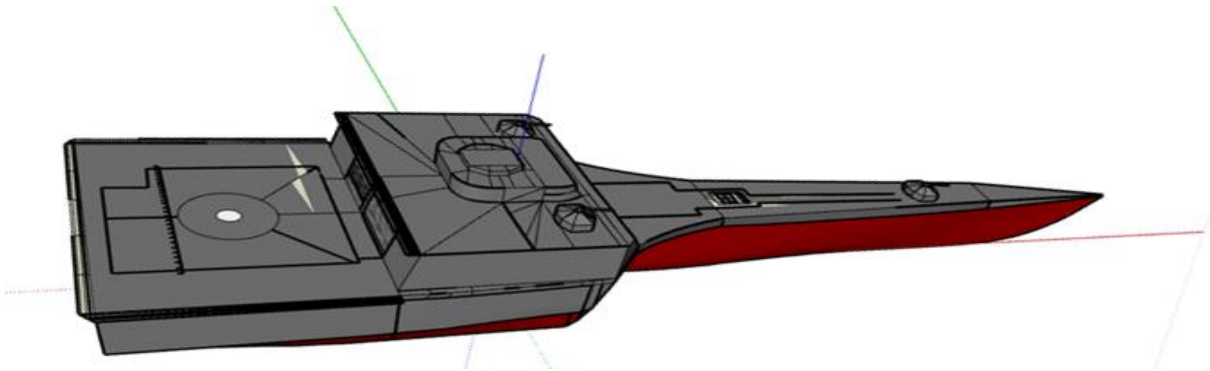
ISSN No:-2456-2165



Ship Concepts Methods, Stealth Performance and Resistance Reduction of DFT2 Case Study

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Abstract:- Resistance reduction and stealth performance in surface combatant warship(trimaran) have nowadays became an important issue to be investigated. Talking about trimaran ship resistance reduction, is to provide an understanding on the ship energy consumption in regard to its efficiency that is related to a considered reduction of the ship dragging, and wave making resistance. Additionally, stealth technology also known as low-observable technology (LO technology) has at present time acquired an integration into many categories and classes of high speed warships particularly trimarans that exist in this new era. The reduction of the Defense Frigate Trimaran2 (DFT2) radar cross section (RCS) is primarily an effort that DFT2 design will consider to improve survivability in opposition (against) to anti-ship cruise missiles (ASCHs), and radar homing. Stealth technology known as sub-discipline of the tactics utilized by militaries as well as passive and active electronic countermeasures, from which a range of methods being covered are utilized on ships, submarines, missiles, people, and so on to decrease detections (that is, being invisible) to radar, infrared, sonar as well as other detection methods. On the other hand, fiber, coating, polymer additives, special roughness, and surfactants when applied on the ship's surface hull, can have and ability of reducing drag in fluid flow.

The main aim of this paper is to provide an understanding on DFT2 concepts methods (Concept Operation, Concept Exploration, and concept Development), resistance reduction (wave making reduction) and stealth performance (Radar-absorbent, Radar stealth countermeasures and limits) of DFT2 for the Union of Comoros. This research will provide an exploration of the capabilities and abilities that are considered as actual efforts for use of stealth in surface combatant vessels as well as providing an insight on how reduced RCS might carry out tremendous varieties of warfare missions. The importance of this paper is focused on the resistance reduction and stealth performance as the requirement process of DFT2 design concept methods.

Keywords: *Trimaran, Ship Concept Model, Resistance Reduction And Wave Making Resistance, And Stealth Performance.*

I. INTRODUCTION AND MOTIVATION

The use of multihull ship (trimaran) on the missions and requirements of the Navies has been continuously developed and run into rapid growth in recent years, leads the Naval architects and Naval engineers to make every efforts on creating new concepts for multihull vessels. Trimaran is a type for multihull vessel comparing it to monohull vessel, and trimaran has more characteristics in few aspects, i.e. efficiency indicating that trimaran has proper peculiarity (features) such as extended deck, lower draft and better transverse stability compared to monohull vessels[2]. In this research, DFT2 is being selected as trimaran vessel for the Union of Comoros, regarding the fact that three hulls are linked to one another, which nowadays arises a lot of significant attention because trimaran has large deck area with shallower-draft (small draft)[2].

This research's main objective is focused in a problem of wave resistance reduction that DFT2 might encounter when operating. In addition to that, the complexity of monohull vessel and trimaran ship can be compared and kept in consideration. This complexity affect the part of the ship resistance excessively, i.e., the interaction between viscous and wave resistance components in a trimaran. To reduce DFT2 wave making resistance, the ship configuration must contain high length to breadth ratio, providing the ship low length to draft ratio allow this present research

ISSN No:-2456-2165

accessing the unreachable area of DFT2 compared to the one of monohull with the same length or dimensions.

DFT2 will not only consider the reduction of ship resistance, enumerate the vessel concept methods, but also stealth performance (Stealth technology). Taking into account the use of stealth technology also known as LO technology, in this research is a way to decrease high level of radar detection. LO technology is a military sub-discipline used during mission tactics, as well as on passive and active electronic countermeasures. Using this technology, DFT2 will include range of methods that will permit the ship to conduct less visibility or being undetectable to radar, infrared, sonar and other detection methods carried out by surface warfare.

The term "soft kill" performance is area for conducting research as it has received an important attention (thoughts) considered as an ongoing effort of expendable chaff systems by decreasing DFT2's radar crass section (RCS) significantly. The chaff cloud will behave as defenses chaff to mask the ship from active radar of distant ships, close-in quick-blooming chaff and flares for confusing radar in activity. In another word, the chaff cloud would become a more attractive target to the missile seeker and therefore more effective at seducing the missile away from the ship[5].

II. CONCEPT OPERATION, CONCEPT EXPLORATION AND CONCEPT DEVELOPMENT

I.1 Concept Operation

DFT2's concept of operations will be based on the Mission Need Statement (MNS) for ship Intelligence Surveillance Reconnaissance (ISR), search and rescue, drug Interdiction and Smuggling, and maintain the safeguard of the country's sea state. The ship must operate from the Naval base on the main island or on each one of the sub-bases located on the other islands, up to the high seas environment. The islands are approximately distanced between 21.6 nautical miles, 43.2 nautical miles, and 108 nautical miles from one island to another. DFT2 must be able to carry on an ISR of about 7 to 10+ days on a coastal zone and littoral, and also 30+ days on high seas [8][10].

The primary DFT mission serviceable areas and capabilities include[8]:

- Port and Coastal Security (PCS)
- Search And Rescue (SAR)
- Drug Interdiction (DRUG)
- Migrant Interdiction (AMIO)
- Protect Living Marine Resources (LMR)
- Other Law Enforcement (OLE)
- Secondary: Defense Readiness (DR)

Life circle or service life for the ship design is projected to be 30 to 40 years. This life circle is an extended timeframe which providing flexibility in improving, maintaining and promoting the ship's capability over time is demanded[7]. Some missions are to consider, it comprises Surface Action Group (SAG), Homeland shield, Self-operation missions, and escort (civilian ships, merchant ships, and commercial ships). The ship will furnish OPs within these mission area such as AAW, ASuW(SUW), GMLS, including ISR and LAMPS. DFT2 will also provide mission operations independently regarding, supporting special operations, search and rescue, humanitarian operations support, and peacetime presence. Table 1 give a simple description of priority capability:

Table 1 Description of priority capability

	Priority capability description	Threshold system (equipment used)
1	Maintain AAW, Guided Missile Launching System (GMLS)	32cell VLS, SRBOC, SLQ-32(V2), 160 cells MK57 + 8 cells KEI, SPS-73 or the Type 751/762 radar
2	Maintain ASuW in deep or shallow waters	1x155m AGS, SPS-73, Small Arms, TISS, FLIR, GFCS, 2x7m
3	Mission package (MP): BT, ASuW, ISR	LCS MP
4	Mobility, LAMPS	25 to 36 knt, 2160 nm and above, 7 to 30+ days, LAMPS haven (flight deck)
5	Survivability and self-defense	Mine detection sonar, CIWS
6	Core ISR (C4ISR with sequences)	C4i system(Enhanced C4ISR / Basic C4ISR)
7	Core ASuW	57 mm gun, 2x50 Caliber gun, 1x155m AGS, SPS-73, Small Arms, TISS, FLIR, GFCS, 2x7m, RHIB, MK46 Mod1 3x CIGS

I.2 Concept Exploration

Trade-off is being conducted through this process and DFT2 design space has been found as well by the use of computing methods such as Matlab software to generate a multiple-objective generic optimization (Brown and Salcedo 2002). On [7] a simple ship synthesis model was used to balance the design, to assess feasibility and calculate cost, risk and effectiveness. In this concept a series of non-dominated frontiers are given as the DFT2 alternative design are classed in the order of cost-risk-effectiveness. A non-dominated frontier (NDF) represents ship designs in the design space that have the highest effectiveness for a given cost and risk[8]. Concept exploration yields one concept baseline design or more than one, which is completed in concept development and preliminary design. Contract design constitute the finishing stage of the full specifications for the ship, which point a contract is made with shipbuilders for the construction of the ship. The last stage of design is done by ship builders in relation with the constructor of the ship, which is the detail design. To complete these five methods, the ship builders (ship designer) and the constructor of the ship can go through 16 to 20 years to complete the work as shown in Figure 1[7].

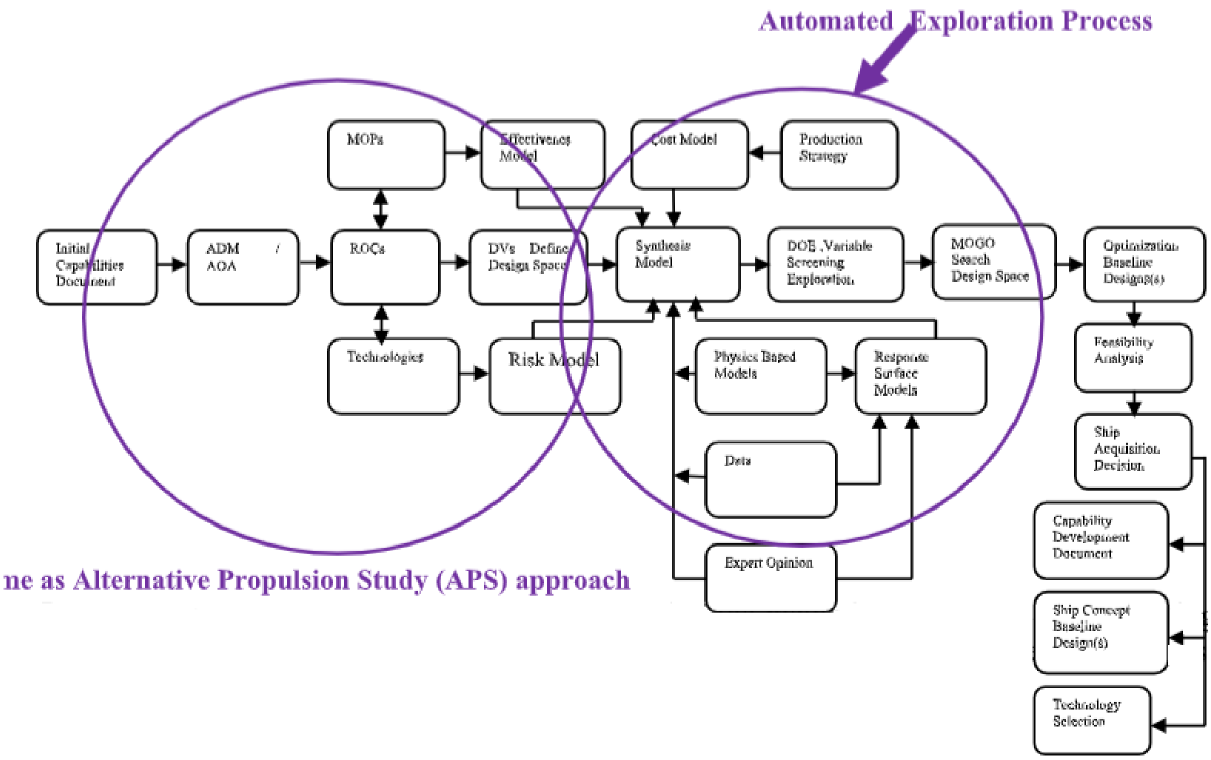

Figure 1 - Concept Exploration (Brozn 2005) [8]

In this process, our point of view is to keep in mind the methods and approach that is being carried out on the design method of ASC vessel, so that developing reference missions, required operational capabilities, identifying applicable technologies and developing an effectiveness model will be carried out. In addition to that, a technology risk model and large design space are defined so that a broad range of technologies with different risk may be considered. The mission scenarios developed are unique to the Design Reference Missions scenario that DFT2 requires Table 2.

Table 2- SAG and *BMD* Mission

Days	**Mission Scenarios**
1 to 2	Cruise from the main base to the other sub-bases/ board crews
3 to 6	Port of call, replenishment forces and embark modules, ASuW, AAW, SY-1, SS-N-22, C-802KD
7 to 12	Carry out ops for AAW, ASuW, and SY-1, SS-N-22, C-802KD
13 to 14	Engage air threat self-defense
15 to 20	POC/ maintenance and repairs
21 to 22	Conduct CIWS/ mine detection and mine avoidance operations
23 to 26	Carry out operations against littoral threats
27 to 29	Engage anti-missile operations (air, surface, and underwater)
30+	POC/ general maintenance,/refueling and replenish forces

I.2.1 Trade-Off Studies, Technologies, concepts, and Design variables

Existing technologies and concepts necessary to provide mandatory functional capabilities are identified and defined in terms of performance, cost, risk, and ship characteristics (weight, area, volume, power). On [8] Trade-off studies are performed using technology and other concept design variables used to select trade-off options in a multi-objective genetic optimization (MOGO) for the total ship design. Form Rhino software (Figure 2) is describing a complete hull form of DFT2, and technology, concept trade spaces, and parameters are described in the following sections.

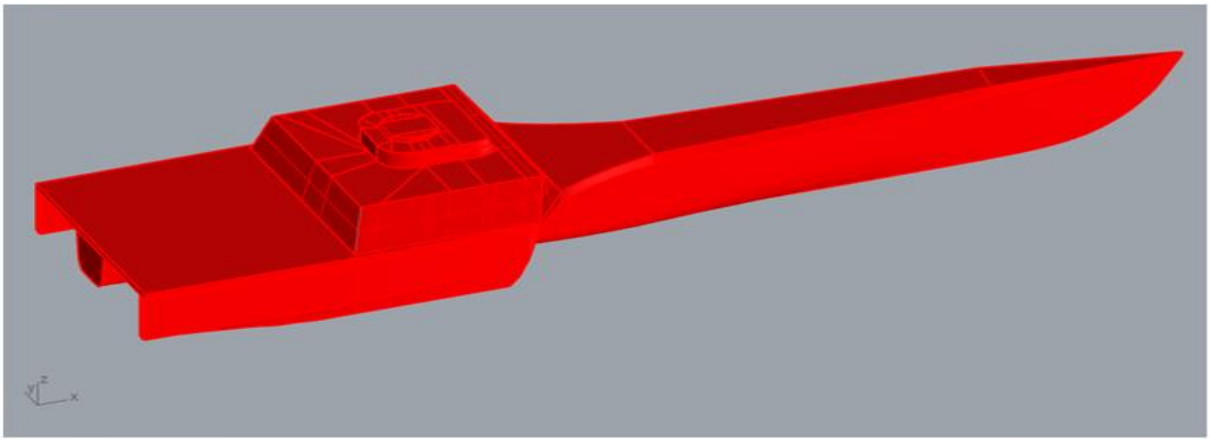

Figure 2 - DFT parent Hull Form (RHNO)

I.2.2 Hull Form Alternatives (HFA)

To get DFT2 hull form, three main non-dimensional numbers are used. They are Transport Efficiency (TE), Transport Factor (TF), and Froude number (Fr). The associated equations are presented on the next page [10] [25].

However, the TF concept was utilized for choosing ship types that can hold a needed load at a high speed. TF is a non-dimensioned between, speed, endurance, and propulsion power, that is estimated by using one of the following equations [4][24]:

$$\mathrm{TF} = \frac{W_{FL}\ V_S}{SHP_{TI}} = \frac{\left(W_{LS} + W_{Fuel} + W_{Cargo}\right)V_S}{SHP_{TI}}$$

$$\mathrm{TF} = \left(5.052\frac{KW}{MT \times Knt}\right)\frac{\Delta V_S}{WPR} = 30.7@25knt$$

Therefore, the following Table 5 enumerate the hullform from preliminary assessment, which provide result to conclude the hullform estimation from different comparisons.

	Table 5-Hullform Preliminary Assessment Summary							
	RCS	Cost	Hull length	Seakeeping stability	Large compartment for machinery space	Reliability	Helicopter mission and others	Total assessment
Catamarans	2	2	2	3	3	4	3	19
Mono-hulls	4	4	3	2	3	3	3	22
Surface effect ships	3	3	1	1	2	2	1	13
Trimarans	2	2	3	4	4	4	4	23

I.2.3 DFT2 Hull Form Concept Exploration Design Space Summary

The following **Table 6** summarizes the hull form design space for DFT2 after assessment and calculation.

Table 6 – Baseline Hullform Characteristics	
Hull Form Type	Trimaran
Displacement (Mt)	907.185-1814.369 (Mt)
L	80-100 m
B	19.24-24.411 m
D	4.8 - 10.4m
T	4.8 - 10.4m
C_P	0.45-0.53
C_X	0.65-0.74
C_{RD}	0.7-1.0

I.2.4 Machinery Plant Alternatives

Power transmission, power plant, and propulsor (thruster) alternatives options are well thought-out in the process of DFT2 ship design throughout this section.

The vessel is provided by two power transmission alternatives: In (1) is a mechanical drive system, from which the main engines are joined to the propulsor in a way of a traditional reduction gear with a turbo generator to increase power; the second in (2) is an integrated power system (IPS), which is a power plant that will conducts the generators, and allows the ship to acquire electricity supplying to the power motors (advanced AC induction motors) joined with the propulsors. The mechanical driving system will concentrate on the currently standard on all Chinese Navy conventional combatants, also using the IPS as it can guarantee more flexibility and easier maintenance, and grasps the support of Navies for future projects. The mission of DFT2 demands that the ship must be capable to carry out operations at high speeds, so a high power performance and density configuration is needed and necessary. In addition to that not only alternatives with gas turbine engines will be considered but also diesel engines will be kept in mind to be used as shown in the following figure.

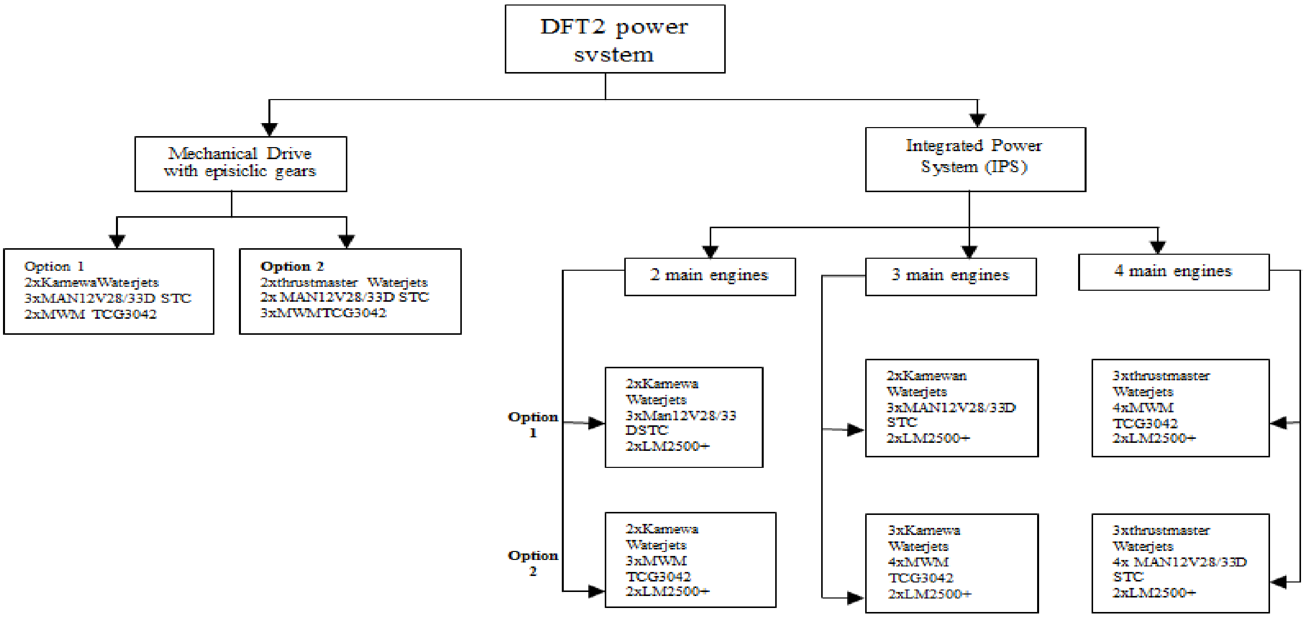

Figure 3 - DFT Propulsion Trade -Off Alternatives

I.3 Concept Development

Concept Development of DFT2 is in succession after Concept Exploration, from which follows the design spiral as shown in Figure 3, providing better understanding. Ship arrangements, systems, the general concepts for the ship's hull are developed in this section (Concept Development). These general concepts are created and enhanced into detailed systems and subsystems that meet the requirements of DFT2 needs. The analysis and parametric utilized in Concept Exploration are consideered to reduce the design risk.

Once the objectives, missions and requirements are identified in Concept Exploration the Concept Development immediately follows. The design spiral for Concept Development, Figure 3, iterates through the hull, subdivisions, arrangements, power and propulsion, structures, weights, seakeeping, and cost. DFT2 must meet the objectives and requirements obtained in Concept Development, listed in the baseline design principle characteristics. Concept Development explore further into the values gathered in Concept Exploration by means of refining the results obtained, matching the volume requirements, gratifying the missions, keeping in consideration the conformity of the standards set by CCG (Comoros Government).

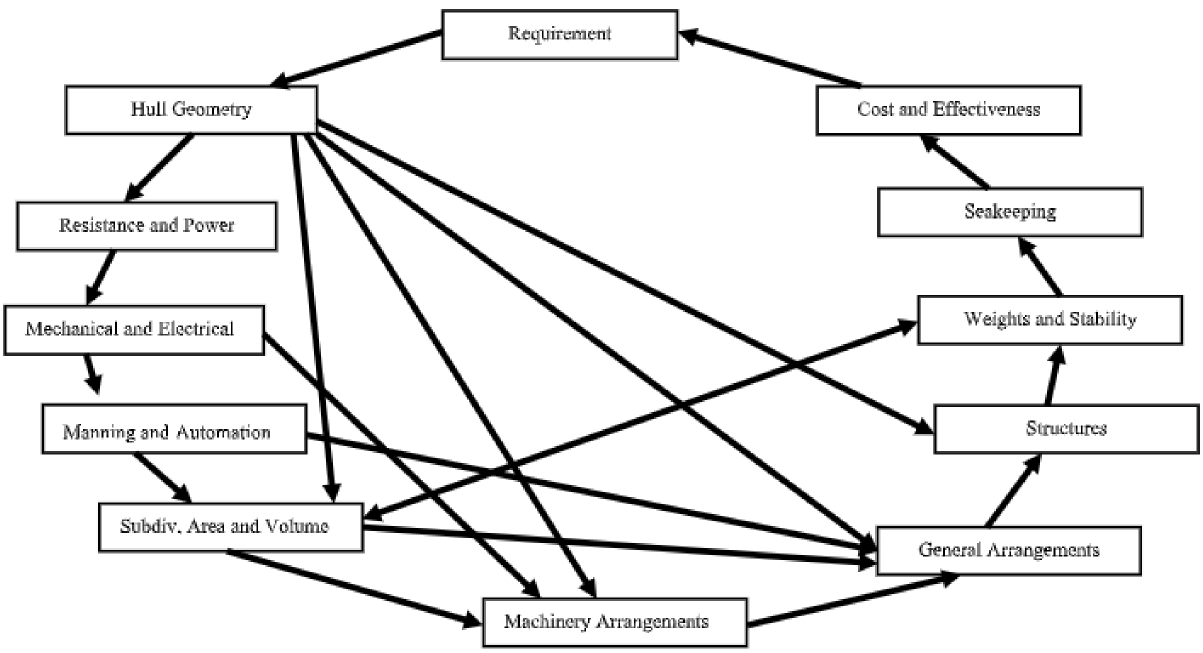

Figure 4 - Concept Development Design Spiral [2]

I.3.1 GENERAL ARRANGEMENT AND MISSION OPERATIONS CONCEPT (CARTOON)

Finalizing deck house geometry, all general arrangements, and hull form geometry that is carried out on the preliminary step, a ship cartoon arrangement was developed for areas supporting mission operations, propulsion, and other critical constrained functions. HELIC, and LAMPS operations and support where primary considerations are well thought-out for the ship arrangement development. The dimensions of the HELIC, and LAMPS, and their required equipments for operations and supports are based on the most accurate data available (gathered). These dimensions were used to arrange combat alternatives in the hangar and mission bay areas. Scaled layouts of the hangar, flight deck, and the mission bay areas are shown in Figure 5 to 11.

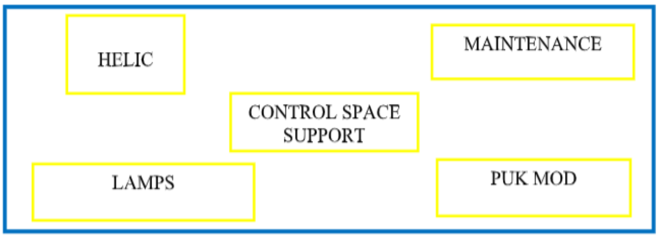

Figure 5 - Hangar Bay Lower Level Arrangement

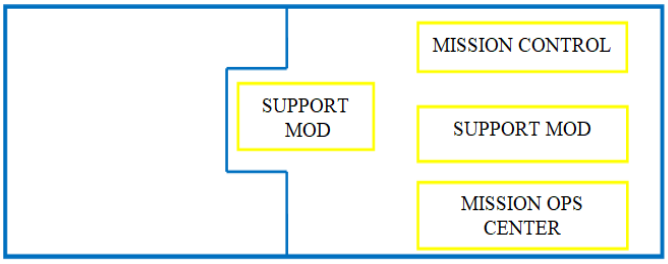

Figure 6 - Hangar Bay Upper Level Arrangement

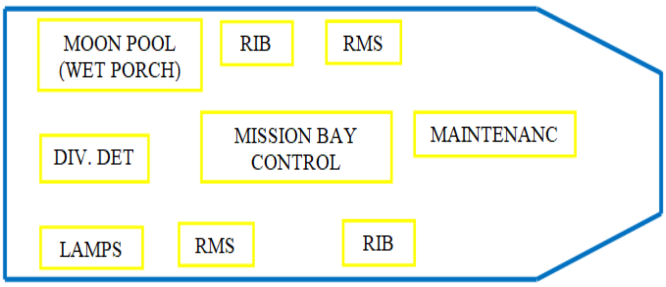

Figure 7 - Mission bay Arrangement

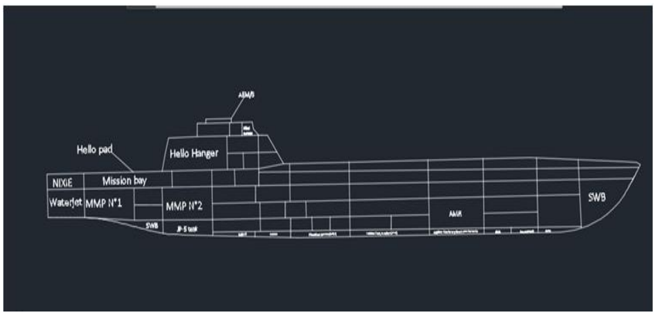
Figure 8 - Profile view (Cartoon AutoCAD)

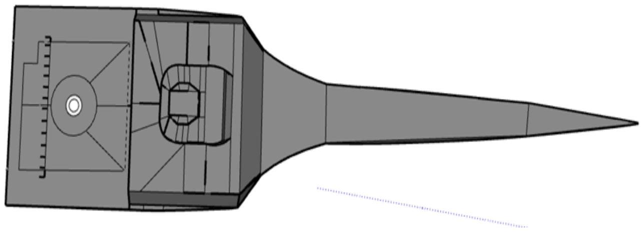
Figure 9 - Top side view (Skechup)

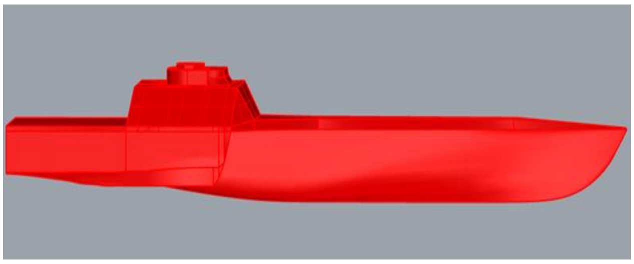
Figure 10 - Front side view

I.3.2 Machinery Room Arrangements

Two Main Machinery Rooms (MMRs) were selected to be arranged, MMR N°1 and MMR N°2, also an Auxiliary Machinery Room (AMR) is being considered. Each of the two MMRs is prepared for caring out one main engine (LM2500+) with one generator plant MWM TCG3042, and the third gen set (Man12V28/33DSTC) is located in the AMR. The MMRs are situated at (1) aft amidships and the MMRN°1in it, and (2) at forward amidships arranged for the installation of MMRN°2, where the inlets and exhausts air are structured on the ship sides. The main aim of the sides air inlets and exhausts is to avoid the protrusions on the flight deck and the impacts on the available area in the mission bay, which would be affected if top exhausts were to be used.

I.4 HULL FORM AND DECK HOUSE

I.4.1 Hull form

The baseline hullform performed through the Concept Exploration is a modification carried out on the basis of the given parent hullform (name classified). In Concept Development, on the one hand this baseline hullform is being changed and personalized by increasing the transom to give a space for laying down the waterjets, due to the fact that the parent hullform is containing propellers. On the other hand some parts were to be kept all along the process this include the center hull beam, the distance between the outer hulls and center hull, creating a stable top deck of the aft of the ship for a weight reduction. To be able to consider these changes, the hull form dimensions are to be re-optimized and balanced. A comparison is being carried out to highlight the concept development of DFT2 hullform with the baseline hullform as shown in Table 7.

Table 7 - DFT Hullform Characteristics

	Baseline	DFT
LWL	141.243 m	97,724 m
B	24,411 m	29,966 m
T	4.368 m	4,027m
D_{10}	11.240 m	10.020 m
□	1608 MT	964,9 MT

I.4.2 Deck house

The deck house is arranged for flight control, chart room, aviation hangar, and the bridge, from which LAMPS, HELIC, and their modules for support and holders are laid down. The bridge (pilot house) is located in the forward upper middle of the deckhouse as Figure 12 enumerates the bridge location, where a good and strategic position for acquiring a necessary forward visibility. On the aft end of the deck house is arranged the Flight and Recovery Control (FARC) department, where the main purpose is to provide supports to the LAMPS and HELIC operations. An Advanced Enclosed Mast/Sensor (AEM/S) for DFT2 from which Radar and the different antennas are set up within it, is located on the top forward of the bridge (deckhouse) as shown in Figure 13 which is displaying a profile view of the AEM/S located on the deck elevation.

A Surface Search Radar (SSR) responsible of the navigation and surveillance by means of configuration for DFT2 applications, and a radar video from consoles display that provides a means of performing manual radar search, and detection and tracking functions is considered. This radar can either be the SPS-73 or the Type 751/762 radar incorporated within the AEM/S encloses the upper deck. The SPS-73 or the Type 751/762 volume will be controlling the ship's deck height and width. A Powerful shipboard Protection as a SLQ-32 EW system located on the lower deck of AEM/S providing early warning, early identification, with a direct finding capability for simultaneous multiple threats which. The upper deck right side internal shell of AEM/S is appointed with an advanced hybrid frequency-selective surface that allows the ship's own radar in and out, but not foreign radar[10].

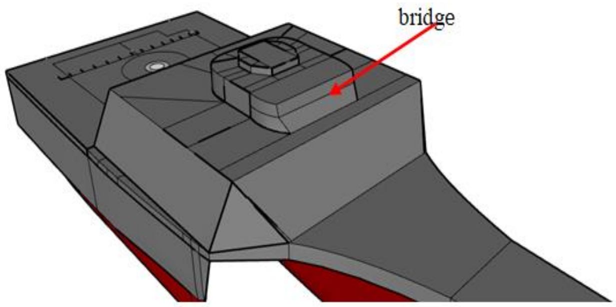

Figure 12 - Bridge location (Sketchup)

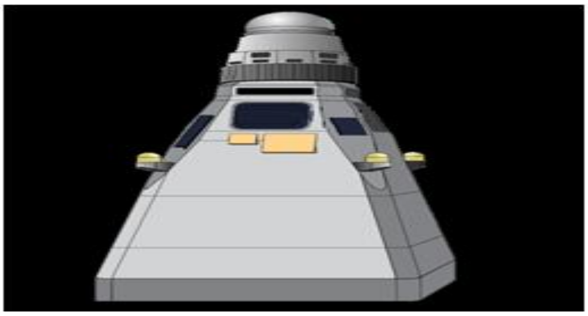

Figure 13 - AEM/S

III. RESISTANCE REDUCTION AND WAVE MAKING RESISTANCE

II.1. Ship resistance

Ship resistance can be defined as a force required to drag (tow) the ship without interference from pulling ship, this resistance is characterized by a combination of four resistance and can be specified as[34]:

- Frictional resistance, which occurs when the ship hull and the viscous fluid are wrapped up with a friction layer formation
- Wave making resistance, which is generally characterized by the creation of waves at free surface due to the energy transferred by the ship
- Eddy resistance, this is described as the flow separation that occurs due to non-streamline flow at the ship stern
- Air resistance, which is described as the load which the windage area of hull and superstructure experience from the wind

The sum of Wave making resistance and eddy resistance is known as residuary resistance, and apart from the above stated, the following statements are also considered in this section for ship resistance[34]:

- Waves and the wave breaking resistance
- Resistance for a ship sailing in a seaway
- Resistance due to ship's turning
- Shallow water resistance

The frictional resistance component is calculated on the basis of Reynolds number and wetted surface area together with a hull roughness allowance. EHP = ACT (VS) ^3, (A →Wetted Surface Area)

II.2. Resistance reduction

For a general understanding on the above mentioned, this section will provide ways on how DFT2 resistance is possible to be reduced. Firstly, considering Bülent danişman , Ömer gören , and Sander çalişal (2002), resistance reduction of the ship is possible by means of *raising (increasing) the beam* whereas smoothing the shoulders of the ship in a moderate way with a relative increased Froude numbers, more detail in the following sections. Then, a mathematical justification carried out, by the method of Michell's integral, providing details on the concept of *parabolization of the ship waterlines* by increasing the beam (resulting to a reduction of the parallel middle-body) leading to a decrease of the wave resistance in the Froude number region, assumed to be ranged between approximately, $0.2 < Fn < 0.4$[27].

II.2.1. Theoretical background

During the preliminary steps of the theoretical analysis , mathematical analysis were performed for the effect of the beam increment on the wave resistance using Michell's integral theory. To decrease the fluid flow (wave making resistance) to a steady state case, a coordinate system fixed with respect to the ship is set up, as the origin is amidships with the x-axis positive towards the motion's direction. Assuming the vessel is at stationary, where a velocity in uniform flow (c) equally to that of DFT2 superimposed (laid over), located on the negative x-direction, and expressed by the following expressions:

$$\bar{u}=c+u;\ \bar{v}=v;\ \bar{w}=w$$

A numerical model is being considered in the process of calculating the reduction of the ship wave making resistance, for this purpose a simplification was conducted by considering the wall-sided of the ship model with a parallel middle-body in the interval –L/4 < x < L/4 with parabolic waterlines along the complete length of the hull. The following equations are one of the form of Michell's integral, and can be expressed as:

$$R = \frac{4\rho g 2}{\pi c^2}\int_1^{\infty}\frac{\lambda^2}{\sqrt{\lambda^2-1}}[P^2(\lambda)+Q^2(\lambda)d\lambda] \quad (1)$$

where

$$P(\lambda) = \int\int f_x(x,y)\exp\left(\frac{g\lambda^2}{c^2}y\right)cos\left(\frac{g\lambda}{c^2}x\right)dxdy \quad (2)$$

$$Q(\lambda) = \int\int f_x(x,y)\exp\left(\frac{g\lambda^2}{c^2}y\right)sin\left(\frac{g\lambda}{c^2}x\right)dxdy \quad (3)$$

c ⟶ Ship's speed
ρ ⟶ Water density
g ⟶ Gravitational acceleration

if the restriction of the tangent plane of DFT2 surface is introduced, and makes a small angle with the xz-plane, that means, $\frac{\delta g}{\delta x} \ll 1$; $\frac{\delta g}{\delta z} \ll 1$, this lead us to two equations of the boundary condition on the surface of the ship as follow:

$$\frac{\delta\Phi}{\delta y} = c\frac{\delta g}{\delta x} = cf(x,z); y = g(x,z)$$

or

$$\frac{\delta\phi}{\delta y} = cf(x,z); y = 0$$

To formulate a unique solution considering the above equations, additional boundaries (restrictions) must be initiated as the DFT2 is assumed to move forward into still water, and it will be taken that the waves are trailing aft. furthermore, the perturbation velocities are zero at infinite depth. the velocity potential ϕ must therefore satisfy the following requirement:

- $\nabla_\varphi^2 = 0;\ -\infty < x < \infty;\ 0 \le y < \infty;\ 0 \le z < \infty$
- $\frac{\delta^2\varphi}{\delta x^2} = \frac{g}{c^2}\frac{\delta\varphi}{\delta z} = 0; z = 0;\ -\infty < x < \infty;\ 0 < y < \infty$
- $\frac{\delta\varphi}{\delta y} = cf(x,y); y = 0;\ -\infty < x < \infty;\ Z \ge 0$
- $z \Rightarrow \infty;\ \varphi = 0$
- $x \Rightarrow +\infty;\ \varphi = 0$
- $y \Rightarrow \mp\infty;\ \varphi = 0; -\infty < x < \infty; Z \ge 0$

The details of (1) to (3) are also found in Wehausen and Laitone (1960). Where an assumption of a shallow draft to reduce the effect of the exponential term in P and Q functions is being considered. The function Q consist of the integrals for the aft (sometimes taken as the bow) and stern regions, without contribution from the parallel middle-body.

Furthermore, the wave resistance may either increase or decrease depending on the value of Q by addition of parabolic waterlines which in turn increase the beam and the parallel middle-body, λ values as far as they vary and when Q is negative, this will cause the wave resistance to decrease. For further understanding, Çalışal et al. (2002) simplifies this numerical model, where a decrease in wave resistance was obtained in the Froude number range of 0.2 < Fr < 0.4[27].

II.3. Accuracy of CFD

II.3.1. Model and experimental setup

In this section, Maxsurf software is used to provide wave making resistance analysis, and resistance results acting on the ship. The analysis results denote an understanding on the experimental to validate the ship study results. Table 8 shows DFT2 model particularities used for the experimental (analysis).

Table 8. Principal Particulars of Ship Model

Name	DFT2 Model	Unit
Length, (L)	100	m
Breadth, (B)	24	m
Depth, (D)	6,738	m
Draft, (T)	4,027	m
Block coefficient, (C_b)	0,549	-
Wind velocity, (V)	14.50	m/s
Wind attack angle	0-180	degree

II.3.2. Computational analysis

In this part three computational tools will be kept in consideration, 1) a tool for calculation wave resistance characteristics. This will be carried out through the Maxsurf software, from which a slender body analysis and hull resistance curve as shown in the following figures. 2) a calculation of a boundary layer flow or a viscous flow calculation providing a form factor variation results, 3) a total resistance coefficient (Total free surface resistance coefficient) calculation of the vessel highlighting the results of the total resistance coefficient vs the ship speed, as Figure 16 demonstrates.

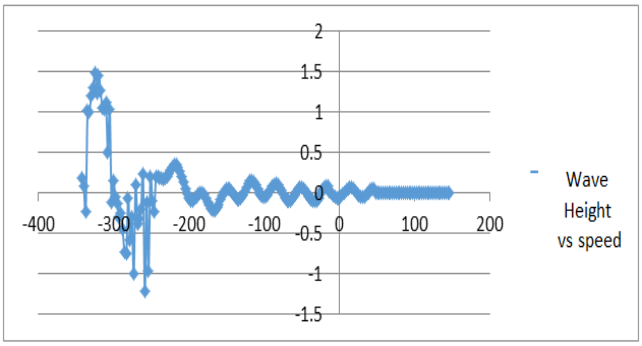

Figure 14- Slender body analysis and hull resistance curve

ISSN No:-2456-2165

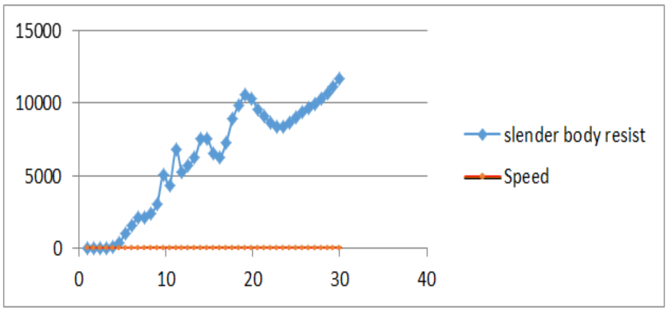

Figure 15- Slender body resistance vs speed curve

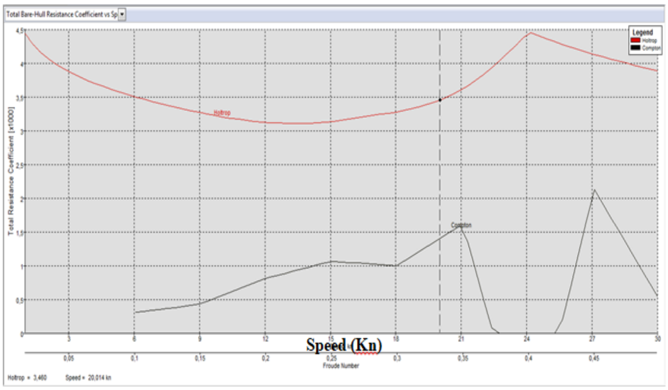

Figure 16- Tatal Resistance coefficient vs speed curve

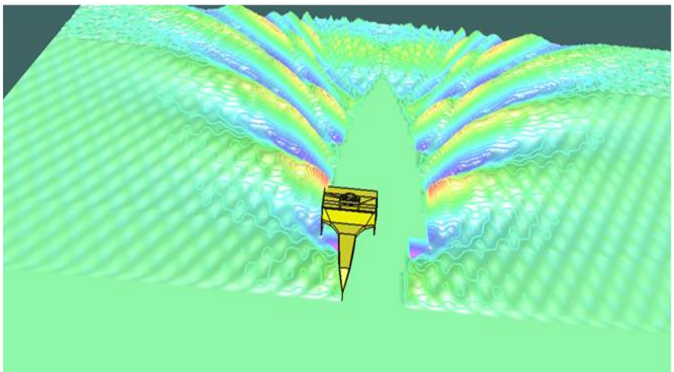

Figure 17- Wave making resistance (Maxsurf)

IV. STEALTH PERFORMANCE

III.1. Stealth in a surface warship

Stealth (steal technology) is a military tactics and passive and active electronic countermeasures known as sub-discipline, where in the current days stealth in not something new to naval warfare. As mankind continue to develop the idea of hiding from enemies for centuries by using the vast area of the ocean, this has led Navy ships to rely on stealth technology (LO technology) to avoid detection, hide from enemy attack, and also conduct the enemy to a level of tiring position so as to conduct a surprise attack on enemy vessels.

Different methods can be applied for developing specific shape for DFT2 that will decrease detection by redirecting electromagnetic radiation waves from radars, this leads this section to provide some methodologies usable for the enhancement of DFT2 stealth:

A) "Low observable" Signatures

The use of LO technology, is among of the methods applied in the paper by means of reducing DFT2 RCS to the minimum level as that of a deployed active decoy known as chaff cloud. In theory, chaff cloud draw targets to the missile seeker leading to redirecting the missile away from the ship. DFT2 is gas turbine surface combatant that possess five diverse signature emission, DFT2 utilizes Radars from which electromagnetic radiation waves are emitted, the shape of the ship also is a source of emitting signatures that conduct the vessel to a detection mode and therefore provide an advantage to the enemy to attack. The different signatures given in this section has to be reduced to provide the result of stealth required for the ship. The following points are methods or ways carried out through this section to improve DFT2 stealth performance:

B) Radar Cross Section (RCB):

RCS is being defined in regard to Merrill i. Skolnik [44] as *"The radar cross section of a target is the (fictional) area* symbolized as (σ measured in m²) *intercepting that amount of power which, when scattered equally in all directions, produces an echo at the radar equal to that from the target".* This means that the RCS area is going to be bigger than that of the actual geometric area, caused by radar energy reflected by the ship and, "...influenced by the size of the ship, its angular orientation, the absorption coefficient of the materials from which it is constructed, and by the frequency of the illuminating radar[45]."

Despite the fact that DFT2 might have an ability of reproduce radar energy, individual parts of the superstructure and smaller objects also replicate energy separately because of shape of each object (gunmounts, radar antennas, lifeline stanchions and deck lockers) once their sizes and orientations are directed to the incoming radar energy. Mathematically, a radar range calculation can be adopted to give an approximation on how to decrease RCS, this is given by the following equations.

$\sigma = A_P \text{ x } R \text{ x } D$

$$R_{fs} = \left[\frac{P_P.G^2.\sigma.\lambda^2}{(4\pi)^3.K.T_0.B.F_n.(S/N).L_S}\right]^{1/4} \qquad (4)$$

Where:

A_P → The projected object surface

R → Reflectivity, re-radiated fraction of intercepted power by the target

D → Directivity, ratio of the maximum intensity of the radiator to the intensity of an isotropic source

R_{fs} → Maximum Detection Range

PP→ Peak Power

G → Transmitter/Receiver Gain (usually the same for monostaticradar)

λ → Wavelength of Radar Frequency = $\frac{c}{f_0}$, (c → speed of light, f_o →radar operating frequency

σ → Radar Cross-Section of Target

k → Boltzmann's Constant (1.38×10−23 J/K)

T_O→ Temperature of Radar (in Kelvin)

B → Radar Bandwidth= $\frac{1}{\tau}$, (τ→radar pulse width)

F →Noise Figure of Radar Receiver
L → Radar Losses
S/N →Radar Threshold for Detection

The result of these equations provide an understanding on how proportional the detection range(R_{fs}) of a radar can be towards RCS of the target having a power of ¼ or σ¼. In another word the range is proportional to the fourth root of RCS. In symbols, $Range = k \times \sqrt[4]{RCS}$, where k is a constant that depends on the radar and the situation[45]..

This gives as the ability to conclude on the reduction of RCS, i.e. by reducing the RCS in 30000 times, the detection range will be reduced to 30 times, hence DFT2 stealth enhancement on the reduction of the RCS is possible. As a result the vessel can carry out its mission without being discovered. To make this understandable an example is being conducted from (KoK and Steven Loke Yew) is shown below[43].

Example:
An Electrical and Electronics Engineers (IEEE) C-band radar with the following parameters:
Peak Power, *PT* = 1.5 MW
Antenna Gain, *G* = 45 dB
Operating Frequency, f_o = 5.6GHz
Wavelength, $\lambda = \frac{c}{f_0} = \frac{3\times10^8}{5.6\times10^9} = 0.053571\,m$
Radar Temperature, *To* = 290K
Pulse Width, τ = 0.2 µs
Radar Band width, $B = \frac{1}{\tau} = \frac{1}{0.2\times10^{-6}} = 5MHz$
RCS, σ = 100000 m^2
Noise Figure, *F* = 3 dB
Radar Losses, *L* = 6 db
Radar Threshold Detection *S/N* = 20 dB

By utilizing the equation, (4) and breaking the above parameters and converting them in to dB unit, the equation becomes:
$(R^4)dB = (P_T + G^2 + \lambda^2 + \sigma - kT_oB - (4\pi)3 - F - S/N_{min})dB$

The following table represent the calculating of each individual parameters in dB:

Table 9- dB calculating results

P_P	G^2	λ^2	$(4\pi)^3$	F	kT_oB	S/N(S/N)	KT_oB	σ
61.7609	90	-25.4213	-136.9875	32.9763	3	6	20	50

Equation (5) gives the followings:

$R^4 = 61.7609 + 90 – 25.4213 + 50 + 136.9875 – 32.9763 – 3 – 6 – 20$
$= 251.3508\ dB = 1.3648 \times 10^{25}\ m^4$ (1)

$R = \sqrt[4]{1.3648 \times 10^{25}} = 1922.06$ Km

By decreasing RCS up to 10dB or 10m^2, (1) becomes:

$R^4 = 251.3508 - 10 = 241.3508dB = 1.3648 \times 10^{21}\ m^4$
$\rightarrow \quad R = \sqrt[4]{1.3648 \times 10^{21}} = 192.206$ Km

DFT2 stealth will consider the use of Radiation-absorbent material (RAM), which is a Radiation-absorbent material, this will suck up (absorb) the emitted energy from an enemy vessel or aircraft radar emitting into the coating of the RAM and will change it to heat instead of reflected it back. Figure 18 represent a radar absorbent material utilized on a stealth bomber skin.

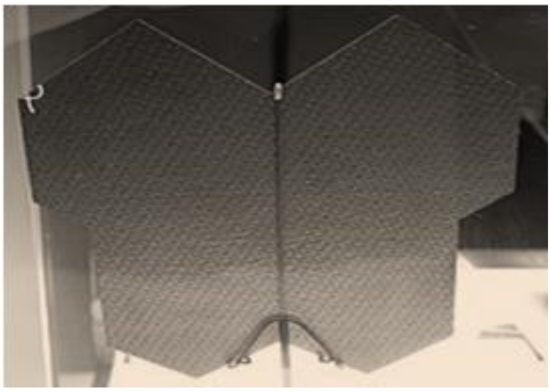

Figure18-B-2 bomber Skin (wikipedia)

2. *Infra-red (IR):* thermal radiation located in electromagnetic range is able to IR signal, this signal is emitted particularly in the Middle IR spectrum. "This region corresponds to a heat source temperature between 500 and 1000 degrees Kelvin[5]. " The inlet and exhaust gases releases high temperatures ranged at approximately 750 degrees Kelvin that emitting a radiation strongly in the MIR region, therefore, the level of IR radiation in that areas covers 2 percent of the ship's total surface and can produce 99 percent of a total MIR of the ship signature. "It is important to note that it is these concentrated MIR sources which serve to attract anti-ship missiles with IR or dual mode (IR/radar) seekers." Decrease and camouflage the concentrated heat in the ship's machinery exhausts is primarily important for a well enhanced stealth of DFT2.

3. *Acoustic:* The creation of sound waves which can occur internally or externally of the water have an ability to travel through the water or the air, and might be collected by a hydrophone which result to an acoustic noise. This noise in is also known as an acoustic signature of the ship formed by a combination of all the sounds creation from the machinery (i.e. machinery noise, propeller noise "if in use", hydrodynamic noise, and if any, the ship's sonar noise, and so on). DFT2 acoustic signature can be decreased by utilizing or adopting the following methods in two areas. At first, the passive sonar detection can be reduced as the ship can ship generate noise in a certain level that should be lowered or masked from

transmitting its signature to the surrounding. Secondly, during active sonar activities, a reduction of the reflection created by the ship known as the sound reflection (Target Strength)has to be carried out. Figure 19 provide an understanding on the propagation of acoustic noise developed by the machinery equipments in the ship.

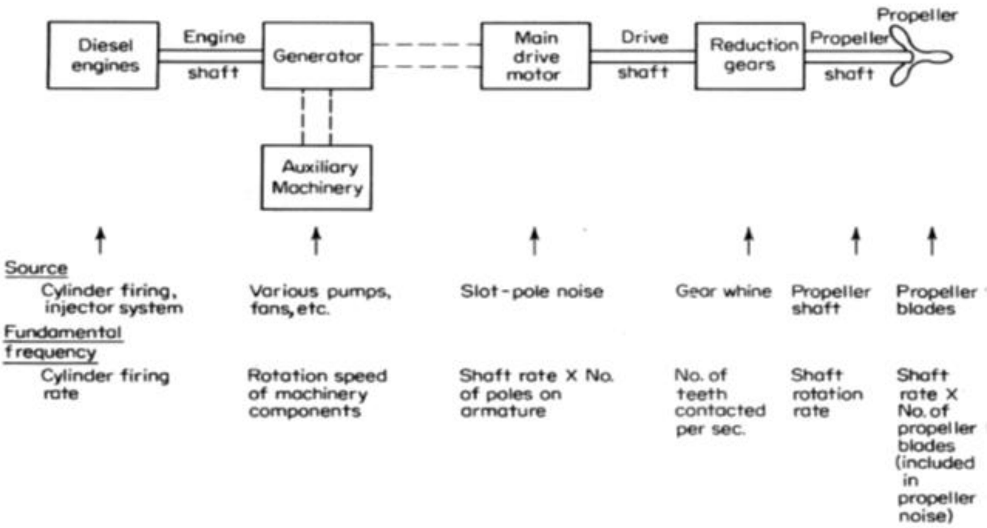

Figure 19- Machinery Noise Sources on a Diesel-electric Vessel From[43]

4. *Electronic:* Signatures are emitted by active electronic producers

That are propagating their signatures into the atmosphere. The primary way of reducing or decreasing electronic signature is to quiet or silence by means of turning off the equipments (EMCON); nonetheless, the ship will automatically lose all active detection and radio communications capabilities.

3. *Visual:* Big ships are easy to be detected through human naked eyes in the day light due to the size. A ship's wake is visually detectable from the air and from space; the wake has a surprisingly long persistence[5].

V. CONCLUSION

The present paper offers study methods on the improvement of stealth performance of DFT2, ship resistance reduction, through different Concepts regarding Concept Operation, Concept Exploration, and Concept Development study by considering the design space optimization that is being carried out using different software such as Maxsurf, Rhino, Sketchup, and AutoCAD. The main goal for this paper is the study of DFT2 concepts design, resistance rection including wave resistance, and stealth technology perfomance.

Methods to reduce DFT2 resistance, were in general was found by the utilization of interaction effects between the main hull and the deck hull for wave resistance reduction using Computational analysis. Additionally, the reduction of wave resistance being among of the methods considered in this paper, where the attention was to focused on the form factor change for viscous resistance, to the impact of parabolization on seakeeping, added resistance, and so on. Furthermore, Stealth performance is among the main key carried out through this paper.

However, stealth design rely on physics and experience in the surroundings of a logic experience-based and physics-based, and rules of thumb as well. These logics are somehow not sufficient of reaching far in the designing concept of stealthy vessel. "Stealth engineers need very highly sophisticated computational models and a great deal of measured data for input to them. These allow them to simulate in the computer the RCS signatures of the designs their envision and recognize where changes are needed. "

Finally, this paper provide a probability of DFT2 to acquire the perfect resistance, stealth enhancement by going through the different ship design concepts, that will allow CCG to conduct their assigned missions accurately.

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