

Submarines “Made in Germany” – Current Status and Future Prospects

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Germany is international market leader in the production of non-nuclear submarines. In addition to the experience gained in over a hundred years of building submarines, this is mainly due to the acknowledged expertise of the German Navy and the technological leadership of the German shipyard and engineering industry. Submarine building is therefore one of the most important – if not the most important – core competence factors of system engineering in the German armaments industry.

The Class 212A submarine with its air-independent fuel cell propulsion system set new dimensions in performance standards, and this has also had a great impact on the export market. In order to keep ahead in the field of technology, a wide range of further developments were and are envisaged, and some of them will be addressed in this article.

The submarine today

Submarines possess inherent qualities that make them better suited than any other platform to undertake certain tasks:

- **Invisibility:** Unbeatable undetectability in comparison with all other forces and units
- **Survivability:** The combination of undetectability and robustness provides excellent survivability.
- **Seaworthiness:** When submerged the submarine is largely independent of the weather, unlike all other ships.
- **Endurance:** The submarine can remain in the area of operations for many weeks without the need for any outside support.

The main operational scenarios for which submarines are eminently suitable are derived from these characteristics.

For almost a hundred years, the main task of submarines was to be a weapon with which to wage war against merchant shipping and to act as a deterrent against a technically well equipped and numerically superior potential opponent, or as a last resort to fight him.

The submarines' task was restricted to covert activities against surface vessels and after the end of World War II additionally to anti-submarine warfare.

A single submarine can bind a large number of units of the opposing force and just the



Class 212A submarine in rough sea.

Photo: MF

knowledge of its existence in a sea area may deny the opponent the use of sea lines of communication.

However, today the scope of tasks of the submarine has been considerably extended. The most important characteristic of the submarine is now perceived as its ability not to influence the scenario directly at all. The following situations may serve as examples:

- The observation of illegal activities is only effective if it is not detected.
- Observations can be made using radar and radio ESM without revealing the presence of the observer.
- Covert transit and insertion of Special Operations Forces can be carried out without their means of transport giving them away.
- It is possible to have an invisible presence in the area at a time when an obvious appearance is considered undesirable to avoid escalation in an uncertain political situation.
- The submarine's ability to carry out covert operations allows it to approach into risky waters close to the coast, where surface vessels would be constantly exposed to the threat of asymmetrical forces.
- A submarine equipped with UUVs can carry out covert reconnaissance of minefields without giving the opponent advance warning of a planned assault force landing.

To perform such tasks the modern submarine, unlike its predecessors, must be able to communicate worldwide with other arms and units, combined forces and allies.

The following paragraphs describe the most important technical advances that enable the

modern submarine to respond perfectly to today's scenarios.

The Command and Weapon Control System

The weapon control system on a submarine consists of subsystems for sensors, Command & Control and effectors. It is provided with a variety of sonar sensors as well as optical and electronic surface sensors for the detection, analysis and classification of surface units, submarines and torpedoes. The sensors allow for comprehensive command and control of the submarine and for deployment of long-range wire-guided torpedoes and missiles.

A modern, “state-of-the-art” submarine command and weapon control system must give the submarine crew optimal support at all times so that the tasks associated with the mission can be fulfilled. Today, sensors and effectors are mostly fully integrated, a large number of functions are automated and the interaction with the operators takes place via user-friendly human-machine interfaces.

With the ISUS90 system manufactured by Atlas Elektronik, German industry takes a worldwide leading position in command and weapon control systems for non-nuclear submarines. The projects realised in recent years (both for the national and for export markets) have enabled a basic configuration to be established that can accommodate future technological and functional adaptations to keep

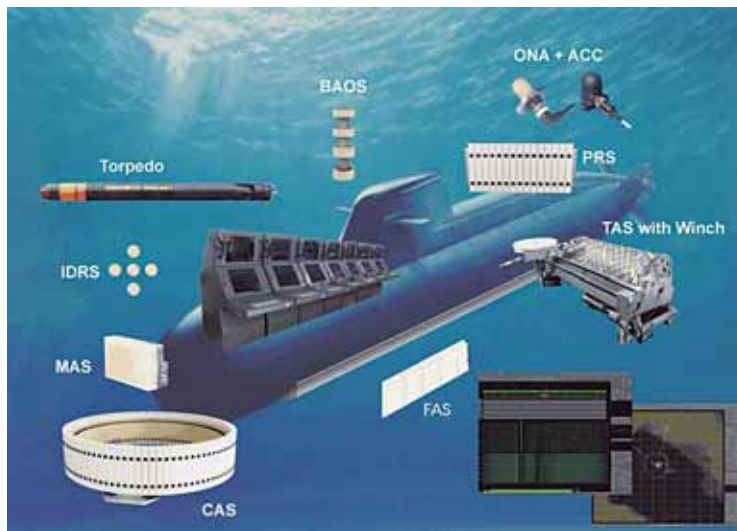
the system right up to date with new developments in engineering.

An ISUS90 with updated technology and functionality has been implemented for Class 212A, 2nd batch submarines. For the first time, a new laminar lateral antenna has been incorporated, with which the new Advanced Ranging Sonar (ARS) promises to give improved performance in comparison with the flank array used until recently and to provide range data considerably superior to what was obtained using previously available systems.

Future demands on the submarine Command & Control system can already be discerned. These include, for example, such functions as a Forward Looking Sonar (FLS) and the ability to deploy Unmanned Underwater Vehicles (UUV), as well as the need for secure acoustic communication with a submerged submarine.

The change to new – asymmetrical – threats has also led to a shift in the weighting of the submarine’s tasks, with a new focus on activities above the water surface and/or over and on land. For such purposes, surface sensors mounted on hoistable masts as well as the ability to communicate from a secure, i.e. deep submerged position are essential. The systems to meet these needs are being developed in close cooperation between HDW and the German specialists in hoistable masts, GABLER Maschinenbau GmbH.

The two newest submarines of Class 212A, 2nd batch, will therefore be equipped with the CALLISTO communication system, a combination of hoistable mast and floating buoy antenna, where the floating buoy is located on the top of a hoistable mast. The towing connection between the submarine and the floating buoy



Abbreviations

ACC:	Accelerator
BAOS:	Broadband Active Operating Sonar
CAS:	Cylindrical Array Sonar
FAS:	Flank Array Sonar
IDRS:	Intercept Detection Ranging Sonar
MAS:	Mine Avoidance Sonar
ONA:	Own Noise Analysis
PRS:	Passive Ranging Sonar
TAS:	Towed Array Sonar

antenna system is provided by a hybrid cable, which takes up the tension arising during towing while also providing communications and sensor data transfer and the power supply for the buoy.

When the submarine needs to communicate from a deep submerged position, the buoy is released and rises under its own buoyancy to the surface with the rolled up cable reeling out behind it.

The multi-functional antenna allows transmission and reception via UHF SATCOM and UHF LOS, as well as reception of VHF, GPS and HF. The buoy can additionally be equipped with a viewing system and radar warning system to improve self-defence capabilities and help avoid collision with small surface craft. In an effort to keep a measure of control over the gap between the decreasing number of submarines in operation with the navies and the constantly increasing range of tasks and missions these submarines (and their equipment) are required to perform, there is a trend towards using modular systems.

At GABLER Maschinenbau, another development project in this field is close to completion:

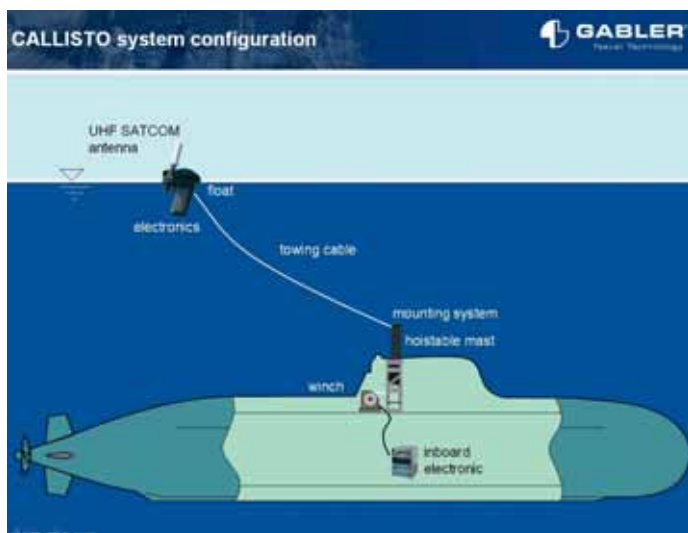
The modular multi-purpose mast “TRIPLE M”. This is a pressure-proof container about 3 m long with 0.8 m interior diameter that can be hoisted from the submarine sail. It is designed to accommodate sensors or weapons adapted from other services (army/air force) that are not resistant to pressure or seawater. They in turn are hoisted from within the container and can then be operated from inside the submarine.

The payloads that have been tested and/or envisaged are the following:

- An automated launching system for a small unmanned aircraft (UAV) which can radically increase the viewing/surveillance and reconnaissance area covered and controlled by the submarine.
- A machine gun for use at close quarters and for self-defence at periscope depth or when the submarine is on the surface.
- Much larger ESM antennas than it has previously been possible to accommodate on a submarine underneath a pressure-proof radome.

Demonstrators for the pressure-proof container and the drone launcher have already been successfully tested.

In the field of underwater communications, the UT3000 system manufactured by L3 Elac now provides a fully digital underwater telephone capable of transmitting both voice and data communications. On the basis of this system, development is now in progress both of an acoustic IFF capability and of a long-range underwater communication system with low detection probability.



CALLISTO communication system.

Graphic: Gabler

Weapons

The heavyweight torpedo is still the main weapon of modern submarines. It can be employed over long distances against surface vessels or other submarines without revealing the position of its platform. Its ultimate effectiveness on reaching its target is achieved by no other conventional weapon. Connected to the submarine by a fibre-optic cable, it also serves as a remote sensor.

The peak of this development features the DM2A4 torpedo built by Atlas Elektronik. In addition to the fibre-optic technology already mentioned, it has an integrated active/passive sonar system, a modular battery concept and a PM motor. It is characterised by long range, high speed and low signatures. Torpedo firing exercises with the German and Italian Navies

in the Mediterranean gave an impressive demonstration of these features.

For employment against surface and land targets, medium and long-range heavy missiles are gaining in importance. The currently more or less standard missile for use against sea targets and with “land attack capability” is the SUB-HARPOON – although admittedly it is meanwhile rather outdated. The prime example of a cruise missile for use exclusively against targets on land (range > 1,000 km) is the American TOMAHAWK. Efforts are being made worldwide to navalise more missiles for their employment from submarines, for example the Norwegian engineering company Kongsberg is considering producing a submarine version of their Naval Strike Missile (NSM).

A completely new approach and so far a unique missile system is offered by IDAS – “Interactive Defence and Attack System for Submarines”. This fibre-optic guided missile is primarily being developed for self defence against anti-submarine helicopters, the most dangerous enemies of the submarine. Through the fibre-optic lead the IDAS missile remains connected to the submarine. Its IR camera transmits a constant stream of target images via the fibre-optic cable, which are displayed on the weapon control console monitor screen.

The operator on board the submarine is able to use the same communication channel to influence the missile – e.g. by selecting a different target or selecting a specific point of impact, or even aborting the mission entirely. This capability makes the weapon suitable for use in a possible escalation situation – a genuine innovation with regard to weapon employment by a submarine. It also allows IDAS to be employed successfully against surface targets at sea or targets on land close to the coast, while largely avoiding collateral damage.

All the weapons referred to above can be fired from standard torpedo tubes. The same also applies to mines, which should just be mentioned for the sake of completeness.

The propulsion system

Right from the beginning, submarines have used electrical power when submerged, but especially this field has seen dramatic improvements in recent years. It is already hard to imagine how to do without air independent propulsion (AIP). The most successful AIP system uses the fuel cell. This system allows the non-nuclear submarine to remain deep submerged for 2-3 weeks completely independent from an outside air supply, improving the covert aspect of its mission. The risk of detection is significantly reduced thanks to AIP, as the boat does not need to snorkel. The scope of the sub-



Triple M multipurpose mast equipped with UAV.

Photo: MF

marine’s possible tasks and operational scenarios is therefore widened immensely.

Today, AIP is a decisive factor in evaluating the submarine’s ability to safely carry out covert operations, when the need to snorkel could severely prejudice the mission’s chances of success, e.g. in covert tasks for intelligence gathering, reconnaissance and surveillance or when inserting Special Operations Forces. With the Class 212A submarines, the German Navy has ultra modern AIP boats that have already given excellent performance in service all over the world.



Emplacing the IDAS missile.

Photo: MF

As a participant in the NATO surveillance and patrol operation “Active Endeavour”, the German Navy Class 212A submarine U32 broke the world record for constant submerged operation by a non-nuclear submarine when it was en route to the Spanish naval base of Rota in spring 2006. At the end of its tour of duty the submarine came home, after more than two and a half months on active duty – a clear demonstration of the endurance capabilities of these modern submarines.

But development does not stand still in the field of fuel cell technology either: HDW is now engaged in the development of a methanol reformer plant to generate hydrogen from methanol on board the submarine. The advantage compared to the system used today of storing the hydrogen on board in metal hydride storage cylinders becomes apparent for large submarines with extended AIP operation periods. While for compact boats like Class 212A, hydrogen storage on board is a suitable option both commercially and with regard to space, it is more effective for larger submarines to generate the hydrogen on board from liquid hydrocarbons.

Another milestone in propulsion technology will be reached with the future use of high-performance lithium polymer batteries. The submarine of the future will not only gain in endurance at slow speeds, which is the case with AIP, but also especially at sprint speeds and for cruising. Since lithium polymer batteries became an essential part of our everyday lives through their widespread use in mobile and cordless telephones or laptop computers, important progress has been made to solve the safety problems of the early phase with improved construction procedures and battery management systems.

A necessary step for this kind of battery to be used on board submarines lies in increasing the size of the cells by the order of one to two degrees of magnitude in comparison with the current state of the art. The challenges this posed to production technology have been overcome in a joint development between HDW and the German manufacturer GAIA.

Without increasing the size of the battery room, these new battery modules can increase the battery capacity in comparison to the tradi-

tional lead acid batteries by a factor of approximately two for long-term discharge and four for high speeds. In addition, lithium batteries are substantially lighter than lead acid batteries, making them particularly suitable for use together with the heavy metal hydride hydrogen storage cylinders of the fuel cell system, as the submarine design engineer is able to increase the amount of energy carried on board for AIP without having to make far-reaching changes to the basic design of the submarine.

Apart from their capacity, lithium polymer batteries also offer a number of other advantages for use on a submarine:

- The cells can be charged using a very high charging current, reducing the time that has to be spent at snorkel depth with the associated greater risk of detection.
- The cell capacity can be 100% used, another capacity advantage in comparison to lead acid batteries.
- Lithium polymer batteries are maintenance-free: they can be stored in any charged condition; they use no distilled water; they give off no gases; Water cooling is not required; the battery efficiency is very high due to the low internal resistance.

This last advantage is simultaneously the only disadvantage: The low internal resistance causes very high short-circuit currents, which have to be handled by appropriate measures in the ship's network.



IDAS missile after launch.

Grafic: MF

such missions, the submarine must have extremely low signatures to make it difficult to detect, identify and classify. New developments in the field of signature minimisation and control, such as active noise reduction, promise to offer additional ways in which to decrease the noise level or acoustic target strength and the magnetic and electrical signatures.

Whereas in the past passive sonar systems were mainly used to detect submarines, today active sonar is experiencing a comeback because the modern submarines have become so quiet that passive detection ranges were no longer adequate.

The modern active sonar equipment uses very low frequencies to achieve long ranges. To

any other unit for certain tasks. No other ship binds so many of the opponent's forces or is able to deny the opponent the use of certain sea areas just by the mere fact of its possible presence. The export success of the German shipbuilding industry gives ample and impressive support to this need.

In spite of all this it should not be forgotten that time and again the German Navy with its excellent international reputation has made it possible for new cutting-edge technology to be introduced. The fuel cell integrated into the German Navy Class 212A submarines set an international point of reference.

This has allowed the evolution of non-nuclear submarines to catch up with their enormous nuclear sisters – or in many respects even to overtake them, in particular since the smaller non-nuclear boats do not suffer from the numerous disadvantages of the “nukes” like signature management, logistics and expense.

Especially the three major areas of progress consisting of AIP, communications and modularity have given the non-nuclear submarine seriously increased operational abilities, leading to a notable increase in the scope of missions to which it can usefully be assigned. Its additional capabilities and significantly increased underwater endurance imply that the submarine will have even more important roles to play in the 21st century than was already the case in the 20th.

It is to be hoped that in spite of the current precarious financial situation the German Navy will stand by development projects in the field of submarine technology, and after decommissioning the Class 206A submarines new boats will be ordered to ensure that the Submarine Squadron remains regenerative and viable in the long term. ■

Photo: MF



U33 during sea trials.

At the present time HDW and GAIA have tested the first 500Ah cells and are continuing with tests on the first full scale battery modules and partial batteries including the battery management system. Identical cells have been installed on “Planet Solar”, a catamaran destined to round the world on solar power.

counter this new danger, HDW is cooperating with the German Armed Forces Technical Centre for Ships and Naval Weapons WTD71 to develop acoustically effective materials that absorb or deflect the incoming sound waves, ensuring that the submarine will retain its tactical advantage over surface units.

Signatures

The decisive characteristic of a modern non-nuclear submarine is its ability to undertake covert operations. In order to be successful in

Conclusion

Still today the submarine is an essential component of the modern navy. Its aptitude for clandestine operations make it better suited than

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