit and manoeuvres spaces and the instrumentation ergonomics, and it enables the designer to determine and introduce the necessary changes to develop and optimise the design.

Fig. 9 shows some images related to an integrated bridge system preliminary design developed by the Authors. Fig. 10 shows the entire room where the bridge console is located. The 3D CAD SW, which has been used, is Pro/ENGINEER.

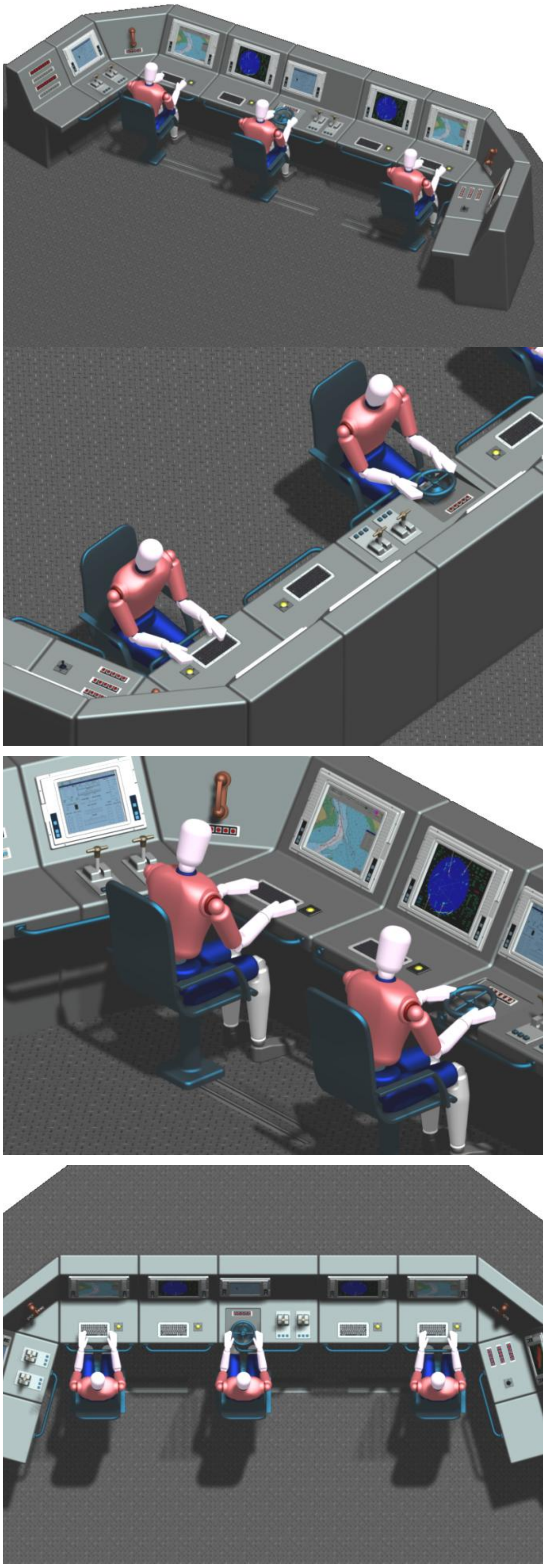

***Fig. 9 Integrated bridge console preliminary design.***

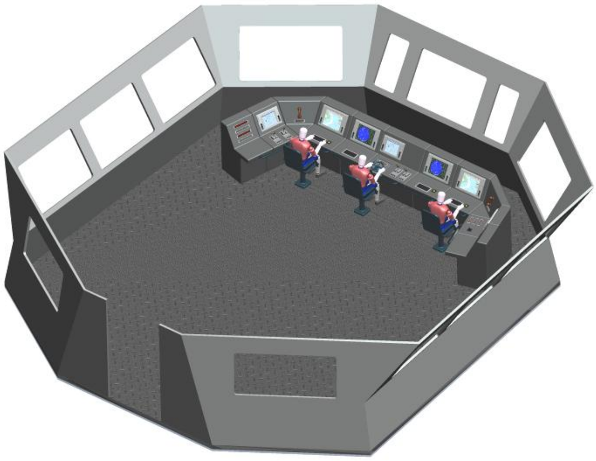

***Fig. 10 Integrated bridge console preliminary design.***

Among the most critical points emerged during the development of the present work some have to be pointed out:

- the customer demands can be incomplete at the beginning and can change more than once during the design development; it is convenient to defer 3D modelling as much as possible, aiming to optimise the preliminary design in a 2D CAD environment;

- the choice of components is bound to preferential relations between shipbuilder and the components builders; this limits the choice about the components types and models.

## 5 Conclusion

In conclusion, the most relevant aspect in the preliminary design of an integrated bridge system for a mine hunter vessel is the correct selection and disposition of instrumentation. The use of 2D and 3D CAD SWs allows to reduce times and to optimise the design development.

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