How a shortage of manpower was turned into a successful, efficient design and build process

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Synopsis

The Walrus Class ocean going submarines were designed for Cold War missions. Their strategic, NATO based, operational area was the North Atlantic. Already during their building phase at the end of the Cold war the political scene altered. Fortunately, this diesel electric submarine proved easily adjustable to the new circumstances without major technical changes.

The four Walrus boats have been active in many different areas and with new missions. To continue to perform several mission critical operational systems had to be updated and to ensure the operational performance until 2025-2030 fundamental improvements were considered necessary.

For the Life Extension Program the Naval Staff carried out a study to establish the Operational Requirements as a basis for the LEP.

MoD experienced shortage in a technical knowledge base in numbers and in capability. This was compensated by an industry initiative, based on existing working traditions in the Netherlands of collaboration between MoD, the research institutes and the industry, the so called “Triple Helix/Golden Ecosystem”. The Dutch Underwater Knowledge Center (DUKC) proposed to provide support for the LEP engineering phase. Subsequently five of its members formed a joint design team and presented a generic plan to DMO. The participating companies agreed to form an independent consulting engineering team.

The essential ingredient for this collaborative process is the jointly felt responsibility for performance, cost control and delivery times. The contract was on a “price not to exceed” basis. This was an important condition for cost control because initially there were only limited and general technical requirements.

The second novel aspect was the interaction with the various navy departments involved. WESP had direct interaction not only with the DMO project organization but also with the Naval Shipyard, the Joint IV Command, the Submarine Service and the Operational school. The DMO team gladly reciprocated, resulting in an effective communication scheme.

The WESP team was an integral part within DMO project teams during the dialogue and selection phase with the contractors. The main responsibility or the WESP teams was the assessment of platform integration risks and mitigation measures during the different engineering phases. The LEP planning recognized three phases: an engineering study phase aimed at the selection of new components and defining new arrangements, a detailed design phase and an implementation phase. The Naval Dockyard would be responsible for the LEP related shipyard work.

WESP proved that experienced professionals from (in this case four) industrial companies and a research institute, working as a team of independent consulting engineers interacting directly with DMO specialists has been the success factor for the engineering of the LEP. It shows that a shortage can be turned around into a programmatic success and it demonstrated that such a submarine ecosystem is mandatory for the upkeep of the submarine service.

1. Introduction:

The Walrus Class submarines were designed during the Cold war and intended to spend their time on patrol in the Northern Atlantic. Being long-range ocean-going boats they proved to be very adaptable to the present day missions. Over the years the Walrus Class has given the RNLN submarine service their “niche expeditionary capability”. When the time for their replacement neared it became clear their life needed to be extended to continue service and bridge the gap until the first of the new class would be operational. At the same time, it was also apparent modernization of some of the combat and weapon systems was required. It was decided to implement the Life Extension Project in conjunction with the regular long-term base maintenance. Dutch submarine lineage.

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2. Dutch Submarine Lineage

Cornelius Drebbel (1572-1633), first invented a submarine and is rumoured to have demonstrated his submersible to the English King James I in the 1620's. However, the story of the submarine service of the RNLN begins when the Koninklijke Maatschappij de Schelde took the initiative in 1904 to build a type Holland-9 submarine, named "Luctor et Emergo", for its own account. On demonstrating the submarine to the Navy, the submarine was purchased and commissioned in 1906 as Hr. Ms. O-1. Since those days, except for the years 1942-1969, the submarines for the RNLN were built by Dutch shipyards. In the post war period the first domestic design was a so called triple hull type, (the Dolfijn Class of which four were build), see [01]. But when USN Nautilus reached the North Pole in 1957 the nuclear promise brought the RNLN back to the US to request nuclear technology transfer for a Dutch SSN. This was denied by the US Administration in 1960, but the RNLN had already obtained the drawings of the diesel electric Barbel Class as a possible future platform. So, as it turned out, the submarine based on this US design – the Zwaardvis Class – became a diesel boat. Two were build and operated until 1994 when the next generation, the Walrus Class, had come into service. Their design proved to be successful both for open ocean and littoral environments. Parallel to the Walrus Class two Sea Dragon Class boats were designed and build in the Netherlands.

3. The Submarine Knowledge Base

This lineage of Dutch submarines and the experience of the Submarine Service, that is recognized worldwide, has been the cornerstone of its so-called niche capability. It has also made the men, and nowadays women, proud of their boats. All shore-based maintenance of RNLN submarines today is carried out at the Naval Dockyard. Over the years much experience has been accumulated with the result that the maintenance cost of the Walrus Class is markedly lower than has been reported by various navies operating (ocean going) diesel subs. Also, the availability (per boat/year) is proportionally higher. The collaboration of MoD, industry and research establishments – the so-called triple helix - has always been the cornerstone of the Dutch submarine knowledge base.

It is in line with this tradition that the Life Extension Project (LEP) of the Walrus boats was addressed. In 2003, a Defence White Paper made clear that the Netherlands government acknowledged the importance of keeping a Dutch submarine capability. Following this White Paper, the Naval Force has been reorganized preparing the fleet for the future. New capabilities had to be developed for "Operations other than war". As part of this process it was decided that the operational life of the Walrus Class had to be extended from 25 to 35-40 years. To live up to this requirement several operational systems had to be updated and functionality had to be added

4. Limited Human Recourses

The years of budget cutbacks that the MoD experienced, has affected the technical knowledge base in numbers and in capability. Since the time the Walrus Class was introduced into the submarine service no new submarines have been build. Furthermore RDM, the submarine building yard, closed in 2004. Shortly before that closure several companies and research institutes with submarine experience formed a platform to exchange information, support (mutual) marketing efforts and initiate and jointly carry out concept studies with the objective to maintain submarine technology. The name adopted for the platform is DUKC (Dutch Underwater Knowledge Center). A representative of DMO has, over the years, been an observer during their meetings. DUKC consists of system integrators, engineering and design companies, equipment suppliers and research institutes.

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Figure 1: Walrus Class Submarine

When DMO planned the LEP it was found they needed outside assistance. In response, DUKC proposed to provide support for the engineering phase of the LEP.

5. A Proposal Based On Preliminary Requirements

LEP involved a number of modifications, summarised, in a menu consisting of four areas, as:

1. Replacement of the Combat Management System with a new functional software package for the Combat Management System to be developed “in house” by DMO’s Joint IV Command. This includes specifically designed Multi-Function Control Consoles carrying COTS HW components and processors. The Central Control Room must undergo a major upgrade because of the replacement of the Navigation periscope, the new MFCCs, the modification of the Navigation console and the implementation of Electronic Maps (WECDIS).

2. In addition to that, several electronic equipment spaces will be rearranged where obsolete cabinets will be replaced by new hardware.

3. An Optronic sensor integrated into the CMS to replace the navigation periscope

4. Addition of a SHF SATCOM high data rate COMMS(NEC), network enabled capabilities.

The requirements for these modifications were still in a preliminary state. The LEP planning recognized four phases: an engineering study phase aimed at providing well researched grounds for selecting the new components and defining new arrangements, a detailed design phase, an implementation phase and a test and trials phase. The Naval Dockyard would be responsible for the LEP related shipyard work to remove, modify and install all equipment and systems.

In response to these requirements five members of DUKC (Nevesbu, RH Marine, TNO, Nedinsco and Technovia) formed a joint design team and presented a generic plan of work packages to DMO. The proposal was a novelty in the sense that all five participating industries would work under one contract with standard conditions identical for them all. One company would be the acting legal and financial administrator for the group. A project manager was given the task of integrating the design work and overall project management. The participating companies agreed and accepted that they would form a team of independent consulting engineers with no preferred position for equipment choices by DMO and during the implementation phase.

The contract was concluded on a “price not to exceed” basis. This was an important condition for cost control because initially there were only limited and general technical requirements as mentioned above. The project named WESP (Walrus Engineering Support Project) was set in motion by DMO. The WESP team itself proposed work packages to generate a design basis and define technical solution sets for the modification of the submarine itself. Apart from a set of uniform general conditions the desired deliverables could be formulated in four separate “one-page functional work assignments” reflecting the above “menu” of modifications.

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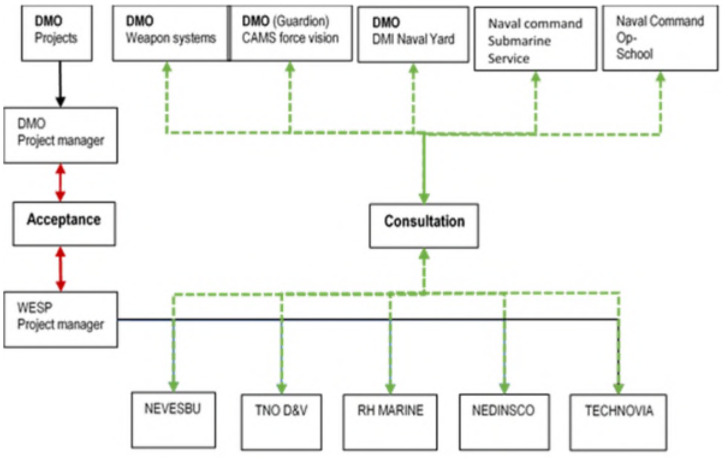

Figure 2: Project structure

The second novel aspect was the interaction between the WESP team and the various navy departments involved. WESP had direct interaction not only with the DMO project organization but also with the Naval Shipyard, the Joint IV Command, the Submarine Service and the Operational school. The DMO team gladly reciprocated, making an effective communication scheme possible as shown in figure 2. This was necessary to design, propose and select technical solution sets for the desired new functions following from the CONOPS and SEWACO plan. To avoid a cacophony of discussions between the actors of the WESP team, with members working on their particular items of the modifications and their counterparts in the various DMO departments, a strict but flexible form of communication was established. Technical meetings on (isolated) topics could be scheduled involving WESP team members and DMO representatives and the meeting results were communicated project wide. These could concern straightforward issues as agreeing on the outcome of a shock calculation or elaborate design solutions when alternatives were presented for the rearrangement of the central control room. The advantage was direct interaction between the relevant players and specialists with (parallel) identified lines of communication on technical issues. This was called “consultation”.

The other important line of communication was the formal line involving “acceptance” of performance, progress and results. Acceptance included the major technical decisions. This acceptance of results and the fundamental decision making was the prime responsibility of the DMO program manager and the WESP project manager and was organized with informal and formal reviews.

The functional and commercial choice for selecting a component or system supplier was solely responsibility of DMO. WESP however was involved in the selection process several times for direct technical advice with respect to system to platform integration on feasibility of proposed solutions and interfaces. This involvement continued until (contractual) technical interfaces were completed. In this way procurement work for the major components went on in parallel with the engineering of (platform) interfaces with these components. Due to the complexity this was accepted by all parties involved, including (potential) suppliers (OEMs). In the execution it proved to be an effective way to reduce the technical risks.

A report by the RAND Corporation [02] shares the experience of design and build projects in the UK, the US and Australia. The report states: *“the design and build process should go further than merely involving builders in the design process. The design should also be informed by operators, key suppliers, maintainers and the technical community…. However throughout the design process it is important to keep in mind that the ultimate design and construction target is a submarine that is cost-effective in its post-delivery and ILS period of life”* It may be concluded that the LEP design process concurs with the lessons of the RAND study.

At the start of the basic design phase the applicable requirements, criteria and analysis methodologies have been agreed between DMO and WESP.

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These requirements, criteria and methodologies for design and verification have been compiled into a Basis of Design (BoD). After review of, and agreement on the BoD with all stakeholders the BoD formed the basis for the detailed platform integration design. Review of the detailed design can then be performed against the BoD, see [04] and [05].

At completion of the detailed platform integration design final interface meetings with the suppliers where organized to cross check the interpretation of the translation of the interface definition as supplied by the supplier into the platform modification design.

The platform design has been detailed to production packages up to a level of detailing to leave no room for interpretation during the execution to avoid spending costly time during execution on interpretations.

6. What’s Different

The approach of the Life Extension Project was for WESP not different from how a large more widely experienced team should engage a complex design problem such as a new submarine design. The conditions for success include a few prerequisites, summarized here.

At the start of a large-scale design contract Defence /DMO shall clearly define the expected “work product” and the contractor shall fully understand of what the product shall be. The Dutch submarine knowledge base evidenced by the collaboration under the triple helix plus the experience of many years with the Walrus Class assured a full understanding on both sides in a short time. This stands for what is sometimes called the Submarine Enterprise.

For complex design undertakings the engineering management shall generate a decomposition of the full design process into tasks according to the expertise involved prioritized by integrated design risk. Such decomposition clearly depends on the above-mentioned full understanding of the product and its integrated design risks and shall be available at the beginning of the project. For WESP the decomposition into subtasks and work packages was already made before the order was awarded and became part of the contract documentation.

At the same time one needs flexibility to adjust the subtasks and work packages when knowledge of the design challenge, its associated risk areas and hence insight matures, the knowledge base.

These subtasks (especially in the concept phase) should be executed with sufficient detail to cover all the aspects of influence. But at the same time, one should avoid a narrow focus by being too detail oriented. The insight gained during the subtasks should contribute to the knowledge base.

It should be noted that at the start of the project DMO had not yet made their choice of potential replacement components or systems and WESP should investigate the best fit solution based on the platform integration impact on the existing submarine configuration. Ranking of solutions within the technical terms of the assignment was part of the “work product”. The ranking was input for the procurement process. This allowed DMO to take the considered platform integration efforts and risks into account when making the final equipment selection.

Engineering management shall conduct frequent in-process reviews of the progress, the content, manage the interfacing between various (sub) systems and components to finally warrant system integration. As the WESP team was invited to offer their support it was paramount that the in-process reviews were done in collaboration with the stakeholders on the defence side. Most of these ad hoc reviews, called consultation in Figure 2, were by initiative of WESP. Several formal design reviews were held for DMO to formally decide and accept the work product. These formal reviews profited from the consultations as most issues had been discussed and agreed on in principle on a more informal level.

It should be noted that unscheduled consultations with stake holders can either become a nightmare of undocumented partial technical agreements or suffer from an overly bureaucratic reporting system and associated paperwork. Because of the long experience within the Dutch Submarine Enterprise the agreed documentation of consulting meetings was limited and to the point with the understanding of what other team members, not attending, would need. The intermediate design reports became the cap stones of such consultations creating no surprises.

An important contribution to the effective performance of WESP was the DMO procurement strategy. The WESP participating companies agreed to work under identical general conditions making it convenient to have one identical contract for each of the participating companies. The decomposition plan was included in the contract documents so that each member was aware of what his tasks were. One of the five companies was assigned as the administrator of the project. Based on monthly internal reviews reporting of time and money spent as well as progress made against spent hours was reported and agreed between project managers of DMO and WESP, triggering payments. All in all, a very efficient management structure.

It should be noted that the success of the WESP approach versus a possibly large widely experienced team was the willingness of the representatives of five companies to collaborate as an integrated design team. The positive interaction with the Defence stakeholders as noted in Figure 2 contributed to a great extent.

7. Redesign Of The Central Control Room

An example of the way how WESP operated, is the interactive redesign of the central control room.

The Walrus Class submarines are designed with a central control room to manage both the platform control and monitoring as well as the external battle. This control room needed to be reconfigured to adsorb the new multi-functional consoles for the combat management system, adding a commander console, integration of WECDIS and integration of network enabled capabilities. The changes in the combat system and updated CONOPS asked for rethinking of the layout.

For the new arrangement, the TNO participants of the WESP team were leading in setting up the dialogue with DMO, the submarine service and the Op-school. A number of workshops were used to generate concepts for the optimal design of MFCCs and their arrangement in the central control room, see [03]. The workshop planning involved three phases: the establishing of functional demands, the concept design phase and a design definition. During the concept phase design solutions for two levels of ambition *(conventional and revolutionary)* where established. The *conventional* layout provided a solution matching the existing platform interface points, staying close to the existing situation. The *revolutionary* layout was only limited by the physical boundaries of the submarine. Both layout solutions have been rated by the user panel on effectiveness.

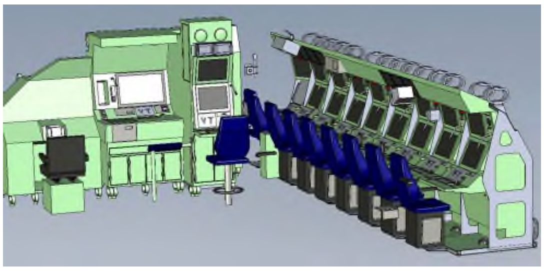

Figure 3: The Evolutionary Layout

Based on the *revolutionary* layout the WESP platform integration team has tailored the *conventional* layout to replicate the strong points of the revolutionary layout while respecting the existing platform interfaces. The process resulted in the *evolutionary* layout a significant improvement of the effectiveness of the command room while limiting the number of to be modified platform interface points, hence reducing the risk during the execution phase. Based on the *evolutionary* layout WESP has writing input for specifications for the various to be purchased equipment such as the MFCCs.

Figure 4: The Modified Control Room

8. Rearrangement Of Electronic Hut

Integrating a large amount of new electronic equipment into an existing submarine is no simple task. Especially if one wants to respect the original requirements and design philosophies of the submarine. Understanding and respecting the newbuild design philosophy of the submarine is key to make the midlife modification a success. It ensures that the "look and feel" of the submarine remains unchanged, safety measures remain affected, the submarine remains consistent.

During the concept phase the WESP team made an inventory of possible locations for new electronic equipment. For these possible locations the characteristics such as maximum allowed head dissipation, applicable shock loads, available power connections, security classification, etc where collected. The constraints of the possible locations have been added to the requirements for the new systems and managed during the purchasing phase, reducing platform integration complexity and hence risk.

A significant effort has been spent in communications with the suppliers to optimise their equipment to suit the platform boundaries. All this effort has resulted in an optimum re-use of the space respecting the submarines performance requirements, the habitability, and the operational effectiveness.

Figure 5: Electronic Hut After Conversion

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9. Conclusion

The WESP engineering study was followed by a detailed design phase that was completed mid-2013. The first submarine undergoing the modifications was Zr.Ms. Zeeleeuw, which boat is now operational as well as Zr.Ms. Dolfijn.

WESP proved that experienced professionals from (in this case four) industrial companies and a research institute, working as a team of independent consulting engineers interacting directly with DMO specialists has been a success factor for the engineering of the LEP. For the program it helped to control progress and expenditure.

The framework of a "price not to exceed" contract offered flexible control based on progress and actual costs. The contract ensured that the WESP project was transparent to all parties and could be carried out within the limited budget even when working with only preliminary technical requirements at the start. It provided MOD a "no surprise" Engineering Data Package without undue risks.

During the engineering phase WESP supported the procurement process for the equipment and services for the implementation phase. This has been beneficiary for DMO, but also for the suppliers regarding proper technical interfacing resulting in risk mitigation for all concerned.

Platform consequences have been weighted in the supplier selection. There are important technical choices made at an early stage, reducing the project risks

By evaluating the Platform Consequences in an early stage of the program we not only reduced the risk but also reduce on production hours and get a better submarine.

This engineering approach has a beneficial effect on the costs, if only by making major engineering choices already in the procurement process and actually reduced the risks.

This approach has enabled Defense /DMO to run a complex program and act as a Smart Buyer. The experience and knowledge base of the Dutch industry and research institutes developed over the years during the development and operations of RNLN submarines has been determinative for the effectiveness of the WESP approach.

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