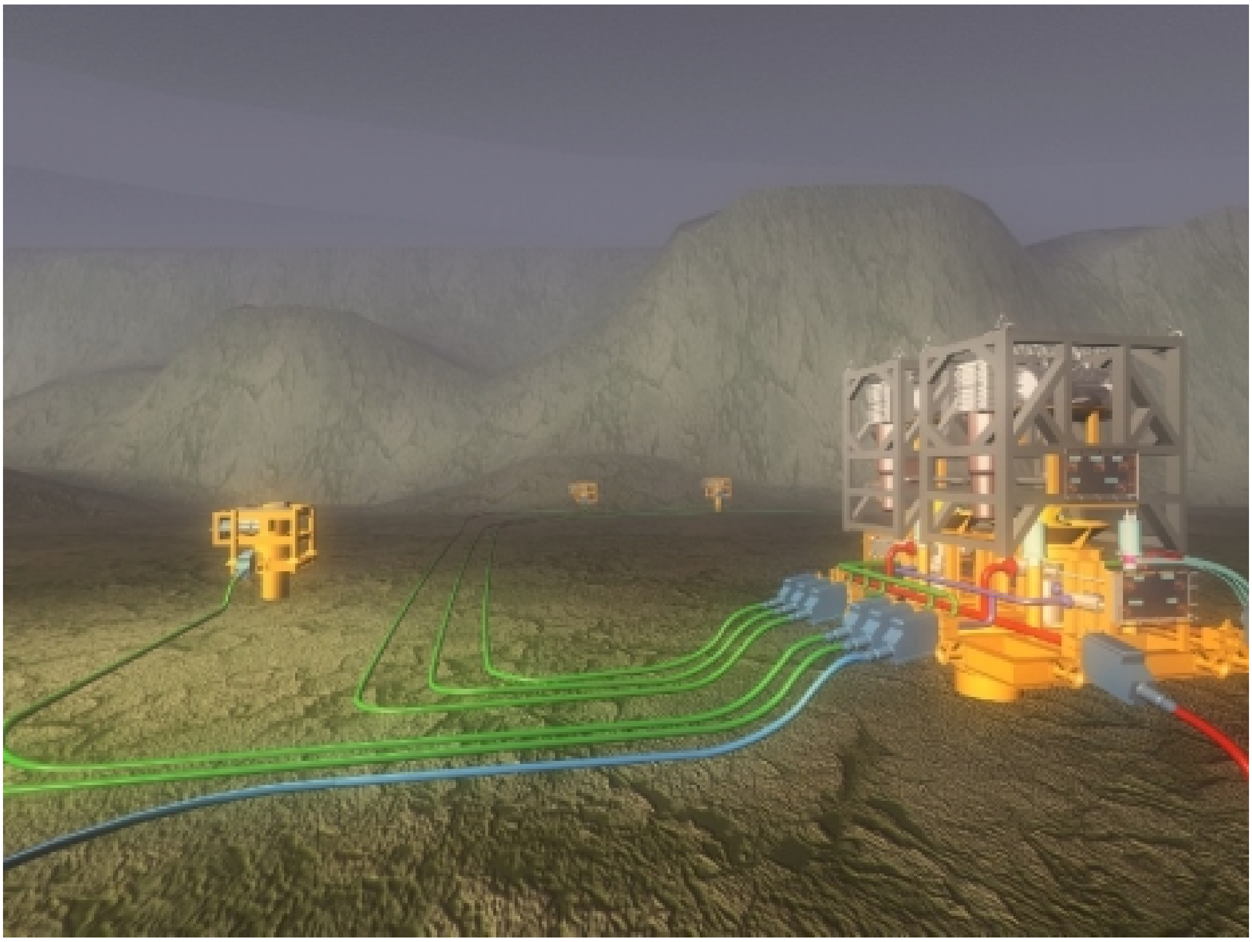
System-Modular Installations for Incremental Field Development and Cost-effective Separation Systems



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Introduction

This paper briefly propounds the advantages of seabed separation and boosting and then introduces an all-electric, System-Modular method of incremental field development that provides flow assurance and reliability. The theme is continued, showing that early oil can be achieved whilst minimising CAPEX and maximising the net present value (NPV) of the field, and illustrates how fields can be developed on an incremental basis, without needing to commit all the necessary equipment at the outset.

Enhanced production from subsea reservoirs by means of seabed separation and boosting

Seabed separation and boosting maximises subsea hydrocarbon extraction by reducing the effective depth of the reservoir. The production rate can therefore be increased and field life can be effectively extended. Using Brent fluid data, it has been calculated that the application of first stage separation and boosting on the seabed can increase production by up to 75% when compared with surface separation. This conclusion was first published by Alpha Thames Ltd in a paper entitled *Evaluating the feasibility of subsea separation in deepwater fields and its effects on the necessary infrastructure* which was given by David Appleford and Mike Taylor (Process Engineering Consultant) at the “Deeptec ’98” conference, 27th January 1998. Whereas the maximum production advantage is to be gained in deepwater scenarios with long tiebacks, the paper also showed that seabed separation and boosting provides significant advantages for short tiebacks in moderate water depths. Additionally, the application of seabed separation and boosting makes it possible to re-deploy FPSOs to other fields or releases platform facilities for other purposes. Calculations prepared by two separate operators, using actual field economics, indicate savings of between $2 to $4 per barrel when utilising seabed separation and boosting instead of conventional field development techniques. These calculations were completed for a variety of fields in the North Sea and Gulf of Mexico.

Seabed separation and boosting can overcome the need for multiphase pumping or ESPs; each of the separated liquids is pumped at a constant rate, with the gas being transported by virtue of the pressure in the separator. Constant speed pumps obviously do not require speed control equipment; the latter is often bulky, costly, will reduce overall system reliability and has step-out distance limitations. Fluid levels in the separator are continuously monitored and are adjusted as necessary by fast-acting modulating valves that are fitted with electric actuators. These actuators have been developed and thoroughly tested by Alpha Thames.

Flow assurance and reliability

Seabed separation also significantly reduces the propensity for slugging and the formation of hydrates in the export lines. It also significantly reduces the need for injected chemicals necessary for hydrate prevention and for inhibition of corrosion. It has been found that this one factor can result in very significant cost savings, even to the extent of rendering viable a field that would otherwise not have been developed.

The System-Modular installation known as an AlphaPRIME™ Central Processing Unit (CPU) comprises at least two identical operating System-Modules, both of which operate continuously so that there are no problems associated with starting up “dormant” equipment. If one System-Module has to be removed for any reason, such as planned maintenance or reconfiguration, the remaining System-Module(s) continue(s) to function so that there is no need to shut-in the wells or interrupt production.

In an application utilising two System-Modules, each module would normally be sized for 60% of peak throughput, i.e. the system could handle 120% of peak flow. This would allow 60% of peak flow to be maintained during System-Module change-out, without shutting in any of the wells or ceasing production. Because the maximum peak throughput from the field would only occur for a comparatively short period of time, each System-Module could have the capacity to process up to 100% of the total throughput during most of the field life. A typical single System-Module has a throughput of 20,000 bbl/d or 250 mmScfd. However, the capacities of the System-Modules can be varied at the design stage, to suit the Clients' requirements.

Reliability is essential for seabed installations, especially in deepwater, and it has been addressed in the following ways. The processing, boosting, monitoring, control, and power distribution systems are integrated into each System-Module at the design stage. Upon completion of assembly, this approach enables thorough system integration testing of the complete process (contained within each System-Module) to be undertaken in the factory. The test programme includes a period of "burning-in". This ensures that all the equipment is compatible and any faults can be thoroughly investigated and rectified prior to each System-Module leaving the factory.

It is important to bear in mind that the apparent cause of a fault may turn out to be a symptom as opposed to the root cause. In the field, should a fault develop, the System-Module (with the complete process system) is recovered whilst production continues via the remaining System-Modules. This permits thorough investigation of the fault and ensures that any initial misdiagnosis does not require further costly intervention to recover additional equipment.

The System-Modules are electrically controlled by well-proven, industry standard, programmable electronics. The power distribution is "hard wired" within the System-Module which contains all the necessary transformers and switchgear. Each System-Module has a main transformer within a pressure-balanced housing. Each module is supplied by means of an integrated services umbilical (ISU) that delivers high-voltage power, electric control and injection chemicals. The absence of hydraulics, the utilisation of all-electric power and control, and the minimal number of wet-mateable interfaces combine to optimise reliability. The high-power, high-voltage connection is provided by means of the ELEx Connector that has been developed by Alpha Thames, or, alternatively, by any suitable proprietary connector of the Client's choice.

The System-Modules can also be interconnected to form a "ring main" to/from the host. This has the advantage that any one System-Module can be isolated by means of switchgear in the adjacent System-Module(s) and/or that at the host facility. Therefore, it is possible to isolate and retrieve any System-Module, whilst maintaining power to the remaining modules, even if its switchgear is faulty.

Alpha Thames take a risk-based approach to reliability; detailed failure modes, effects and causes analysis (FMECA) is undertaken in order to identify all possible failure modes and to enable highly reliable solutions to be realised that, in the unlikely event of failure, only result in loss of performance rather than a complete loss of function.

Furthermore, as each System-Module is "burnt-in" before it is shipped to site, early-life failures (as illustrated in the "bathtub" curve, Figure 1) can be identified and eliminated during factory testing. This confers a significant benefit upon its in-field reliability and performance as is illustrated by the graph, which shows how any early life failures (which are the most financially significant) are identified and resolved whilst the System-Module is on test in the factory. The module is only field-installed when the entire system has been functioning faultlessly for the required period, ensuring that it will then be functioning at its optimum reliability. If required, stump testing can also be undertaken immediately before deployment to guard against any effects of transit. The systems are self-monitoring, ensuring that any untoward trend in equipment performance is identified and that the necessary remedial action is taken before equipment failures take place, ensuring that the System-Modules are recovered for maintenance before the wear-out phase begins. This ensures that optimal system reliability is maintained because the equipment is only in the field during its useful-life phase. Although preventative maintenance is the norm for topsides and shore-based industry in general, this philosophy has not, until now, been available to subsea systems.

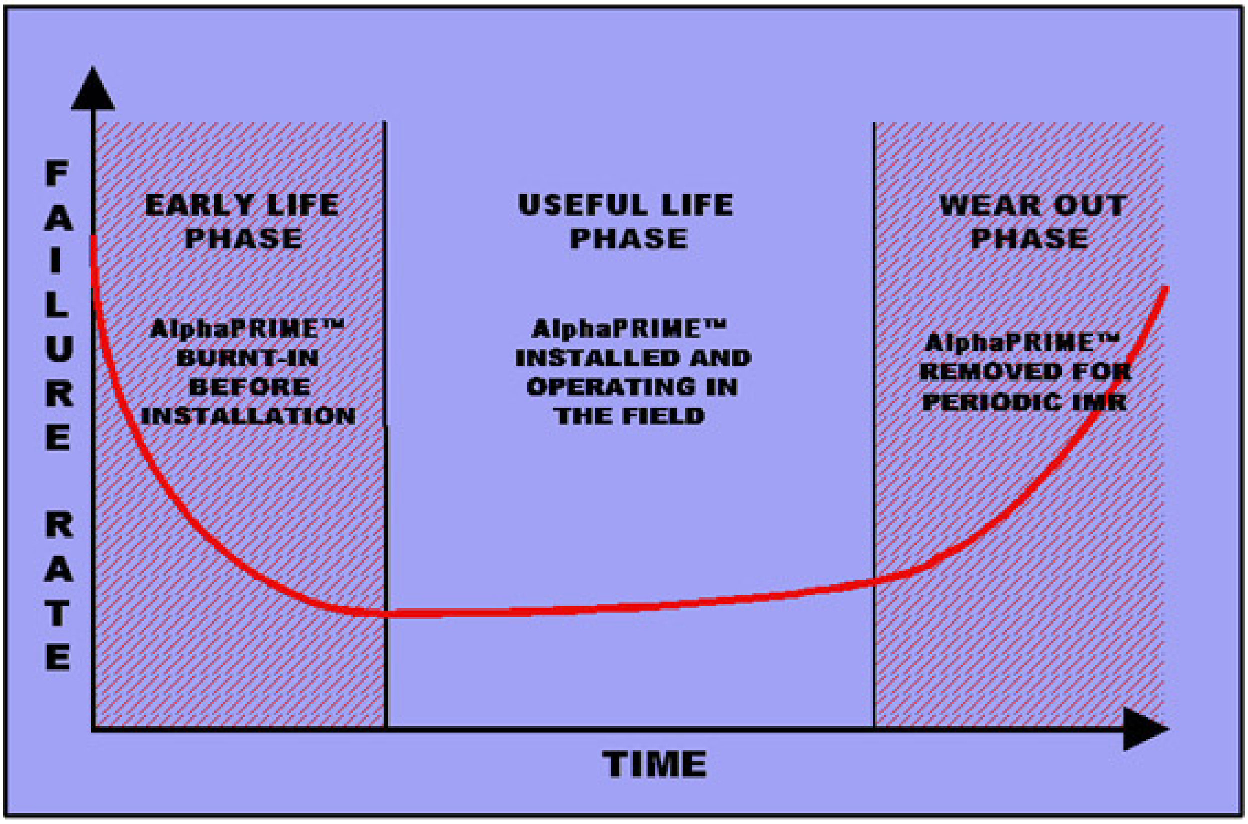

Figure 1- Reliability "Bathtub" Curve showing the optimum reliability of AlphaPRIME™ in the field

Incremental field development for maximised NPV

The AlphaPRIME™ CPU consists of a simple Docking-Manifold (see Figure 2a) that is installed, usually on a monopile, on the seabed. The Docking-Manifold contains only field-proven equipment and does not include controls or actuated valves. In a "green field" scenario, early installation of the Docking-Manifold can be made at the same time as the pipelines. The fluid connections for the System-Modules are provided by multiported wellhead-type connectors which, initially, can be fitted with simple System-Modules: FlowCaps (see Figure 2b) that enable the early flow and monitoring of first oil. Connections to the pipelines are made using any proven proprietary pipeline connection system.

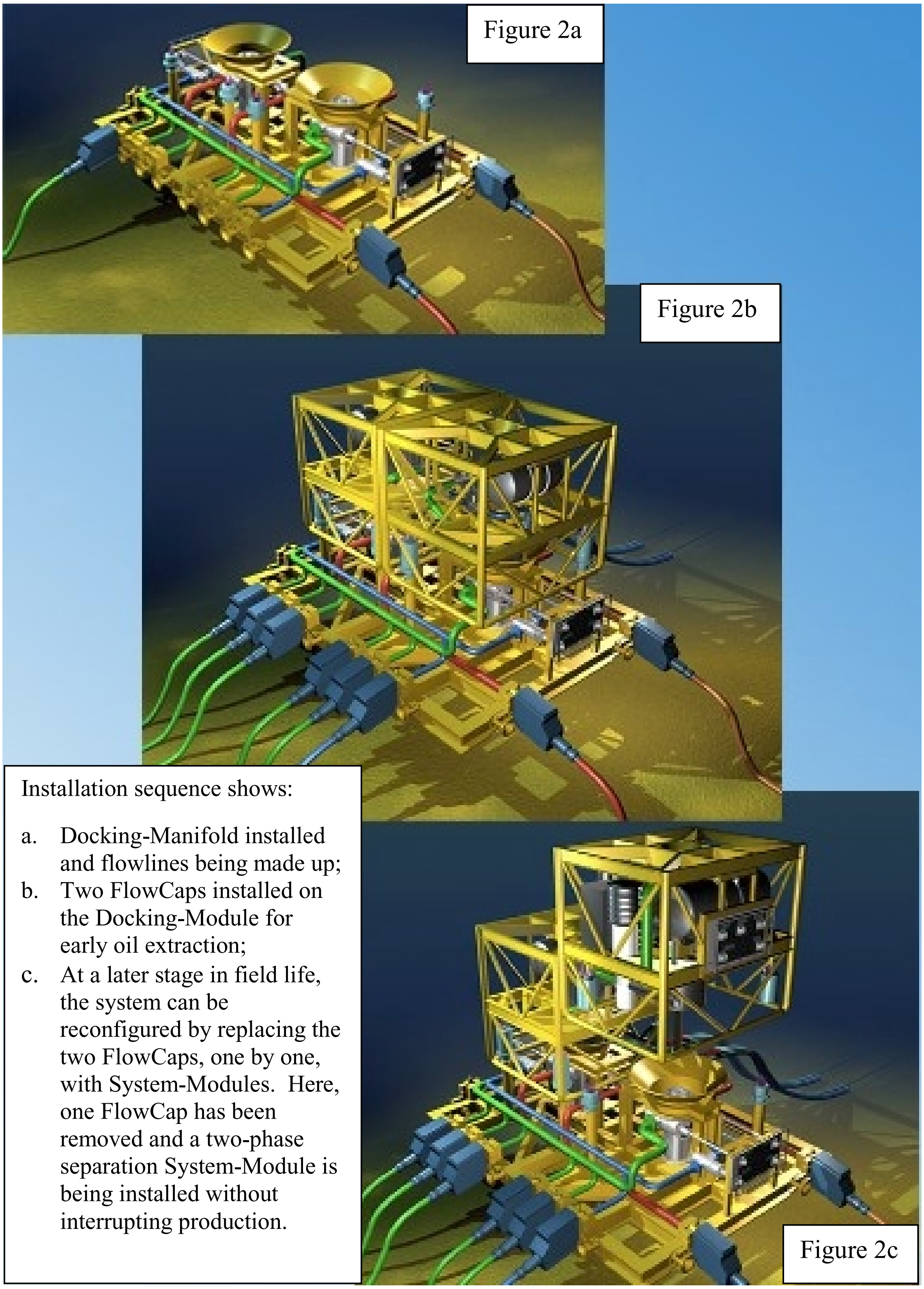

Figure 2 – AlphaPRIME™ CPU: Installation Sequence

The Docking-Manifold normally accommodates two System-Modules (see Figure 2c) which, in turn, can accommodate a wide range of systems and equipment to suit any field scenario such as: manifolding; two-phase, three-phase or even four-phase (including sand handling) separation and boosting; and water re-injection. The separation systems can be gravity-based or dynamic. In this way, the Docking-Manifold is analogous to an electrical double socket, into which the current "processing" requirement of the field can be plugged.

This method enables a field to be developed incrementally, first oil being obtained shortly after the installation of the initial, basic equipment which may be a "FlowCap" that enables the produced fluid to flow through the Docking-Manifold to the selected host facility. NPV is maximised by early oil and low initial CAPEX, and the cost of more featured System-Modules is incurred later in field life once field performance is clearly understood. The System-Modules can be reconfigured at any time during field life, either in response to changing field characteristics (such as increasing water cut) or to include new technology when it becomes available (such as subsea gas compressors) without needing to interrupt production or shut-in the wells. As already discussed, seabed separation and liquid boosting enhances reservoir drawdown. It significantly increases the production rate in the early years of field life thus significantly enhancing NPV; it also increases overall yield thus prolonging viable field life.

If required, additional CPUs can be installed and tied-in to the first CPU, as the field is developed further or as additional wells or satellite fields are developed. A System-Modular installation can be regarded as the central processing unit (CPU) of the complete field development; it can act as a control centre that provides feedback data, monitoring performance in real-time, especially as it operates autonomously yet offers the operational flexibility of being reprogramable from the host facility. Moreover, the System-Modules can interface with reservoir monitoring and testing. The System-Modules can distribute power to neighbouring seabed systems and, if required, they can be configured to include hydraulic power units (HPUs) in order to power and control conventional hydraulic trees.

Minimising installation/commissioning windows

It may be seen from the foregoing that a System-Module that is delivered to the field is a fully tested, self-contained system that is capable of operating autonomously but in concert with identical System-Modules in the installation. As each module has only three wet-mateable interfaces, installation is readily accomplished within short weather "windows". Commissioning consists of little more than leak testing these connections and basic functional testing. Significant cost savings are therefore achievable. The subsequent retrieval of a System-Module for maintenance or for re-configuration and, ultimately, its decommissioning are also readily accomplished.

Figure 2 shows the installation sequence for an AlphaPRIME™ CPU. The Docking-Manifold is normally installed on a monopile (depending upon the seabed characteristics) and can be installed at the same time as the pipelines are laid. It should be noted that the Docking-Manifold only contains "dumb" equipment (e.g. ROV-operated valves) and that during the subsequent operation of the complete CPU, the valves within the Docking-Manifold remain open, except when it is necessary to retrieve a System-Module. Pipeline connections to the Docking-Manifold are by means of proven proprietary connection systems. The male halves of the high-power, high-voltage connectors (on the terminations of the ISUs) are also located in the Docking-Manifold.

The Docking-Manifold always accommodates at least two System-Modules. These have a footprint of only 5 m by 4 m and they weigh between 25 and 80 tonnes, depending upon the equipment within them. They are deployed, one at a time, from a DSV or similar vessel equipped with an A-frame and are installed with the aid of a work-class ROV. The interface connections are readily made and tested, and the ROV opens the valves either side of the multiported connector (on the Docking-Manifold and on the System-Modules) using standard API ROV interfaces. Commissioning consists only of leak testing and basic functional testing in order to prove the power and controls connections; significant cost savings are therefore achievable.

Alpha Thames successfully completed underwater trials of an electrically powered and controlled prototype System-Module in September 1999. This was the culmination of the ÆSOP Project that was supported by the Commission of the European Communities and by a JIP; the in-water trials of the System-Module (as shown in Figure 3) were witnessed by DNV and by representatives of the EC, Conoco, Statoil, Shell and British Borneo. This demonstrated that a System-Module, configured for two-phase separation, could be taken from the dockside and installed onto the Docking-Manifold and (in shallow water) and commissioned in less than twenty minutes.

Figure 3 – Demonstrating the ease of installation and commissioning of Alpha Thames' prototype System-Module during its in-water trials

The retrieval of a System-Module is a similarly diverless operation, requiring the same kind of vessel and a work-class ROV. The shutdown procedure for the System-Module is initiated at the host facility. When complete, the electric power to the System-Module that is to be removed is switched off, whilst the remaining System-Module(s) continue to operate. The ROV undertakes the hydrocarbon flushing procedure and closes the isolation valves on either side of the multi-ported, wellhead-type connector. The high-voltage, high-power connector socket in the System-Module is retracted from its plug in the Docking-Manifold; the controls and chemical injection connector is also disconnected. The System-Module can then be removed from the Docking-Manifold.

At the end of field life, the entire installation can be removed by recovering all the System-Modules, disconnecting the flowlines and the ISUs, and retrieving the Docking-Manifold. If required, the monopile can be cut off at, or just below, the mudline.

Conclusions

The all-electric, System-Modular method of incremental field development provides flow assurance and reliability. Early oil can be achieved whilst minimising CAPEX and maximising the net present value (NPV) of the field. Furthermore, fields can be developed on an incremental basis, without needing to commit at the outset, all the additional equipment that may be needed subsequently.

System-Modules can accommodate a variety of seabed processing equipment including first-stage separation and boosting, all of which combine to achieve the cost-effective development of new fields and also mature fields that might otherwise be regarded as of rapidly diminishing value. Existing infrastructure can be utilised to great advantage when employing the system in such fields. Seabed separation widens the scope for utilising existing infrastructure, as step-out distances can be increased. A System-Modular installation can release surface facilities, such as FPSOs, for use on other fields.

CAPEX costs are significantly reduced in many ways, such as the opportunity to make pipeline savings. Risks and installation time are minimised because of the thorough system integration testing that is undertaken before shipping the System-Modules and because wet-mateable interfaces have been reduced to the barest minimum. Production is enhanced over a longer period and operation is optimised with minimum expenditure e.g. on injected chemicals. Re-configuration, in response to changes in field characteristics or newly available technology, can be readily achieved. Maintenance and decommissioning costs are similarly reduced.

Seabed processing can be the key to achieving additional revenue and significant cost reductions, particularly for fields that are difficult or uneconomic to produce by traditional means. However, System-Modules are not confined to seabed separation alone. They can also be applied to installations in lakes and other inland scenarios. Furthermore, as part of an AlphaPRIME™ CPU, they provide an all-electric total field development solution for the control and processing of subsea hydrocarbons. AlphaPRIME™ enables the monitoring and powering of all the systems and equipment from the wells to the host facility thus enabling fields to be developed on an incremental basis. It also enables a “plug and play” approach to be adopted from a location that may well be remote from the field in question.

The technology described in this paper has existed for many years; it is only the System-Modular approach that is novel. The extensively patented System-Modular method of deploying, operating and retrieving seabed processing systems utilises only existing technology. As has been explained, it offers a means of developing a field incrementally, consequently spreading CAPEX over the life of the field instead of principally at the beginning.

Having examined all the issues involved, it can be concluded that the challenges of subsea field development, in particular flow assurance and high reliability combined with ease of installation and recovery, can be overcome by adopting the System-Modular approach to field development.

In conclusion, the System-Modular approach is the ideal method by which the benefits of separation systems can be utilised to achieve maximum net present value on a great variety of existing and new field developments.