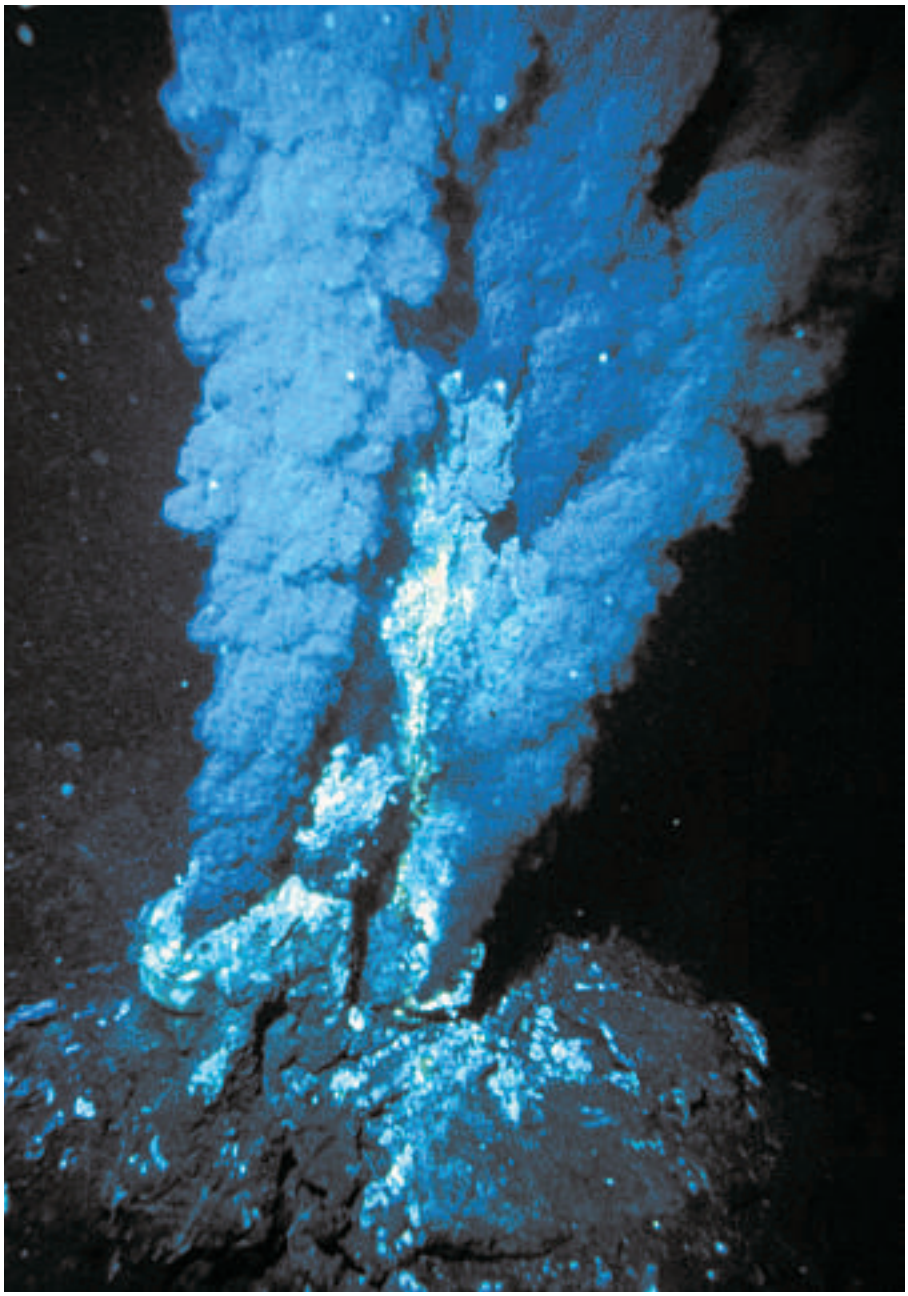
Deepwater

NuDeep™ technology for subsea development

10,000 feet down, on the bottom of the ocean, you will find one of the most hostile environments on the planet. Pressures of 4000 psi that would easily crush all but the strongest steel vessel; currents that threaten to drag off anything that is put there; and water chilled to sub-zero temperatures. The cost of major installations in this alien world is counted in the billions of dollars.

This is where, through a project called NuDeep™, ABB is planning to put subsea production technology. R&D efforts to position ABB prominently in the subsea deepwater oil and gas production facilities market underscore the company's commitment to meeting customers' ultra-deep water needs through reliable, commercially attractive solutions.



Black smoker at a mid-ocean ridge hydrothermal vent
Photo courtesy of National Oceanic and Atmospheric Administration (NOAA)

In initiating the NuDeep™ project, ABB is taking a market-driven approach to the development and commercialization of its next-generation subsea Deepwater Production System. The project underscores ABB's conviction that there is substantial potential for reducing the total cost of subsea field developments (including drilling and completion, pipelines and risers, and subsea facilities) while also increasing the competitiveness of subsea facilities technology for overall field developments.

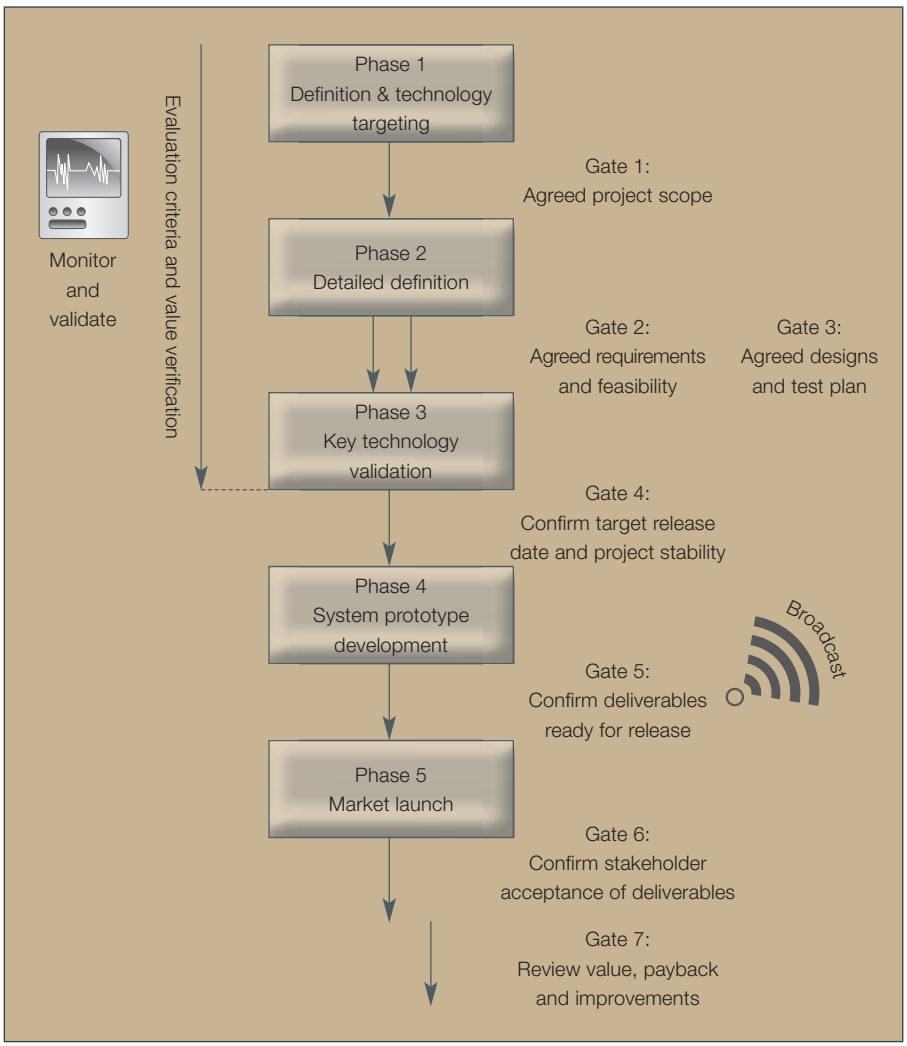
The NuDeep technology will open up the deep and ultra-deep water frontier to make development projects considered to be uneconomical and technically unfeasible today economically viable in the future. At the same time, this technology will reduce the effect of a key market constraint, namely access to deepwater capable rigs, by allowing 2nd and 3rd generation rig utilization for deepwater fields, as well as the use of smaller and lighter installation vessels.

Market-driven development

As mentioned, development of the NuDeep technology is market-driven. Key focus areas are:

- Reduced project cycle time and other areas related to first oil
- Reduced time to reach field production plateau
- Improved production rate and accumulated production/time unit
- Improved total recovery factor
- Reduced capital expenditure
- Reduced operational expenditure
- Improved system availability and component reliability

Overall responsibility for the NuDeep™ project lies with the ABB deepwater development team, located in Houston.



The various phases of the NuDeep program

In a first step, ABB defines the problems and technology targets to provide a basis for determining alternative concepts and main systems. The top-level drivers and resulting concepts are then thoroughly validated, both internally and externally.

Drivers and solutions

Time to first oil has always been important to our customers. Traditional thinking here is to reduce equipment delivery times in order to reduce the overall cycle time. This is still important and the NuDeep program has accordingly set specific targets for system engineering, manufacturing, testing and installation. Other important aspects of first oil are flexibility, to allow more to be done in parallel, from exploration-drilling all the way to well clean-up and final system commissioning. The NuDeep program will provide solutions with benefits for parallel operations and installation, early production and step-wise developments, as well as reduce or eliminate the interdependencies that lead to sequential operations.

NuDeep allows a substantially shorter time to first oil by bringing the wells on-stream faster. If, for example, a shorter time to first oil is not the objective, NuDeep can also accommodate longer reservoir modeling times and later drilling start-up.

Total recovery is another important factor for our clients. In most cases, it is linked to the cost of well intervention and the feasibility of performing intervention operations subsea. The NuDeep team is working on two main fronts in the total recovery area: First, to develop systems that will reduce intervention costs on subsea wells by more than 20 percent. Second, to truly integrate subsea processing functionality and equipment with the more traditional subsea production equipment to obtain a total subsea production system.

Development efficiency is traditionally linked to minimum capitalized expenditure. While this is still valid, NuDeep increases the focus on NPV5 (Net Present Value at year 5), NPV10, etc. It is vital to minimize pre-investments and to defer additional investments until they are needed.

Happy anniversary!

NuDeep has an illustrious predecessor – SUBSIS. The world's first seabed separation plant will shortly celebrate its first two years of operation in the North Sea.

Multinational oil and gas company Norsk Hydro calls it its favorite platform – a remotely operated, environmentally friendly system that is boosting oil output while driving down costs.

The subsea processing plant was developed by ABB for Norsk Hydro's Troll oil field. In almost two years of almost faultless operation, SUBSIS has separated hundreds of thousands of liters of water and oil at a depth of 340 meters below the sea's surface.

A Norsk Hydro spokesman explains that Troll wellstreams can contain up to 80 percent water. With SUBSIS, water is separated from oil on the seabed, a task which previously had to be performed on the floating platform. This water is then injected straight back into the reservoir, an environmentally clean operation.

The spokesman describes the Troll system as "a major breakthrough towards the vision of a platform-free future. It's new technology that makes operations more environmentally friendly," he says. "And saving energy cuts production costs. It's our favorite platform.

"By moving the separation process from the platform to the seabed, we save energy and development costs, and we achieve zero discharge of produced water into the sea."

Technical solutions

The NuDeep Deepwater Production System consists of four main systems: NuComp™, NuFlow™, NuProc™ and NuTrols™.

NuComp™ – subsea trees and wellheads

This subsystem constitutes the reservoir/completion interface to the subsea production system. Essentially a lightweight tree, it is primarily for slender drilled production, injection and dual-purpose wells, and is designd such that slim and lightweight risers and surface or near-surface BOP (Blow Out Preventer) systems can be used. The lower weight has the effect of reducing the rig tension requirements, thereby increasing the depth capability, and of reducing mud volumes and steel run in the hole.

NuComp can also be configured for heavy casing programs when necessary.

The subsystem can accommodate a wide range of BOP sizes and configurations. A 13-5/8″ BOP system (subsea, surface or split-stack) is foreseen, but more conventional 18-3/4″ or 16-3/4″ sizes can also be used.

The current NuComp tree design features a 16″ OD (16″x14-1/4″/14-1/2″ ID) riser system, with a tubing hanger of 13-1/2″ and a 10-3/4″ casing hanger. Future versions of NuComp will target sizes of 14″, 12″ and 9-5/8″ for these three, respectively.

The NuComp production wells configuration has the following characteristics:

- 5½″ monobore or 7″ swaged completion, matched to a 5½″ DHSV (downhole safety valve).
- 1¼″ annulus access is incorporated.
- Operable/testable annulus barrier in the tubing hanger, which eliminates a tubing spool (alternatively eliminating wire-line runs and dual bore diverted workover riser).

- Eight configurable downhole utility penetrations incorporated (hydraulic, electric and fiber-optic).
- In cases without gas lift at the riser base, NuDeep can facilitate this on the manifold or downhole.
- Monitoring, bleed-off and pressurization of 'B' annulus is incorporated in the design.

The water injection version of NuComp will have a 7″ tubing, swaged completion.

A dual-purpose version of the NuComp tree is under development. This offers disposal re-injection or pressure support water from the NuProc subsystem.

A production well NuComp tree is 50–70% lighter than one utilizing existing tree technology.

The NuComp system design reduces the running time during drilling and completion operations by more than 20% for nearly all completions. This reduction is achieved by:

- Elimination of wire line runs on rig time, eg by applying a 'floating plug' tool for subsea installation and retrieval of the tubing hanger plug.
- Parallel operations, such as deployment of the NuComp tree on a lift-line from the rig.
- Installation of NuFlow jumpers off critical path rig operations
- In inside tubing intervention, the NuComp subsystem allows use of intervention BOP and drill-pipe riser. This is particularly time-saving in multi-well campaigns.
- NuComp is designed to interface subsea wire-line and subsea coiled tubing systems

All in all, NuComp results in a 10–15% reduction in intervention costs on the tree system.

NuFlow™ – jumpers and manifolds

This subsystem features all the flow control functionality of the NuDeep Deepwater Production System. Its main components are:

- Infield flowlines and jumpers
- Manifolds
- PLEM/PLETs (Pipeline End Manifold/Terminations)
- In-line tees
- Production chokes and associated instrumentation
- Operational pressure containment valves
- Multiphase flowmeters or other special-purpose metering

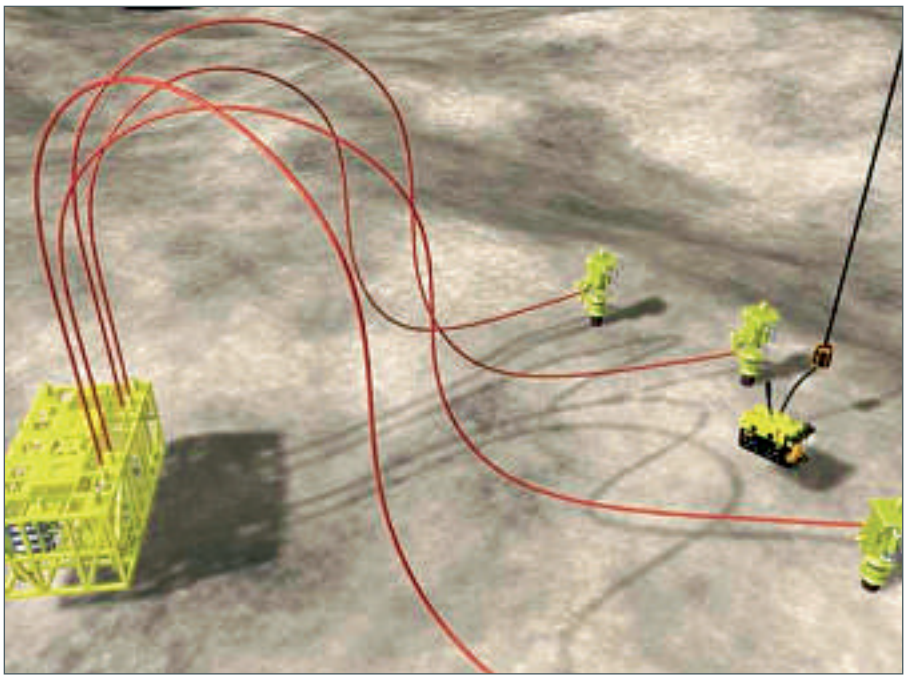
An important feature of NuDeep is that the traditional choke location on the tree has been changed. This is either moved to the manifold or integrated in the jumper systems. One of the main reasons for changing its position is the well stream's shear history. Locating the subsea processing subsystem upstream of the choke significantly improves separation performance.

NuDeep™ will open up the deep and ultra-deep water frontier to make development projects considered uneconomical and technically unfeasible today economically viable in the future.

NuFlow offers a whole range of operational benefits:

- Faster installation, made possible by the elimination of critical path operations (essentially enabling parallel operations), for operations conducted from the drilling rig as well as from installation vessels.
- Maximum flexibility for operational sequences and system configuration.
- Standardized interfaces between the various functional blocks/subsystems of NuDeep and those internal to NuFlow.
- Less need for expensive custom tools and support structures.
- Lighter, lower-cost vessels can be used for deep and ultra-deep water installation work.
- Logistics are improved: rig and support/installation vessel operations may be combined during drilling.

The novel NuFlow jumper system is available in three basic versions:



Four-well cluster manifold system

- Lazy-wave JAS (Jumper Arc System) – primarily for connection between the NuComp system and manifold or between NuProc and a PLEM. This jumper can be made of either steel or composite, but composite has shown to be the material that will give the best fit-for-purpose design.
- JAS – primarily for longer connection distances, eg between a manifold and a PLET.
- SMART – true horizontal jumpers, intended for applications where the JAS cannot be applied, eg cases where a high functionality or conventional type jumper is required

All NuFlow jumper types are installed in a single-point lift and run in the vertical mode, deployed only by a lift-line and assisted by an ROV. For the Lazy-wave JAS the first end connection will be a stab and hinge-over and the second a vertical connection. The horizontal section of the jumper makes it safer to operate a subsea BOP and other well intervention equipment, ie there is less risk of collision with, and damage to, the jumper. This meets the key requirement that the jumper be left undisturbed during these operations.

The lazy-wave configuration, established with a combined system of bend-stiffeners, buoyancy and insulation, provides so much jumper flexibility that there is no need for accurate metrology for jumper tailoring and installation.

The standard JAS jumper does not need a horizontal section as it will feature connection between installations without heavy module activity near the jumper.

The SMART jumper, in a conventional or high functionality version, will, as it presently stands, require accurate metrology. However, it is designed to be installed as a single lift run in the vertical mode, hence eliminating the need for a spreader bar or spool lifting frame.

In a comparison between a 6″ conventional jumper and Lazy-wave JAS of the same diameter, the reduction in 'as-installed' costs was more than 25%, when offshore tailoring was considered not to be on the critical path.

NuProc™ – subsea processing

The NuDeep system relies on NuProc functionality for:

- Higher production rates, thanks to a reduced reservoir back-pressure (higher draw down.) This has a significant impact as the water depth and water production increases.
- Enhanced total recovery. Deep and ultra-deep water well production is possible even with high water cut, as well shut-in due to water production is deferred.
- A positive impact on overall field development optimization, as less processing equipment is required topside. In some cases, pipeline dimensioning and insulation requirements can also be reduced.
- A positive impact on flow assurance challenges in deep and ultra-deep water, as water removal will shift the well stream outside the hydrate area and/or significantly reduce the required inhibition chemical consumption.

NuDeep technology provides cost-effective answers to traditional problems and combines them with solutions that increase production and customer revenue.

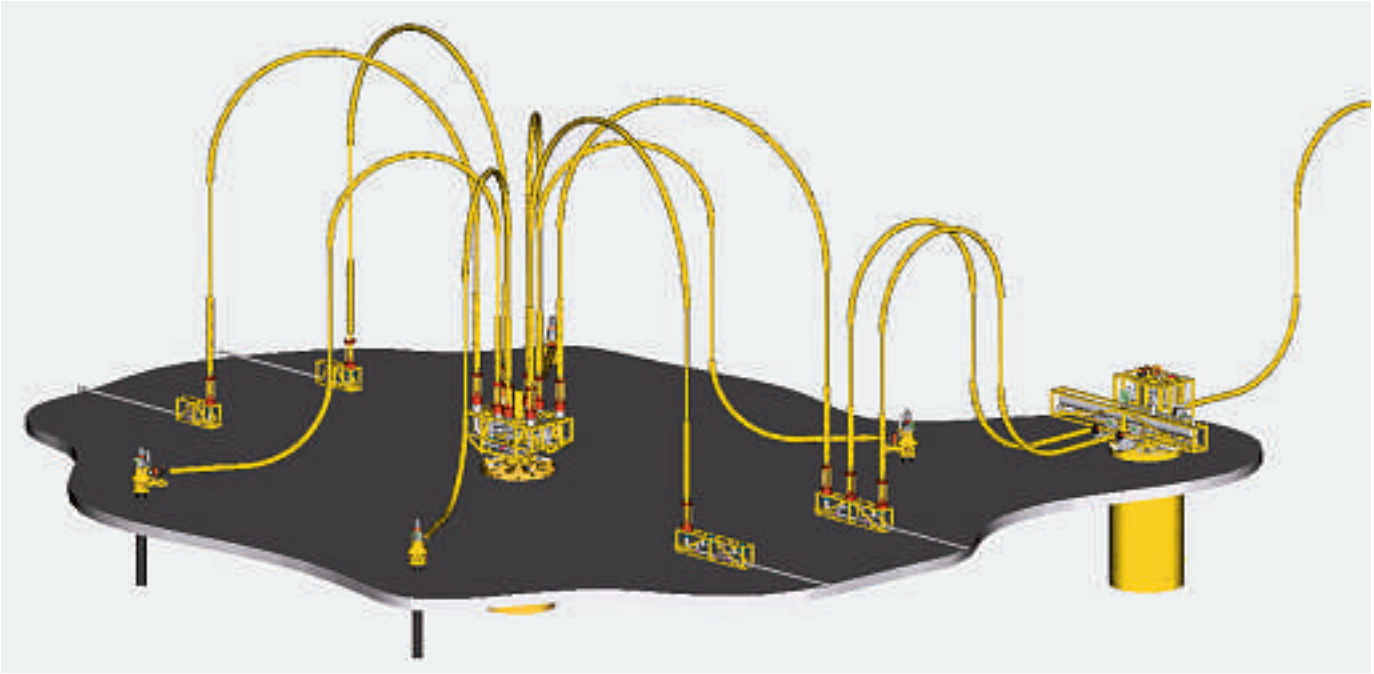
NuProc features a very reliable, yet compact, deepwater subsea processing system. The weight and size of the horizontal separation vessel have been significantly reduced by means of innovative integrated electrostatic coalescer technology. This exposes the mix of water and oil to an electrostatic field which orientates the dipolar water droplets contained in the oil phase in such a way that they 'collide' and coalesce. The water droplets so formed quickly grow, reducing the time the fluid needs to be in the separator for adequate phase separation. It also keeps the mix out of the hydrate area in most cases.

For cases where separation is inadequate, ABB has developed and patented a second-stage oil and water mix treatment device. This utilizes di-electrophoresis, which uses electrostatic field concentrations to force the water droplets into designated sections of the separator to form 'strings' of water. Tests show that this impacts the required retention time by a factor of 10, allowing the separation vessel to be ten times smaller. None of these methods require rotating machinery or a significant supply of power, as the electrostatic field in each of the two devices can be established without much electrical energy.

Both the electrostatic coalescer and the di-electrophoresis water concentrator are designed such that they can be integrated into the horizontal separator vessel. Separate modules, flow connectors, etc, are therefore not required. Electrical power is supplied to both devices at low voltage, step up to the required level taking place inside the separation vessel.

The weight, size and modularity of the separator vessel facilitate the configuration of distributed separation systems. A per-well configuration is even envis-

NuDeep tree. The traditional choke location on the tree has been moved to the manifold or integrated in the jumper systems.



aged; this can be especially applicable for a step-wise development, where wells are brought on stream over a period of time and some produce more water than others. Otherwise the system will be centralized, with the number of 'slender separators' required to handle the applicable liquid production. Water purification and re-injection will mostly be centralized in order to reduce the electrical and control infrastructure.

In deep water, and especially ultra-deep water, applications, there is usually very little free gas. However, where large volumes of free gas are present, a gas/liquid separation device may be used upstream of the oil/water separator. A compact cyclone for gas/liquid separation is under development at ABB, the topside version of the device being already installed in the field. Other functional requirements related to produced water purification (de-oiling) and particle removal (de-sanding) may apply, depending on the field. Devices for handling these are under development.

NuTrols™ – subsea control systems

This new control system being developed for NuDeep features a very flexible design and a control pod with distributed functionality. The single most important development goal is that the NuTrols mini-pod shall be ROV deployable, with no need for fine-tuning of ballast and buoyancy or for other specialized tools.

Main features of the new control system are:

- A lightweight pod for simplified installation and retrieval in deep and ultra-deep water; also with knock-on effects for the design of other NuDeep subsystems.
- Communication over optical fiber or wire.
- System configuration allows standardized, simplified engineering.
- High design flexibility for easy system and retrofit expandability.
- Local data processing possible when needed.

The NuTrols system features a basic functionality pod, the primary purpose of which is to control hydraulic valves, collect instrument readings and sensor data, relay control commands, and provide electrical power to direct control valves (DCVs), etc. A power pod is also being included in the NuTrols suite of building blocks to supply the extra electrical power needed to accommodate NuDeep's extended functionality (eg, low-voltage/medium-power loads for subsea processing).

NuDeep commitment

NuDeep technology takes full account of the challenges facing our customers by providing cost-effective answers to the traditional problems and combining these with solutions that increase production and customer revenue.

NuDeep goes ultra-deep, to 3000 meters (10,000 feet) and more, and facilitates long-distance oil/gas transportation. As the next-generation ABB Deepwater Production System, it improves greatly on the traditional functionality of such systems, with improved life-of-field logistics from exploration through abandonment.

Technical information for this article was provided by Nils-Arne Soelvik and Lars-Petter Sollie, both with ABB Offshore Systems Inc, Houston, USA.