INTRODUCTION

The Subsea Deployment System (SDS) is a method for recovering subsea structures, spools, mattresses, wrecks and debris from the seabed and then transporting them to shore without recovering them to the surface offshore. It avoids the need for a heavy lift vessel (HLV) and allows even very large structures to be recovered using only an anchor handling tug or small construction vessel. It can also operate in greater water depths and in more environmentally hostile locations than is possible with most current vessels.

The system can be used to lift a payload (structures, skips or wrecks) and/or to transport the payload to shore. Alternatively it can be used as a very large fully submersible skip.

The system is a potential step change in the decommissioning of subsea structures and clean-up work.

ADVANTAGES

- Low cost (OPEX and CAPEX)
- Low tech and failsafe
- Large lifting capacity without using an HLV
- Operations insensitive to weather
- Minimal dynamic loading
- Structures recovered without lifting to deck
- Deployment vessel can be parked at the seabed for prolonged periods in all weather

APPLICATIONS

The system can be used to recover large payloads such as subsea structures, wrecks or purpose built skips from the seabed without the need for a large crane vessel. In this instance the Subsea Deployment Vessel (SDV) docks on to the payload and is then de-ballasted until the system is marginally buoyant. The combined assembly is then transported directly to shore using a subsea tow. See below for the outline method.

Typically the capital cost of the SDV is less than 10% of the capital cost of a crane with a similarly rated capacity. The SDV is essentially a “dumb” barge with no major ancillary equipment and hence the operating costs are also low.

All offshore lifting and transportation operations are performed subsea. This avoids the often critical phase of lifting the loads through the splash zone to the deck of the crane vessel rendering the overall operation inherently safer and increasing the operational weather window.

Historically many subsea structures have not been designed to accommodate a single piece recovery, i.e. the original design may not have allowed for the weight of marine growth, and flooded members or seabed break-out loads.

This may result in concerns regarding the integrity of the structure and the safety of the lift operation. However, with SDS the break-out and dynamic loads are negligible and because the structure is not recovered to the surface the impact of the additional weight from marine growth and flooded members is minimised.

The recovery of spools, mattresses and general seabed debris to the surface can also be problematic involving multiple lifts to deck and a risk of dropped objects. However, if using the SDS in conjunction with large purpose built skips, the spools, mattresses and debris and even small subsea structures can be lifted directly into the skip at the seabed which is quicker and inherently safer.

The skips, which can be placed at strategic decommissioning locations and remain at the seabed for prolonged periods, would be deployed and recovered in the same manner as a subsea structure as described in the outline method below.

This option enables construction vessels to work more efficiently since they do not need to recover each lift to the deck. It also means that the deck is kept clear of recovered debris and structures so there is no need return to shore to offload.

As an alternative to skips, large frames or pipe racks can be used for the recovery of large pipelines or bundle sections. Similarly wrecks can be recovered using a purpose made interface/lifting frame that can be deployed at a wreck location for a prolonged period while the wreck is secured before lifting.
OUTLINE METHOD

A typical decommissioning operation will consist of the following steps of which some are explained:

- Load-out of empty SDV
- Surface Tow
- Submerged Tow
- Positioning over and connecting to the payload
- De-ballasting
- Raising from seabed
- Submerged Tow
- Surface Tow
- Offloading payload

**Surface Tow**

The SDV and payload, when close to shore, will be towed in the Surface Tow Mode with only the castles and control chain towers breaking the surface.

**Submerged Tow**

When the water depth is suitable, the tow vessel will adjust the tow wire and tow chain clump weight. The tow chain clump weight will cause the SDV to submerge. By reversing the operation the SDV can be brought to the surface.

The tow vessel can adjust its speed and the length of the tow wire to maintain the SDV at a suitable depth. The SDV may be lowered as the water depth increases by paying out on the tow wire. The position and inclination of the SDV will be monitored throughout by acoustic interrogation.

**Approach and Set-down**

When approaching the field, the tow vessel will slow down and adjust the tow wire to keep the tow chain clump weight off the seabed until in a designated parking area.

The tow vessel will then pay out the tow wire until the clump weight rests on the seabed. The SDV will now be “anchored” and float above the seabed.

Ideally the length of the tow wire between the clump weight and SDV will be marginally greater than the distance between the parking area and the final target location. This allows final set-down without the need to lift and re-position the tow chain clump weight.

**Positioning and Docking**

The SDV will be positioned by means of two control chains suspended from the surface vessel and lowered into the chain towers.

The height of the SDV will be adjusted by raising or lowering the control chains and the position and orientation of the SDV will be adjusted by moving the surface vessel and / or the crane.

Once the SDV is in the correct position and orientation it will be landed onto the payload by lowering the control chains. The control chains will then be fully lowered into the chain towers and temporarily disconnected. The control chain connector will be located on the top of the chain tower ready for reconnection after ballasting. The payload will be connected to the SDV prior to de-ballasting.

The weight of the control chains will contribute to the initial on-bottom stability, i.e. prior to de-ballasting.
**Tow Chain Clump Weight**
The tow chain clump weight is inserted into the tow wire to provide the necessary weight to submerge the SDV from the deep draught tow condition to the submerged tow condition. It also acts as an anchor for the SDV when parked on the seabed.

**Ballast Chain Lockers**
Ballast chain lockers are placed at each corner. They are used to trim the SDV to suit the weight and CoG of the structure prior for the tow.

They are also used to hold the ballast weight which replaces the structure weight (this is relevant where syntactic foam is used for buoyancy in deep water).
Control Chains and Chain Towers
The control chains are lowered into chain towers to gain control of the SDV during installation.

The weight of the chain supported by the SDV at the base of the chain towers is used to control the height of the SDV.

The length (weight) of chain suspended within the chain towers provides lateral and rotational control of the SDV.

Payload - SDV Interface
The payload – SDV interface (not shown) are used to support the payload within the SDV.

Castles
The castles are positioned above the majority of the permanent buoyancy tubulars and will be the only part of the SDV apart from the chain towers that will protrude above the waterline in the deep draught condition. This facilitates fine tuning of the trim.

Tubulars
The SDV consists of upper and lower tubulars. Upper tubulars are permanently de-ballasted to provide buoyancy for the SDV. Lower tubulars will be ballasted/de-ballasted depending on the payload.

The buoyancy is located as high as is practical to maximise the separation between the CoG and CoB when the SDV is submerged.
**Float-off and Tow**

The installation vessel will now re-connect to the two control chains and raise them until the SDV and payload are neutrally buoyant. Further raising of the control chains will lift the SDV and payload clear of the seabed.

The SDV will then be manoeuvred in a near reverse of the installation procedure until clear of any subsea assets. The control chains will then be removed completely from the towers allowing the SDV to float above the seabed while still anchored by the tow chain clump weight.

**Lift-in**

The SDV shown on the centre pages is designed such that the structure can be lifted directly through the SDV for load-in to shore.

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**KEY FEATURES**

**Stability**

The SDV is designed to be inherently stable throughout all stages of submergence and when fully submerged the CoB is well above the CoG.

**Dynamic Response**

The control chain is not directly connected to the SDV and only rests within the chain tower, therefore the surface vessel and SDV can move independently.

Rapid vertical movement of the surface vessel only raises and lowers the control chain and not the SDV. Consequently there will be minimal variation in the down-line tension.

The mass of the SDV and payload is large compared to the weight of control chain and consequently the motion of the chains due to surface vessel motions causes minimal dynamic response of the SDV.

**Docking Control**

Lengths of chain suspended from the surface vessel are lowered into the chain towers to perform two main functions.

Primarily the weight of the chain supported at the base of the chain towers is used to make the SDV neutrally buoyant.

Secondly the length (weight) of chain suspended within the chain towers provides lateral control of the SDV.

The position and orientation of the SDV can be adjusted by moving the surface vessel.

**SDV to Payload Interface**

The interface connection between the subsea deployment vessel and subsea structure will vary depending on the structure to be recovered and the load-in method.

In most cases this will involve the use of project specific interface devices which are attached between the original lifting points or other suitable locations and the SDV. The interface devices may also serve as lifting beams if required for the load-in.

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[Diagram of SDV and Surface Vessel motion relationship]

[Diagram of Control Chain]

[Diagram of Lift-in process]
WEATHER SENSITIVITY

Lift-out, Load-out, Float-out and Float-over
The load-out/in will be subject to weather restrictions. However, it will be performed in relatively sheltered locations and consequently these restrictions should not result in significant delays.

Surface Tow
The surface tow can take place in relatively rough seas and in most cases the transition to and from the submerged tow will occur close to shore in benign conditions.

Submerged Tow
The submerged tow of the SDV and payload is largely unaffected by the surface weather conditions. The limiting criteria are therefore more likely to be associated with the operational weather limitations of the tow vessel.

The towing operations can be suspended at any time by parking the SDV on the seabed and anchoring it with the tow chain clump weight.

Loss of Buoyancy
During tow, the SDV and payload will be marginally buoyant and will therefore be able to withstand some loss of buoyancy.

It is likely that any loss of buoyancy will be gradual. The trim of the SDV will be monitored and will give early warning of any loss of buoyancy. Consequently the SDV may be brought to a safe location for rectification. This could be simply by removing ballast chain.

Adverse Weather
Although adverse weather is unlikely to affect the SDV and payload, there may be occasions where the weather is unsuitable for the tow vessel. In such cases the tow chain clump weight will be lowered to the seabed leaving the SDV safely anchored.

SDS INHERENT SAFETY
The potential for catastrophic failure is minimised by having a ‘close to neutral’ submerged weight for the SDV and payload.

Tow Rigging Failure
If there is a rigging failure between the tow vessel and the tow chain clump weight, the chain clump weight will sink slowly to the seabed and act as an anchor for the SDV. If the water depth is greater than the length of rigging between the SDV and the tow chain clump weight, the SDV will be pulled under and will float at a known height above the seabed. Otherwise the SDV will float on the surface but will still be anchored by the weight of the chain clump weight.

If there is a rigging failure between the SDV and the tow chain clump weight the SDV will float to the surface.

Docking and Recovery
During docking of the SDV and subsequent recovery of structure motions will be minimal in significant sea states; however, working conditions and ROV operating limits are likely to be the limiting criteria, typically Hs 3.5m. This compares with a typical limiting sea state of Hs 2.0m for a conventional lifted installation. In certain areas this may significantly increase the weather window and associated schedule benefits as demonstrated by the following chart.
SUBMERSIBLE SKIP / BARGE

An alternative version of the SDV is a fully integrated submersible/barge. This can enhance the recovery of structures, spool pieces, mattresses etc. during decommissioning work. As with the discrete skips described above, it can be used to transport seabed architecture and debris from the field to shore but it has the advantage that the hold of the skip can be fully de-ballasted to minimise its draught. This allows the payload to be taken into relatively shallow ports. The skip can be used for both subsurface and surface transportation.

Skip Basics

The upper tubulars are fully sealed and permanently buoyant whereas the lower tubular compartments are designed with a ballasting facility. The side and double bottom compartments are generally fully flooded and open to the sea. A remotely operated system is used to control the de-ballasting function of the hold which consists of centrifugal pumps powered by the pressurised air in the lower tubular compartments.

Surfacing the Skip

To bring the skip to the surface, the tow vessel recovers the chain clump weight. The skip will then rise to the surface due to its excess buoyancy where it will float with just the upper tubular members breaking the surface. The seawater trapped inside the ‘hatch coaming’ is allowed to escape to match the outside seawater level via check valves/gates. The remaining water in the hold is removed using pumps which are driven by the compressed air stored in the lower tubulars until the hold is “dry”.

Skip Stability

The stability of the skip when submerged is achieved by a positive separation between the CoG and the CoB. During surface operations the flooded side tanks ensure that hull free surface effects do not cause instability during ballasting operations.