"DOLPHIN"

Genesis or The birth of the project

In the end of the 50's, following endless debates argues and effort the Israeli Submarine flotilla was established when the Israeli Navy (IN) purchased from the British Navy two old, WWII, "S" class submarines.
The second generation was comprised of three second-hand "T" - conversion class also been bought from the British, which one of them, the I.N.S. "DAKAR", had been lost in the Mediterranean on it's way to Haifa.
A substantial change occurred in the third generation in the early 70's when Vickers Shipyards in Barrow, England, built three new "GAL" class submarines based on existing and proved German design (IKL). No more second-hand boats but still on the safe side of existing submarines in a friendly navy.
By that time the IN gained an important operational and technical experience, which could lead to a further step of having, it's own development of a modern submarine.
This means that the Navy can suit and "tailor" the submarine capabilities to the operational requirements, which derived out of the arena and the enemy you are about to face.
So as for the forth generation of submarines in the IN, it is for the first time when the Navy have the opportunity to design and develop its own boat in accordance to its needs and operational requirements - the ultimate under-water combat system.
As early as 1984 the IN started with the so-called "Concept design" involving the Dutch Wilton - Fejnord and the German IKL companies and later in 1986 the preliminary design had started.
At those early stages the Navy had the "SAAR 5" program running in parallel and the main activity on the submarine subject was executed both in Germany (IKL, Lübek) concerning the platform and US (Rockwell, California) as for the combat systems.
The ambitious modernization program of the Navy urgently needs a creative solution, which would enable the US funds and still select a capable and experienced shipyard in the conventional submarines.

On October '88 the negotiation with the German Consortium (HDW, Kiel & TNSW, Emden) had started in New York, not before several delegations paid a visit to the IN and investigated the actual needs and operational capabilities. Among them were RADM Durby of the JCS and Mr. Dov Zackheim ('85 and '86 respectively).
Meanwhile in the IDF and the Defense Ministry there is furious debate with regard of the national priority of the program in general and the submarines in particular.
Finally Defense Minister Rabin approve the submarine program on July '89 and as a result the contract is signed in New York on August 25th.
Early in 1990 there was the struggle on the Combat system selection, which had won by the companies Loral & Kropp-Atlas.
Heavy pressure of the IDF combined with budgetary burden leads Defense Minister Arens, on November 30th '90, to a regretful and unfortunate decision to terminate the submarine contract. In spite of several Ministers resistance to Arens' termination of the program, PM Shamir except the rule and make it final... but not for long.

The unexpected assistance

On January 15th 1991 the Gulf War broke out and the next day Israel experienced for the first time the long distance ballistic missiles attack on its civilian population.
An Israeli delegation is sent to Germany and late at night on January 30th Chancellor Kohl approves an assistance package including the construction of two Dolphin submarines. The project is again on its way and the contract is rewritten and signed on April '91.
It was not before '93 when the IN command stated its policy and priority in such manner that could result in terms of contract amendment on April '94 which actually added the third boat to the scope of work.
The first of class was launched and named in Emden on April 15th '96 and the third on July 9th '98.
All along the project a Navy staff comprised of experienced submariners and engineers were posted as inspection team in all major locations of activities.

INS "Dolphin" on surface, during sea trails

As early as Sub-Con '95, very well organized by the German industry in Kiel, we could sense that the "Dolphin" is about to be a leading submarine, representing a state of the art technology and fulfill highly crossbar of operational demands and requirements.

The Operational Concept

Israel has a long coast along the eastern edge of the Mediterranean considered to be a strategic asset, the only open free gate to the western world. No nation would voluntarily give up such an asset of an open sea with its two facets, the surface as well as the under-water domain. Obviously it should be on the Israeli agenda as well.
In the mid 80's the existing submarines in service were about to commence the mid-life conversion and in combat we were about to face already exist as well as future threats like the ASW Helicopters and long range ASW capabilities. This situation

dictated up grading of the submarine force, which led to a new type of boat.
The classic submarine tasks may be defined as follow:

a) Destruction of enemy vessels.
b) Blockade capability of enemy ports or shipping lanes.
c) Intelligence gathering.
d) Transference combat activities to enemy's homeports.
e) Assistance and support to other forces.

The Israeli Navy is no differing from all other navies.
Taking into account the arena and the threats we are about to face, it was necessary to extend the submarine capability to stay submerged and still keep maximum combat readiness.
The transit average speed of advance (SOA) normally would limit the boat and might cause a situation of "missing the action". Therefore the submarine has to be able to reach long distance destinations at a shortest possible time in a maximum discrete manner.
Extending the submarine capability to stay in the enemy waters would save unproductive transits as well as increasing the operational flexibility in combat scenarios. Hence we ought to increase the engagement capabilities by having more torpedoes and missiles to a greater range. The availability of the weapon is, among other factors, a function of number of tubes, variety of armament and capability of quick reliable reload.
Aiming a design goal of greater survivability in an environment of modern ASW platforms and Helicopters it is bound to reduce drastically the indiscretion rate which means less time snorting for more SOA in a lower level of self-noise.
Using modern long-range weapons dictates also long range detection and classification capabilities to maximize the advantages derived from the armament in use. It means, among other features, long range low-frequency sonar and great effort to keep low level of self-noise at all modes of operation.
Increasing the efficiency of the crew can be obtained by setting higher degree of reliable automation as well as considerable improvement in their living conditions.
The modular design of major systems would enable future growth in accordance to new operational requirements, which expected to arise along the submarine service.

As all the above mentioned considerations might lead to a much larger displacement, yet there are some arena features force the designer to give a great deal of attention and priority to high maneuverability in constrained shallow water which means limited submarine displacement. Let alone this constrain would also serve the requirement for high degree of survivability as well as low target strength to stay undetected.
Having said that we can summarize the operational requirements and the design goals of the submarine as follow:

a) Extend the submarine capability to stay ***submerge*** with ***maximum combat readiness*** and capabilities.
b) Extend the boat ***endurance at sea***.
c) Extend the ***operational range*** while shortening the transit period to given destination.
d) Considerable improvement of ***indiscretion rate***.
e) Extend the submarine ***range and availability of engagement*** (torpedoes & missiles).
f) ***Integrated Combat and platform*** system to a greater efficiency with for ***future growth*** capability.
g) Reliable Platform ***Automation*** system, to increase crew efficiency and safety operation.

As one may conclude having all these requirements in consideration was an enormous challenge of achieving maximum design goals in a minimum space and volume.

<u>Combat system:</u>

The combat system should be considered as the heart of the "stealth machine" while all other platform systems have to serve the purpose of positioning the boat in the right place, at the right time at the adequate depth. By that it will be possible to extract the submarine advantage upon its opponent and achieve the ultimate superiority.
The more integrated and sophisticated the combat system is, more likely it would support decision-making process of the commanding officer and the attack team. Moreover, integrated system accelerate the process detection and classification thus give an early warning of possible threats which helps to avoid being detected, able to fulfill its task.
Hence, despite all technology sophistication the end result very much depends on the command-team capabilities to monitor

control and "criticize" the computer recommendations. This process would ensure the weapon would pursue the real targets and not the virtual ones.
Unlike combat systems of old generations, where it was comprised of group of "stand-alone" systems with limited number of functions, the "Dolphin" combat system is an integrated one, enabling all the sub-system work together to create an optimum tactical picture by using Multi-function Consoles (MFC).
The modern surface vessels and submarines, the long range of detection and weapon capabilities set a significant challenge to the submarine's combat system which is expected to detect, analyze, classify and recommend solutions and assign the weapon as fast and accurate as possible. This means implementation of high level of automation and technology.
A major part of the "Dolphin" combat system was developed by STN-ATLAS as few steps forward from successful sonar and combat systems like ISUS 83. It is ISUS '90 "tailored" to the specific requirements of the IN to manage, handle and control its own sonar as well as all other Government of Israel Furnished Equipment (GOIFE) such as Periscopes, ESM, Communication, Navigation etc.
The system consist of:

- *Detection sensors*: Acoustic (including LOFAR sonar)
  Electromagnetic (radar, ESM)
  Optronic (optic, Video, IR)
- *Tactical data*: Signal analysis
  Classification
  Target Motion Analysis (TMA)
  Self-noise monitoring
- *Tactical situation display:*
- *Weapon control:* Threat analysis
  System and weapon status
  Fire control solutions
  Pre-setting and firing of weapons
  Control of wire-guided torpedoes
- *Weapons*: Torpedoes
  Missiles
  Mines
  Decoys

In order to intensify the system efficiency it handles and controls also “external” systems like Periscopes & Optronic control:

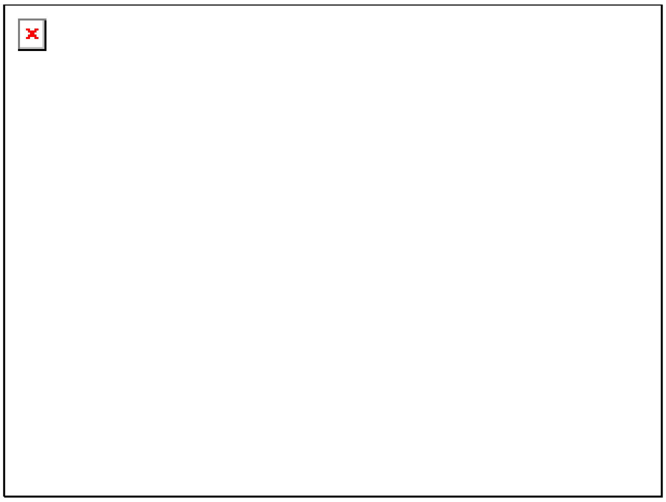
- ESM.
- Data link.
- External & Internal Communication.
- Navigation functions.

Some vital data that might influence the boat’s mission like battery capacity, machinery & hull integrity and self-noise monitoring can be displayed to the command team.

Sub-systems and sensors:

- *Sonar:*

The sonar consists of Low Frequency Sonar (LOFAR) with the Flank-Array mounted on the hull on both sides. It is also includes the Cylindrical Array (CA) in the bow, which complementary to the acoustic detection in medium frequencies and ranges.



Front view of Dolphin class submarine

The Passive Ranging Sonar (PRS) consist of three antennas on each side of the submarine casing, helps allocate targets in the medium and short ranges.
The Intercept Antenna (IA), installed on the casing, would detect and analyze any kind of acoustic transmission and would give sufficient alert on threats which might endanger the submarine.
The Under Water Telephone (UWT) usually considered as communication mean but can also serve, in some instances, as a provision of detecting very close and risky vessels.
As the sonar system is the major detection tool while submerge, with the LOFAR sonar it expands the detection ranges enormously. Consequently the number of targets to be tracked and evaluated at the same time is significantly high. As a result

of information over-flows the workload has to be divided among few operators, depend on the submarine mode of operation.
In-order to build the tactical picture an extensive use of the TMA is done, manually or automatically.
In such complex system each sensor can contribute a piece of information. Having all pieces gathered together is not enough mainly because of information overflow, which makes it almost impossible to maintain. It is the way of integrating these so many pieces of information, which makes the tactical display relevant, and rightfully represents the outside world. Otherwise it could be a waste of time.
As all acoustic sensors greatly influenced by self-noise, Own Noise Arrays (ONA) distributed all over the boat to monitor the submarine self-noise level. Their task is to detect any exceptional noise in sensitive areas and platform systems, which mainly disturb the sonar efficient operation and might betray the submarine presence.

- *Periscopes:*
Two Kollmorgen periscopes are installed in the “Dolphin”. The search one is a special development for the IN equipped with IR capabilities, ESM directional antenna, optic & video, and communication antenna. Both periscopes are penetrating the hull. The attack one is obviously thinner to enable better undetected final approach. The stabilized picture improves somewhat the magnification.
The real change is a cultural change in the operating concept as no longer only the captain or the officer of the watch have the outside world picture. From now on one can rotate the periscope and the optic, video or IR output can be seen on the screen of the console by all Combat Information Center (CIC) members at the same time.
The integration of so many sensors on the periscope is a technology challenge and also gain some operational advantages as in one sweep you may collect a cable from the headquarter or other own forces, detect threatening emitters and build up the surface tactical picture in a very short time.

- *ESM:*
On-board the “Dolphin” an Israeli “Elbit” Elint system is installed, expected to give full picture of all threatening

emitters within few seconds after the antenna breach out the water. Signals can be received either via the periscope or the horn antenna, which is combined with the secondary communication mast.
Obviously the main Elint antenna would achieve better accuracy and most probably better detection ranges as a result of greater sensitivity. Hence its operation would be limited in areas where the exposure of the antenna might harm the submarine.
The ESM data is displayed as an integrated system in the STN-ATLAS console.

- *Communication:*
Traditional requirement from submarine communication system is to enable transmissions and reception of several bands of frequencies at the same time, as well as support of navigation system like GPS and OMEGA.
As already mentioned the "Dolphin" has two communication masts for redundancy in all bands (HF, VHF, and UHF). The search periscope enables reception of variety of signals.
The system itself, external and internal, is of Israeli TADIRAN, "tailored to the specifications of the IN for "SAAR-5" and "Dolphin" projects.
Future growth would allow interception of VLF transmissions from shore facilities.
The communication system is very flexible and enables assigning of each station to any communication net onboard.
As an emergency resort, on the surface, there is the emergency antenna enabling communication on HF band.

- *Radar:*
Although most submariners do not like radar as it might expose the submarine location, a special Kelvin-Hues radar antenna is installed on a non-penetrating mast.

- *Weapon control:*
The integrated STN-ATLAS combat system has all vital information on the tubes and weapons. As soon as a target is selected, the adequate weapon is assigned and automatically the relevant firing data is injected as a pre-setting to the selected weapon. In case torpedo was fired a guidance

procedure can be initiated, either automatically from the combat system or manually by the operator. More than one torpedo at a time can be guided by the system, towards one or more targets.
Weapon handling is managed via the Torpedo Control System (TCS) in the forward compartment (loading, reloading, flooding the torpedo-tubes etc.).

Platform technical description and philosophy

The safety concept, based on the traditional German design, is primarily based on the high strength of the pressure hull. In case of malfunction or accident, it is assumed that the pressure hull will remain intact and the submarine can be brought to the surface quickly by blowing out the ballast tanks using Emergency Blowing System.
To support this concept, each opening in the hull is double sealed from the sea (i.e. Hull valve and Secondary Hull valve). The valves are monitored and controlled from the Engineering and Monitoring Control System (EMCS). From this station the crew is also, control and monitor all the technical system with maximum efficiency and safety.
The need for increasing maneuverability is relevant for operations in coastal and shallow waters, and is met by the high performance x-rudders configuration and the position of the forward hydroplanes on the forward casing, operated from the Steering Station (STSN) by one helmsman.
One of the major factors in the modern ASW is the Signature of the submarine, therefore Signature Management was one of the major efforts in the design and the construction of “Dolphin” class submarine.
The ability to achieve long missions is also related to the reliability of the technical system with high level of redundancy.

The main three rules in the system design were:

a. Redundancy of at least 50% for vital units (i.e. three sets are installed, two sets are for the most demanding mode of operation).
b. Fail safe concept for most remote operating units and systems (i.e. fail in the EMCS to control the system will set

the system to a safe setup, or in case of power fail the individual unit will shutdown to it's safe position.

c. Cascade mode of operation, from the high level down to the lowest one:
   - Automatic mode, or complete sequence.
   - Operating from the Local Operating Panels.
   - Operating centralize location of hydraulic control blocks.
   - Manual operating of the individual valve.

Main Characteristics

Dimensions

Overall length -	56.4 m
Height -	12.7 m
Pressure hull diameter -	6.75 m
Standard displacement -	1550 t
Diving Depth -	greater than 250 m

Propulsion plant

1 Double armature Propulsion Motor
3 set of diesel Generators – MTU 16V396
2 set of batteries cells

Speed and Endurance

Max speed	20 kn
Max snorting speed	12 kn
Submerge endurance	Few days
Cruising range, (result of SOA)	4500 nm

Armament

10 multi purpose tubes
Up to 9 reloads

Accommodation

Complement	35+10
Banks	35
Provision	1 Month

Hoistable Masts

Secondary Comm. Mast with ESM
Radar Mast
Search Periscope with optronic capability
Attack Periscope
Snorkel

Main Communication Mast

Towards the horizon ……

Bird view: sailing to sea trails.

The Hull

"Dolphin" class Submarine hull configuration is the traditionally "Single Hull" Submarine. The line design is optimized to get low resistance and to avoid flow Noise. Closing all the openings that are not in use permanently also eliminates flow noise, achieving the effect of "Closed Hull".

The pressure hull of "Dolphin" is made out of the well known and proven steel for submarine with high strength and elasticity – HY 80.

The strength of the pressure hull is calculated with safety factor of two. The design and the construction were proven by diving test to depth greater by 25% of the Maximum Operating Depth, and Strain measurement in more than 100 location along the hull.
The pressure hull has been optimized to the maximum useable space inside the pressure hull for a limited maximum displacement. This constrain was given during the design, in order to meet the requirement for a “Coastal Submarine”.
This unique design allows a two-deck arrangement along most area of the boat.

The general arrangement (from fwd to aft):

Upper deck

- Accommodation – crew quarters, cold store and kitchen.
- Combat Information Center (CIC)
- Technical Control Center (TCC)

Second deck

- Torpedo Tubes and Weapon Storage Room
- Electronic Room
- Converters Room and machinery

Lower level

Battery rooms, Machinery room, tanks and bilge.

Engine Room (ER) is located in the aft part, has one deck, main components located in the ER:

- Main Propulsion Motor
- Three Diesel Generators
- Hydraulic station

- Two High Air Pressure compressors
- Main Bilge Pump

On the lower level in the engine room:

- Tanks and air conditioning room.

For maintenance purposes, in the ER top there is “Maintenance Hatch” allows taking out complete Diesel Engine without the necessity to cut the hull.

Hydrodynamics and maneuverability

With Optimum line design and with relative low length to diameter ratio, "Dolphin" Submarine has very high maneuverability. It is steered by high performance x-rudders configuration and forward hydroplanes located on the forward casing.

From practical reasons of mooring alongside the peer, the size of the x- rudders was limited to the hull diameter, therefore two stabilizers has to be added in order to get positive dynamic stability in all speeds.

Maneuvering and controlling the boat is done from the STSN, which is double seat, “One Man Control” Stick wheel configuration, design by “Ferranti” which later taken over by GEC Marconi.

The STSN is fully redundant system, the major features are:

- Cascade mode of operation, from fully AutoPilot down to emergency mode, which is purely hydraulic.
- Hydroplanes are switched over to redundant hydraulic circuit.
- Integrated Safety Envelopes. Based on boat condition (i.e. speed, depth, pitch and the distance from the surface or the seabed), the hydroplane deflection are limited.
- Recommended steering.
- Recommended compensating and trimming.

"Dolphin" - General view

<u>Engineering and Monitoring Control System (EMCS)</u>

From the EMCS the crew Controls and Monitor the technical system with maximum efficiency and safety. Also the EMCS has very high automation level, includes fully automatic modes or complete sequence of operation (i.e. close loop mode), the Operator has fully control on the step by step procedure and he can interrupt whenever he needed. Safety functions may be overridden by Hard Wire control directly form the EMCS console (mainly, pressure hull openings).

The system architecture includes ten (10) Local Processing Units (LPU's) that are distributed along the boat, connected by a redundant bus system (SI-NEC-H1) with four control and monitoring computers with high-resolution color screens at the Central Control Station.

EMCS – Central Control Station

Each technical System interfaces are directed to one LPU which are equipped with SIMATIC S5-155U programmable controllers, therefore the system philosophy of operation and modes of operation (e.g. safety limitation, open loop – individual component, close loop - full procedures) software is located in this LPU computer. With this configuration it is possible to operate the Platform Technical Systems from the Central Station and directly from the LPU's via the Local Operating Panel (LOP) located on the LPU itself.

The major challenge of the development was the definition of an overall operating concept that laid down in detail, this process involved each individual technical system for simple and safe operation. The IN invested in this evaluation and process it's best long experience in submarine operation, working together with Siemens and shipyard experts.

The main principle is to keep the operator in the loop. This means that apart from safety-relevant functions, the control system does not automatically start processes and change values, but the process must always be started by the operator, and reference values recommended by the control system must always be confirmed.

The Man-Machine Interface (MMI)

As a result of special attention to the MMI, the operator control and operates the boat with the four display screens, Dedicated Control & Monitoring Panels (DCMP) and Hard Wire

Control Panels (HWCP) which are mainly for safety units (e.g. Secondary Hull Valves). Depend on the frequency of operation, each unit or complete process may operate from few locations (e.g. keyboard and screens, DCMP and HWCP).

Ship's Technical System

Propulsion system

The propulsion system is a conventional one. Consist of two of Batteries sets supply the power to the main switchboard. The main switchboard connects the Batteries and the Main Propulsion Motor in a way that it's possible to supply the necessary power needed by the propeller.
The Main Propulsion Motor is directly connected to the propeller via the flexible coupling, by the Propeller Shaft.

Torpedo Tubes

Arrangement of torpedo tubes (during construction)

The 10 Multi Purpose tubes are installed forward, penetrating the forward dome. These tubes are design to 21-inch diameter weapons. The weapons may be Swim-Out or ejected by hydraulic piston.
Quick reloading is possible with the Embarkation and Storage System, which is installed behind the tubes. The spare weapons

are ready to load since they are seating just behind each tube set.
Most of the functions of loading and firing the weapons into the tubes is done from the Tube Control System (TCS) and the Embarkation system. Some of the functions are done in "close loop" process (e.g. tube flooding or draining, set to ready, fire sequence)

Hiostable Masts

In order to allow high speed in periscope depth, all masts are streamline faired. The fairing avoid direct sea load on the mast, therefore vibration are reduced to minimum. The fairing is also reduced the wave making which is one of the main parameters for RCS and optical recognition.
To minimize the waste of internal space, most of the masts are "non-penetrating masts" i.e. telescopic extension in the bridge fin. The penetrating ones are the periscopes, since their optical line of sight, and main comm. Mast since it's long wipe antenna.
The new snorkel concept, allow "preparing to snorting" under water.

Accommodations

In order to keep the crew in shape for long stays at sea, the Accommodations were design to allow them to rest, to eat or to have entertainment in parallel. i.e. banks rooms are dedicated for sleeping, and in addition there are messes for eating etc. Increased number of toilets was installed in order to improve crew comfort. Large space of refrigerator room let keeps fresh food for long time.

Emergency Deballasting System

With the experience of the Hydrazine Emergency System which is installed on the existing submarine, "Gal Class", and with consideration of the advantage and disadvantage of that system, the IN has decided to develop new Emergency Deballasting System which is working on High Pressure (HP) air installed onboard. The principle is very simple: supply large amount of air into the Forward Main Ballast Tanks in the shortest time possible.
The emergency blowing system consists of: approx. 9 m^3 of HP air in 250 bar, large diameter piping system (DN80) and special

developed control valve, that controlled the overpressure in the main ballast tanks.

The advantages of this system are:

- Very safe system (compared to the hydrazine).
- The blowing process can be stopped and restart again at anytime.
- The system remains in function after use. Only the HP air bottles need to be refilled.

***The Disadvantages are*:**

- The blowable volume is depends on the depth (i.e. it is not possible to completely empty the main ballast tanks in the maximum diving depth.

Safety envelope

The Safety Envelope (SE) defines the domain that the submarine must stay in, to guarantee that in case of emergency situation, special recovery maneuvers will avoid the loss of the submarine.

The two cases are major malfunction in the control surfaces and water inrush.

Using the performance of the Emergency Deballasting System, the SE was derived from the results of a large number of maneuvering simulations, which were done on different sets of initial conditions.

The results were represented by set of empirical equations, which are basically, continue limiting the control surfaces deflection angles, depends on the boat conditions (speed, trim, depth, and distance from surface or seabed).

In case of water inrush, the use of Emergency Deballasting is mainly depends on depth end the ability to tight the boat.

The SE is integrated in the STSN. Therefore the helmsman gets information about the free space for maneuver, or alarms, in case the boat penetrate the SE. In automatic mode (Auto Pilot engaged) the control surfaces are actually limited to for a specific deflection calculated by the SE.

Rescue and Escape

Whenever the recovery actions are failed, the crew may rescue itself from the sunken submarine with the aid of Rescue Jerkin and the supported system- Built In Breathing System (BIBS).

If the Boat lay down on the seabed and still intact, the crew may wait to rescue by the DSRV, or to escape from the access trunk with the Hood Inflation System (HIS).
To support the rescued crew there is one raft including distress transmitter, packet into a sphere. When the sphere released from the submarine and get to the surface, it is open and the raft afloat and the distress transmitter start transmit SOS.
In addition it is possible to send signals to the surface via the Submerge Signal Ejector (SSE).