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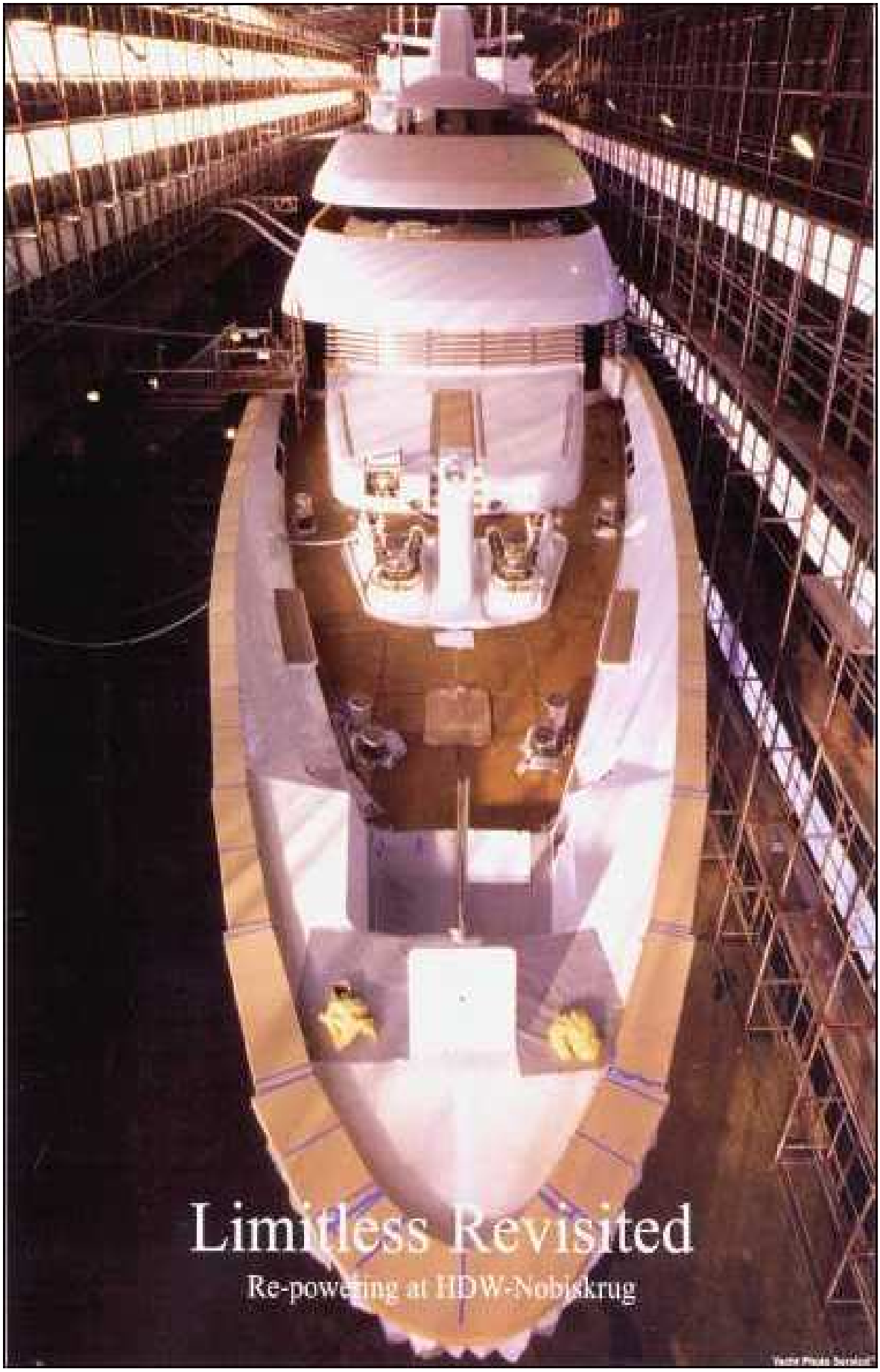

Limitless Revisited
Re-powering at HDW-Nobiskrug

The Ship

When launched in 1996 and commissioned in 1997, *Limitless* went beyond the perceived limits of yacht technology. Some of her equipment, systems or software were developed uniquely for the yacht, such as the joystick-operated dynamic positioning (DP) and the remote telemetered data sent from tenders to the charting software. The bridge software was effectively an integrated bridge using one-off software design to integrate the elements rather than an off-the-shelf integrated bridge. Other features such as combined diesel and diesel electric propulsion and anti-roh tanks were not new but a cross-application of technologies from other maritime fields. It was not that the systems of *Limitless* had never been fitted to other yachts or ships, although it was probably the first time quite so many had found their way on to one project at the same time. To call *Limitless* a prototype would be incorrect, yet there is no question we have all learned from the systems and approaches taken to her construction, most of which have worked successfully. Limitless was way ahead of her time and she could be seen as a 10-year R&D project, which has been fine-tuned during this refit. The yacht's systems are certainly complex and the work that has been carried out has been for refinement, optimisation, updating and refit. This refit does not propose to reduce complexity except perhaps in the propulsion, where the controllable pitch propeller (CPP) makes motor control shightly simpler.

The Refit

The refit, which came to an end in February this year, effectively started long before work began in dry dock number one at HDW-Nobiskrug on 1 August 2003. It had to: the sheer scope and complexity of the work appeared almost impossible to achieve in the time. Planning began long before and at least as early as summer 2001.

There are really two refits in one; the first is the work to improve functionality or refine existing systems; the second is 'normal' maintenance and repair and cosmetic and minor structural improvements. The project was envisaged by Captain John Barwood then planned and conceived by Jouke van der Baan and Jeroen Waalewijn of Seahorse.

Jouke had been a hydrodynamic and powering consultant from the early planning stages of the build of *Limitless*. In 2001

Captain John Barwood asked Jouke if he would be prepared to have a more comprehensive and active involvement; he agreed and began with the selection process for the new automation, control, and power and propulsion systems.

By May 2002 the Owner had appointed Jouke and his new business partner Jeroen Waalewijn as overall Project Managers.

In January 2003 Charles Miller commenced as Project Co-ordinator, while Jouke continued in a role best described as Owner's Engineering Project Manager assisted by Jeroen. Latterly Jeroen would deal mainly with onsite operations.

Three yards were approached and asked to bid for this project; HDW-Nobiskrug won the contract. This was not based solely on price but also on criteria, quality, time and value. It was on this basis that Nobiskrug was awarded the contract. A spokesman for the Owner said Nobiskrug was true to its word and completed on time and to the quahity promised.

Owner's Supply

Given the complex engineering modifications using new equipment with extensive lead times, many more items than 'normal' were Owner's supply. It is not unusual for AV and perhaps fabrics and the like being such; it is much less common to find props and shafts in this category. This is hardly surprising, though, considering that to be available in time the shafts and props had to be ordered in August 2002 — eight months before the contract was signed between yard and client. Limitless has traditionally been a project where many speciahist sub-contractors have long-standing commercial rehationships with the Owner. 1 visited the project the day after they had flooded the dock, near to the dose of the two- to three-week commissioning period

and a few days before the start of dock and sea trials.

Propulsion/Shaft Line
To understand what was to be achieved it is necessary to recap on the original propulsion concept for *Limitless.*

Original Propulsion Concept

Manoeuvring Mode Manoeuvring on and 0ff the dock was by thrusters only. They were controlled via a single joystick that could also operate through an EMRI Dynamic Positioning System in an extended manoeuvring mode, which could additionally utilise the propulsion propellers. Forward are two fixed thrusters, aft one retractable azimuth-ing thruster.

Electric Mode From a possible 1-rpm (shaft) the vessel is powered by electric motors with rpm control by variable frequency drives through a reversing gearbox to fixed propellers.

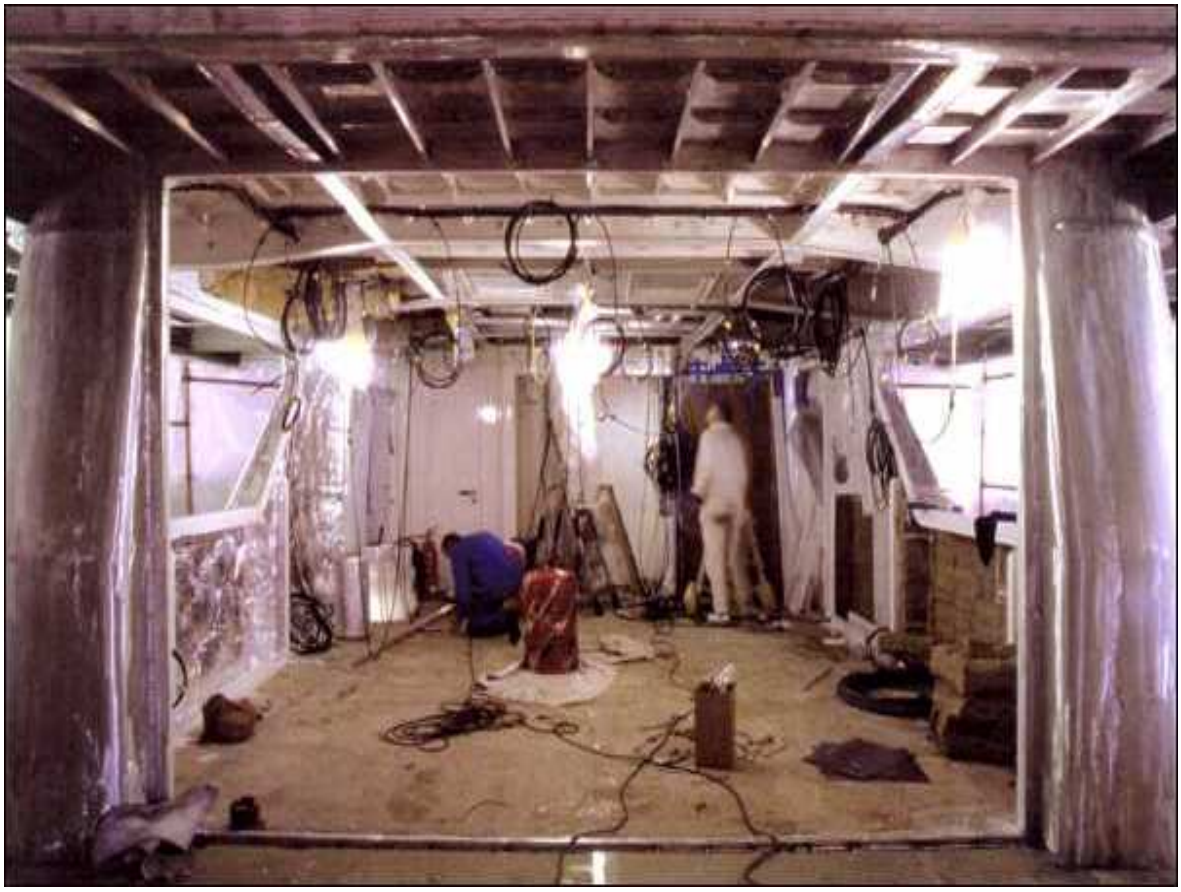
Diesel Mode The diesel main engines alone drive the props for a speed range of approximately 16 to 20 kt.

Boost Mode The gearbox combines the output of both the diesel engines and electric drive motors to push the vessel to a maximum of 25 kt.

The pitch of the fixed pitch propellers was essentially a compromise to suit the diversity of operating modes, speeds and combinations of prime movers, but biased towards achieving top speed. The power curve of a diesel engine is quite different from that of an electric motor, which is linear throughout its rpm range.
As originally pitched, the props were able to provide the required top speed; however, they did so at the expense of excessive loading of the main diesel engines in Diesel Mode.
Initially, the props were removed, repitched and slightly reduced in diameter. This produced a mild but insufficient improvement. Subsequently new props were fitted. These achieved the correct loading for the main engines but could not achieve the original top speed. Also Boost Mode could no longer be used as the diesel engines were already at max rpm in Diesel Mode. It became evident to Jouke that the only solution was to replace the fixed pitch propellers with controllable pitch propellers. Gearbox control was also problematic. Transitions between modes were not smooth and Captain Barwood told me that in the original configuration it was impossible to manoeuvre using props because of the long time delays. These time delays also made it difficult for the dynamic pos~ tioning to respond as required and inhibited functionality.

Although not a specific refit goal he expressed a hope that "conventional" manoeuvring using props and thrusters might be a bonus of the new configuration. Once the decision was made to replace the shaft line it was also found from calculation and testing at Mann that the shaft brackets could be improved in view of the technological advances since launch.
The original A and I brackets were a complex shape, using cast hubs and machined arms. They were Epo-cast, not welded in place, and had a built-in distortion or twist to optimise water flow.
Following Mann's research the new brackets have been mounted in positions better optimised to local flowlines and are manufactured with optimised sectional shapes producing a betten foil section less sensitive to angle of attack. The decision was made to use CPPs by Rolls Royce KaMeWa Ulstein. Fortunately these units were of only 50—80 mm greater diameter than the original shafts; this meant the extremely costly and difficult job of fitting new stem tubes would not be necessary. Bearings, seals and oil distribution boxes would, however, have to be replaced. Also all the machinery, of course, had to be re-aligned after the new shafts were installed. In the new mode of operation the gearboxes would no longer be reversing but would act only as clutches. The system controlling the gearboxes was changed and simplified.

The use of CPP now changes the way electric motors and diesel engines are used in the three modes:



Post Refit Propulsion concept
Manoeuvring Mode As before refit.

- *Electric Mode*

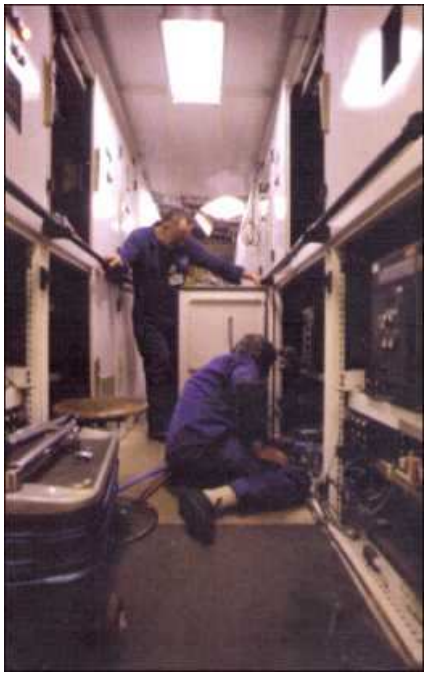
Each electric motor will now operate at a pre-selected rpm defined by the Combinator Control Curve to optimally bad its generator and avoid light bad cavitation damage to the propeller. Rolls Royce KaMeWa has defined cavitation safety margins based on extensive model-based research performed at its Kristinehamn Labs. Choice of ahead or astern and speed control will be by varying and, where necessary, reversing pitch.

- *Diesel Mode*

Here, as before, diesel engines only will be used. This is probably the most complicated control mode as both diesel engine rpm and propeller pitch will vary to produce a given speed or to optimise transition between speeds. The Combinator Control Curve again defines these parameters.

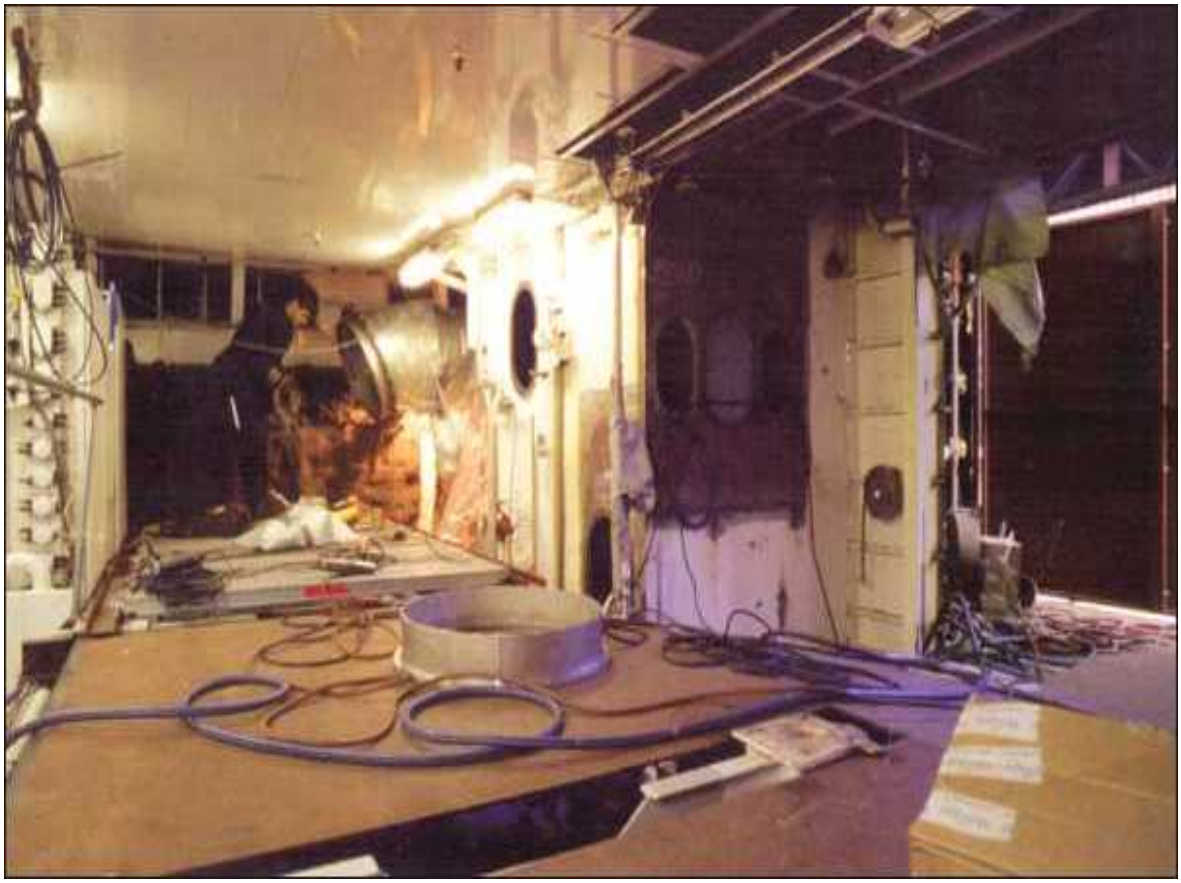
- *Boost Mode*

Again, as before, a combination of electric motor and diesel engine will be used on each prop. This time, though, this will be at fixed rpm, with pitch change only providing acceleration and setting the required speed.



The new non-reversing mode of gearbox operation should provide smoother transF tion with decreased time delays. There was no intention to increase speed or fuel efficiency. As M.D. Jan Ehlers pointed out, CPP is inherently less fuel-efficient than FPP; larger hubs and less optimal flow make this inevitable. However, in this particular case, Jouke advised me it is anticipated that the new CPP propulsion will provide fuel efficiency equivalent to the original props. Most importantly the mains will operate more efficiently and be correctly loaded at all operating speeds.

Propulsion Control System
The Kongsberg Auto Chief C 20 Power Management System is used to provide operator-friendly propulsion control. Despite the Auto Chief performing quite complex operations behind the scenes', the captain will simply control all three modes of main propulsion using a tradition-ab (in appearance only!) twin-lever control. Optimum pitch and rpm settings and design curves for the three propulsion modes are defined by the Combinator Control Curve. To derive these, Seahorse, with specialised support on electrical tasks from Deltamarin, carried out the majority of the calculation of optimum pitch and rpm settings for all three propulsion modes. These curves are programmed into the Auto Chief. The software chooses and adjusts machinery parameters for each speed setting.



Auto Chief controls the CPPs, gearboxes and main engines electronically and the electrical drive motors via variable frequency drives.

The VFDs have been renewed. Imtech Marine & Offshore was contracted by Seahorse to carry out this work. They fitted VFDs from Vacon PLC of Finland. These new liquid-cooled VFDs are capable of controlling 3.8 MW. More compact than the original system, having separate power and control sections, they represent state-of-the-art motor control. These VFDs were launched by Vacon in only June 2003. Imtech is also using these controllers for commercial shipping clients: a contract to fit 1.8 MW units to four chemical tankers is on-going.

Alarm, Monitoring & Control System

The Kongsberg Data Chief C 20 was chosen for this application. Given the complexity and type of propulsion system it's not surprising to discover that Limitless's electrical generation and distribution system is complex too. A problem had developed. In certain modes the propulsion gensets provide power to the hotel service busses. When leaving this mode and

handing hotel loads over to hotel gensets black-outs of unacceptable duration were occurring. The gensets could not be paralleled automatically and handover had to be done manually. Seahorse brought in Finnish engineering consultants Deltamarin to analyse the problem and suggest a solution. This problem was complex: the system must control four engines of two different sizes with two different types of governors, in one case electronic, the other mechanical. Following study they identified a solution and concluded the Kongsberg Data Chief automation system could handle this additional task, additional because when the C20 was originally selected paralleling of all tour gensets was not anticipated. After mechanical strengthening and modification of the busbars, harmonisation 01 the various grid voltages and implementation ot the Kongsberg control the goal was achieved: providing transfer and paralleling of power automatically, seamlessly and without black-outs.

DP and Wing Controls

The DP system has been completely modified and the software upgraded. Although the EMRI system could have been replaced with a Kongsberg product Seahorse felt sufficient confidence in the Danish manufacturer to choose upgrade over replacement. The aforementioned functionality problems were, they felt, due to gearbox delays. With the new simplified gearbox operation it is felt the DP system

will function fuily when commissioned by EMRI after the yacht's arrival in the Caribbean. The joysticks on the bridge wings have been augmented with conventional thruster control levers

ER *and Ship's System Improvements*

Originally the vessel used two 20 m3/d Alfa Laval vacuum distillation watermakers augmented with two HEM 25-ton-per-day RO units. During this re-fit the desalination was converted to all-RO. The installation was rearranged and a custom HEM 40-ton RO system added in place of the vacuum units. These in combination with the original 25-ton units will now handle all the yacht's desalination requirements. Ingmar Grip of HEM commented: "Vacuum distillation systems work very weil in situations with constant controlled waste (engine) heat . . . for yacht use the heat output is too variable except on crossings, so product quantities are often below expectations."

Much of the machinery except the main and auxiliary engines needed to be stripped out of the engine room and reinstalled or replaced. Space also had to be made to accommodate the two new CPP hydraulic power packs and a new working air system. Piping modifications were made to improve access and functionality.

The main engine muffiers were replaced and fitted with new insulation. This represents only part of the re-exhausting of the main engines carried out by MarQuip and Nobiskrug with the aim of reducing backpressure. The shape of the main engine exhausts were changed and re-located from underwater to a iocation on the water line. A spray system for water injection was installed. The muffiers are enormous items almost the size of the main engines themselves. Removing and installing these along with other work necessitated the cutting of a number of access holes in the ship.

The main engines were de-rated and the turbos changed. The original ABB equipment was replaced by Napier units to pro-

duce higher scavenge pressures and to provide a better air supply to the mains.

Wiring
Because of the improvements to Audio-Visual (AV), monitoring and control systems vast amounts of wiring were stripped out and new wiring puiled by the yard. Aimost no area was unaffected by this, including the Owner's areas as weil as technical spaces. Changes of wiring type (the control system, for example, uses fibre optics) meant that for these systems virtually all the wiring was renewed. "Looking back, this was a lot of work in the time," observed Tony Gale.

Bridge MCR & Networks
Limitless has three discreet data networks, using NMEA, CANbus and Ethernet separately and in combination.
Office: E mail, office and ship's business tasks.
KMSS: Kongsberg Auto and Data Chief, power management, alarm monitoring, machinery automation & control.
Operational: Lighting radar, Nav, HVAC, fire mimic, etc.
Vintimar was extensively involved in the original build and brought that experience along with new and upgraded software to the refit. During this refit Vintimar installed two updated data switching systems: one on the bridge, the other in the MCR. These will allow data from the networks to be displayed and controlled at will on any of eight touch screens in each area. Forward and aft areas of the bridge were rebuilt to accommodate these new equipment arrangements. Touch screens provide access to the ship's networks without interconnecting them. The networks are stand alone for reasons of preserving stability, redundancy and the avoidance of viral infections on mission critical systems. In fact, Ws not strictly accurate to say there is no interface, there is actually a biological one
-the human operators in bridge or MCR!
Although wisely retaining stand-alone instruments as back up, this approaches full glass cockpit integrated bridge functionality. The original control software for lighting, HVAC, conning, fire mimic maintenance and stability programme software has been upgraded. Vintimar also provided consulting services throughout the refit.

Ventilation
The intake and exhaust air system for the engine room was re-worked. Over time in

operation the system was found to have some hot spots, notably around the gen-sets. It was also felt that increased flow rates would prove beneficial. Charles Miller asked Bob Costello Associates to address this problem. BCA had provided Owner's consultancy during the final build stages of *Limitless*. They improved aero-dynamics around the fans and removed the acoustics enclosures from the gen-sets, substituting a non-enclosing baifle arrangement. The sound attenuators were removed and newly designed ones installed. The target was, of course, to achieve increased performance without increased transmitted machinery or ventilation noise. Pressure in the engine room has increased from 130 to 400 Pascals," Bob Costello told me, "and 100% of design flow rate has been achieved."

AudioVisual

The AV system was completely replaced. All the audio and video reproduction components were also renewed. As the Owner prefers 'real' discs a hard-drive audio or video on-demand system was not appropriate. The distributed system feeds from three pairs of Sat TV receivers for U. S., European and Caribbean satellites. Access to 1,600 CDs and three DVD changers that can control a couple of hundred DVDs are also available to eight zones. Various areas also have local DVD players and changers in addition to access to the PVID network.

Superstructure

The gym has been moved to the observation deck. To accommodate this the house was extended into what was formerly an open deck area, new doors were installed matching those on the other deckhouses. The original lower-deck gym was converted to a bunkroom.

The deckhead height was defined by the existing forward structure. Efforts were made to maximise interior height to allow proper and easy use of the gym equipment. This drove material choice such as aluminium sound-dampening flooring rather than sound-insulating plywood and rubber laminates, producing a small but both critical and contractual gain of a few millimetres!

The new AV racks were located here from their original position on the bridge; their move also caused a large proportion of the extensive wire pulling mentioned above. Additional dedicated fancoils were installed to deal with this equipment's exhaust heat.

Maintenance aspects of the refit

A variety of planned maintenance items were carried out. The Caterpillars, except generator engines, were overhauled as appropriate to their hours. The mains had already undergone major overhaul in 2001 before the experimentation using different prop pitches commenced. Now they were de-rated to suit the new propulsion configuration. The electric drive motors were removed, overhauled and re-insulated. The forward RIB store control hydraulics were rebuilt. The gangways were removed and returned to the builder ALJO to be overhauled, serviced and hydraulics rebuilt where necessary. On refitting, new door seals were fitted throughout. The massive stern platform was removed, reinstalled and refitted with new hydraulic rams. The sealing systems of the platform and the rams were improved to enhance reliability and longevity of components. New carpeting was fitted through the Owner's area.

Documentation

Nobiskrug will correct the as-built drawings to as-refit drawings. Given the large amount of Owner's supply equipment this will require extensive involvement and tasksharing with Seahorse who placed these orders on the Owner's behalf. Seahorse will also carry out the calculations tor, and produce, a new stability booklet.

For the benefit of both client and yard a combined photographic and conventional stock-take of the vessel's condition and equipment was made at the beginning of the refit.

THE SHIPYARD

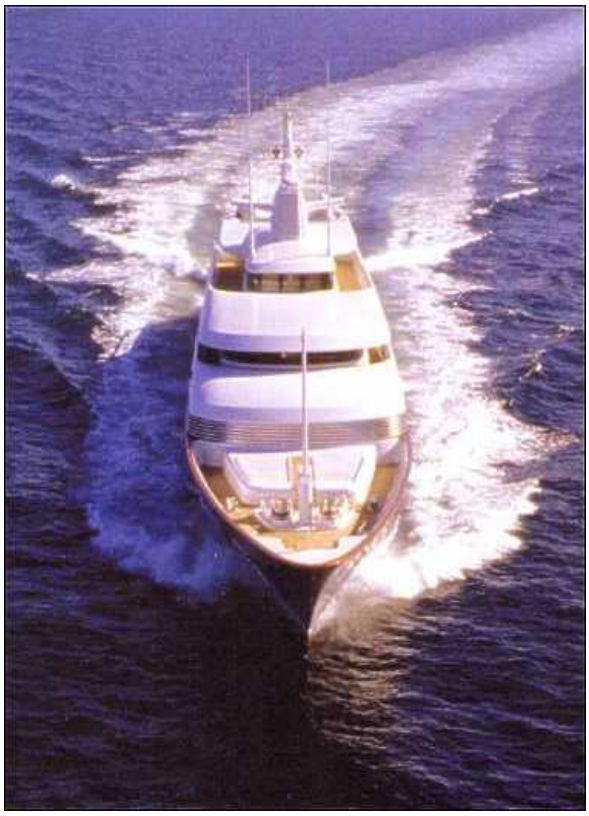
HDW-Nobiskrug is situated in Rendsburg on the Kiel or Nord-Ostsee Kanal about 100 km from Hamburg and 34 km from Kiel, home of its parent company HDW Schiffbau. The HDW group headed by HDW Schiffbau has three additional shipyards: HDW-Nobiskrug, Kockums AB of Sweden and Hellenic Shipyards Co. Additional group members are electrical and engineering company HDW-Hagenuk Schiff stechnik GmbH of Kiel, Hamburg and Bremerhaven and 50% of a logistics and ouffitting company MARLOG Marine Logistik GmbH of Kiel. This provides an extremely wide breadth of supply in many maritime fields —all effectively in-house. The Kiel yard has enormous capacity tor constructing and repairing large vessels, military craft and now very large yachts. *Octopus* and Mipos were built there and HDW-Nobiskrug had some sub-contract involvement in both these projects. 1 have heard (though not from HDW) that the Kiel yard may in the near future secure a contract to construct an extremely large private yacht for a well-known yachting client. They also produce non-nuclear powered submarines. As tonnage (size) litigation denies the usage of nuclear power, HDW and the German Navy spearheaded the usage of atmospheric air-independent propulsion technologies aboard their boats, and today the PEM (Polymer Electrolyte Membrane) hydrogen/oxygen-based fuel cell system is not only fully functional, but also in active deployment. I wonder who will be the first innovative and environmentally friendly Owner to specify such a propulsion technology for a large yacht, assuming that such would be technically and financially appropriate. Certainly, virtually silent operation would be their reward.

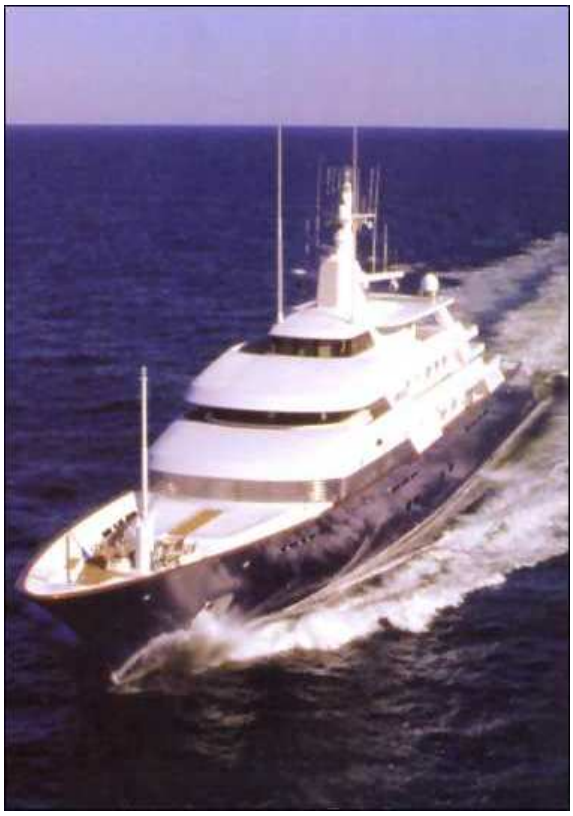
Christian Schäfer, Marketing and Sales Manager at HDW-Nobiskrug, told me that during NATO manoeuvres, German navy subs are particularly welcome sparring partners as they possess the capabilities to sneak past even formidable U. S. aircraft carrier protection lines, and manoeuvre themselves into fully feasible weapon launch positions.

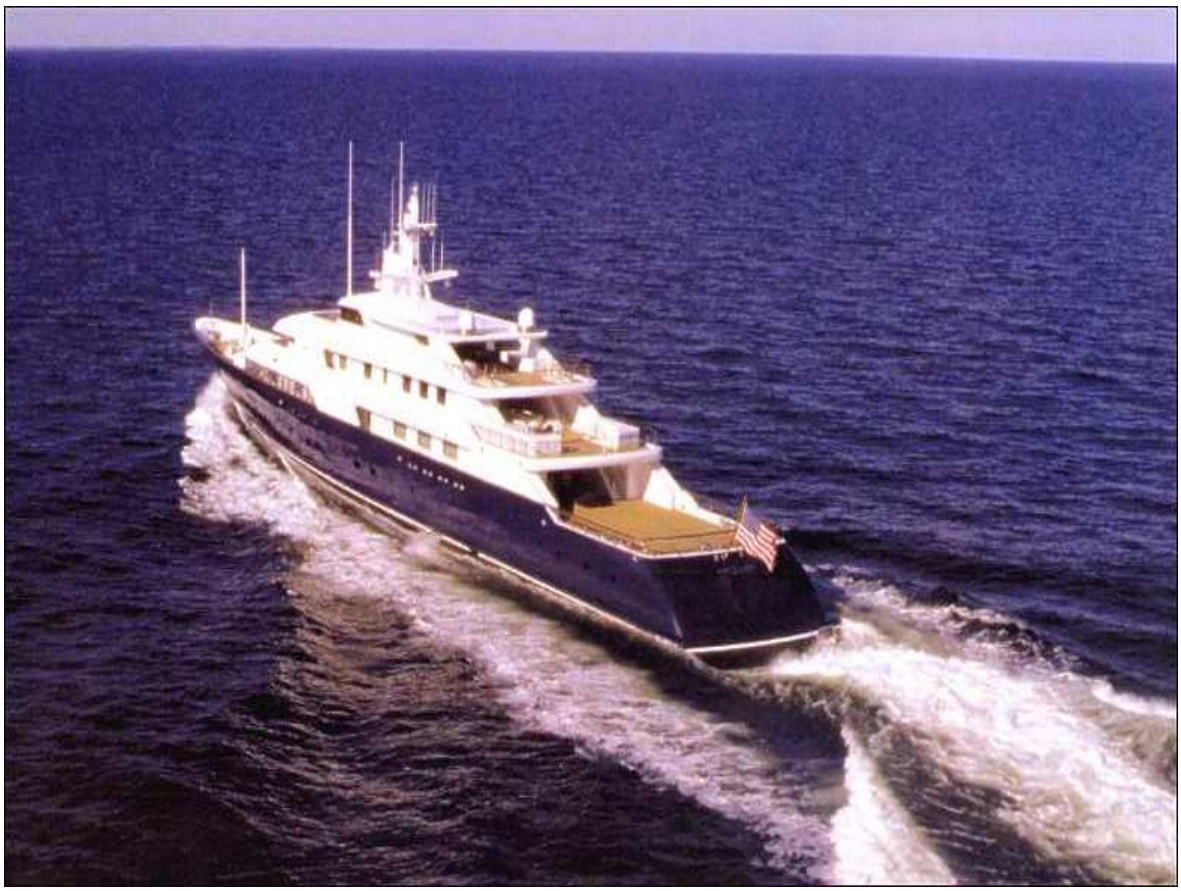
Christian came to the yard after eight years at Abeking and Rasmussen; he finished in sales but, coming from an interior design background, he started in the design office. One of his stranger projects before Abeking was producing interiors tor 'instant' supermarkets where post-Communist Siberian oil workers could spend their newly acquired hard currency. A more recent newcomer to the yard is Tony Gale; formerly of Blohm + Voss he joined HDW-Nobiskrug just before the *Limitless* project commenced.

HDW-Nobiskrug may be the smaller yard but that is a relative statement: they have two traditional building slips of 150 metres in length and two dry docks of 155 and 193 metres. *Limitless* currently occupies the 155-m dock and the 92-m *Tatoosh* was constructed in the larger dock. South of the slips is a large steel cutting and 'block' assembly building. Blocks of vessels are pre-fabricated here then taken to the slipways using special 'trucks' and cranes where necessary.

The yard has a 99-year commercial shipping refit and repair history, shifting from mainly new construction to emphasising this actiw ty after Germany — as with all European shipbuilders — lost most of the ship-construction







market to Far Eastern shipyards. The yard still builds ships, but very specialised ones. Currently on the ways and launching (in the traditional manner) the day after 1 left was one of a six-ship contract, the last of which should deliver in 2005. These are for a riverboat company that provides cruises on the Rhine and Donau. An overall length of 127 m is coupled with an extremely narrow beam flat bottom and the ability to gain 0.5 m of draft and fold or drop everything on 'top' to pass under bridges. Although their exteriors are not yacht finish these ships have an extremely high quality of interior fit-out; this work is done in house by HDW-Nobiskrug.

HDW-Nobiskrug seek a strong involvement in the yachting industry but do not propose to abandon the bread and butter commercial shipping business. In fact they are also involved in a bewildering diversity of supply. They cut steel for other shipyards; they have machine shop capability to machine very large steering components like ships' rudder stocks. They also manufacture aluminium windows for commercial buildings. I was even shown specialised quality control XRay cabinets built for microelectronics manufacturers. As already observed, the *Limitless* contract demanded a very short refit time; the yard's commercial re-fit background bolstered their confidence in agreeing to this. Cruise lines divide re-fit periods by the hour not the day and HDW-Nobiskrug completed a six-day refit of the cruise ship Bremen which had a 16.00 hours completion 'date' with passengers boarding for a cruise at 17.00. Having committed to join the yacht market Nobiskrug decided that refit and repair should not be abandoned solely to the high prestige of new construction.

Following the aforementioned *Tatoosh* construction for Kusch Yacht Agentur that completed in 2000 came the unfortunate Lürssen-built Ontario (ex-Falco) after her intimate contact with an uncharted rock off Rhodes. She arrived by barge with massive hull damage and water damage to her interior and engine-room. Her refit ran to 11 months. The yacht had to be not only restored to pre-accident condition to the satisfaction of Bureau Veritas, but also brought up to date. An additional difficulty was presented by the localised nature of the interior damage; it was restricted to the starboard side. The renewed interior fit-out had to match perfectly the existing port side finish. The yacht was re-

engined; new generators and exhaust were also required. A considerable amount of piping and associated systems were replaced. Surprisingly, the Owner decided not to put the yacht into MCA compliance, but even so effort was made to achieve regulatory compliance in the areas of fire retardancy and sewage treatment. Shafts were replaced and a new MCR was added in the engine room.

What is the future for the yard?

Once *Limitless* departs, work will begin to create a super yacht hall over dock 1 to replace the temporary structure used for this refit. On the day of my visit M.D. Peter Güldensupp had just returned from a meeting at HDW in Kiel with the parent company's blessing to commence building the superyacht hall. It will be climate controlled and of sufficient dimension to accommodate the air draft of 100-m-plus yachts. The dock itself will be versatile though; three sets of lock gates will allow it to be divided for multiple projects.

The yard won what Christian describes as a ~High Gloss" new construction project of 67 m for delivery in 2006, about which they are being extremely tight-lipped. I believe I'm allowed to say it is by the Hamburg-based design company Newcruise and will feature some innovative construction techniques. Christian tells me they hope to provide more information just before the 2004 Monaco show if the client permits. This will be constructed in the new hall. HDW Group members have a diversity of specialities — the Kockums website, for example, details yacht-sized littoral warfare vessels of unusual design and exotic composite construction. I can envisage future cross-fertilisation of design and construction techniques between group companies producing some unusual yacht construction projects. A rather new concept proposed is a repair or refit 'flying squad' which will arrive at a cooperating shipyard or dockside in, for example, the Med, to provide special skills work for a particular client of that yard. This is a brave move, though potentially a synergistic one. Principals of French Mediterranean shipyards recently met to discuss what might be done to win back and indeed stem the loss of clients who have left to other countries' shipyards. A major problem they have identified is lack of a strong local skills base in certain disciplines. Such a co-operative venture may be one answer to this deficiency.

I would like to thank all those on client and yard sides who took the time at 'the worst of times' — just pre sea trials — to tell me about the project.

Captain Tork Buckley